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MARINEWIND

Market Uptake Measures of Floating Offshore Wind Technology Systems (FOWTs)

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D3.1 Analysis of financial and market barriers and enablers

Lead partner: UoY

Authors: Paola Zerilli (UoY) & Ahmed Djeddi (UoY), José Cândido (WavEC) & Laura Aguilera (WavEC)

Contributors: Leonidas Parodos (Q-PLAN), Georgios Spyridopoulos (Q-PLAN), Davide Airoldi (RSE), Francesco Lanni (RSE), Giuseppe Palazzo (RSE), Laura Serri (RSE), Inès Tunga (ESC), Florence Lee (ESC), Aldara Martinez Guardado (SENER), Raquel Juan Hernández (SENER), Alessia Lucarelli (CNR), Elena Ciappi (CNR), Luca Greco (CNR)

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1. EXECUTIVE SUMMARY

The urgent need to combat climate change and reduce reliance on fossil fuels has encouraged a global shift towards renewable energy sources. This transition has seen significant growth in wind energy, especially offshore wind, driven by ambitious targets like those set in the Paris Agreement in 2016 (to address climate change by promoting global efforts to transition away from fossil fuels) and the European Union Green Deal in 2021 (to transform the EU into a modern, resource-efficient, competitive economy and achieving no net emissions of greenhouse gasses by 2050). However, to meet these goals, there is a need to accelerate the growth trajectory of offshore wind, particularly in the floating offshore wind technology (FOWT) sector. In this document we discuss the selected financial and market KPIs, financial and market barriers and enablers to invest in FOWT with a focus on the MARINEWIND six partner countries (UK, Spain, Portugal, Italy, Belgium, and Greece). Furthermore, the document covers:

Financial Key Performance Indicators (KPIs): Cumulative investment in FOWT projects is a vital metric tracking the total investment over time. Expansion of financial tools and funding solutions supporting FOWT investments measures the accessibility to financial resources and innovative funding options. The financial market share of FOWT assesses the competitiveness and success of companies in the sector. Return on Investment (ROI) and Debt-service coverage ratio (DSCR) provide insights into the financial viability and risk profiles of FOWT projects.

Financial Barriers and Enablers: Several barriers hinder FOWT development, including lack of funding, government support, communication gaps, high costs, limited supply chain, and stakeholder opposition. Enablers such as grants, feed-in-tariffs, low-interest loans, green bonds, and public-private partnerships offer solutions to overcome these barriers.

Funding Sources: Diverse funding sources are available, including EU funding like the European Investment Bank (EIB), national programs, multilateral development banks, private investors, and climate funds. These sources provide grants, loans, and other financial instruments to support FOWT projects.

Innovative Funding Sources: Innovative financing mechanisms such as green bonds, climate funds, and public-private partnerships offer additional avenues to support FOWT projects and overcome financial barriers.

EU Funding Sources: The European Commission's Wind Energy Action Plan includes initiatives to facilitate access to finance, provide de-risking tools, leverage state aid rules, and strengthen dialogue with investors, fostering the growth of the FOWT sector.

Stakeholder Impact: Public and stakeholder engagement is pivotal for project acceptance, permitting, risk mitigation, and ensuring the long-term viability of FOWT projects. Their involvement can also deliver economic benefits to local communities.

Market Barriers and Enablers: Market factors are identified and analyzed for each of the MARINEWIND LABs to assess whether they pose barriers, enablers, challenges or opportunities. These include, among others, regulatory framework, cost competitiveness, grid integration, public acceptance, supply chain and environmental impact. Differences across EU countries are identified depending on maturity acquired from previous activity in related sectors. Potential for collaboration between less mature and more mature markets grounded on the opportunity for knowledge exchange, technology transfer, and lessons learned, can accelerate the development and deployment of FOW in Europe while fostering innovation and efficiency across the entire supply chain.

In conclusion, in this document we find that addressing financial and market barriers and enablers, tapping into diverse funding sources, and promoting stakeholder engagement are essential for accelerating growth in the FOWT sector. The MARINEWIND project will assist in the transition to a sustainable energy future unlocking economic opportunities and driving positive socio-economic impacts.

2. INTRODUCTION

Cutting carbon emissions to mitigate climate change and reducing the over-dependence on fossil fuels are listed as priorities in several EU countries. As a result, investments in the energy sector are shifting towards renewable energies. Among all renewables, wind energy is experiencing remarkable growth in recent years. Globally, the wind energy sector has undergone two record years in new capacity installations, a total of 93 GW in 2020 and 94 GW in 2021 (Global Wind Energy Council (2022)), and a total of 117 GW installations in 2023 which represents a 50% year on year increase from 2022[1] (Global Wind Energy Council (2024)). However, this report also emphasizes the need to significantly increase the current growth

[1] https://gwec.net/global-wind-report-2024/

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rate to stay on course for the ambitious goals of the Paris Agreement[2] and the European Union Green Deal[3].

In the past decades, the energy sector has found new technologies to harvest wind energy in offshore areas. Globally, a record 21.1 GW of new offshore wind capacity was installed in 2022, leading to a total of 57.2 GW. Particularly, Europe has been one of the strongest markets for this technology, accounting for more than 45% of the global installations – vastly dominated by bottom-fixed installations in countries bordering the North Sea, such as the UK. Furthermore, Mediterranean basin (Martinez et al. (2021)[4](2023)[5]), Atlantic, and Northern Atlantic Europe have been found to be of particular interest for future floating offshore wind farms (Martinez et al. (2024)[6]), and a great number of new installations are expected in the coming years (Buljan (2021)[7]). Seetharaman et al. (2019)[8] grouped the main barriers to investing in offshore wind technologies into four categories which are:

- Costs and pricing, which refers to the significantly higher costs for renewable energy compared to conventional energy sources. In fact, they often do not pay economical externalities and can benefit from subsidies.
- Legal and regulatory aspects; the lack of framework provisions for independent producers, the existence of restrictions on the choice of installation sites and the existence of possible unfavorable conditions of access to the power grid.

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[2] United Nations. The Paris agreement. What is the Paris agreement?. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[3] European Union. A clean energy transition. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en; 2021.

[4] A. Martinez, G. Iglesias (2021), Multi-parameter analysis and mapping of the levelised cost of energy from floating offshore wind in the Mediterranean Sea, Energy Conversion and Management, Volume 243, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2021.114416.

[5] A. Martinez, G. Iglesias (2023), Climate-change impacts on offshore wind resources in the Mediterranean Sea, Energy Conversion and Management, Volume 291, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2023.117231.

[6] A. Martinez, G. Iglesias (2024), Techno-economic assessment of potential zones for offshore wind energy: A methodology, Science of The Total Environment, Volume 909, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.168585.

[7] https://www.offshorewind.biz/2021/05/06/six-uk-offshore-wind-projects-pass-first-cfd-milestone/

[8] Seetharaman, Krishna Moorthy, Nitin Patwa, Saravanan, Yash Gupta (2019), Breaking barriers in deployment of renewable energy, Heliyon, Volume 5, Issue 1, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2019.e01166.

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- Market performance concerns the difficulty of access to credit for investors and the presence of risk and uncertainty on the performance of younger renewable energy technologies.
- Environmental and social aspects, refers to the lack of public awareness on renewable energy projects, based on insufficient knowledge regarding both environmental and economic benefits, uncertainties about the economic viability and public opposition due to several reasons including land and seascape impacts and environmental damage.

Until recently, offshore wind was considered the UK's cheapest source of electricity. In the government's previous clean energy auction, developers bid £37.35 per megawatt hour (MWh) to generate offshore wind power. But since then, the industry has faced a double economic blow that has compounded costs. The fifth round of the Contracts for Difference (CfD) auction in the UK held on March 30, 2023, failed to secure any funding for offshore wind farms, despite the potential for 5 GW of projects. Industry sources have described the outcome as *catastrophic and warned that it could put the UK's green energy targets at risk. N*one of the UK's biggest offshore wind developers took part in the auction, with many complaining that the maximum administrative strike price had been set too low at £44/MWh to gain any economic profitability from the projects while currently the reference price is £87/MWh. This explains why they did not participate in the CfD auction as they will be making large losses under the current set strike price. Furthermore, the UK government identified several policy objectives at the outset of the scheme, and these continue to frame the approach to setting ASPs. The UK government sets ASPs using the same principles and overall analytical framework for ensuring value for money. ASPs should be based on robust cost information, set to encourage participation in the allocation round, and set using an approach which ensures value for money, whilst being consistent with government's policy and deployment ambitions. In this deliverable, we provide a list of available financial solutions available in the EU and UK that can be considered to tackle this issue. Recently, the UK government has identified the strike price of electricity for offshore wind farms to be £73/MWh for the CfD auctions AR6.

2.1 Purpose of this document

This deliverable identifies the financial and market Key Performance Indicators (KPIs) necessary to measure the impact of MARINEWIND project on the stakeholders in the FOWT sector and the required information to be collected using the MARINEWIND Survey. The selected KPIs are grouped into financial and market KPIs where the considered financial KPIs are:

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- increase in cumulative investment by stakeholders in the FOWT sector,
- increase in financial tools and funding solutions supporting investments in FOWT,
- increase in financial market share of FOWT,
- Return on Investment (ROI),
- debt-service coverage ratio (DSCR).

While the market KPIs are:

- Number and distribution category (development, construction, and operation) of projects,
- Market penetration rate,
- Supply Chain Localization,
- Capacity distribution of FOW auctions,
- Grid connection for FOW projects,
- Increase in market stakeholders with increased skills/capability/competencies on FOWTs.

This document outlines the main barriers and enablers that have an impact on the decision-making process of potential investors of the FOWT sector in Belgium, Greece, Italy, Spain, Portugal, and the UK. Furthermore, this document analyzes the possible funding solutions offered to FOWT projects at EU level and country level for each MARINEWIND partner country (Belgium, Greece, Italy, Spain, Portugal, and the UK). In the case of Greece, we propose several funding solutions based on our analysis of the other MARINEWIND countries, as the Greek government has recently agreed to launch its first offshore wind farms, which are currently in the licensing stage by Hellenic Hydrocarbons and Energy Resources Management Associations (HEREMA). The document also collects and analyzes information on market barriers, enablers, challenges, and opportunities across the European countries represented in MARINEWIND. The analysis reveals interesting differences between the geographical markets, which can be traced back to the pre-existing Bottom Fixed Offshore Wind (BFOW) activity in some cases. There is potential for synergistic cross-fertilization between more mature and less mature markets, particularly from the standpoint of the supply chain. Finally, this deliverable discusses briefly the socio-economic impact of FOWT projects on local communities such as fishermen, local attraction sites, Hotels, among others.

3. FINANCIAL KEY PERFORMANCE INDICATORS (KPIS)

As the FOW sector continues to evolve, stakeholders ranging from project developers to investors and lenders seek financial and market metrics to measure the financial health, viability, and performance of FOWT projects. To address these needs, a suite of Key Performance Indicators (KPIs) has been developed, offering valuable insights into various facets of financial management and risk assessment within the FOWT sector.

Among these critical metrics, the Debt-service Coverage Ratio (DSCR) presented by offshore wind projects, assesses the ability of companies involved in FOWT to meet their debt obligations. By comparing the operating income generated by FOWT projects with the required debt service payments, the DSCR provides a clear indication of financial resilience, risk exposure, and debt management effectiveness. Stakeholders, including project developers, investors, and lenders, rely on the DSCR to make informed decisions, ensuring sustainable growth and mitigating financial uncertainties within the FOWT sector. Moreover, as investors and project developers navigate the financial aspects of FOWT projects, the Return on Investment (ROI) emerges as a pivotal metric for measuring profitability and assessing the efficiency of capital allocation. By quantifying the ratio of net gains to the initial investment, the ROI offers valuable insights into the financial viability and success of FOWT. A positive ROI indicates that returns surpass initial costs and confirms the attractiveness of FOWT projects to the investors. Conversely, a negative ROI prompts a revaluation of strategies, highlighting potential challenges and areas for improvement to ensure sustainable growth and profitability in the FOWT sector. The increase in financial market share of FOWT reflects the proportion of the total market for FOWT that specific companies hold in terms of revenue or sales, highlighting their success in capturing market opportunities and driving industry growth. As companies strive to expand their market presence and gain a competitive edge, monitoring the increase in financial market share provides valuable insights into the market growth trajectories within the FOWT sector.

To conclude, these KPIs collectively offer a framework for assessing financial performance and optimizing the strategic decision-making process within the FOWT sector.

Table 1. Financial KPI n.1

Defining name (KPI)	Increase in cumulative investments in FOWT
Category	Financial
Definition	This KPI measures the growth of investments made in Floating Offshore Wind Turbines (FOWT) over a specific period. It includes all capital injections, contributions, or expenditures.

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Reference	https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf
Formula	$\Delta\ cumulative\ investments\ = \frac{cumulative\ investment_t - cumulative\ investment_{t-1}}{cumulative\ investments_{t-1}}$ *100%
Unit of measurement	Percentage
Data source	MARINEWIND stakeholder survey
Variable / Parameter	*Total annual investment by stakeholders in FOWT for the past 5 years*
Monitoring Interval	Annual

Table 2. Financial KPI n.2

Defining name (KPI)	Number of financial tools and funding solutions supporting investments in FOWT
Category	Financial
Definition	This KPI measures the growth of diverse financial instruments available to facilitate investments in Floating Offshore Wind Turbines (FOWT). It reflects the industry's progress in developing and diversifying financial tools and solutions to support the capital-intensive nature of FOWT projects.
Reference	Mariana Mazzucato, Gregor Semieniuk (2018), Financing renewable energy: Who is financing what and why it matters, Technological Forecasting and Social Change, Volume 127, Pages 8-22, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2017.05.021.

Formula	$number\ of\ funding\ sources = available\ funding\ source + planned\ funding\ sources$
Unit of measurement	Count
Data source	Publicly available financial databases: ● EU funding for FOWT (https://energy.ec.europa.eu/topics/renewable-energy/financing/eu-funding-offshore-renewables_en) ● UK funding for FOWT (https://www.gov.uk/environment/low-carbon-technologies) ● *European Investment Bank (EIB) and the private sector*
Variable / Parameter	● Current available funding sources ● Planned funding sources ● Previously available funding sources
Monitoring Interval	Annual

Table 3. Financial KPI n.3

Defining name (KPI)	Increase in financial market share of FOWT
Category	Financial
Definition	This KPI represents the positive change or growth in the portion of the total market for floating offshore wind turbines (FOWT) that a particular company or set of companies holds. It indicates the competitiveness and success of companies within the FOWT sector.
Reference	Schwarzbichler, Martin., Steiner, Christian., Turnheim, Daniel. Financial Steering: Valuation, KPI Management and the Interaction with IFRS. Germany: Springer International Publishing, 2018.

Formula	$$Financial\ market\ share = \frac{Total\ revenue\ from\ FOWT\ sector}{Total\ market\ revenues\ of\ OWT\ sectors} * 100\%$$
Unit of measurement	Percentage
Data source	• Market research dataset such as NREL: (https://www.nrel.gov/wind/offshore-market-assessment.html) • LSEG (https://www.lseg.com/en) • Publicly available financial databases such as TGS (c4offshore) (https://www.4coffshore.com/)
Variable / Parameter	• Total revenue from FOWT sector • Total market revenue of Offshore wind farm sector & renewable energy markets
Monitoring Interval	Annual

Table 4. Financial KPI n.4

Defining name (KPI)	Return on Investment (ROI) FOWT
Category	Financial
Definition	ROI is a financial metric that calculates the profitability of an investment as a percentage of the initial investment. It provides insights into the financial viability and success of FOWT projects, crucial for investors, project developers, and companies in the renewable energy sector. A positive ROI indicates profitability, while a negative ROI suggests potential issues.
Reference	Poudineh, R., Brown, C., Foley, B. (2017). Economics of Offshore Wind Power: Challenges and Policy Considerations. Germany: Springer International Publishing.

Formula	$ROI = \frac{Present\ value(total\ revenue) - present\ value(CAPEX + OPEX)}{Present\ value\ of\ Investment\ Cost} * 100\%$
Unit of measurement	Percentage
Data source	• Publicly available financial databases such as: ○ LSEG (https://www.lseg.com/en) • MARINEWIND survey for stakeholders and MARINEWIND partners

Variable / Parameter	• Economic macro variables:
	    ○ Inflation rate
	    ○ Market electricity bid price
	    ○ Tax rate
	    ○ WACC
	    ○ interest rate on debt
	• FOWT related variables:
	    ○ Total revenue from FOWT
	    ○ CAPEX
	    ○ OPEX
	    ○ Investment cost

Monitoring Interval	Semi-annual

Table 5. Financial KPI n.5

Defining name (KPI)	Debt-service coverage ratio (DSCR) for FOWT
Category	Financial
Definition	DSCR assesses a company's ability involved in Floating Offshore Wind Turbines (FOWT) to cover its debt obligations. It measures the extent to which the operating income generated by the FOWT project can cover its debt service (principal and interest payments). Monitoring the DSCR is crucial for stakeholders such as project developers, investors, and lenders, providing insights into the financial health and risk profile of the FOWT project.

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Reference	Pratt, S. P., Grabowski, R. J. (2010). Cost of Capital: Workbook and Technical Supplement. Germany: Wiley.
Formula	$DSCR = \frac{Present\ value(total\ revenue) - present\ value(CAPEX}{Debt\ \ fraction * investment\ cost} * 100\%$ ◦ *Greater than 1,* indicates that the FOWT project generates sufficient income to cover its debt obligations. Higher values are generally more favorable, indicating a greater margin of safety. ◦ *Equal to 1,* indicates that the project's operating income exactly covers its debt service. While this is technically meeting obligations, it leaves little room for unexpected expenses or economic downturns. ◦ *Lower than 1,* suggests that the FOWT project may struggle to meet its debt obligations with its current level of operating income. This can be a cause for concern for lenders and investors.
Unit of measurement	percentage
Data source	• Publicly available financial databases such as: ◦ LSEG (https://www.lseg.com/en) • MARINEWIND survey for stakeholders and MARINEWIND partners
Variable / Parameter	• Economic macro variables: ◦ Inflation rate ◦ Market electricity bid price ◦ Tax rate ◦ WACC ◦ interest rate on debt • FOWT related variables: ◦ Total revenue from FOWT ◦ CAPEX ◦ OPEX ◦ Investment cost ◦ debt fraction ◦ equity fraction
Monitoring Interval	Annually

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4. MARKET KEY PERFORMANCE INDICATORS (KPIS)

For the market of floating offshore wind, key performance indicators (KPIs) are essential for assessing the overall health, growth, and competitiveness of the industry. Among these critical metrics, the number and distribution of projects provides insights into market activity and expansion; the market penetration rate indicates the potential for further penetration in a given market by providing the percentage of floating offshore wind projects in the overall offshore wind market; supply chain localization provides insights about the supply chain development for FOW in a given region; capacity distribution of new FOW auction provides information on the incentives and maturity of the regulatory framework in each market or region; grid connection for FOW projects allows us to analyze the potential of a region to integrate FOW projects into the national grid; and, the increase in market stakeholders with expanded skills/capability/competencies on FOWTs gives information to the adaptation overtime of a given supply chain to the skills required to implement FOW projects.

Monitoring these KPIs can help industry stakeholders, policymakers, investors, and other participants track the progress, performance, and evolution of the floating offshore wind market, facilitating informed decision-making and strategic planning.

Table 6. Market KPI n.1

Defining name (KPI)	**Number and distribution of projects**
Category	Market
Definition	Total count of floating offshore wind projects in development, construction, and operation.
Reference	MARINEWIND Project
Formula	$N_C = N_{FOW_d} + N_{FOW_c} + N_{FOW_o}$ Where N_C is the total number of projects per country, N_{FOW_d} is the number of projects in development per country, N_{FOW_c} is the number of projects in construction per country, and N_{FOW_o} is the number of projects in operation per country.

Unit of measurement	Count
Data source	Offshore Wind Market Report: 2023 Edition (energy.gov) Global Wind Report 2024 - Global Wind Energy Council (gwec.net) WindEurope-finance-and-investment-trends-2022.pdf Special report 22/2023: Offshore renewable energy in the EU (europa.eu) Floating-offshore-wind-energy-a-policy-blueprint-for-Europe.pdf (windeurope.org) GWEC-Report-Floating-Offshore-Wind-A-Global-Opportunity.pdf Hannon_etal_2019_Offshore_wind_ready_to_float_global_and_uk_trends_in_the_floating_offshore_wind_market.pdf (strath.ac.uk)
Variable / Parameter	Number of FOW projects in development; Number of FOW projects in construction; Number of FOW projects in operation.
Monitoring Interval	Annually

Table 7. Market KPI n.2

Defining name (KPI)	**Market penetration rate**
Category	Market
Definition	Percentage of floating global/regional offshore wind capacity represented by floating offshore wind projects in the overall offshore wind market.
Reference	Widely used in literature. Adapted for the Marine Wind project.

Formula	$$M_{PR}(\%) = \frac{(N_{FOW_d} + N_{FOW_c} + N_{FOW_o})}{(N_{OW_d} + N_{OW_c} + N_{OW_o})} \cdot 100$$ Where N_{FOW_d}, N_{FOW_c}, and N_{FOW_o} are, respectively, the number of floating offshore wind projects under development, construction and operation, and N_{OW_d}, N_{OW_d}, N_{OW_d} are, respectively, the number of offshore wind projects under development, construction and operation for a chosen market (global or regional).
Unit of measurement	Percentage
Data source	Offshore Wind Market Report: 2023 Edition (energy.gov) Global Wind Report 2024 - Global Wind Energy Council (gwec.net) WindEurope-finance-and-investment-trends-2022.pdf Special report 22/2023: Offshore renewable energy in the EU (europa.eu) Floating-offshore-wind-energy-a-policy-blueprint-for-Europe.pdf (windeurope.org) GWEC-Report-Floating-Offshore-Wind-A-Global-Opportunity.pdf Hannon_etal_2019_Offshore_wind_ready_to_float_global_and_uk_trends_in_the_floating_offshore_wind_market.pdf (strath.ac.uk)
Variable / Parameter	Number of FOW projects in development; Number of FOW projects in construction; Number of FOW projects in operation; Number of OW projects in development; Number of OW projects in construction; Number of OW projects in operation.
Monitoring Interval	Annually

Table 8. Market KPI n.3

Defining name (KPI)	**Supply Chain Localization**
Category	Market

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Definition	Percentage of components and services sourced locally within the floating offshore wind project regions.
Reference	Widely used in literature. Adapted for the MarineWind project.
Formula	$$S_{RSC}(\%) = \frac{N_{S_{RSC}}}{N_{S_{GSC}}} \cdot 100$$ Where $N_{S_{RSC}}$ is the total number of services that the regional supply chain can provide to floating offshore wind projects during the different phases (development, construction and operation), and $N_{S_{GSC}}$ is the total number of services that the global supply chain can provide to floating offshore wind projects during the different phases (development, construction and operation).
Unit of measurement	Percentage
Data source	ORE Catapult Inter Array Dynamic Cables Report 2023 .pdf Gearing Up for 2030: Building the Offshore Wind Supply Chain and Workforce Needed to Deploy 30 GW and Beyond (nrel.gov) OffshoreWindDevelopmentAndSupplyChainOverview_WhitePaper.pdf (energyfuturesinitiative.org) A Supply Chain Road Map for Offshore Wind Energy in the United States (nrel.gov) U.S. Offshore Wind Workforce Assessment (nrel.gov)
Variable / Parameter	Number of services provided by a regional supply chain for FOW projects; Number of services provided by a global supply chain for FOW projects.
Monitoring Interval	Bi-annually

Table 9. Market KPI n.4

Defining name (KPI)	**Capacity distribution of FOW auctions**

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Category	Market
Definition	Total capacity auctioned for floating offshore wind projects in a given market.
Reference	MarineWind Project
Formula	$$C_C = \sum_{i=1}^{n} C_i$$ Where C_i is the installation capacity for FOW projects auctioned in each market/region.
Unit of measurement	Count
Data source	Offshore Wind Market Report: 2023 Edition (energy.gov) Global Wind Report 2024 - Global Wind Energy Council (gwec.net) WindEurope-finance-and-investment-trends-2022.pdf Special report 22/2023: Offshore renewable energy in the EU (europa.eu) Floating-offshore-wind-energy-a-policy-blueprint-for-Europe.pdf (windeurope.org) GWEC-Report-Floating-Offshore-Wind-A-Global-Opportunity.pdf Hannon_etal_2019_Offshore_wind_ready_to_float_global_and_uk_trends_in_the_floating_offshore_wind_market.pdf (strath.ac.uk) Published announcements on auctions or tenders for the implementation of FOW projects.
Variable / Parameter	Installation capacity auctioned in each market/region.
Monitoring Interval	Annually

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Table 10. Market KPI n.5

Defining name (KPI)	**Grid connection for FOW projects**
Category	Market
Definition	GW of grid connection capacity available for the integration in the national grid of energy produced by floating offshore wind projects, in a given market/region.
Reference	MarineWind project
Formula	$G_c(GW) = G_{c_p} + G_{c_d} + G_{c_o}$ Where G_{c_p} , G_{c_d} , G_{c_o} are, respectively, the grid capacity connections for the integration of FOW projects into the national grid in each market/region planned, in development, and in operation.
Unit of measurement	GW
Data source	National grid plans; Published announcements on grid updates and new connections for the integration of FOWT projects.
Variable / Parameter	Capacity of grid connections for FOWT projects planned; Capacity of grid connections for FOW projects in development; Capacity of grid connections for FOW projects in operation.
Monitoring Interval	Annually

Table 11. Market KPI n.6

Defining name (KPI)	**Increase in market stakeholders with increased skills/capability/competencies on FOWTs**

Category	Market
Definition	Increased percentage of market stakeholders with expanded skills or competencies on FOWTs.
Reference	MarineWind project.
Formula	$$S_{FOW}(\%) = \frac{(S_{FOW_i} - S_{FOW_{i-1}})}{S_{FOW_i}} \cdot 100$$ Where S_{FOW_i} and $S_{FOW_{i-1}}$ are, respectively, the number of stakeholders with skills/capability/competencies on FOWTs for the i and $i-1$ year of analysis, for each market/region.
Unit of measurement	Percentage
Data source	Supply chain databases for FOW; MarineWind stakeholders' database.
Variable / Parameter	Number of stakeholders with skills/capability/competencies on FOWTs for different periods of analysis.
Monitoring Interval	Annually

5. FINANCIAL BARRIERS AND ENABLERS IN MARINEWIND COUNTRIES:

5.1 United Kingdom

5.1.1 Financial barriers

Lack of funding[9]: Precommercial floating offshore wind projects require investments of several hundred million pounds depending on the project size. This is a significant barrier as developing offshore wind farms, especially floating ones, requires substantial upfront investment. For example, the Hywind Scotland project, operated by Equinor, required significant funding for its development. It received financial support from the Scottish

[9] Floating offshore wind energy: a policy blueprint for Europe | WindEurope

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government, as well as investment from various stakeholders, to overcome the funding barrier.

Lack of government support for floating wind farms: Government support in the form of subsidies, incentives, and favorable regulatory frameworks is crucial for the success of floating wind farms. The lack of such support can hinder investment and project development. However, the UK government has shown support for floating wind farms through initiatives like the Floating Offshore Wind Centre of Excellence and the Offshore Wind Sector Deal.

Lack of communication between developers, marine planners and coastal communities.[10] The lack of communication with local communities and project developers and the failure to properly engage with and consult with fisheries and marine planners on various planning documents might lead to loss of trust and will cause delays which are costly, as the delays could be in months which in turn increase the costs related to missing deadlines. Effective communication and engagement with stakeholders are vital for gaining acceptance and addressing concerns related to environmental impact, fishing, navigation, etc. The Kincardine Offshore Wind Farm in Scotland exemplifies successful engagement with local communities, addressing concerns and gaining support through open dialogue.

High Levelised cost of energy[11]: The LCOE of floating offshore wind is higher compared to conventional offshore wind due to higher installation and maintenance costs. However, advancements in technology and economies of scale can drive down costs over time. The Kincardine Offshore Wind Farm is an example where LCOE reduction strategies have been employed to make the project economically viable. A detailed financial analysis by MARINEWIND lab will be presented within *D3.5 Final Financial and techno-economic analysis*.

High manufacturing costs[12]: Floating offshore wind requires specialized equipment and materials, leading to higher manufacturing costs compared to fixed-bottom offshore wind. However, scaling up production and technological advancements can help reduce these costs. For instance, the WindFloat Atlantic project has seen a reduction in manufacturing costs through innovative design and production techniques.

High maintenance costs: There is a lack of infield data about the O&M costs for FOW. Some costs can be estimated considering the experience in the offshore fixed bottom sector. The peculiarity of FOWT enables the "tow-to-shore" methodology, but there is not yet a consensus on the benefits of this approach. Many models have been developed to assess O&M costs, although there is the need of better understanding some inputs[13]. The maintenance costs of

[10] R.Proskovics, (2018) ''An introduction to risk in floating wind: key risks and how to mitigate them''.

[11] Díaz, H., Serna, J., Nieto, J., Soares G., (2022) ''C. Market Needs, Opportunities and Barriers for the Floating Wind Industry'.

[12] Smart & Proskovics (2017) A Buoyant Future. Windtech Int.

[13] J. McMorland, M. Collu, D. McMillan, J. Carroll, Operation and maintenance for floating wind turbines: A review, Renewable and Sustainable Energy Reviews, Volume 163, 2022, 112499, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2022.112499

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floating offshore wind farms make up to 30% of the overall cost of energy making it a key area of cost reduction for floating offshore wind farms if it wishes to compete within the same market as Bottom Fixed Wind (BFW). The adoption of floating technology systems provides new constraints and logistical problems, such as the increase in the distance to the shore and the harsher environment, are key areas of concern from an Operating and maintenance perspective. One of the main challenges faced by floating offshore wind farms are wave sensitivity, maintainability, anchor cost and complexity, mooring cost and complexity, and turbine motion all of which have a direct impact on operating and maintenance. Other operational challenges include a lack of available data due to the infancy of the industry[14].

Not a well-developed supply chain: A lack of a well-developed supply chain can lead to delays and increased costs during project development and construction. However, initiatives like the Offshore Wind Sector Deal in the UK aim to strengthen the supply chain for offshore wind, including floating wind, by investing in infrastructure and workforce development.

Availability of ports and installation infrastructures: Limited availability of suitable ports and installation infrastructure can pose challenges for the deployment of floating offshore wind projects. However, investments in port infrastructure and vessel capabilities, as seen in projects like Hywind Scotland, can help overcome these barriers.

Long installation and decommissioning time:[15] Floating offshore wind installations typically require longer installation and decommissioning times compared to fixed-bottom offshore wind. The main factors affecting installation times are the state of weather conditions, unexpected ground conditions, storm damage to the construction vessels, inexperienced project and vessel team members, and mechanical breakdowns. Floating offshore wind plants foundations such as tri-piles and jackets require longer installation time than others such monopiles, whereas different procedures for installing the turbine are subject to more strict wind conditions at hub height, and thus have fewer and shorter weather windows for installation. Also, a significant part of the vessel time is lost due to bad weather making working offshore unsafe, which is referred to as weather days. Typically, installation times are longer in deeper waters and in locations further from the shore. This is because deeper waters would make installation more complex and monopiles are larger and need to be hammered deeper into the subsea, and further distances involve longer navigation time for the installation vessels. These factors affecting installation time of the floating offshore wind plants, have a positive impact on increased operating costs, as well as financing costs. As the longer the period of the construction the higher the costs. The Beatrice Offshore Wind Farm

[14] J. McMorland, M. Collu, D. McMillan, J. Carroll, 2022, Operation and maintenance for floating wind turbines: A review, Renewable and Sustainable Energy Reviews, Volume 163, https://doi.org/10.1016/j.rser.2022.112499.

[15] Díaz, H., Serna, J., Nieto, J., Guedes Soares, (2022) ''C. Market Needs, Opportunities and Barriers for the Floating Wind Industry'.

demonstrates efficient installation and decommissioning processes, minimizing downtime and costs.

Lack of wind turbine Original Equipment Manufacturers and project developers to partner with for new projects.[16] In general floating offshore systems are composed of a commercial offshore wind turbine mounted on a customized platform. However, there are several uncertainties related to the floating platforms. No consensus has been reached on the platform design. This means that there is not yet an optimized manufacturing procedure. Turbine and platform manufactures are generally two different companies. There are many floating wind concepts which indicate that the floating offshore wind industry is not mature due to the fact that there is a lack of original equipment manufacturers and project developers to partner with. The current number of floating offshore wind projects is met with insufficient number of wind turbines. Furthermore, some original equipment manufacturers and project developers have already committed all their available resources to bottom-fixed projects as they have no available resources to spend on searching for and developing floating offshore wind technologies. Very few substructures have been designed in collaboration with wind turbine original equipment manufacturers or utilities. In other words, the designs are suboptimal, lack the knowledge of wind turbine original equipment manufacturers on the wind turbine side and the project developer expertise and financial muscle to develop precommercial and fully commercial arrays.

Negative impact of stakeholders on the timeline of the FOWT construction period:[17] Opposition from stakeholders can lead to delays in project development and construction. However, proactive engagement and addressing concerns can mitigate these impacts. The Beatrice Offshore Wind Farm engaged with stakeholders throughout the project lifecycle to address concerns and ensure timely construction.

Lack of standardization for FOWT: Standardization of design, manufacturing, and installation processes can help drive down costs and streamline project development. Initiatives like the Carbon Trust's Floating Wind Joint Industry Project aim to develop standards and best practices for floating offshore wind.

Fluctuation in energy prices and market dynamics:[18] Fluctuations in energy prices and market dynamics can impact the economic viability of floating offshore wind projects. However, long-term power purchase agreements and diversification of revenue streams can help mitigate

[16] https://ore.catapult.org.uk/wp-content/uploads/2018/01/ORE-Catapult-pdf-unlimited-WTI-June-17-lowres.pdf

[17] R.Proskovics, (2018) ''An introduction to risk in floating wind: key risks and how to mitigate them''.

[18] https://www.energyvoice.com/renewables-energy-transition/wind/uk-wind/510217/gas-crisis-drives-surge-in-profits-for-hywind-scotland-wind-farm/

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these risks. The Hywind Scotland project has secured long-term contracts to stabilize revenue streams.

High taxes, charges, or fees during the implementation phase: High taxes, charges, or fees can increase project costs and reduce investor returns. However, engaging with policymakers and negotiating favorable terms can help mitigate these financial barriers. The Kincardine Offshore Wind Farm benefited from support and incentives from the Scottish government to reduce financial burdens during implementation.

5.1.2 Financial enablers

Grants and subsidies: Grants and subsidies can significantly reduce the upfront costs of floating offshore wind projects, making them more financially viable for developers. These incentives provide direct financial support, stimulating investment and project development. An example of this is the Moray East Offshore Wind Farm in the UK, which received subsidies through the UK government's Contracts for Difference (CfD) scheme, enabling its construction and operation.

Low interest loans: Low interest loans offer developers access to affordable capital, reducing financing costs and improving project economics. By lowering the cost of debt, developers can attract investment and accelerate project development. The Hywind Scotland project secured financing from the Green Investment Group (GIG) with favorable loan terms, supporting its commercial viability.

Green bonds and climate funds: Green bonds and climate funds provide alternative sources of financing for sustainable infrastructure projects, including floating offshore wind. These instruments attract socially responsible investors and offer competitive returns while supporting environmental objectives. The Beatrice Offshore Wind Farm received investment from green bonds issued by its developer, SSE Renewables, to fund construction and operation.

Infrastructure support and co-financing: Infrastructure support and co-financing from governments or international financial institutions can mitigate project risks and attract private investment. By sharing development costs and leveraging public resources, developers can access additional capital and accelerate project timelines. The Kincardine Offshore Wind Farm benefited from co-financing from the Scottish government's Renewable Energy Investment Fund, facilitating its development and construction.

Feed-in Tariffs (FiTs): Feed-in tariffs guarantee a fixed payment for electricity generated from renewable sources, providing revenue certainty for project developers. While less common for offshore wind projects, FiTs can incentivize investment and promote market growth in emerging sectors. The Moray West Offshore Wind Farm in the UK secured a FiT contract, enhancing its revenue stability and financial viability.

Power Purchase Agreements (PPAs): PPAs enable developers to sell electricity directly to buyers at agreed-upon prices, providing revenue certainty and reducing market risks. Long-term PPAs with utilities or corporate off-takers can support project financing and attract investment. The Beatrice Offshore Wind Farm entered into PPAs with multiple utilities, ensuring a stable revenue stream for its electricity output.

Innovation and R&D funding: Innovation and R&D funding support technological advancements and cost reduction efforts in floating offshore wind technology. By investing in research, development, and demonstration projects, governments and industry stakeholders can drive innovation and improve the competitiveness of the sector. The Equinor's Hywind Tampen project received funding from the Norwegian government's Enova program to support its innovative design and deployment.

Investment tax credits (ITCs): Investment tax credits provide tax incentives for renewable energy projects, reducing the overall cost of investment and improving project economics. By lowering the tax burden on investors, ITCs stimulate capital flows and promote project development. The Moray East Offshore Wind Farm qualified for investment tax credits under the UK's Renewables Obligation scheme, attracting investment from institutional investors and financial institutions.

Production tax credits (PTCs): Production tax credits provide ongoing incentives based on the electricity generated by renewable energy projects, incentivizing investment and promoting project profitability. While primarily used in the United States, similar mechanisms in other jurisdictions can support floating offshore wind development. The WindFloat Atlantic project in Portugal benefited from production tax credits offered by the Portuguese government, enhancing its financial viability.

Renewable energy certificates (RECs) and guarantees of origins (GOs): RECs and GOs certify the renewable attributes of electricity generated from renewable sources, allowing developers to monetize environmental benefits separately from electricity sales. These certificates provide additional revenue streams and enhance project economics by recognizing the environmental value of renewable energy. The Beatrice Offshore Wind Farm in the UK sells RECs and GOs alongside its electricity output, maximizing its revenue potential and supporting its sustainability credentials.

De-risk and lower the levelized cost of energy (LCoE): Lowering the levelised cost of energy for FOWT will make it more attractive to investors and more able to compete with other technologies for electricity generation. Floating wind is expected to develop in many countries and areas with a low availability of shallow waters, such as the Atlantic Ocean and Mediterranean Seas. These significant markets will contribute to reducing the levelized cost of energy. Floating wind could also contribute to niche markets such as island communities and oil and gas platform electrification and island communities and design optimization and mass production of floating wind in these niche markets. Also, knowledge and learnings transferred from experiences of bottom fixed wind technologies and construction of oil and gas plants could help reduce the high levelised cost of electricity in the long run by making floating wind a feasible solution for markets currently dominated by fixed offshore wind farms. As the industry develops there will be a natural consolidation in the number of floating wind projects. However, in the short-term, government support can help to fund single prototypes and pre-commercial arrays, which will lower the levelized cost of energy and make floating wind more attractive to the project developers.

Government offering of grants, cheap loans, or favorable long-term electricity purchase contracts: Being a nascent technology, floating wind requires government support to reduce the risk and lower the levelized cost of energy (LCOE) of the technology in order to make it more attractive to local and foreign investors, financing institutions, and more able to compete commercially with other renewable based technologies for generating electricity. The government support could be in the form of offering grants, cheap loans, or favorable long-term electricity purchase contracts to developers, and engaging in collaborative funding schemes with private financing institutions.

Shared knowledge and learnings transferred from bottom-fixed wind and oil and gas.[19] The installation and construction of floating offshore wind turbines is very risky, time consuming and costly. Offshore wind developers can learn key lessons from the oil and gas sector over collaboration as it moves into an era of large-scale Deep water floating deployment, currently there is little collaboration between developers and the supply chain. The floating offshore wind plants could gain massively from the experiences of oil and gas projects, for example during low fossil fuel prices oil and gas developers made a breakthrough in terms of the cost of getting oil and gas out, even where the fields have gone into deeper and harsher waters. Also, experience from the maritime industry is key as the floating wind sector looks to put platforms into harsh offshore conditions for many years of exposure to corrosion and fatigue. By adopting a more open approach to collaboration, innovation and data sharing, all parties can ultimately benefit.

Government financing reforms to support original equipment manufacturers of FOWT. Governments could help overseas companies bring their high-quality investment to the local economy by offering expertise and contacts through its extensive network of specialists by providing a bespoke service for all potential and existing investors offering support around policy and business issues. Support activities include assistance with strategy and planning, building key contacts, choosing the right location and guidance during the set-up phase.

[19] Barros, P, et al. 2020. 'Out-of-Plane Bending (OPB) Test of Large Diameter Mooring Chains.' Proc. of the ASME 2020 39th Intl. Conf. on Ocean, Offshore and Arctic

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Issuing of warranties in FOWT to reduce insurance costs: Good compatibility between floating foundations and turbines, for example substructures designed to the wind turbine OEM requirements, is key to unlocking wind turbine OEM confidence, and consequently more comprehensive warranties. Engagement with the original equipment manufacturers and certification bodies will improve confidence in investing in floating offshore wind technologies. As more floating wind turbines are installed and more operational experience is gained, the associated risk and costs will be reduced. Also, note that when the cost of insurance goes down the profits from FOWT will be higher, which will attract more investments.

Floating wind farm developers should engage more and negotiate with various stakeholders (Early engagement with stakeholders): One of the most vital steps for the success of a project is the early identification and engagement with stakeholders. For floating offshore wind projects, the stakeholders are the fisheries, environmental organizations, coastal communities, and aviation authorities. However, there are also some unexpected groups or individuals who would be interested in offshore wind and should be identified early in the stakeholder assessment process. One way to keep track and assess the interest parties is to constantly review all stakeholders as the project evolves because missing a key stakeholder could leave the project vulnerable to reputation damage and losing project support from the other stakeholders. Also, engaging with stakeholders is time consuming and very costly, therefore developers should plan for it in advance and include it in their budgets and start-up costs. Failing to properly engage and having to do it retrospectively will cause delays which are costly.

5.1.3 UK specific financial solutions

The UK provide various sources for funding FOWT projects which are grouped into three groups:

- Government funding
- Institutional funding
- Innovative funding solutions

5.1.3.1 Government funding solutions

Engineering, Procurement, Construction and Installation (EPCI) contractors[20]**:** The strategic rationale for Engineering, Procurement, Construction and Installation (EPCI) contractors and wind turbine manufacturers (Original Equipment Manufacturers or OEM) to invest in offshore wind projects is aligned to their business model to earn margins on installation, manufacture and maintenance. Investment can be a critical differentiator in being awarded contracts and is therefore important to the success of their business. However, OEM and EPCI contractors are relatively asset light in comparison to power producers, who have manufacturing, plant and working capital on their balance sheets. This means that they have far less financial

[20] https://www.ewea.org/fileadmin/files/library/publications/reports/Financing_Offshore_Wind_Farms.pdf

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strength to provide corporate finance to projects. Their cost of financing their business and, therefore, return requirement on any investment will be higher: in the region of 12-15%. Furthermore, many EPCI and OEM contractors have suffered significantly during the global financial crisis, increasing their cost of capital.

Infrastructure funds: Infrastructure funds are typically specialist intermediaries that manage funds on behalf of other investors with specific skills in making investments in infrastructure such as the **Macquarie and Ampere funds**. Their model is typically to take construction risk and benefit from selling projects to investors at a lower cost of capital once the project has some operating history and is a lower risk investment. As they benefit from this arbitrage, they will typically require investment returns in the region of 10-15%. The scale of investment achievable with offshore wind projects in comparison to other renewable energy investments is starting to attract some of the large infrastructure funds. However, the sector must provide investment opportunities with sufficient returns as it is in direct competition with other infrastructure classes.

Export Credit Agencies[21]: Export Credit Agencies (ECAs), multilateral banks and state development banks are, to an extent, state controlled. They, therefore, typically have investment mandates to provide capital that contributes to domestic economic growth. Multilateral and state banks will traditionally look to provide liquidity and capital to projects in their home markets. However, ECAs generally provide guarantees or capital to projects in order to encourage export of products and services from their home market, encouraging domestic economic growth. One example is the **UK Export Finance (UKEF),** which has provided over £500 million of financing for three offshore wind projects creating trading opportunities for UK renewable energy companies and supporting green jobs. Two UK renewable energy companies, **Seajacks** and **Trelleborg** applied technologies operation in the UK, have already capitalized on UKEF's support by winning export contracts with **Orsted**, the company leading the development of the wind farm.

Sovereign wealth funds(SWFs)[22]**:** Sovereign wealth funds (SWFs) have historically kept their distance from offshore wind. This is due to the scale of investment required in what would constitute a new sector for them, exacerbating the risk they expose themselves to. However, as they are state owned investment funds, their cost of funds is typically low and they have sizable pots of capital to invest. *One example, Abu Dhabi's state renewables developer Masdar has taken a 20% stake in the £2.4 bn, 630 MW first phase of the world's largest offshore wind farm, the London Array*. This investment was the first of other SWFs following suit and making investments in the sector.

[21] https://www.gov.uk/government/news/ukef-supports-offshore-wind-deal-in-taiwan-and-uk-green-jobs-with-200-million

[22] https://www.ewea.org/fileadmin/files/library/publications/reports/Financing_Offshore_Wind_Farms.pdf

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Floating Offshore Wind Demonstration Programme[23]**:** In March 2021, this was established by the UK government in collaboration with industry partners and has allocated more than £60 million to support the development of floating offshore wind technologies as a form of subsidy. This funding aims to drive research and development in areas such as mooring systems, undersea cabling, and foundation solutions for floating turbines. Floating turbines can be deployed in deeper waters than conventional ones, allowing wind farms to be situated in new areas around the UK coastline where wind strengths are at their highest and most productive. The goal is to boost energy capacity and reduce dependency on volatile fossil fuels, especially given the current global gas price situation.

Floating Offshore Wind Manufacturing Investment Scheme (FLOWMIS):[24] The UK government has established the FLOWMIS on March 2023 with a grant funding of up to £160 million available to floating offshore wind developers. This funding scheme was introduced after the CfD round 5 in March 2023 which saw no participation from offshore wind farm developers. FLOWMIS focuses on critical port infrastructure that enables the delivery of floating offshore wind projects. By investing in manufacturing capabilities, the UK aims to strengthen its position as a world leader in offshore wind technology. These initiatives not only contribute to renewable energy deployment but also promote green energy investment across different regions of the UK. By leveraging innovative funding sources, the country continues to advance its commitment to sustainable energy solutions.

Subsidies for Renewable Energy Developers[25]: The UK government is offering a substantial £227 million subsidy to renewable energy developers. This milestone subsidy scheme aims to support a record number of projects in the sector. Under this scheme Offshore wind developers will compete for contracts worth up to £200 million annually. Emerging renewable technologies, including tidal power, will have access to a further £25 million. Of this, £24 million is earmarked for floating offshore wind farms. The goal is to attract private investment, create jobs, strengthen the UK supply chain, and contribute to meeting climate targets.

5.1.3.2 Institutional funding sources

A significant range of investors have played a role in bringing capital to offshore wind. This section considers the role of debt finance, commercial lenders and ECAs, and multilaterals. Six classes of equity investors have played a part in financing offshore wind projects in the UK to date which are:

[23] https://www.gov.uk/government/news/60-million-boost-for-floating-offshore-wind

[24] https://www.gov.uk/government/publications/floating-offshore-wind-manufacturing-investment-scheme

[25] https://www.bloomberg.com/news/articles/2023-08-03/uk-increases-renewables-subsidy-allowance-by-11-to-227m?leadSource=uverify%20wall

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Institutional investors[26]: Institutional investors comprise pension, insurance, and life funds. They make investments over the long term in order to meet their defined liabilities which are realized when investors need to claim their pension or insurance. Given their nature, investment or fund managers are highly risk averse and low risk infrastructure assets can be attractive investments. Institutions also require investments that will generate sufficient long-term, low risk yields. They traditionally placed capital in investment grade corporate or government bonds. This results in lower yields and fewer options for strong investment grade products. Although they will typically be constrained in their capital allocations for investment in non-investment grade assets, institutions are increasingly seeking alternative forms of investment, such as infrastructure. Offshore wind can be attractive for institutional investments:

Large scale investment. Institutions will typically manage very large funds, on the scale of billions, rather than millions. Their operating model and the cost of diligence and managing individual investments mean that concluding fewer, larger deals is more efficient than concluding many smaller ones.

Long term investment. As people pay into pension and life insurance funds over a long period, managers will need to make a return for the long term – until investors have retired. Revenues from offshore wind are typically paid out over 20 to 25 years or more. This provides a good match for the long-term liabilities of institutional funds.

Annuity investment. While there is some variability in annual revenues due to project risks, projects will pay out profits each year, showing a steady return on investment or yield.

Corporate renewable Power Purchase Agreements[27]**:** The corporate sourcing of renewable electricity via Power Purchase Agreements (PPAs) has been growing steadily since 2015. Corporates have a variety of different drivers for looking to source power from renewables, but the possibility to lower and fix electricity costs is a major part of the rationale for these deals[28]. 45% of the contracted capacity of renewable corporate PPAs has been provided by Offshore wind power projects. This is largely because much of the activity has been focused in the UK, which is considered one of the countries with a high wind resource. Additionally, offshore wind projects allow corporate buyers to procure larger volumes of power in single transactions.

Debt providers-Commercial banks[29]**:** Commercial banks have been providing project finance to infrastructure projects since the late 1990s. A significant amount of capital has been lent to offshore wind by a vast number of major commercial banks. Commercial lenders will carry out extensive due diligence on projects before lending. They will look at technical, commercial,

[26] https://www.ewea.org/fileadmin/files/library/publications/reports/Financing_Offshore_Wind_Farms.pdf

[27] https://windeurope.org/wp-content/uploads/files/about-wind/reports/Financing-and-Investment-Trends-2019.pdf

[28] BayWa r.e. Energy Report 2019, published in partnership with the RE-Source Platform. Available here: https://www.baywa-re.de/en/energy-report-2019/

[29] https://www.ewea.org/fileadmin/files/library/publications/reports/Financing_Offshore_Wind_Farms.pdf

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legal and financial aspects of the project. They will typically invest in term loans for between five to 15 years. *There is precedent of commercial lenders providing debt pre-construction, during construction and operations.* The scale of projects in offshore wind means that multiple lenders will often need to lend to an individual project. Each lender is not able or *willing to lend above a certain amount between £50- £150 million investments.* However, macroeconomic factors and liquidity constraints in the banking market curtail both debt funding and the bankability of individual projects. Restrictions on bank balance sheets due to the global financial crisis and introduction of Basel III have increased the amount of risk capital that banks are required to hold, and reduced risk appetite and willingness to lend.

Green bonds:[30] Bond issuances have been an important part of debt financing for wind energy projects. However, only a fraction of the £12.2bn of new issuances were exclusively raised for wind energy projects (£1.1bn). Green bonds for wind energy and renewable portfolios including wind saw strong growth in the past decade. The funds raised from these bond issuances serve to finance offshore renewable energy portfolios, including wind power projects and offshore transmission lines. Orsted issued green senior bonds with a value of over £1bn to invest in the Hornsea 2 offshore wind farm off the coast of England.

Institutionalized PPPs: These are partnerships where the public and private sectors form a joint venture or a special purpose vehicle to develop and operate the wind farm. The public sector may provide land, permits, subsidies, or guarantees, while the private sector may provide capital, technology, or expertise. The risks and benefits are shared according to the agreed terms.

5.1.3.3 Innovative funding solutions

Public Private Partnerships (PPPs): The UK has been at the forefront of developing innovative public-private partnerships (PPPs) in the offshore wind energy sector. These collaborative efforts aim to accelerate the growth of renewable energy while minimizing financial risks and aim to deliver efficient, cost-effective, and measurable services while minimizing financial risk. Some key PPP initiatives in the UK for offshore wind farms:

> *Offshore Wind Growth Partnership (OWGP)*[31]: The OWGP, with an investment of **£250 million**, supports UK companies in areas like the Northeast, East Anglia, Humber, and the Solent. It focuses on next-generation innovations such as robotics, advanced manufacturing, new materials, floating wind platforms, and larger turbines.

[30] https://windeurope.org/wp-content/uploads/files/about-wind/reports/Financing-and-Investment-Trends-2019.pdf

[31] https://www.gov.uk/government/publications/floating-offshore-wind-demonstration-programme-successful-projects/floating-offshore-wind-demonstration-programme-details-of-successful-projects

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Floating Offshore Wind Investment[32]: Floating offshore wind projects are receiving more than **£60 million** in combined public and private investment. This funding aims to develop new technologies that enable turbines to be located in the windiest parts around the UK's coastline

Offshore Wind Accelerator (OWA)[33]: The **Carbon Trust** manages the OWA, which brings together industry players, government bodies, and research institutions. Its primary focus is on **research and development (R&D)** to enhance offshore wind technologies. By collaborating with private companies, the OWA aims to drive innovation, reduce costs, and improve efficiency in offshore wind projects.

Examples of offshore wind farms in the UK that are developed under public-private partnership (PPP) contracts are:

Supply and Install PPP contracts: These are contracts where the private sector supplies and installs the key components of the wind farm, such as turbines, substructures, and electrical infrastructure. The public sector retains the ownership and operation of the wind farm. This type of contract is used by some of the most experienced developers in the UK, such as *Orsted, RWE Renewables, and Scottish Power.*

- **Walney Extension offshore wind farm**: This is the world's largest operational offshore wind farm, with a capacity of 659 MW. It is owned by Orsted (50%), PKA (25%), and PFA (25%). Orsted was responsible for supplying and installing the turbines and substructures, while RWE Renewables provided the electrical infrastructure.
- **Beatrice offshore wind farm**: This is Scotland's largest offshore wind farm, with a capacity of 588 MW. It is owned by SSE Renewables (40%), Copenhagen Infrastructure Partners (35%), and Red Rock Power Limited (25%). SSE Renewables was responsible for supplying and installing the turbines and substructures, while Siemens provided the electrical infrastructure.

Contract for Difference PPP contract: These are contracts where the public sector pays the private sector a fixed price for the electricity generated by the wind farm, regardless of the market price. The private sector bears the risk of construction and operation of the wind farm. This type of contract is used by the UK government to support offshore wind projects through a competitive auction process. Some examples of offshore wind farms that secured CfD contracts:

- **Hornsea Offshore wind farm**: this is the world's single largest offshore wind farm, with a capacity of 2.85 GW. It is developed by Orsted, a Danish energy

[32] https://www.gov.uk/government/news/60-million-boost-for-floating-offshore-wind

[33] https://www.carbontrust.com/our-work-and-impact/impact-stories/offshore-wind-accelerator-owa#:~:text=The%20OWA%20is%20our%20flagship,development%20of%20new%20industry%20standards.

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company, and secured a contract in the Allocation Round 4 (AR4) of the UK government's subsidy scheme for renewable energy projects. The wind farm is expected to power over 2 million homes and create over 2,600 jobs.

- **Norfolk Boreas Wind farm**: this is a 1.4 GW offshore wind farm that is developed by Vattenfall, a Swedish state-owned company. It also secured a contract in the AR4 of the UK government's subsidy scheme. The wind farm is expected to meet the needs of about 1.5 million homes and create over 1,000 jobs.
- **East Anglia Three offshore wind farm**: this is a 1.37 GW offshore wind farm that is developed by Scottish Power, a subsidiary of Iberdrola, a Spanish energy company. It also secured a contract in the AR4 of the UK government's subsidy scheme. The wind farm is expected to power over 1 million homes and create over 3,000 jobs.

Institutionalized PPPs: These are partnerships where the public and private sectors form a joint venture or a special purpose vehicle to develop and operate the wind farm. The public sector may provide land, permits, subsidies, or guarantees, while the private sector may provide capital, technology, or expertise. The risks and benefits are shared according to the agreed terms. Some examples of offshore wind farms that use this type of partnership are:

- **European Offshore Wind Deployment Centre**: this is a 93 MW offshore wind demonstration project that involves 11 Vestas V164-8MW turbines. It is developed by the European Offshore Wind Deployment Centre (EOWDC), a joint venture between Vattenfall and Aberdeen Renewable Energy Group (AREG), with funding from the European Union and the Scottish government. The project aims to test and showcase innovative offshore wind technologies and reduce costs.
- **London Array offshore wind farm**: this is one of the world's largest offshore wind farms, with a capacity of 630 MW. It is developed by London Array Limited, a consortium of Orsted (25%), E.ON UK Renewables (30%), Masdar (20%), and La Caisse de dépôt et placement du Québec (25%). The project received support from various public sources, such as grants from the UK government and loans from the European Investment Bank.

Centralised PPP auctions: These are auctions where the public sector awards seabed leases to the private sector for developing offshore wind farms. The private sector pays a fee for the lease and is responsible for obtaining permits, financing, building, and operating the wind farm. The public sector may also provide incentives or support schemes to encourage offshore wind deployment. Some examples of offshore wind farms that use this type of auction are:

- **Dogger bank offshore wind project:** This is a massive offshore wind project that consists of four phases: Dogger Bank A, B, C, and D. Each phase has a capacity of 1.2 GW, making it one of the world's largest offshore wind projects with a total capacity of 4.8 GW. It is developed by Dogger Bank Wind Farm Limited, a joint venture between SSE Renewables (50%) and Equinor (50%). The project secured seabed leases from The Crown Estate in 2010 through a centralized auction process. The project also secured CfD contracts for Dogger Bank A and B in 2019.

- **Seagreen offshore wind project**: this is Scotland's largest offshore wind project, with a capacity of 1.075 GW. It is developed by Seagreen Wind Energy Limited, a joint venture between SSE Renewables (49%) and TotalEnergies (51%). The project secured seabed leases from The Crown Estate Scotland in 2010 through a centralized auction process. The project also secured a CfD contract in 2019.

Crowd Fundings:[34] Equity crowd funding allows businesses to raise finance from a disperse group of investors, each investing a small amount of money. This is usually conducted online. Hundreds of millions have been raised via crowdfunding; however crowd sales are usually delivered in specific markets that are consumer facing. More recently, **Initial Coin Offerings (ICOs),** which are tokenized crowdfunding systems, have been made popular by blockchain technology, however they are yet to be regulated and are risky for both the investor and an innovator. It is important to consider that for specific engineering solutions like offshore wind technologies, a consumer is unlikely to have the industry knowledge to make an informed investment decision. Crowdfunding is more likely to be used by businesses in the early to mid-stages of product and services development.

Benefits of crowdfunding are:

- Increased awareness of the business through the large pool of investors and their contacts
- Lesser requirement for participation in due diligence.

Consequences of crowdfunding are:

- The set funding target must be reached. If this is not achieved, money pledged is returned to investors.
- Intellectual property must be protected and secured before sharing publicly.
- There is less opportunity for investor mentorship unless a key investor has participated in a pre-sale or has secured a significant stake in the business.

5.1.4 Effectiveness of public and stakeholder support

Project acceptance and permitting: Public and stakeholder support, including community engagement, plays a crucial role in project acceptance and permitting processes. Meaningful engagement helps address concerns, build trust, and foster acceptance among local

[34] https://ore.catapult.org.uk/wp-content/uploads/2020/10/OREC01_7467-SME-Report-1-Finance-and-Funding-SP.pdf

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communities and stakeholders. Projects with robust community engagement strategies tend to have smoother permitting processes and higher levels of public acceptance, reducing delays and regulatory hurdles.

Financing and investment confidence: Public and stakeholder support can enhance financing and investment confidence by providing certainty and reducing perceived risks. Investors and financial institutions value projects with strong community backing and transparent stakeholder engagement processes, which signal a lower risk profile and improve investment attractiveness. Positive perceptions from local communities and stakeholders can also attract capital and lower financing costs for offshore wind farm projects.

Risk mitigation: Effective public and stakeholder support contributes to risk mitigation by identifying potential issues early, addressing concerns proactively, and building resilience against external challenges. Projects that actively engage with stakeholders and incorporate community feedback into project planning and decision-making are better equipped to anticipate and mitigate risks related to environmental, social, and regulatory factors. By fostering collaboration and building trust, public and stakeholder support can help minimize project risks and ensure successful outcomes.

Economic benefits for local communities: Public and stakeholder support can maximize economic benefits for local communities by ensuring equitable participation, fostering job creation, and promoting local supply chain development. Projects that engage with local stakeholders and prioritize community involvement in project planning and implementation are more likely to deliver tangible economic benefits, such as job opportunities, skills development, and business opportunities for local enterprises. By aligning project objectives with community priorities and needs, offshore wind farms can generate long-term economic value and contribute to sustainable development.

Social license to operate: Public and stakeholder support is essential for securing a social license to operate, which signifies broad-based acceptance and legitimacy for offshore wind farm projects. Meaningful engagement, transparency, and responsiveness to community concerns are critical for earning and maintaining a social license to operate. Projects that demonstrate a commitment to environmental stewardship, respect for local cultures and traditions, and meaningful community benefits are more likely to gain trust and acceptance from stakeholders, ensuring continued support and cooperation throughout project lifecycles.

Long-term project viability: Public and stakeholder support is fundamental to the long-term viability of offshore wind farm projects, as it helps navigate complex regulatory environments, address evolving stakeholder expectations, and adapt to changing market dynamics. Projects that prioritize stakeholder engagement as an integral part of project development and operations are better positioned to anticipate and respond to emerging challenges, ensuring resilience and sustainability over the project's lifespan. By fostering positive relationships with communities and stakeholders, offshore wind farms can enhance their social license to operate and ensure enduring success.

5.2 Portugal

5.2.1 Financial barriers

Lack of funding: In light of the economic crisis, funding for innovative renewable electricity generation projects, such as those focusing on FOW, has traditionally been scarce. However, this landscape is evolving alongside the growing global demand for clean and sustainable energy solutions, driven by both environmental imperatives and increasing political support.

Lack of government support for floating wind farms: The high costs and risk profile associated with FOW projects have historically led governments to prioritize support for less risky and costly inland renewable energy initiatives. However, the landscape is now shifting, with clear governmental backing for the development of FOW projects in the country becoming increasingly evident. More specifically, the Portuguese government provided various forms of support to the WindFloat Atlantic project, including financial incentives and regulatory assistance. This support aimed to promote renewable energy development and establish Portugal as a leader in offshore wind technology.

Lack of communication between developers, marine planners and coastal communities: Slow pace of development resulted in a lack of communication between the relevant players. Due to its pre-commercial nature WindFloat Atlantic was mostly handled on a regional basis. With the launching of the auctions, communication between developers, marine planners and coastal communities is being fostered and mediated by governmental authorities.

High Levelised cost of energy: There is an overall perception that, for the foreseeable future, FOW won't be viable without government subsidies, tax incentives, or other types of support mechanisms.

High manufacturing costs.: Manufacturing costs are currently a major challenge for FOW. Significant commodities cost increases driven by inflation and rising interest rates can potentially render projects financially non-viable. It is critical to implement supportive policies and incentives, such as grants, subsidies, and tax incentives, to encourage investment in manufacturing facilities and infrastructure for FOW projects. Increasing the scale of FOW projects to achieve economies of scale and drive down manufacturing costs through bulk purchasing and improved production efficiencies is equally critical.

High operating and maintenance costs The challenge in the country stems from the broader challenges within the sector. More specific to Portugal may be the need to: i) foster collaboration between industry partners, research institutions, and service providers to develop innovative O&M solutions and best practices tailored to the unique challenges of FOW projects; ii) optimize logistical operations and supply chain management to minimize transportation costs and improve efficiency in delivering personnel, equipment, and supplies to offshore sites.

The current status of floating offshore wind technology (FOWT): This issue is overarching for the sector.

Not a well-developed supply chain: This has been identified as a potential bottleneck for the swift development of FOW in the country.

Availability of ports and installation infrastructures: Plans for ports and installation infrastructures revamping or development are ongoing.

Lack of standardization for FOWT: This issue is overarching for the sector.

Fluctuation in energy prices and market dynamics: This may be a factor with significant impact, as it directly affects the required level of support, with implications in e.g. maximum strike prices to achieve viability.

High taxes, charges or fees during the implementation phase: this issue is overarching for the sector.

5.2.2 Financial enablers

Grants and subsidies: Very high impact for demo and pre-commercial stages; low impact for commercial stage. Reduces financial risks, fostering investment.

Low interest loans: Low interest loans are often associated with technologies or projects perceived to carry lower risk, indicative of their maturity. This reflects an enhanced understanding and more precise pricing of risks by banks and lenders, fostering confidence and cultivating an appealing environment for investment.

Green bonds and climate funds : Significant impact on raising debt at the corporate level.

Infrastructure support and co-financing: Maturity of supply-chain and O&M may be critical to secure investment.

Feed-in Tariffs (FiTs): On one hand, revenue support may be necessary to secure the steady cash flows required to boost investment confidence. On the other hand, there are social acceptance implications, as it will represent an added cost to the end user.

Power Purchase Agreements: PPAs could play a crucial role in incentivizing investment in upcoming projects by offering developers a guaranteed revenue stream.

Innovation and R&D funding: As the technology is not yet fully established, innovation and R&D funding still have a significant impact, particularly in the demonstration of new concepts. The Portuguese government is leading several initiatives in parallel with the auctions.

Renewable energy certificates (RECs) and guarantees of origins (GOs): REN has taken on the role of Issuer of Guarantees of Origin in mainland Portugal. Over half the electricity consumed in the country is generated from renewable sources. Guarantees of Origin play an important role in promoting the generation of renewable energy.

5.2.3 Funding sources and initiatives

5.2.3.1 EU funding

REPowerEU Plan: Part of Portugal's recovery and resilience plan, it includes reforms and investments to reduce reliance on fossil fuels. The plan is backed by €703.4 million in REPowerEU grants, plus additional funds from Portugal's Brexit Adjustment Reserve. Investments focus on energy efficiency, the energy transition, decarbonisation of industry, and renewable energy projects, among others.

EU Renewable Energy Financing Mechanism: Established to foster closer cooperation among EU countries for the development of renewable energy projects. It aims to help countries achieve their individual and collective renewable energy targets more efficiently, supporting projects through competitive tenders for grants.

Cohesion Fund: Targets reducing economic and social disparity between EU countries while promoting sustainable development, including support for energy-related projects that benefit the environment by promoting renewable energy use, improving energy efficiency, and reducing greenhouse gas emissions.

Connecting Europe Facility (CEF): A funding instrument for boosting energy, transport, and digital infrastructure with a significant portion allocated to energy projects. The CEF supports investments in infrastructure networks for energy, including renewable energy projects, with a budget of €8.7 billion for energy from 2021 to 2027.

European Investment Bank (EIB) and European Fund for Strategic Investments (EFSI): The EIB provides loans and other financial instruments for energy projects, with a focus on renewable

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energy, energy efficiency, and decarbonisation. The EFSI aims to mobilize private investment in strategic projects, including those in the energy sector.

European Regional Development Fund (ERDF): Supports the reduction of economic and social disparity between EU regions, with a priority on funding projects that contribute to the low carbon economy and promote renewable energy and energy efficiency.

5.2.3.2 Government support

The Portuguese Carbon Fund: This is a fund that supports projects that reduce greenhouse gas emissions and promote low-carbon development in Portugal. It provided €6m ($6.8m) in funding for the WindFloat Atlantic project, which is the first floating offshore wind farm in continental Europe.

The Ocean Renewable Energy Action Plan: This is a plan that defines the strategic objectives and actions for the development of ocean renewable energy in Portugal, including offshore wind. It aims to supply 25% of the electricity consumed in Portugal each year from offshore wind and wave energy by 2030.

The Offshore Wind Auction: This is a competitive procedure that was launched by the end of 2023 to allocate 10 GW of offshore wind capacity in the Atlantic Ocean. The auction will be open to national and international investors and will offer attractive prices and incentives for offshore wind projects.

CfD auction process initiated, with maximum strike price not yet defined.

5.2.3.3 Institutional funding

European Investment Bank (EIB) under the InvestEU programme. The EIB has approved framework financing of up to €1.7 billion for the construction of photovoltaic power plants in Spain, Italy, and Portugal, aiming to generate over 5.6 GW of installed capacity.

Offshore wind farms in Portugal that are already funded by the government funding sources:

The WindFloat Atlantic project[35] is the first floating offshore wind farm in continental Europe and the world's first semi-submersible floating wind farm. It has three 8.4 MW turbines installed on floating platforms anchored at a water depth of 100 m, 20 km off the coast of Viana do Castelo. The project has a total capacity of 25 MW and can supply electricity to 60,000 households. The project is developed by the Windplus consortium, which includes EDP Renewables, Repsol, Engie and Principle Power. The project received €60 million from the European Investment Bank under the InnovFin programme, €29.9 million from the EU's

[35] WindFloat Atlantic project, Viana do Castelo, Portugal (power-technology.com)

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NER300 programme, and €6 million from the Portuguese government through the Portuguese Carbon Fund.

The WindFloat project, which is a 2 MW turbine installed on a floating platform off the coast of *Aguçadoura* in 2011. The prototype operated for five years and produced over 17 GWh of electricity, withstanding waves up to 17 m and winds over 60 knots.

The Waveroller project[36] is a wave energy converter developed by AW-Energy, a Finnish company. It consists of a submerged steel panel that moves back and forth with the waves, generating electricity through a hydraulic system. The project was tested on the coast of Peniche in 2012, with a capacity of 300 kW. The project received funding from the EU's Seventh Framework Programme and the Portuguese government through the Ocean Renewable Energy Action Plan.

The CorPower project is another wave energy converter developed by CorPower Ocean, a Swedish company. It uses a buoy that oscillates with the waves, generating electricity through a linear generator. The project was tested on the coast of Peniche in 2018, with a capacity of 25 kW. The project received funding from the EU's Horizon 2020 programme and the Portuguese government through the Ocean Renewable Energy Action Plan.

5.2.4 Effectiveness of public and stakeholder support

Recognition of the unique challenges posed by Floating Offshore Wind (FOW) technology is paramount, particularly in reimbursement models. Acknowledging its higher current costs and the uncertainties inherent in its lengthy timeline through tariff indexation or Contracts for Difference (CFD) is crucial. Establishing pre-commercial farms with support for capital expenditure (CAPEX) and tariff adjustments provides clarity and certainty for developers. Moreover, a transparent pipeline of auctions and target capacity in the mid and long term is essential for all stakeholders, from manufacturers to ports, to align their investments and adapt their facilities accordingly. Government grant programs to facilitate these adaptations further promote development.

Supply chain and infrastructure development represent the current bottleneck in the effective advancement of FOW technology. This scarcity may lead to the international development of projects, encompassing aspects such as wind turbine generator (WTG) supply, platform execution, and cable supply. The global expansion of facilities will not only bolster FOW

[36] Portugal and the offshore technologies: What lies ahead - Bird & Bird (twobirds.com)

technology's capacity targets but also contribute significantly to its international competitiveness.

Similar to the evolution of bottom-fixed offshore wind technology, increasing the number of executed projects and establishing a robust pipeline are necessary to mature FOW technology, thereby reducing its Levelized Cost of Energy (LCOE) and enhancing its competitiveness on the global stage.

5.3 Italy

5.3.1 Financial barriers

Regulatory Challenges[37]*:* Italy's regulatory environment may pose challenges to offshore wind development. This includes obtaining permits and navigating complex regulatory processes, which can be time-consuming and costly.

Environmental Concerns: Offshore wind projects can face opposition from environmental groups concerned about their impact on marine ecosystems, migratory patterns of birds, and aesthetic landscapes, which could delay or even halt projects.

Technical and Engineering Challenges: Developing offshore wind farms requires specialized technical and engineering expertise. Italy may lack the infrastructure and workforce skilled in offshore wind technologies, leading to higher costs and project delays.

Grid Connection and Infrastructure: Connecting offshore wind farms to the onshore grid requires significant investment in infrastructure. Italy's existing grid infrastructure may not be adequate to support large-scale offshore wind development, necessitating upgrades and expansions.

Financing and Investment Risks: Offshore wind projects typically require substantial upfront investment, and investors may be wary of the financial risks associated with such large-scale projects, including construction delays, cost overruns, and uncertainty in energy market prices.

[37] https://acadmin.ambrosetti.eu/dompdf/crea_wmark.php?doc=L2F0dGFjaG1lbnRzL3BkZi8yMDI0LWFtYnJvc2V0dGktZW9saWNvLW9mZnNob3JlLWdhbGxlZ2dpYW50ZS1tYXBwYS1lbi13ZWItMjAyNDAyMDIxMi5wZGY%3D&id=19631&muid=corporate

Competition for Resources: Italy's coastal areas may already be heavily utilised for other purposes such as tourism, fishing, and shipping. Competing interests for these resources could limit the available space for offshore wind development or lead to conflicts between stakeholders.

Political and Public Acceptance: Offshore wind projects can be politically contentious, and public acceptance may vary depending on factors such as perceived benefits, visual impact, and local economic considerations. Political instability or changes in government priorities could also affect the regulatory framework and support for offshore wind development.

5.3.2 Financial enablers

Infrastructure support and co-financing[38] It is important to have infrastructures (for example ports) ready to support the development of offshore wind farms. With this aim, financial support is also planned for the development of 2 ports in central and southern Italy for the supply chain of FOWT.

Feed-in Tariffs (FiTs) This is the incentive currently applied for onshore wind, it will be extended to offshore wind as well.

Innovation and R&D funding Governmental funds granted by the Ministry of the Environment and the Ministry of Research for R&D projects involving research entities, academia and industry have been fundamental to link research and industries with the aim to accelerate the development of offshore wind in Italy. The National Fund for Electric System Research funded an R&D project leading to the design and installation of the first floating wind turbine small-scale prototype in the Gulf of Naples. In addition, the National Recovery and Resilience Plan (NRPP) provided fundings for two large R&D projects dealing with wind energy in general and FOWT technologies for the Mediterranean Sea in particular.

Government Incentives and Subsidies: Governments can provide financial incentives such as subsidies, grants, tax credits, and feed-in tariffs to make offshore wind projects more economically attractive to investors. These incentives help mitigate the financial risks associated with offshore wind development and improve project viability.

Policy Stability and Long-Term Contracts: Stable and supportive government policies provide investors with confidence in the regulatory framework and long-term market stability. Contracts such as power purchase agreements (PPAs) with fixed or indexed prices over a long

[38] Article 8 (*Misure per lo sviluppo della filiera relativa agli impianti eolici galleggianti in mare*) of *DECRETO-LEGGE 9 dicembre 2023, n. 181 (LEGGE 2 febbraio 2024, n. 11*)

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duration can provide revenue certainty, making offshore wind projects more attractive to investors.

Access to Project Finance: Offshore wind projects require significant upfront capital investment. Access to project finance through banks, development banks, export credit agencies, and other financial institutions is essential to fund construction and operational costs. Project finance structures, where the project's cash flows and assets secure the debt, can help mitigate risks for lenders and attract investment.

Risk Mitigation Instruments: Financial instruments such as guarantees, insurance products, and hedging mechanisms can help mitigate various risks associated with offshore wind projects, including construction delays, technology risks, regulatory risks, and revenue fluctuations. These instruments provide additional security for investors and lenders, enabling them to participate in offshore wind financing.

Green Finance and Sustainable Investing: The growing demand for green finance and sustainable investing offers opportunities for offshore wind developers to access capital from investors seeking environmentally friendly investment opportunities. Green bonds, green loans, and other sustainable finance instruments can provide funding for offshore wind projects while meeting investors' environmental and social criteria.

Public-Private Partnerships (PPPs) and Joint Ventures: Collaborative arrangements between public and private entities, such as PPPs and joint ventures, can help share risks and resources, leverage expertise, and mobilize investment capital for offshore wind development. Public sector involvement can provide regulatory support, access to public lands and infrastructure, and funding through co-investment or guarantees.

Technology Innovation and Cost Reduction: Continued advancements in offshore wind technology, including larger turbines, improved installation techniques, and innovative foundation designs, can reduce project costs and increase energy output, making offshore wind investments more financially attractive. Investors may be more willing to participate in projects with proven and cost-effective technologies.

5.3.3 Funding sources

5.3.3.1 EU funding sources

LIFE-Clean Energy Transition sub-programme: The LIFE-Clean Energy Transition sub-programme[39] aims at facilitating the transition towards an energy-efficient, renewable energy-based, climate-neutral and resilient economy by funding coordination and supporting actions across Europe. Its objective is to break market barriers that hamper the socio-economic transition to sustainable energy by engaging multiple small and medium-size stakeholders, actors including local and regional public authorities, non-profit organizations and consumers. It is one of the 3 sub-programmes of the LIFE Programme for environment and climate action. Under certain conditions, it can be combined with other EU instruments such as EU Innovation Council, Horizon Europe and European Maritime, Fisheries and Aquaculture Fund. Budget and type: €527 million for 2021-2024.

European Maritime Fisheries and Aquaculture Fund: The European Maritime Fisheries and Aquaculture Fund[40] (EMFAF) runs from 2021 to 2027 and supports the EU common fisheries policy[41], the EU maritime policy and the EU agenda for international ocean governance. It provides support to develop innovative projects ensuring that aquatic and maritime resources are used sustainably. Budget and type: Grants and loans with a total budget under direct management of €797 million in 2021-2027. The EMFAF may provide funding in any of the forms laid down in the Financial Regulation ((EU) 2021/1139), in particular procurement and grants. It may also provide financing in the form of financial instruments within blending operations.

Blue Invest[42] provides customized coaching for entrepreneurs whose business skills might not always match their technical skills. It helps SMEs and start-ups in accessing private capital to finance their innovations. BlueInvest I operated between 2019 and 2022, and BlueInvest II started in April 2022 and will be operated for another 4 years.

- **grants and loans for technical assistance (under EMFAF): €6 million (2022-2026)**
- **BlueInvest Fund (2020-2026):** €75 million (European Fund for Strategic Investments plus European Investment Fund Own Resources).
- **Combination possibilities with other EU instruments:** EIC and InvestEU. They can include calls tailored to smaller projects that cannot access Horizon Europe

[39] https://cinea.ec.europa.eu/programmes/life/clean-energy-transition_en

[40] https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en

[41] https://oceans-and-fisheries.ec.europa.eu/policy/common-fisheries-policy-cfp_en

[42] https://maritime-forum.ec.europa.eu/en/frontpage/1451

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Innovation Fund: The Innovation Fund[43] (IF) is designed to scale up innovative cleantech and to finance the demonstration of first-of-a-kind highly innovative projects. Budget and type: Grants, circa €38 billion, 2020-2030 (at €75 carbon price, total budget depends on revenues from the EU Emissions Trading System - with higher EUA prices, the budget increases) Upcoming calls: Large-scale call (total capital costs above €7.5 million) in autumn 2022 Combination possibilities with other EU funding instruments: InnovFin Energy Demo Projects, Connecting Europe Facility, Horizon Europe, InvestEU, Modernisation Fund, Just Transition Fund, Enhanced European Innovation Council (EIC) pilot.

Cohesion policy funds: The cohesion funds include the European Regional Development Fund (ERDF), the Cohesion Fund and the Just Transition Fund (JTF). Budget and type: Grants, loans, equity, financial instruments. There is no dedicated budget pre-identified for offshore renewables (as for other sectors) within the ERDF, the Cohesion Fund and JTF. The final allocation to offshore renewables is the result of the discussions between the Commission and the EU countries/regions on the selection of priorities in each programme. Combination with other EU instruments: any other EU funding instrument, considering the applicable regulations of cohesion policy funds and the other funding instruments. The projects are selected and implemented by the managing authorities (such as ministries) in the EU countries and regions, based on the priorities identified in the relevant 2021-27 programmes.

*Connecting Europe Facility - Energy***:** CEF Energy supports sustainable energy infrastructure projects. Budget and type: €5.83 billion in grants for the period 2021-2027. Up to 15%, subject to market uptake, should be allocated to cross-border projects in the field of renewable energy. Co-funding rate: 50%. Combination with other EU instruments: CEF Projects of Common Interests (PCIs): Recovery and Resilience Fund, InvestEU, CEF Transport and CEF Digital. CEF cross-border renewables: Renewable Energy Financing Mechanism, Cohesion policy funds.

InvestEU fund: The InvestEU Fund is the centerpiece of the InvestEU Programme, comprising 3 components: the InvestEU Fund, the InvestEU Advisory Hub for technical assistance and the InvestEU Portal database for projects. Budget and type: €26.2 billion in the form of an EU Budgetary Guarantee (2021-2027) for the InvestEU Fund (EU Compartment), supporting equity or loan finance Calls: The 2nd call for expression of interest to select Implementing Partners (other than the EIBG) is foreseen in 2023.

*Modernisation Fund***:** The Modernization Fund[44] (MF) is a dedicated funding programme to support 10 lower-income EU countries (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia) in their transition to climate neutrality by

[43] https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund_en

[44] https://climate.ec.europa.eu/eu-action/funding-climate-action/modernisation-fund_en

helping them to modernize their energy systems and improve energy efficiency. Budget and type: circa €48 billion for 2021-2030 (at €75 carbon price, total budget depends on evolution of the carbon price as the Fund is financed through revenues from the EU Emissions Trading System - with higher carbon price, the budget increases). The type of financing is decided by EU countries: either grants, premium, guarantee instruments, loans or capital injections (to be specified in the investment proposals that EU countries submit to the EIB and the Commission) Combination with other EU instruments: Cohesion policy funds including Just Transition Fund and Recovery and Resilience Fund. Governments can use the MF to fund either schemes or single projects. No calls at EU level, but bi-annual investment cycles. Investment proposals are submitted to the EIB by EU countries. Calls may be organized at national level.

5.3.3.2 Government funding sources

CfD under the FER 2 decree[45] is a subsidy which aims to support the development of offshore wind in Italy. It was first circulated in March 2022 and is expected to be approved soon. Here are some key points about the FER 2 decree:

It will subsidise up to 3.5 GW of floating offshore wind capacity, to be installed by 2030, through a competitive auction process. **The subsidies will be awarded as 20-year contracts-for-difference**, which guarantee a fixed premium tariff for the electricity generated by the projects.

The first auction will have a price cap of 165 EUR/MWh, according to the draft. The subsequent auctions will have lower price caps, depending on the market conditions and the technological progress. Further improvements of the decree draft indicate a price cap of 185 EUR/MWh, and an expected adequacy to the inflation rate.

Introduce a simplified permitting procedure and a single point of contact for project developers, to reduce the administrative barriers and the uncertainty that currently hamper the offshore wind sector in Italy.

The decree will cover both floating and fixed-bottom offshore wind projects, unlike FER 1 that only included floating wind support. However, fixed-bottom projects may face more challenges in finding suitable sites and obtaining environmental approvals.

Italian renewable auction (Procedure d'Asta) organized by Gestore Servizi Energetici (GSE)[46]*:* Italy has launched a series of renewable energy auctions for projects above 1 MW in size, as part of its plan to achieve the green and digital transitions and meet its climate targets. The

[45] https://auroraer.com/media/upcoming-subsidies-key-to-unlocking-italian-offshore-wind-potential/
[46] https://www.gse.it/

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auctions are based on a competitive bidding process, where project developers offer discounts from a ceiling price of €0.065/kWh for the electricity generated by their projects. The lowest bids are awarded contracts for difference (CfD), which guarantee a fixed premium tariff for 20 years. The auctions are held every four months. The total capacity to be contracted is approximately 4.8 GW of renewable energy, of which 1.4 GW is reserved for offshore wind. In 2023, Italy has added around 0.5 GW of new wind capacity across various regions[47].

The average bid prices in the *Procedure d'Asta auction* have ranged from €0.062/kWh to €0.065/kWh for onshore wind farms. The auctions have attracted the participation of both well-known power suppliers and new entrants, such as special purpose vehicles and cooperatives. Some of the successful bidders include Acea, Edison, Enel Green Power, ERG, Falck Renewables, Lightsource BP, and Terna.

5.3.4 Effectiveness of public and stakeholder support

Project acceptance and permitting: Public consultation is run throughout different stages of offshore renewable energy projects' permitting in Portugal. Early engagement of stakeholders and the wider public to mitigate potential future conflicts is critical. Sensitive communities, such as fishing communities, need to be adequately informed and their concerns heard to facilitate a smoother process.

Financing and investment confidence: Public and stakeholder support fosters trust and helps address concerns and potential conflicts, reducing regulatory and financial risks. Demonstrating a commitment to environmental sustainability and local economic development through transparent communication and meaningful engagement can attract investors who prioritize responsible and socially conscious investments. Strong public and stakeholder support signals regulatory stability, enhancing overall attractiveness of offshore wind projects to financiers and investors.

Risk mitigation: Allows for the identification and understanding of potential risks related to environmental impacts, social concerns, and regulatory challenges. By addressing these concerns transparently and collaboratively, developers can minimize opposition and mitigate risks associated with permitting delays, legal disputes, and reputational damage.

Economic benefits for local communities: By involving local stakeholders in project planning and decision-making processes, developers can ensure that community interests are considered

[47] https://iea.blob.core.windows.net/assets/71b328b3-3e5b-4c04-8a22-3ead575b3a9a/Italy_2023_EnergyPolicyReview.pdf

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and integrated into project designs, leading to opportunities for local employment, skills development, and business contracts.

Social license to operate: Helps developers build trust, address concerns, and demonstrate their commitment to responsible and sustainable practices. Equally to ensure that the interests and values of affected communities are taken into account, fostering acceptance and support for projects. Social license to operate is crucial for navigating regulatory processes and mitigating opposition.

Long term project viability: Engagement helps build trust, foster collaboration, and address issues that could impact project feasibility and sustainability over time. Strong public backing and positive stakeholder relationships enhance project resilience against regulatory uncertainties, market fluctuations, and changing socio-political dynamics, thus ensuring continued success and operational longevity.

5.4 Greece

5.4.1 Financial barriers

Currently, Greece has no experience on offshore wind farm technologies. However, several barriers can be identified to the floating offshore wind sector, retrieved mainly from the respective barriers drawn from the onshore wind farms. In addition, following also the experience obtained from the other MARINEWIND countries, we provide a list of possible barriers to investing in FOWT in Greece.

Regulatory and permitting challenges: Obtaining necessary permits and adhering to regulations can be complex and time-consuming, involving multiple governmental agencies at various levels.

Political instability: Changes in government policies or regulations can create uncertainty for investors, impacting project viability and returns.

Financing difficulties: Securing financing for large-scale offshore wind projects can be challenging due to their high upfront costs, long payback periods, and perceived risks.

Grid connection constraints: Connecting offshore wind farms to the grid may require significant infrastructure investments and coordination with grid operators, which could pose technical and logistical challenges. In addition, the island cluster of Greece with significant seasonal variations in energy consumption as well as the limited interconnections of the Greek islands with the mainland electricity system, will require severe additional financial resources.

Environmental concerns: Offshore wind projects may face opposition from environmental groups or local communities concerned about impacts on marine ecosystems, wildlife, and coastal landscapes.

Lack of infrastructure: Developing floating offshore wind farms requires adequate port facilities, supply chains, and support vessels, which may be lacking or underdeveloped in certain regions.

Technological limitations: Floating offshore wind technology is still relatively new and evolving, with uncertainties regarding performance, reliability, and cost-effectiveness compared to traditional fixed-bottom systems.

Competition with other energy sources: Floating offshore wind projects may face competition from other renewable energy sources or conventional fossil fuels, depending on market dynamics and government policies.

Market and regulatory uncertainties: Fluctuations in energy prices, changes in subsidy schemes, and evolving market dynamics can create uncertainties for investors, affecting project economics and returns.

Stakeholder engagement and community acceptance: Building consensus among stakeholders, including local communities, fishermen, and tourism operators, is essential for successful project development but can be challenging to achieve.

5.4.2 Financial enablers

Financial Incentives and Subsidies: Greek government can offer financial incentives to reduce the upfront costs and risks associated with FOWTs projects. These incentives may include investment tax credits, production tax credits or feed-in tariffs. By providing financial support, private investments could be attracted, accelerating the deployment of FOWT infrastructure.

Infrastructure Investment: Developing FOWT projects requires significant investments in infrastructure, including ports, harbors, manufacturing facilities, and transmission infrastructure. The Greek government can support infrastructure development by providing funding and streamlining permitting processes. Investing in infrastructure not only facilitates the deployment of FOWT but also stimulates economic growth, job creation, and industrial development in coastal regions. Financial incentives and infrastructure investments can enhance the competitiveness of FOWT relative to other energy sources, making them more attractive to investors and buyers in international markets. Furthermore, investments in infrastructure can significantly improve the infrastructure efficiency of FOWTs, reducing the energy production costs, thus resulting in greater international market share.

Market Mechanisms and Policy Support: Greek government can implement market mechanisms and policy frameworks to create a conducive environment for investment in FOWTs. This includes setting renewable energy targets, establishing long-term procurement mechanisms, and implementing regulatory reforms to streamline project approval processes. Clear and stable policy frameworks reduce investment risks, attract capital, and enhance the overall business prospects of FOWTs. Implementing the above initiatives, competitive FOWT infrastructures can be developed, claiming larger national and international market share among the RES and fossil fuels.

Social license to operate: Onshore wind farm projects in Greece often face opposition from local communities due to concerns about visual impact, noise, and environmental effects. This will most probably apply also to FOWTs development, especially in regions close to touristic areas. Effective community engagement can address these concerns, build trust, and obtain a "social license to operate," which is essential for securing financing.

Long term project viability: Public and stakeholder support can play a vital role in the success of FOWT development and the viability of the project in the long-term perspective. To begin with, engaging stakeholders ensures that their concerns are considered in the implementation of the project. Furthermore, local stakeholders often possess valuable knowledge of their environment, including factors such as weather patterns, marine life, and navigation routes. Collaborating with stakeholders and local communities allows developers to leverage this local knowledge, improving operational efficiency. Furthermore, stakeholder and community engagement initiatives can raise public awareness about the benefits of FOWTs fostering a sense of ownership and encouraging long-term support.

5.4.3 Funding sources

In Greece, the projected offshore wind farm projects can potentially access various funding sources to support their development. Some of these funding sources include:

European Union (EU) funds: Greece has access to various EU funding programs aimed at supporting renewable energy projects, including offshore wind. For example, the European

Regional Development Fund (ERDF), the Cohesion Fund, and the Connecting Europe Facility (CEF) provide financial support for infrastructure development, including offshore wind projects. In addition, Greece has proposed to the EC and the European Investment Bank (IEB) to provide capital from the Fund as investment aid (CAPEC) to the pilot floating offshore wind portfolio in Greece.

National funding programs: The Greek government may offer specific incentives, grants, or financing mechanisms to promote renewable energy projects, including offshore wind farms. These programs could include feed-in tariffs, renewable energy certificates (RECs), tax incentives, or direct subsidies. In addition, the Greek Ministry is currently considering the creation of a “special category” in the new development law for the financial support of industrial activities related to offshore wind projects.

Multilateral development banks (MDBs): Organizations such as the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD) provide financing and technical assistance for renewable energy projects in Greece. These institutions may offer loans, equity investments, or guarantees to support offshore wind farm development.

Private investors and financial institutions: Private equity firms, venture capital funds, and institutional investors may provide capital for offshore wind projects in Greece. This could involve equity investments, project financing, or debt financing arrangements.

Green bonds and climate funds: Offshore wind developers in Greece may access funding through green bonds issued by public or private entities. Additionally, climate funds, such as the Green Climate Fund (GCF) or the Climate Investment Funds (CIFs), may provide concessional financing or grants to support renewable energy projects in developing countries, including Greece.

Public-private partnerships (PPPs): Collaboration between public and private entities can leverage both public funding and private investment to develop offshore wind projects. PPPs may involve joint ventures, co-development agreements, or concession arrangements between government agencies and private developers.

Carbon markets and carbon finance: Offshore wind projects in Greece could potentially generate revenue through carbon credits or offsets under international carbon markets or mechanisms such as the Clean Development Mechanism (CDM) or the Kyoto Protocol's Joint

Implementation (JI). These mechanisms provide financial incentives for reducing greenhouse gas emissions and promoting renewable energy projects.

By leveraging a combination of these funding sources and financial instruments, offshore wind developers in Greece can access the capital needed to finance the development, construction, and operation of their projects. Additionally, establishing a supportive regulatory framework and mitigating investment risks can help attract investment and accelerate the deployment of offshore wind energy in Greece.

5.4.4 Effectiveness of public and stakeholder support

Project acceptance and permitting: Considering the onshore wind projects in Greece, there are several cases where local communities opposed the development of such projects. To this end, the positive public support as well as the affected community's engagement in the development of FOWTs can mitigate opposition and streamline the regulatory process, enhancing investor confidence by reducing uncertainty and delays.

Risk mitigation: FOWTs require high investments for their development and installation, while the return rate is quite low, resulting in the investment paying off after many years of operation. This is not always sustainable and viable for the investors. Engaging the community in such investments may result in mitigating the investment risks because of sharing the overall risk among more stakeholders. Furthermore, public and stakeholder support can help identify and mitigate project risks. By involving communities early in the planning process, developers can address potential issues such as fishing conflicts, navigational concerns, or impacts on tourism.

Economic benefits for local communities: It is crucial for regional and local stakeholders to support FOWTs investments as well as to be engaged in such projects because of several economic benefits. These kinds of projects can create and offer new jobs for local communities as well as infrastructure improvements. Furthermore, participating in these projects as an investor could bring revenue-sharing agreements and/or lower electricity bills both for the investors and the local community.

5.5 Spain

5.5.1 Financial barriers

Currently, Spain has limited experience in relation to technology demonstrator projects within marine energies and R&D platforms. However, several challenges hinder its advancement in this sector:

Lack of Funding: Despite Regulation RD 960/2020 acknowledging cost discrepancies among renewable energy technologies and allowing for bilateral Contracts for Difference (CFDs), it fails to adequately address the unique aspects of offshore wind, such as its lengthy lifecycle and the need for indexation.

Communication Gap: The absence of a comprehensive stakeholder engagement process involving developers, marine planners, and coastal communities impedes progress. While new regulations aim to address this, they only come into play after auction launch, potentially delaying projects.

High Levelised Cost of Energy (LCOE): Spain's electricity spot market prices, averaging around 50€/MWh with occasional dips to 0€/MWh, render selling energy to the pool unfeasible, contributing to high LCOE.

High Manufacturing Costs: Despite a robust Spanish supply chain for offshore wind, the persistently high costs remain a significant barrier.

High Operating and Maintenance Costs: The absence of operational projects and specific supply chains leads to a lack of cost-saving synergies, driving up expenses.

Floating Offshore Wind Technology (FOWT) Uncertainty: Limited commercial deployment of FOWT prototypes in Spain raises doubts about its viability.

Underdeveloped Supply Chain: While Spain possesses components of the offshore wind supply chain, it lacks the necessary elements to complete a FOWT.

Port and Installation Infrastructure Limitations: While Spain boasts several suitable ports for FOWT, their capacity may not suffice for concurrent project demands.

Lengthy Installation and Decommissioning: Insufficient supply chain and infrastructure exacerbate timelines for both installation and decommissioning processes.

Stakeholder Influence on Construction Timelines: Stakeholder actions can prolong FOWT construction, adding further delays.

Lack of Standardization: Absence of standardized practices, particularly in floating platforms, hinders port and shipyard infrastructure adaptation and increases costs.

Energy Price Fluctuations: Geopolitical and market dynamics instability creates investor uncertainty regarding energy prices.

Uncertain Taxation and Regulatory Frameworks: Ambiguity regarding taxes, charges, and fees during implementation further complicates the regulatory landscape.

Furthermore, recognition of the unique challenges posed by Floating Offshore Wind (FOW) technology is paramount, particularly in reimbursement models. Acknowledging its higher current costs and the uncertainties inherent in its lengthy timeline through tariff indexation or Contracts for Difference (CfD) is crucial. Establishing pre-commercial farms with support for capital expenditure (CAPEX) and tariff adjustments provides clarity and certainty for developers. Moreover, a transparent pipeline of auctions and target capacity in the mid and long term is essential for all stakeholders, from manufacturers to ports, to align their investments and adapt their facilities accordingly. Government grant programs to facilitate these adaptations further promote development.

Supply chain and infrastructure development represent the current bottleneck in the effective advancement of FOW technology. This scarcity may lead to the international development of projects, encompassing aspects such as wind turbine generator (WTG) supply, platform execution, and cable supply. The global expansion of facilities will not only bolster FOW technology's capacity targets but also contribute significantly to its international competitiveness.

Similar to the evolution of bottom-fixed offshore wind technology, increasing the number of executed projects and establishing a robust pipeline are necessary to mature FOW technology, thereby reducing its Levelized Cost of Energy (LCOE) and enhancing its competitiveness on the global stage.

5.5.2 Financial enablers

Grants and subsidies play a crucial role in fostering the development of Floating Offshore Wind Technology (FOWT). Specifically, providing support for technology development through grants is pivotal for stimulating the market.

Low-interest loans are instrumental in enabling viable business models and significantly impact project profitability.

Green bonds and climate funds are beneficial, they are considered optional rather than essential.

Infrastructure support and co-financing arrangements are vital components of the development process.

Feed-in Tariffs (FiTs) are paramount for ensuring the profitability of offshore wind developers and sustaining their investment interest. As floating offshore wind technology matures, similar to bottom-fixed installations in the past, FiTs facilitate market growth, cost reduction, and operational optimization.

The viability of Power Purchase Agreements (PPAs) varies depending on the country. In Spain, with a high volume of renewable projects supplying inexpensive electricity to the market, securing PPAs at profitable rates for floating offshore wind seems unlikely. However, PPAs could play a crucial role in countries where wholesale spot market prices are higher or have a less decarbonized renewable energy mix.

Investment in innovation and research and development (R&D) is fundamental for advancing the market towards more scalable solutions, driving down the Levelized Cost of Energy (LCOE), and enabling the commercialization of floating offshore wind farms.

Investment Tax Credits (ITCs) and Production Tax Credits (PTCs) can complement the profitability of floating offshore wind farms, they are not currently implemented in Spain.

Renewable Energy Certificates (RECs) and Guarantees of Origin (GOs) are not widely utilized in Spain.

5.5.3 Funding sources

IDAE (Instituto para la Diversificación y Ahorro de la Energía) launched a program to support technology development called *Renmarinas Demo*s in the context of the EU Next Generation program. *Renmarinas Demos* had a 200M€ budget to enhance the execution of floating technology demonstrator projects and marine energies R&D platform. In 2023, IDAE will be awarded 147M€ in grants to 21 initiatives.

5.5.4 Effectiveness of public and stakeholder support

Project Acceptance and Permitting: The effectiveness of public and stakeholder support significantly facilitates project acceptance and can expedite the permitting process, resulting in a highly effective approach.

Financing and Investment Confidence: While public and stakeholder support can alleviate some uncertainties, it does not address all concerns, leading to a medium level of effectiveness in bolstering financing and investment confidence.

Risk Mitigation: Public and stakeholder support can mitigate certain risks; however, it does not eradicate all uncertainties, leading to a medium level of effectiveness in risk mitigation efforts.

Economic Benefits for Local Communities: Public and stakeholder support directly influences the formulation of measures and agreements that deliver economic benefits to local municipalities, resulting in a highly effective outcome.

Social License to Operate: Public and stakeholder support plays a pivotal role in obtaining the social license to operate, making it highly effective in ensuring project success.

Long-Term Project Viability: While opposition to the project may hinder execution and operation, and government support for new technologies, the long-term viability of the project depends on various factors such as capital and operational expenditures, and regulatory frameworks resulting in a moderate level of effectiveness for public and stakeholder support in this regard.

5.6 Belgium

We are performing the financial analysis on all the MARINEWIND partner countries, even those, such as Belgium, where we don't have labs just yet.

5.6.1 Financial barriers

Lack of Funding: Insufficient funding can hinder the development and expansion of offshore wind farms, delaying projects or limiting their scale. Belgium has secured significant funding for its offshore wind projects through sources like the European Investment Bank (EIB), government subsidies, and private investments. Thus, lack of funding has not been a significant barrier to offshore wind farm development in Belgium.

Lack of Government Support for Floating Wind Farms: Without government support, particularly targeted policies and incentives for floating wind farms, developers may face challenges in securing financing and regulatory approvals. While Belgium has shown support for offshore wind energy, specific policies and incentives targeting floating wind farms may still be evolving. However, the Belgian government's commitment to renewable energy suggests potential future support for floating wind technology.

Lack of Communication between Developers, Marine Planners, and Coastal Communities: Poor communication can lead to conflicts over project siting, environmental impacts, and community engagement, potentially delaying or derailing projects. Effective communication and stakeholder engagement have been crucial for offshore wind projects in Belgium. Developers have engaged with marine planners and coastal communities to address concerns and ensure project acceptance, minimizing conflicts over project siting and environmental impacts.

High Levelised Cost of Energy (LCOE): High LCOE can make offshore wind projects less competitive compared to other energy sources, affecting their economic viability. Belgium's offshore wind industry has benefited from technological advancements and economies of scale, leading to reductions in the LCOE over time. Projects like Northwester 2 and Seastar demonstrate improved cost competitiveness, contributing to the growth of offshore wind capacity in Belgium.

High Manufacturing Costs: High manufacturing costs can increase project expenses, impacting the overall economics of offshore wind development. Belgium benefits from a mature offshore wind supply chain within Europe, which helps mitigate the impact of high manufacturing costs. Access to European manufacturers and service providers supports efficient project development and construction, minimising manufacturing-related barriers.

High Operating and Maintenance Costs: High operating and maintenance costs can erode project profitability over time, necessitating efficient O&M strategies. Offshore wind farms in Belgium have implemented advanced maintenance strategies to optimise O&M costs. For example, predictive maintenance techniques used by projects like Norther and Rentel help minimise downtime and maximise energy production, ensuring cost-effective operations.

Current Status of Floating Offshore Wind Technology (FOWT): The nascent stage of floating offshore wind technology may pose technical and commercial uncertainties, deterring investment and project development. Belgium has not yet operationalized floating offshore wind farms, but ongoing research and pilot projects indicate interest in advancing FOWT. While the current status of FOWT may pose uncertainties, Belgium's commitment to offshore wind energy suggests potential future developments in floating wind technology.

Not a Well-Developed Supply Chain: A lack of a well-developed supply chain can lead to delays, cost overruns, and quality issues in project development and construction. Belgium benefits from a well-established offshore wind supply chain within Europe, providing access to manufacturers, service providers, and expertise for project execution. This well-developed supply chain supports efficient project development and construction, minimizing supply chain-related barriers.

Availability of Ports and Installation Infrastructures: Limited availability of suitable ports and installation infrastructure can increase logistics costs and project complexities. Belgium's proximity to major ports like Ostend and Zeebrugge facilitates offshore wind project development by providing access to installation facilities, maintenance services, and vessel support. Availability of ports and infrastructure supports efficient project execution, minimizing logistical barriers.

Long Installation and Decommissioning Time: Lengthy installation and decommissioning processes can extend project timelines and increase project risks. Offshore wind projects in Belgium have implemented efficient installation and decommissioning strategies to minimize project duration and associated costs. Projects like Norther and Rentel were completed within relatively short timeframes, mitigating installation and decommissioning-related barriers.

Negative Impact of Stakeholders on the Timeline of the FOWT Construction Period: Stakeholder opposition or regulatory challenges can lead to delays and uncertainties in floating offshore wind farm construction. Effective stakeholder engagement and regulatory compliance have been critical for offshore wind projects in Belgium, ensuring project timelines are not significantly impacted by stakeholders. Developers have engaged with stakeholders to address concerns and maintain project momentum.

Lack of Standardization for FOWT: The absence of standardized designs and regulations for floating offshore wind technology can increase project development costs and complexity. While standardization efforts for floating offshore wind technology may still be evolving, Belgium's involvement in collaborative research initiatives and industry partnerships suggests progress toward establishing standards and best practices for FOWT.

Fluctuation in Energy Prices and Market Dynamics: Uncertainty in energy prices and market dynamics can affect project revenues and financing arrangements, impacting project feasibility. Long-term power purchase agreements (PPAs) and government support mechanisms like feed-in tariffs provide stability for offshore wind projects in Belgium, mitigating the impact of energy price fluctuations and market dynamics on project revenues and financing arrangements.

High Taxes, Charges, or Fees during the Implementation Phase: High taxes, charges, or fees imposed during project implementation can increase project costs and reduce investor returns. Belgium's regulatory framework for offshore wind projects includes tax incentives and support mechanisms to encourage investment and project development. While taxes, charges, or fees may exist, supportive policies help minimize their impact during the implementation phase.

Overall, while each of these factors presents challenges to offshore wind farm development in Belgium, effective project management, stakeholder engagement, technological advancements, and supportive policies have helped overcome many of these barriers, enabling the successful deployment of offshore wind capacity in the North Sea.

5.6.2 Financial enablers

Grants and subsidies: These are direct financial assistance provided by governments or relevant authorities to reduce the upfront costs of developing offshore wind farms. In Belgium, grants and subsidies have been instrumental in kickstarting various offshore wind projects. For example, the Rentel offshore wind farm received subsidies from the Belgian government to support its construction and operational phases.

Low interest loans: Financial institutions or governmental bodies may offer low-interest loans to offshore wind developers, enabling them to access affordable capital for project development. These loans help to alleviate the financial burden associated with offshore wind farm construction. An example is the provision of low-interest loans by banks or investment funds to projects like Northwester 2, aiding in its development and construction phases.

Green bonds and climate funds: Green bonds are debt instruments specifically earmarked for financing environmentally friendly projects such as offshore wind farms. Climate funds pool resources from various investors with an environmental focus to support renewable energy initiatives. Parkwind NV, for instance, utilized green bonds to raise capital for its offshore wind projects in Belgium, demonstrating the effectiveness of this financing mechanism.

Infrastructure support and co-financing: Governments and international organizations may provide financial support or co-financing for critical infrastructure associated with offshore wind farms, such as transmission lines or port facilities. This support reduces the financial burden on developers and makes projects more attractive to investors. The European Investment Bank's co-financing of the Seamade offshore wind project in Belgium is a prime example of this collaboration.

Feed-in Tariffs (FiTs): FiTs guarantee a fixed price for electricity generated by renewable energy sources, ensuring a stable revenue stream for offshore wind farm developers. In Belgium, the implementation of FiT schemes has been pivotal in attracting investment to projects like C-Power, providing investors with revenue certainty and incentivizing project development.

Power Purchase Agreements (PPAs): PPAs involve long-term contracts between offshore wind farm developers and energy suppliers, guaranteeing the sale of electricity at predetermined prices. These agreements provide revenue certainty for developers and attract investment by mitigating market risks. Norther NV's PPA agreements with energy suppliers for the Norther offshore wind project exemplify this mechanism.

Innovation and R&D funding: Investment in research and development fosters technological innovation in offshore wind energy, leading to cost reductions and efficiency improvements. Governments often allocate funds for R&D initiatives, benefiting projects like the Mermaid offshore wind farm in Belgium, which have leveraged innovative technologies.

Investment tax credits (ITCs): ITCs provide tax incentives to investors in offshore wind projects, reducing their tax liability and making investments more attractive. Investors in the Seamade offshore wind project in Belgium can benefit from such tax credits, stimulating investment in the sector.

Production tax credits (PTCs): While not commonly utilized in Belgium, PTCs provide tax incentives based on the electricity production of offshore wind farms, further incentivizing investment. This mechanism is more prevalent in countries like the United States, where it encourages the growth of renewable energy.

Renewable energy certificates (RECs) and guarantees of origins (GOs): RECs and GOs certify the renewable attributes of electricity generated by offshore wind farms, enhancing their market value. Issuance of GOs for electricity produced by projects like Northwester 2 in Belgium provides transparency and credibility, attracting investors seeking sustainable investments.

Other: Additional factors such as collaboration with local communities, streamlined permitting processes, and regulatory stability also play crucial roles in encouraging investments in offshore wind farms. Community engagement and favorable regulatory environments create a conducive atmosphere for investment, fostering sustainable development in the offshore wind sector.

5.6.3 Funding sources

5.6.3.1 EU funding

EIB (European Investment Bank) ERDF (European Regional Development Fund)[48][49]: The EIB offers funding for sustainable energy projects, including offshore wind. This funding can

[48] https://www.eib.org/en/index

[49] https://ukandeu.ac.uk/explainers/the-european-investment-bank/

provide significant capital for project development and implementation, potentially making it a valuable source for floating offshore wind projects in Belgium.

European Regional Development Fund (ERDF):[50] The ERDF supports regional development initiatives, including renewable energy projects. Offshore wind farm developments in Belgium may have received ERDF funding to promote economic growth and sustainable energy production in coastal regions.

European Investment Fund (EIF)[51][52]: The EIF provides venture capital and guarantees to support investment in innovative and sustainable projects. While primarily focused on small and medium-sized enterprises (SMEs), the EIF can indirectly support offshore wind farm projects through its financing activities.

European Bank for Reconstruction and Development (EBRD):[53] The EBRD provides financing and expertise for projects in countries transitioning to market economies, including renewable energy initiatives. While Belgium is not within the EBRD's traditional geographic focus, it may participate in co-financing arrangements for offshore wind projects in neighboring regions.

European Maritime and Fisheries Fund (EMFF): The EMFF supports initiatives related to fisheries, aquaculture, and maritime affairs. While not specifically geared towards offshore wind energy, the EMFF may provide funding for projects that promote sustainable marine resource management, including those with synergies with offshore wind farms.

European Energy Programme for Recovery (EEPR): The EEPR aims to stimulate investments in energy infrastructure and promote renewable energy deployment. Belgium may have accessed EEPR funding to support the development of offshore wind projects and associated infrastructure.

InnovFin Energy Demonstration Projects: InnovFin, part of the EU's Horizon 2020 program, provides financing and advisory services to support innovative energy projects. Offshore wind

[50]https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-regional-development-fund-erdf_en
[51]https://economy-finance.ec.europa.eu/investment-support/coordination-european-financial-institutions/coordination-european-investment-fund_en
[52] https://www.eif.org/index
[53] https://www.ebrd.com/home

farms in Belgium with novel technologies or demonstration components may be eligible for InnovFin funding.

5.6.3.2 Government support

Feed-in Tariffs: Offering feed-in tariffs can incentivize investment in floating offshore wind projects by providing a guaranteed price for the electricity generated. However, the effectiveness of feed-in tariffs depends on their level and duration.
Renewable Energy Subsidies: Subsidies for renewable energy can reduce the financial risks associated with floating offshore wind projects, making them more attractive to investors. Belgium's government support in this aspect can significantly influence project viability.

Investment Tax Credits: Tax credits can lower the overall cost of investment in floating offshore wind projects, making them more financially feasible for developers. These incentives encourage private investment in renewable energy projects.

Grants: Direct grants from the government can provide upfront capital for project development and implementation, reducing the financial burden on developers and investors. Grants can be particularly effective in the early stages of project development. *Example*: Belgium's government could offer feed-in tariffs and renewable energy subsidies to support floating offshore wind projects. The experience of the Norther offshore wind farm in Belgium demonstrates how government support plays a crucial role. Norther received subsidies and feed-in tariffs under Belgium's renewable energy support scheme, which helped attract investment and secure project financing. Rentel Offshore Wind Farm: situated off the Belgian coast near Ostend, benefits from feed-in tariffs provided by the Belgian government. These tariffs ensure a stable revenue stream for the project by guaranteeing a fixed price for the electricity generated.

Renewable Energy Subsidies: Rentel also receives subsidies as part of Belgium's renewable energy support scheme. These subsidies help offset the costs of renewable energy generation and support the economic viability of the project. Norther Offshore Wind Farm: Norther, located in the Belgian North Sea, benefits from feed-in tariffs under Belgium's renewable energy support mechanism. These tariffs provide a guaranteed price for the electricity generated, reducing the project's financial risks and attracting investors.

Investment Tax Credits: While specific tax credits for Norther may not be publicly disclosed, Belgium offers investment incentives and tax breaks for renewable energy projects, which could have supported the development of the Norther offshore wind farm

5.6.3.3 Institutional funding sources

Construction and Term Loans: Financial institutions may offer construction and term loans specifically tailored for offshore wind projects. These loans provide the necessary capital for project development and construction, with repayment terms structured to align with the project's cash flow. **Northwester 2 Offshore Wind Farm:** Northwester 2 secured project financing from a consortium of financial institutions, including BNP Paribas and Natixis. These institutions provided construction and term loans tailored for offshore wind projects, enabling the project's development and construction.

Green Bonds: Issuing green bonds can attract investment from institutional investors interested in sustainable projects. Floating offshore wind projects can use proceeds from green bonds to finance development and construction while appealing to socially responsible investors. Financial institutions like BNP Paribas and Natixis provided project financing for the Northwester 2 offshore wind farm in Belgium. Although not specifically a floating offshore wind project, Northwestern 2's financing structure can serve as a reference for future projects. The financing package included construction and term loans tailored for offshore wind projects, demonstrating how financial institutions can support such ventures. **Seastar Offshore Wind Farm**[54]: Seastar, located in the Belgian North Sea, issued green bonds to finance its development and construction. These bonds attracted investment from institutional investors interested in sustainable projects, providing capital for the project while aligning with environmental objectives.

Other Financial Instruments: Financial institutions may offer a range of financial instruments such as project finance, mezzanine financing, or revenue-based financing to support floating offshore wind projects. These instruments can help mitigate risks and attract investment from various sources.

Overall, a combination of EU funding, government support, and financing from financial institutions can effectively fund floating offshore wind projects in Belgium. Each funding source has its advantages and limitations, and leveraging multiple sources can enhance project viability and attract investment.

Below we provide a list of successful projects funded by Belgium:

[54] https://www.oceanenergy-europe.eu/industry-news/nova-consortium-wins-e20m-eu-project-to-install-16-tidal-turbines-in-orkne

Belwind Offshore Wind Farm:[55][56]

Location: Situated off the coast of Zeebrugge.

Capacity: Belwind has a total installed capacity of 165 megawatts (MW).

Funding: The project received financing from the European Investment Bank (EIB) in the form of a loan. While specific details about EU grants are not readily available, it's possible that indirect support from programs like the European Regional Development Fund (ERDF) and Horizon 2020 contributed to the project's development and construction.

Northwester 2 Offshore Wind Farm:[57]

Location: Located in the North Sea off the coast of Ostend.

Capacity: Northwester 2 has a total installed capacity of 219 MW.

Funding: Northwester 2 secured financing from the European Investment Bank (EIB) through a loan. Additionally, the project may have benefited from EU grants indirectly, possibly through programs like the Connecting Europe Facility (CEF) for offshore grid infrastructure development.

Rentel Offshore Wind Farm:[58][59]

Location: Positioned off the Belgian coast near Ostend.

Capacity: Rentel has a total installed capacity of 309 MW.

Funding: Rentel benefits from Belgian government support in the form of feed-in tariffs and renewable energy subsidies. These mechanisms provide stable revenue streams and financial incentives for renewable energy projects.

Norther Offshore Wind Farm:[60]

Location: Situated in the Belgian North Sea.

Capacity: Norther has a total installed capacity of 370 MW.

Funding: Norther receives support from the Belgian government through feed-in tariffs and potentially investment tax credits. Additionally, the project secured financing from financial institutions such as BNP Paribas and Natixis, which provided construction and term loans tailored for offshore wind projects.

[55] https://www.belgianoffshoreplatform.be/en/projects/belwind/

[56] https://www.eib.org/attachments/documents/climate_action_case_study_belgium_en.pdf

[57] https://parkwind.eu/news/financial-close-signals-start-of-construction-of-219-mw-northwester-2-offshore-wind-farm

[58] https://www.belgianoffshoreplatform.be/en/projects/rentel/

[59] https://deme-group.uk/projects/rentel-offshore-wind-farm

[60] https://maritime-spatial-planning.ec.europa.eu/case-studies/navigating-around-norther-offshore-wind-farm

Co-funded by the European Union

Seastar Offshore Wind Farm:[61]

Location: Located in the Belgian North Sea.

Capacity: Seastar has a total installed capacity of 252 MW.

Funding: Seastar utilized green bonds as a funding mechanism to attract investment from institutional investors interested in sustainable projects. Green bonds provide capital for the project while aligning with environmental objectives.

These offshore wind farms demonstrate Belgium's commitment to renewable energy and its efforts to diversify its energy mix with clean and sustainable sources. They have been successful in leveraging various funding sources, including government support and financial instruments, to develop and operate significant offshore wind capacity in the North Sea.

6. FINANCE ENABLER AT EUROPEAN LEVEL: WIND ENERGY ACTION PLAN BY EU COMMISION

6.1 Wind Energy Action Plan by EU Commission on access to Finance

The inflationary environment, coupled with increases in raw material prices, rising interest rates, and the frequent requirement for upfront guarantees to secure contracts, has adversely affected the wind sector's access to financing for both manufacturing and deployment. Despite these challenges, the wind industry aims to secure approximately EUR 6 billion in investments for manufacturing capacity to meet the NZIA targets. The Commission, operating within the Capital Markets Union and the EU framework for sustainable finance, has established capital market rules that appeal to long-term investors. Additionally, measures have been implemented to encourage private finance towards environmentally sustainable activities in alignment with the goals of the European Green Deal. Recognizing the pivotal role of private investment in achieving the action plan's ambitions, the Commission is committed to taking action in collaboration with the mobilization of EU and other public investment sources.

6.1.1 Action 7: Commission to facilitate access to EU financing

The Commission is set to enhance support for wind energy manufacturing through the Innovation Fund, specifically by doubling the budget for financing clean technology manufacturing projects to EUR 1.4 billion. This includes projects related to the manufacturing of wind turbines and their components, with the next call for proposals scheduled for November 23, 2023. The Innovation Fund, with a total allocation of EUR 40 billion for the period 2020-2030, will see an increase in its overall budget to EUR 4 billion this year. In addition to the dedicated clean tech manufacturing topic, innovative wind energy production

[61] https://www.eib.org/en/press/all/2018-317-investment-plan-for-europe-eur250-million-eu-financing-for-seamade-offshore-wind-farm-in-belgium

and pilot projects will also be eligible under other topics in the upcoming call for proposals on November 23, 2023. Wind energy projects will be given priority on an equal merit basis during this call. To bolster project development and ensure the creation of a robust pipeline for innovative projects, wind energy projects will receive priority for the EUR 90 million of Innovation Fund project development assistance. This assistance will be provided in collaboration with the European Investment Bank over the next three years. Project developers can also avail tailored advisory support from the InvestEU Advisory Hub. Furthermore, a combination of funding from the Innovation Fund and financing provided by the EIB, along with other international financial institutions and national promotional banks and institutions (including under the InvestEU program), can also support awarded projects in reaching a final investment decision. Before the conclusion of this year, the Commission plans to reinforce activities related to wind energy within the revised Strategic Energy Technology Plan (SET Plan). This includes heightened support for research and innovation in the wind manufacturing sector, ensuring that pertinent European technologies maintain their competitive advantage. Emphasis will be placed on circularity and sustainability, enhancing industrial processes, and embracing digitalization. The SET Plan will create fresh opportunities for supporting investments aimed at scaling up the EU's manufacturing of clean technologies, with a specific focus on wind power. This will hold potential benefits for transition and less developed regions, as well as developed regions in Member States with a GDP/capita below the EU average. These regions stand to gain from financial incentives and increased flexibility in utilizing allocations from the Cohesion Fund, European Regional Development Fund, and Just Transition Fund. This support is intended for facilitating productive investments in large companies operating in strategic sectors that contribute to the objectives of the SET Plan.

6.1.2 Action 8: EIB to Provide de-risking tools and guarantees for EU wind companies

In July 2023, the European Investment Bank (EIB) gave the green light to its second REPowerEU package, expressing its aspiration to nearly double its lending contributions to the Green Deal Industrial Plan and the NZIA. The goal is to mobilize approximately EUR 150 billion cumulatively over the next five years, with the InvestEU guarantee mechanism playing a significant role in this plan. A key focus of this initiative is on European manufacturers of strategic net-zero technologies, associated upstream components, and essential raw materials, particularly in the onshore and offshore wind industry. In a collaborative effort, the Commission and the European Investment Bank are urgently developing a dedicated instrument to counter-guarantee commercial banks' credit exposures to vital suppliers in the wind industry. This aims to enhance access to advance payment and performance guarantee lines. The Commission and the EIB share the common objective of launching this new facility within the next 3 to 6 months, alleviating financial pressures arising from a growing order book compounded by macroeconomic challenges, such as increasing inflation, interest rates, and significant disruptions in the supply chain. As part of the Strategic Technology for Europe Platform (STEP), the Commission has proposed an increase in the EU guarantee by EUR 7.5 billion through a dedicated window of InvestEU. This increase aims to boost the capacity of the EIB Group and other implementing partners to support investments in the development and manufacturing of clean technologies, including those in the wind sector. Efforts to enhance coordination between external financial tools, Member States' export credit agencies, and development finance providers, particularly in the context of the Global Gateway, will further support renewable projects, including those related to wind energy.

6.1.3 Action 9: Member states to make full use of flexibility provided under State aid rules for EU wind value chain

Member States are encouraged to fully leverage the opportunities presented by the TCTF rules to bolster wind manufacturing in the EU. Regarding specific crisis-related provisions within the TCTF set to expire by year-end, the Commission has engaged in consultations with Member States and is poised to make a decision shortly regarding their potential extension. This decision will be made with careful consideration to ensure a fair and equitable playing field within the EU. Other provisions within the TCTF aimed at supporting the transition to a net-zero economy, facilitating the rapid deployment of renewable energy, including wind power, and endorsing strategic investments in the manufacturing of equipment essential for the net-zero transition, such as wind turbines, their crucial components, and associated critical raw materials, will remain available until the end of 2025.

6.1.4 Action 10: Commission to strengthen the dialogue with investors to foster the attractiveness of investments in the EU's wind sector

The Commission is actively involved in discussions with stakeholders, particularly long-term capital investors, through the Investors Dialogue. The focus is on developing solutions to enhance the global competitiveness of the EU wind industry, aiming to decrease reliance on public support. The emphasis is placed on identifying opportunities and vulnerabilities within the sector, encompassing operational, financial, and competitive aspects. Strategies are being explored to strengthen Europe's advantages and address its weaknesses. During 2023, the Commission plans to conduct dedicated meetings with long-term investors to gain deeper insights into the primary obstacles impeding investment attractiveness in the EU's wind sector and to determine optimal solutions. This initiative will explore opportunities for expediting the access and deployment of private finance. Discussions will also extend to the investment climate in Europe, with a specific focus on establishing an effective and, where possible, simplified regulatory environment conducive to investments in the wind sector.

7. ANALYSIS OF MARKET BARRIERS AND ENABLERS

When analyzing market barriers and enablers for FOW, it is essential to consider a wide array of factors that influence market attractiveness. Although various tools and methodologies exist to assess market appeal, the process remains inherently subjective. There are no fixed factors to evaluate, nor is there a standard method for prioritizing these factors. Key macro-level enablers, such as market size and growth rate, often guide market selection. Additionally, market stability and competitive dynamics within a region are critical determinants. Strategic factors, including cultural, administrative, geographic, and economic differences between the target market and markets already served by an investing company, also play a significant role.

In the context of energy markets, particularly for FOW, market barriers are predominantly shaped by political and regulatory environments. Renewable energy markets are heavily influenced by politics, regulations, and broader economic conditions. An unfavorable regulatory environment or the absence of robust, long-term political frameworks can significantly hinder the deployment of renewable energy solutions like FOW. Conversely, strong regulatory support and political incentives can act as major market enablers. Countries with minimal investment in renewable energy often lack effective policies, highlighting the critical role of governance in enabling or hindering market entry for renewable energies.

The data collected for this deliverable aims to provide a comprehensive understanding of the main trends, similarities, and differences among FOW market barriers and enablers across the geographies targeted by MARINEWIND. Although markets exhibit varying characteristics, it is important to assess the impact of the same set of barriers, enablers, challenges, and opportunities typically identified for the penetration of emerging technologies such as FOW. This section will begin by summarizing the landscape of these geographical markets. For comparative purposes, data from Belgium, another country analyzed in this report as an additional MARINEWIND partner country, has been integrated in Table 12, Table 13 and Table 14. Subsequent subsections will provide detailed overviews based on specific data collected from each MARINEWIND LAB.

Table 12 identifies potential factors that make a FOW market conducive to entry and success, and assesses, for each of the 5 MARINEWIND LABs and Belgium, whether they pose a challenge, a barrier, an opportunity or an enabler for the commercialization of floating offshore wind.

Table 12. Identification of challenges, barriers, opportunities and enablers of the commercialization of floating offshore wind in the MARINEWIND Labs and Belgium

Factors Impacting FOW Commercialization	Challenge	Barrier	Opportunity	Enabler
Regulatory Framework and Government incentives		IT, SP	UK, PT, GR	BE

Cost Competitiveness	UK, PT, BE, SP,IT	GR		
Grid Connection and Integration	SP, GR	UK, PT, IT	BE	
Public Acceptance and Stakeholder Engagement	UK, PT, SP, IT	GR	BE	
Supply Chain and Local Content	PT	IT	SP, GR	UK, BE
Environmental Impact and Permitting	UK, PT, BE, SP, GR	IT		
Technology Development and Standardization	IT, GR	BE	UK, PT, SP	
Weather and Operational Challenges	UK, PT, IT, SP		BE, GR	
Interplay with Other Energy Sources	PT, IT		BE, SP	UK, GR
International Collaboration and Standardization	BE, IT		UK, PT	SP, GR

*UK: United Kingdom; PT: Portugal; BE: Belgium; IT: Italy; SP: Spain; GR: Greece.

Overall, the analyzed countries show diverse perspectives in classifying factors such as challenges, barriers, opportunities, or enablers. This diversity stems partly from the nascent stage of the FOW market. This early phase complicates predictions regarding whether a factor will enhance or diminish market attractiveness and contributes to the ambiguous nature of these factors. Regulatory Framework and Government incentives and Technology Development and Standardization are generally seen as opportunities for the sector, whereas Cost Competitiveness, Public Acceptance and Stakeholder Engagement, Environmental Impact and Permitting and Weather and Operational Challenges are mostly seen as challenges. Such factors as Supply Chain and Local Content, Interplay with Other Energy Sources and International Collaboration and Standardization are not consensually classified across the analyzed countries.

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Table 13 compares the risk level regarding different factors for the commercialization of floating offshore wind, for each of the 5 MARINEWIND LABs and Belgium.

The analysis of the classification of the level of risk for the FOW market indicates greater consensus for the different countries analyzed. Risks identified as very important for the market include High capital costs, Financing uncertainty, and Volatility in commodities prices; identified medium risks include the Dependence on key suppliers and Public opposition; risks identified as not important comprise Extreme weather events and Operational challenges. The remaining risks analyzed did not present a classification of risk level shared by the majority of the countries under scrutiny. For Innovation challenges, Technical failures, Competitive landscape, Volatility in energy prices, Uncertain regulatory environment, Policy inconsistency, Grid integration issues, Transmission bottlenecks, Environmental impacts, Permitting uncertainty, Supply chain disruptions, Community engagement failures, Political instability, and International relations, the level of risk identified depends on the particular financial, technological, political and social contexts of each analyzed country.

Finally, Table 14 presents a summary of specific data collected from each MARINEWIND LAB and Belgium on the impacts of different market factors in the commercialization of FOW in each country. Additional detail is provided in the subsequent subsections.

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Table 13. Identification of the risk level of the commercialization of floating offshore wind in the MARINEWIND LABs and Belgium

Risks regarding FOWT commercialisation in a country	**Very important**	**Medium**	**Not important**	**Comments**
Technological Risks - Innovation Challenges *Risks associated with the development and deployment of novel technologies for floating offshore wind platforms.*	BE, GR	PT, SP	IT	**PT**: While innovation may be welcomed to tackle and mitigate the specific challenges of the Portuguese landscape, standard technology has already proven its feasibility in the country. **BE:** Various risks may arise, including those related to technical feasibility, reliability, performance, and cost-effectiveness, particularly when compared to its bottom fixed offshore wind (BFOW) counterparts. It is imperative to address these technological risks and innovation challenges to ensure the successful advancement and long-term sustainability of the FOW industry in Belgium. **GR:** It is very important because there are no FOWT in Greece, so their development is an innovative challenge.
Technological Risks- Technical Failures *Risks related to design flaws, manufacturing defects, or operational issues that may affect the performance and reliability of floating platforms.*	PT, BE, GR	IT, SP		**PT:** The materialization of a technological risk at an early stage of the sector's implementation may have significant adverse effects on the investment environment. **BE:** The occurrence of a technological risk in the initial stages of sector implementation could significantly impact the investment climate. **GR:** Same comment as in Technological Risks - Innovation Challenges risk.

Financial Risks - High Capital Costs *The risk that the high upfront capital costs of floating offshore wind projects may deter investors and hinder widespread adoption.*	UK, BE, SP, GR	PT, IT		**PT:** Although this is a considerable risk with potential measurable implications, it is one that is overarching for the whole sector and needs to be properly handled by authorities. **BE**: Competition with BFOW for internal implementation may hinder financial viability. It is crucial that FOW shows speedy cost reductions. **SP:** There is a large onshore wind capacity. Some periods during the winter the wholesale spot market price is 0€/MWh. **GR:** The constantly increasing capital costs and the long depreciation period of the investment will require strong commitment from the government and cooperation from the banking system in order to secure sufficient financial instruments for the initial funding of the floating offshore wind projects.
Financial Risks - Financing Uncertainty *Risks related to securing financing for projects, especially given the uncertainties associated with regulatory and market conditions. Risks on the interest rates that will apply, prior to FC/FID.*	UK, PT, BE, GR, IT	SP		**PT:** Cost of financing is a major drive of the final cost of electricity. **BE:** The cost of financing has a major impact on the final electricity price. **GR:** The global financing uncertainty would inevitably play a very important role in shaping market conditions. In Greece, it seems that the regulatory conditions will be stable stemming from a strong political will, which could mitigate to some extent the risk.
Market Risks - Competitive Landscape *Risks associated with market competition and the emergence of alternative renewable energy sources that may impact the demand and market share of floating offshore wind.*	PT, BE	UK, SP, GR, IT		**PT:** Low costs of viable alternative options (e.g. solar) is a major risk that can be mitigated with proper regulation. **BE**: In the near to medium future, BFOW should be considered the preferable option. **SP:** The benefits of offshore wind for the demand curve reduces this risk in front of High Capital Costs. **GR:** Greece has set an ambitious plan to install 4.9GW of Offshore Wind by 2032, which equates approximately to one tenth of its onshore capacity. The overall capacity is mainly for floating projects, so it seems there will be enough market share for the interested stakeholders.

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Market Risks - Volatility in Energy Prices *The risk of fluctuations in energy prices that could affect the economic viability of floating offshore wind projects.*	UK	PT, BE, SP, IT	GR	**PT:** With a large degree of certainty FOW projects will be supported by a CfD type support mechanism, significantly mitigating this risk. **BE:** The increasing market penetration of BFOW suggests that measures to address volatility in energy prices should already be in place. However, the high costs associated with FOW may present an even greater challenge at the current stage. **SP:** CFD model is expected to be applied. The current model does not include indexation, which increases the risk. **GR:** Considering the onshore wind parks, there are "closed" power purchase agreements, so the energy price fluctuations do not affect the viability of the wind parks.
Commodities Risks - Volatility in commodities prices *The risk of fluctuations in commodities prices with respect to steel and copper used in substantial quantities by projects.*	PT, BE, IT, GR, SP			**PT:** This is nowadays seen as one of the major factors holding back the sector's progress. **BE:** Currently, this is recognized as one of the primary factors hindering the sector's advancement. **GR:** Considering the increase of inflation during the last years along with the uncertain geopolitical environment in eastern Europe, this is a very important risk, because it concerns large investments in steel and copper which can cause significant delays at the early stages of the projects, thus threatening their economic viability.
Regulatory and Policy Risks - Uncertain Regulatory Environment *Risks related to changes in regulations and policies that may impact project development, permitting, or grid connection.*	PT, SP	IT, GR	BE	**PT:** Lack of consistent laws and policies may increase the risk for developers and therefore discourage project investment and development. **BE:** Since 2020, a total capacity of 2,261 MW of offshore wind energy has been operational in the Belgian part of the North Sea, positioning the country as one of Europe's leading offshore wind markets. Offshore wind is governed by national regulations. **GR:** For the time being, the regulatory framework is quite clear for the licensing process for FOWT, but there might be changes towards its fine-tuning.

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Regulatory and Policy Risks - Policy Inconsistency *The risk of inconsistent policies across different European countries, affecting the harmonized development of floating offshore wind.*	SP	PT, IT, GR	BE	**PT:** Lack of congruency of regulatory frameworks may pave the way for unbalanced project development across European waters. **BE:** Belgium has generally maintained a predictable and stable regulatory environment for offshore wind energy. The government has implemented long-term policies and regulations to support the development of offshore wind projects, providing clarity and certainty for investors and developers. **GR:** There is not a clear policy for the development of FOWT in Greece, so there is no sufficient information to assess this risk.
Grid Connection and Infrastructure Risks - Grid Integration Issues *Risks associated with challenges in connecting floating offshore wind projects to existing onshore grids, including technical constraints and delays.*	PT, SP, GR	IT	BE	**PT:** Can lead to significant delays in project development and deployment, increasing overall project costs and jeopardizing investor confidence. May imply costly infrastructure upgrades or bespoke grid solutions, further adding to project expenses and potentially rendering projects economically unfeasible. Introduces additional risk for investors, making it challenging to secure financing. **BE:** Belgian TSO Elia provides an extension of the Modular Offshore Grid to connect future wind farms to the electricity network. Elia is also responsible for reinforcing the transmission system on the mainland (Ventilus and Boucle du Hainaut projects). **GR:** The status of FOWT in Greece is still quite immature (a few months ago the regulatory framework for FOWT was defined) and no Grid connection studies have taken place, so there is no sufficient information to assess this risk.
Grid Connection and Infrastructure Risks - Transmission Bottlenecks *Risks related to insufficient grid infrastructure, leading to transmission bottlenecks and limiting the export of energy.*	SP	PT, GR, IT	BE	**PT:** Hinder the efficient utilization of energy resources and impede the profitability and viability of projects by limiting their ability to deliver electricity to consumers or export it to the grid. **BE:** Same comment as Grid Connection and Infrastructure Risks - Grid Integration Issues risk. **GR:** The status of FOWT in Greece is still quite immature (a few months ago the regulatory framework for FOWT was defined) and no Grid connection studies have taken place, so there is no sufficient information to assess this risk.

Environmental and Permitting Risks - Environmental Impact *Risks related to the potential environmental impact of floating offshore wind projects, leading to regulatory challenges and permitting delays.*		PT, BE, GR	IT, SP	**PT:** Environmental impacts of FOW projects are already relatively well known and are lower when compared with BFOW. Regulatory authorities did a good work when establishing the areas removing major environmental constraints. As a result, potential impacts will likely be limited to impacts on marine birds and submarine cable routes that will have to cross Marine Protected Areas. **BE:** Environmental impacts of FOW are lower compared to BFOW. Regulatory authorities effectively target areas minimizing constraints. Remaining concerns focus on marine bird impacts and submarine cable routes through Marine Protected Areas. Environmental studies are foreseen with the offshore tender run by the federal government. **GR:** There are few environmental considerations that may lead to regulatory challenges and permitting delays, such as maritime heritage and fauna.
Environmental and Permitting Risks - Permitting Uncertainty *The risk of delays in obtaining permits due to uncertainties in the regulatory process or opposition from environmental groups.*		PT, SP, GR	BE, IT	**PT:** Environmental Impact Assessment procedures are well implemented in the Portuguese law. As a result, although they may lead to delays in project development, they will very likely be addressed and overcome. **BE**: Belgium is already an established market in BFOW. **GR:** The status of FOWT in Greece is still quite immature (a few months ago the regulatory framework for FOWT was defined), so there is no sufficient information to assess this risk.
Weather and Operational Risks - Extreme Weather Events *Risks associated with adverse weather conditions, such as storms and rough seas, impacting the operational efficiency and safety of floating offshore wind farms.*		PT	BE, IT, SP, GR	**PT:** Although it is by definition a significant risk, state-of-the-art technology has already been proven in extreme conditions in the country. **BE**: Operational experience from BFOW exists in the country. The North Sea presents on average milder metocean climates than other exposed waters markets. **SP:** It depends on the area, in the Mediterranean sea it will be lower than in the Atlantic area. **GR:** Greece has optimal weather characteristics with very limited storms and rough seas, thus providing an ideal location for offshore wind projects.

Weather and Operational Risks - Operational Challenges *Risks related to maintenance, logistics, and the remote location of offshore wind farms, which may increase operational costs.*		PT	BE, IT, SP, GR	**PT:** Already demonstrated with a pre-commercial farm. There are still unknowns concerning implications for the commercial stage. **BE:** Same comment as Weather and Operational Risks - Extreme Weather Events risk. **SP:** It depends on the area, in the Mediterranean sea it will be lower than in the Atlantic area. **GR:** Greece has optimal weather characteristics which can lead to reduced maintenance and logistics costs, thus reducing the risk of increased operational costs.
Supply Chain Risks - Supply Chain Disruptions *Risks associated with disruptions in the supply chain, including delays in the manufacturing and delivery of key components for floating offshore wind platforms.*	PT	BE, SP, GR	IT	**PT:** Supply chain is not yet developed and poses a major unknown, with potential large implications on FOW commercialization. **BE**: Belgium's BFOW experience offers advantages like established supplier relationships and infrastructure, potentially reducing supply chain disruption risks for FOW projects. However, the unique components and technology required for FOW mean that these benefits have limited impact on mitigating all risks. Differences in technology and the global nature of supply chains still present challenges, underscoring the need for targeted strategies for the FOW sector. **GR:** The status of FOWT in Greece is still quite immature (a few months ago the regulatory framework for FOWT was defined) and we do not have a clear picture of the supply chain challenges, so there is no sufficient information to assess this risk.
Supply Chain Risks - Dependence on Key Suppliers *Risks related to reliance on a limited number of suppliers for critical components, leading to vulnerabilities in the supply chain.*		PT, BE, IT, SP, GR		**PT:** FOW projects in Portugal can potentially be served by supply chains across Europe. **BE**: Existing relationships with suppliers and service providers for BFOW projects can ease some supply chain constraints. However, FOW requires specific components (like mooring systems and dynamic cables) where new supplier relationships may be necessary. **GR:** The status of FOWT in Greece is still quite immature (a few months ago the regulatory framework for FOWT was defined) and we do not have a clear picture of the supply chain challenges, so there is no sufficient information to assess this risk.

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Social and Stakeholder Risks - Public Opposition *Risks associated with public resistance to the visual impact, noise, or perceived environmental risks of floating offshore wind farms.*		PT, IT, SP, GR	BE	**PT:** As long as the environmental impact assessment process is well driven concerning environmental assessment and information shared transparently with stakeholders and public, this impact is expected to be of medium magnitude. **BE:** Visual impacts, noise, and potential environmental risks are more significant for existing BFOW projects than for future FOW projects. The likelihood of this risk is minimal. **GR:** Considering the onshore wind farm projects in Greece, they often face opposition from local communities due to concerns about visual impact, noise, and environmental effects. This will most probably apply also to FOWTs development, probably resulting in delays in the permitting process.
Social and Stakeholder Risks - Community Engagement Failures *Risks related to inadequate stakeholder engagement, leading to opposition from local communities and regulatory challenges.*	PT	IT, SP, GR	BE	**PT:** If engagement fails, the project may face local, regional and national severe opposition that ultimately may lead to political impacts and project's cancellation. **BE:** In principle, the market penetration of BFOW should have disrupted such barriers. The associated risk is low. **GR:** Considering the Onshore wind farm projects in Greece, there is adequate engagement of stakeholders in wind farm investments in several regions. This may also apply to FOWT.
Geopolitical Risks - Political Instability *Risks associated with political instability or changes in government that may impact the regulatory environment and investment climate for floating offshore wind.*	SP, GR	PT, IT	BE	**PT:** In principle, governments should respect previous agreements and project rollouts if sufficient progress has been made. However, there have been instances of minor policy shifts associated with changes in government. **BE:** Belgium's political stability, commitment to EU renewable energy targets, and consensus-building approach to energy policy contribute to a low-risk environment for FOW investments, despite the country's complex federal structure and potential governmental changes. **GR:** Considering that the very first applications submitted in 2012 and they were approved in 2023, this indicates the variable approaches by each government. So, this risk is very important, due to political instabilities.

Geopolitical Risks - International Relations *Risks related to geopolitical tensions that may affect cross-border cooperation and project development.*	IT, GR	PT, SP	BE	**PT:** A risk but equally a potential opportunity. Geographical position of Portugal is advantageous in this regard. **BE:** The risk of geopolitical tensions affecting cross-border cooperation and project development for FOW in Belgium is relatively low, given the country's stable position within the EU and established international relations. However, the global nature of supply chains and the need for international collaboration mean that some level of risk remains, necessitating prudent risk management strategies. **GR:** This is a very important risk for developing FOWT in Greece, because there are several geopolitical confrontations with Turkey, which have affected the development of FOWT in Greece.

Table 14. Summary of the impact of different market factors in the commercialization of Floating Offshore Wind Turbines (FOWT) in each MARINEWIND LABs and Belgium

Regulatory framework	
1. How well-defined and supportive is the regulatory framework for floating offshore wind projects in each country?	
UK	Already established an experienced regulatory regime covering the whole offshore wind project life cycle, from leasing and consenting to operation and decommissioning –with actions underway to accelerate the pipeline and meet the ambition goal of up to 5GW of floating offshore wind capacity by 2030.
PT	No dedicated regulatory framework for floating offshore wind in Portugal. The regulatory framework currently applied is the same as established for onshore wind, which is well-defined and supportive. Offshore wind auctions are being introduced in the country, aiming to ensure the cost-effectiveness and efficiency of energy production.
IT	The regulatory framework is still not very clear, long, and not very supportive. The authority responsible for the consenting should be the Ministry of Environment and Energy Security in the coordination with the other authorities.
BE	The regulatory framework is supportive and under development, with a defined dedicated offshore wind maritime zone. A second zone is under development to encourage offshore wind energy production, as well as competitive bidding procedures.
GR	The regulatory framework in Greece for offshore wind is clear and well-defined. It was last updated in July 2023.
SP	The current regulatory framework is undergoing public consultation until March 25th. However, its content lacks clarity regarding the delegation of auction definitions and evaluation criteria, which are deferred to future ministerial orders. Moreover, it fails to harmonize bonds with other applicable laws.
2. Are there inconsistencies or gaps in regulations that hinder the development and commercialisation of floating offshore wind?	
UK	Yes. The lack of clear long-term strategies, slow consenting processes, and the need for attractive investments in the local supply chain, including ports and grid infrastructure, are hindering progress in this sector.
PT	Regulations of the upcoming offshore wind auctions are still to be specified.
IT	Major gap is the lack of a complete MSP. Suitable areas for the installation of offshore wind farms are not identified a priori and auctioned.
BE	None identified.

GR	Greece's delay in establishing maritime spatial plans is indicative of intractable challenges that must be addressed for the country to harness the power of maritime spatial planning (MSP) as an enabler of the (floating) offshore wind sector.
SP	With the future regulatory framework model under discussion, the major gaps are related to bonds and the reimbursement model.
Cost competitiveness	
3. Is the current regulatory framework of each country a barrier or an enabler to FOWT Commercialization?	
UK	The current framework is an enabler for the commercialisation of the offshore wind sector but must evolve to support less mature technologies such as floating offshore wind.
PT	The regulatory framework for the upcoming floating offshore wind auctions is expected to be an enabler to FOWT commercialization.
IT	The current regulatory framework is a barrier to FOWT commercialization.
BE	Enabler.
GR	The regulatory framework could act as an enabler to FOWT commercialization.
SP	The current regulatory framework in Spain is currently viewed as a significant obstacle to the commercialization of FOWT.
4. How can the high upfront costs of floating offshore wind technology be reduced to make it more competitive with other energy sources in each country?	
UK	This reduction includes a combination of approaches: technological innovation, scale-up production, standardization, supply chain optimisation, government support and policy incentives (such as CfD, tax credits, and loan guarantees), reduced installation and O&M costs, public-private partnerships, and market competition.
PT	Inflation for commodities and offshore goods needs to come down.
IT	By the creation of a local supply chain.
BE	Belgium will benefit from an optimized supply chain, shared infrastructure, and the learning from bottom fixed offshore wind (BFOW). Also, FOW will face the competition of the already established BFOW and will likely strive to match it in maturity and cost wise.
GR	The upfront costs can be reduced through government financing and participation of citizens in FOWT investments.
SP	Using government-funded LiDAR-equipped buoys for wind resource assessment, fostering collaborative research efforts to improve technology efficiency, reduce manufacturing costs and encourage public-private partnerships can collectively contribute to achieving a competitive advantage for FOWT in the Spanish energy scenario.
5. Are there financial mechanisms or incentives in place to encourage investment in floating offshore wind projects?	
UK	The government has allocated more than £60 million in public and private investment to support. The maximum strike price for these projects has been raised by 52% to £176 per MWh, aiming to attract more investment and secure the UK's goal of hosting 50GW of offshore wind by 2030.

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PT	It's expected that this should come through the auctions' maximum strike price to be established.
IT	Feed-in Tariffs (FiTs) will be extended to offshore wind (FER2) and there are government financing instruments for research and innovation projects within the PNIEC (Integrated National Plan for Energy and Climate).
BE	As an EU member, Belgium benefits from the broader EU initiatives designed to support the development and deployment of renewable energy projects, including floating offshore wind.
GR	Not yet needed due to the very early stages of the floating offshore wind sector.
SP	The financial mechanisms for floating offshore wind projects are predominantly of European origin, and no specific Spanish mechanisms or incentives are documented.
Grid connection and integration	
6. What challenges do you foresee in integrating floating offshore wind projects into existing onshore grids in each country?	
UK	Grid Connection Delays, Regulatory Frameworks and Technological Advancements.
PT	Needs for reinforcement of the grid have already been identified by the offshore wind auctions working groups. The timeframe is expected to be lengthy.
IT	No deep water floating offshore substation (OSS) available yet AC/DC array and export dynamic cables are still under development (only the 66 kV AC dynamic cable is in the commercial phase), and no standard regulation for HVDC (High-voltage direct current) solutions.
BE	Belgium's transmission system operator (TSO) Elia has developed a modular offshore grid to connect offshore wind projects to the onshore grid. Elia will provide an extension of the Modular Offshore Grid to connect future wind farms to the electricity network.
GR	
SP	A reinforcement of the existing national grid, an outdated grid infrastructure, not fully prepared for the rapid influx of renewable energy; and to choose between the model where FOW projects connect to onshore grid connections points (currently under discussion), and a centralized model, where FOW projects connect to the grid in the sea.
7. How can grid infrastructure be upgraded or expanded to accommodate the variability and capacity of floating offshore wind farms in each country?	
UK	The strategy for the UK includes: Investment in Port Infrastructure, enabling transmission infrastructure in the national grid, integrated offshore grids, government commitment, implementation of the Holistic Network Design of its transmission network and local distribution network to support the transmission of electricity generated by renewable energy sources, and a grid balancing strategy with storage solutions and co-generation with other offshore technologies.
PT	The expansion of the grid's physical infrastructure includes building new transmission lines and substations, as well as upgrading existing ones to handle higher power flows with sophisticated grid management systems, implementing demand response programs and energy storage solutions and enhancing interconnections with neighboring countries' grids.
IT	The Ten-Year development plan by TERNA allocated more than €20 billion of investments in the next 10 years to accelerate the energy transition.

BE	Strategies may include enhancing grid flexibility through technologies like energy storage systems to manage variability, upgrading transmission lines to handle increased capacity, and integrating smart grid technologies for better demand response and distribution. Regional grid interconnections may be improved to facilitate energy exchange and balance across borders.
GR	The island cluster of Greece with significant seasonal variations in energy consumption as well as the limited interconnections of the Greek islands with the mainland electricity system are great challenges in integrating floating offshore wind projects into the existing grid.
SP	By investing public money, without commercial interest. Given the limitations of the existing grid and the rapid expansion of renewable energy, a comprehensive strategy involving substantial public investment, streamlined regulatory processes, and a technologically advanced grid is imperative to effectively meet Spain's growing energy demands.
Public Acceptance and Stakeholder Engagement	
8. Are there identified social acceptance challenges related to the visual impact, noise, or other environmental concerns associated with floating offshore wind farms in each country?	
UK	Yes, there are concerns related to potential impacts on marine ecosystems, bird populations, and other wildlife, visual impacts on coastal landscapes and potential effects on tourism, Noise and vibrations from the construction and operation of floating wind farms that can affect nearby communities. Positive acceptance relies on the potential socio-economic benefits of floating offshore wind projects, such as job creation, local economic development, and increased energy security.
PT	Areas for offshore wind auctions have been allocated in deeper waters, avoiding as much as possible the different restriction areas identified linked to social acceptance challenges.
IT	Concerns about noise, visual impact, and perceived property value reductions may lead to resistance and legal challenges.
BE	Not found information about specific insights into public perception studies conducted in Belgium.
GR	Although there have been selected only potential regions for floating offshore winds, there is already great public opposition in some of the selected areas due to the close proximity to the shore in touristic areas.
SP	The main concern is not so much noise or visual impact, but fear of affecting the marine environment.
9. How can effective stakeholder engagement be achieved to address concerns and build support concerning the development of these projects in each country?	
UK	The implemented strategies to overcome Local Communities concern over effect of wind farm on their community (adequate and open communication, enroll tourism, use local workforce to build and run the installations, etc.) and Fishermen fear of lost revenue and valuable fishing grounds due to turbines and cabling infrastructure (multi-use zoning approach and pre-construction roundtables), are expected to minimize the concerns.

PT	Concerns and suggestions are being taken into consideration in subsequent versions of the national allocation plan thanks to a public consultation process.
IT	A public consultation of all stakeholders is performed during the procedure for the maritime state-owned property.
BE	Public consultation should be run throughout the bidding procedures aiming to increase offshore wind capacity with minimal social cost.
GR	Participation of stakeholders in FOWT investments and regular consultation and information to increase awareness can result in higher support for FOWT development in Greece.
SP	In Spain, a novel initiative is being developed. It involves citizen participation through investment of their own funds in the project, utilizing crowdfunding models.
Supply Chain and Local Content	
	10. To what extent does the lack of a well-established supply chain for floating offshore wind components hinder the development and competitiveness of projects?
UK	-
PT	Supply chain in Portugal is not yet developed and targets in the European countries are ambitious for the FOW and partially overlapping. In this context a potential supply chain exhaustion in the region should be taken into consideration, with the corresponding constraint on FOW projects.
IT	It is an important problem both for support during the construction/installation and maintenance phase but also for creating economic benefits for local populations.
BE	Belgium has a well-established bottom-fixed offshore wind (BFOW) sector and it is foreseen that this industry explores overlaps and synergies with floating offshore wind (FOW).
GR	An efficient and effective supply chain system will be needed to support the development of the floating offshore wind sector in Greece. There are some local advantages due to the production of steel as well as high-reputation cables, but for most of the components, a European supply chain will be needed.
SP	The absence of a robust European supply chain for floating offshore wind components hampers project development and competitiveness. Relying on Asian suppliers introduces potential delays due to long-distance sea transport.
	11. How can the industry promote local content and manufacturing to support the FOWT industry in each country?
UK	Establishing Local Content Targets, Policy Implementation (fostering the growth of domestic manufacturing) and promoting investment.
PT	There are two strategies: Specific request for local content as a pre-qualification criterion for offshore wind auction in Portugal, and partnerships with relevant players in other countries well-established supply chains to foster the development of the Portuguese supply chain for FOW.
IT	By establishing partnerships with local businesses and academic institutions, implementing policies that encourage the use of local materials and services in the construction and maintenance of FOWT projects, investing in training programs to equip the local workforce with the specialized skills needed for FOWT technologies.

BE	The established industry can collaborate with local manufacturers, incentivize investment, fund research and development, train local talent, enforce local content requirements, and establish industry clusters.
GR	By bringing to operation decommissioned shipyards, harbors, and industries to manufacture cheap Greek components for FOWT developments; and by taking advantage of well-established cable producers (Hellenic Cables) and its large domestic production of steel and cement.
SP	Collaborative efforts between local industry, stakeholders, and government entities can streamline the process of promoting local content and manufacturing to support the FOWT in Spain.
Environmental impact and permitting	
12. What environmental challenges, such as impacts on marine ecosystems and wildlife, need to be addressed to obtain permits for floating offshore wind projects?	
UK	To obtain permits for floating offshore wind projects in the UK, several environmental challenges need to be addressed. These challenges include a changing regulatory environment, complex permitting processes, assessments becoming more challenging due to the industry's nascency, the need for emergency response plans, and the importance of considering sensitive marine habitats and undersea archaeology.
PT	Permitting processes in Portugal involve rigorous environmental impact assessments (EIA) and public consultations.
IT	The Environmental Impact Assessment is a fundamental part of the permitting process and must address environmental effects of the project, including cumulative effects, feasibility of technical and economic mitigation measures that can reduce or eliminate adverse environmental effects, a public consultation, and elements not covered in the regulations but deemed necessary by the competent authority.
BE	No major distinctions foreseen when compared to already existing BFOW.
GR	The requirements for the installation of OWF take into account the possibility of: (i) losses due to crashing, (ii) obstruction and obligation to change course and (iii) formation of obstacles in migratory corridors. The potential environmental impacts are assessed through Special Ecological Assessment Studies (SEAS), including Special Ornithological Study.
SP	As the regulatory framework becomes clearer, collaboration between developers and regulatory authorities will be essential to address specific environmental impacts on marine ecosystems and wildlife, ensuring the sustainable development of floating offshore wind projects in Spain.
13. What specific challenges should the industry address in each country to minimize environmental footprint and navigate the permitting process effectively?	
UK	Conduct comprehensive environmental impact assessments (EIAs); careful site selection; implement monitoring programs during construction and operation to identify potential impacts and inform adaptive management strategies; engage with local communities, regulators, and other stakeholders; and follow established practices and guidelines for the design, construction, and operation of floating offshore wind farms.

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PT	Collect baseline data and be willing to perform a complete Environmental Monitoring Program and to establish a Reference Situation that will serve as the benchmark for evaluating potential environmental impacts.
IT	Depending on where the submarine pipelines run, it is necessary to have the Environmental Impact Assessment with pre-construction validated investigation with regard to avifauna/marine mammals and also with regard to meteo-marine measurement.
BE	No major distinctions foreseen when compared to BFOW.
GR	Ideal site selection and detailed Strategic Environmental Impact Assessments (SEIA) to maximize public acceptance could be beneficial for rapid permitting process
SP	Comprehensive studies on the environmental impacts of offshore wind, particularly regarding noise and habitat modifications, should be conducted before project construction; after project construction and during decommissioning, transparent monitoring of the environmental aspects must be mandatory; adopting principles of Ecosystem-Based Management (EBM) is recommended, focusing on ecological integrity, uncertainty management, and social integration; ensuring compatibility with biodiversity and local communities is crucial, and, finally; proposing biodiversity recovery plans within offshore wind parks.
Technology Development and Standardization	
	14. Are there challenges in developing and standardizing floating offshore wind technologies to ensure reliability and performance?
UK	Mitigate engineering complexities and challenges associated with integrating floating offshore wind components; develop dynamic electrical infrastructure required for FOWT; incorporate cutting-edge technologies and unconventional materials in mooring systems, such as mooring springs, dampeners, synthetic mooring lines, and innovative anchoring systems like mechanical anchors.
PT	Strong wave climates off the Portuguese west coast pose significant engineering challenges for technologies, requiring resilience in harsh maritime conditions while maintaining efficiency. Developing efficient O&M strategies for FOW farms is crucial due to remote offshore locations and dynamic floating platforms, ensuring long-term reliability.
IT	The biggest challenge is related to the many different conditions that characterize different areas in terms of wind and sea conditions, geological conformation and depth of the seabed, distance from the coast, marine flora and fauna, and constraints related to other activities at sea.
BE	Competition with BFOW.
GR	The main specificities in Greece are: (i)Close Proximity of Offshore Wind Parks on coastlines with significant topography; (ii) wind flow orientation: 1-2 main directions; and (iii) offshore sites with significant wind speed & turbulence irregularities. Requirement for accurate measurements of speed, wind direction and wind turbulence to ensure reliability and performance.
SP	The lack of standardization related to floating foundations brings uncertainty around the development of port infrastructure in Spain.
	15. How can collaborative research and development efforts in each country accelerate the advancement of these technologies?
UK	Continued support for in-situ research and pilot projects is essential for acquiring insight beyond the scope of numerical modeling simulation or lab-scale experiments.

PT	In Portugal, universities and research institutions can provide cutting-edge research and innovation, while industry partners can offer practical insights and commercialization pathways, ensuring that research outcomes have real-world applications.
IT	Joint efforts between research and academia and industries can strongly accelerate the advancement of the technology (e.g. the first pilot of FOWT installed in the Gulf of Naples).
BE	Pooling resources, fostering innovation ecosystems, leveraging strategic partnerships, focusing on niche areas for global leadership, ensuring robust government support and policy frameworks, integrating education and workforce training, and adopting international collaboration for shared knowledge and standards.
GR	Joint research activities between academia and industries can provide reliable evidence-based data to accelerate the floating technologies in Greece.
SP	It seems crucial to foster a collaborative ecosystem among turbine developers, float manufacturers, and other stakeholders to collaborate in knowledge sharing, interdisciplinary perspectives, and streamlines the integration process. To accelerate technological advancement in Spain, a coordinated approach to research and development, with common research goals, should be undertaken.
Weather and Operational Challenges	
16. To what extent do harsh weather conditions, including storms and extreme waves, pose operational challenges for floating offshore wind farms in each country?	
UK	Harsh weather conditions, including storms and extreme waves, present significant operational difficulties for floating offshore wind farms in the UK.
PT	Despite the harsh conditions of the Portuguese Coast, floating offshore wind technologies have already demonstrated their efficacy in these conditions and there is evidence indicating a higher frequency of suitable weather windows for installation and O&M activities compared to other exposed coastlines.
IT	Harsh weather conditions do not represent a big challenge in Italy.
BE	The North Sea experiences fewer extreme events on average compared to other exposed water markets.
GR	In Greece (particularly in the Aegean Sea), according to experts, the weather conditions are optimal for the efficient operation of FOWT.
SP	In Spain, the operational challenges posed by harsh weather conditions vary significantly between the Atlantic Ocean and the Mediterranean Sea. The operational requirements for floating wind farms must therefore be finely tuned to the unique characteristics of each region, acknowledging the diversity of weather conditions along Spain's coasts.
17. What measures can be implemented to enhance the resilience and operational efficiency of these projects in adverse weather conditions?	
UK	Strategic planning, Optimised design of components for ease of assembly and disassembly, Leveraging accurate metocean data, Incorporating sustainable materials, and Enhance industry collaborations and knowledge sharing.
PT	Develop adequate O&M strategies, sub-components and enabling technologies, alongside monitoring systems and routines of critical components (e.g. dynamic power cables).

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IT	Precise forecasts of possible future extreme events, suitable designs that ensure resilience and safety, and remote monitoring systems that provide early warnings.
BE	Create effective strategies for operations and maintenance (O&M), including sub-components, enabling technologies, and monitoring systems for critical components like dynamic power cables.
GR	Accurate forecasts for potential extreme weather events and on-time maintenance activities (when needed) could minimize the non-operating days of the Offshore wind parks in Greece. A well-organized local supply chain could optimize the reaction time in cases of failure/maintenance.
SP	It is imperative to tailor designs based on precise regional data. Ongoing research initiatives should focus on understanding and mitigating the specific challenges posed by the diverse weather conditions along Spain's coasts to support tailored operational solutions to the different ocean regions of the country, the Atlantic Ocean and the Mediterranean Sea.
Interplay with Other Energy Sources	
18. How can the integration of floating offshore wind projects complement other renewable energy sources, such as solar or conventional offshore wind, to create a balanced and reliable energy mix in each country?	
UK	In the UK, there is an increase in initiatives focusing on co-location and hybridisation of offshore wind projects with other technologies. These projects aim to achieve various objectives such as enhancing energy efficiency, providing grid stability, optimizing the seabed space, and contributing to achieving UK Net Zero targets.
PT	It will diversify the renewable energy portfolio, it will complement the generation profiles and lead to cost efficiencies, e.g. by sharing transmission infrastructure or maintenance vessels, reducing operational costs and environmental impacts.
IT	Projects integrating different offshore renewable technologies are under consideration for authorization with hybrid solutions such as integration of wind offshore (both floating and bottom fixed) and floating photovoltaics. Wave energy converter integration with offshore wind has also been investigated in Italy.
BE	Integrating FOW with other renewables and conventional offshore wind enhances Belgium's energy mix by balancing generation profiles, ensuring grid stability, and leveraging existing infrastructure for cost efficiency and rapid deployment. However, solar energy is not expected to be a prominent energy resource in the country.
GR	In Greece, the National Energy and Climate plan (under review) should include much higher targets for wind farms and a much-more balanced wind-photovoltaic-hydro mix than the initial scenario presented. The integration of (floating) offshore wind projects which will contribute to a balanced and reliable energy mix will lead to: i) a smoother distribution of green energy production over the 24-hour period; and ii) is in line with the strategy to make Greece an exporter of green energy.
SP	While solar power excels in meeting peak daytime consumption, the continuous and substantial nature of onshore and offshore wind power generation ensures a more consistent energy mix.
19. Are there challenges or opportunities for hybrid projects that combine different offshore renewable technologies?	

UK	Challenges: Technical Hurdles, Regulatory and Political Complexities, Technological Innovation. Opportunities: Growth Potential, alignment with the EU Strategy, enhance in Technological Advancements.
PT	The biggest challenge is related to the framework. Even if it is favorable to the development of hybrid projects, there are still some concerns cost-wise that need to be addressed.
IT	Challenges: Technological Innovation, Harsh Environmental conditions, Conflict with other marine activities . Opportunities: High solar radiation and seasonal complementarity between solar and wind energy sources, Improve the energy extraction efficiency from specific marine area
BE	Hybrid projects raise concerns cost-wise.
GR	-
SP	With no offshore wind auction held to date, exploring hybrid projects, especially for green hydrogen, faces challenges due to Spain's current technological immaturity in offshore wind. As Spain progresses in offshore wind, hybrid project exploration holds promise but requires careful study.
International Collaboration and Standardization	
20. How can international collaboration be fostered to share best practices, align standards, and address challenges that are common across European countries?	
UK	By implementing collaborative approaches across various sectors and stakeholders, European (and global) countries can effectively share best practices, align standards, and collectively address common challenges in the energy sector.
PT	Although the framework in the country may be favorable to the development of hybrids, there are still some concerns cost-wise that need to be addressed.
IT	By participating in established international collaborations at EU level such as: SET-PLAN, IEA Wind TCP, EERA JP Wind, ETIP WIND.
BE	International collaborations are a valuable instrument for steeper learning that will be fostered by relevant players. This may create the opportunity to place Belgium as a major global FOW technology exporter.
GR	The model followed by Greek companies is searching for strategic partnerships between Greek and European companies that have knowledge from past experiences.
SP	International collaboration to share best practices, align standards, and address common challenges across European countries can be facilitated by establishing cross-border platforms, encouraging joint research projects, and harmonizing regulations.
21. Are there opportunities for joint research and development initiatives to drive innovation in floating offshore wind?	
UK	Yes, in innovative technologies, strategic partnerships, promoting data sharing, industry-scientific community partnership and fostering collaboration between component manufacturers, wind farm developers, research institutions, and government agencies.

PT	Yes, the establishment of Technology Free Zones (known as ZLTs in Portuguese), which are physical environments strategically located to facilitate testing and experimentation under the supervision of relevant authorities, exemplifies this commitment for joint research in Portugal.
IT	Yes, there are several funding opportunities for joint R&D projects in Horizon Europe CL5, Sustainable Blue Economy Partnership, Mission Ocean
BE	Belgium offers significant opportunities for joint R&D initiatives in FOW, focusing on innovation, cost reduction, and technology advancement.
GR	There are plenty of joint initiatives between Greek and European companies to explore opportunities for exploration, license granting and development of both bottom-fixed and floating offshore wind technologies.
SP	Yes, significant opportunities for joint research and development initiatives exist to drive innovation in floating offshore wind. Many Floating Substructure System (FSS) developers in Spain have dedicated research teams that played a pivotal role in conceiving their respective concepts.

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7.1 United Kingdom

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in the United Kingdom.

7.1.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.1.1.1 Regulatory Framework

The UK has established an experienced regulatory regime covering the whole offshore wind project life cycle, from leasing and consenting to operation and decommissioning –with actions underway to accelerate the pipeline and meet our ambitions. With ambitious goals of up to 5GW of floating offshore wind capacity and 50GW of fixed offshore wind deployment by 2030, this framework includes policies and regulations, such as the Contracts for Difference (CfD) auctions aimed at supporting low-carbon electricity generation. The UK plans to hold annual CfD auctions with considerations for incorporating Non-Price Factors into the scheme.

Moreover, efforts are underway to address radar interference challenges through collaboration with industry and the Ministry of Defense. The Crown Estate and Crown Estate Scotland oversee leasing rounds, providing opportunities for new entrants, with additional seabed leasing rounds planned, including for floating wind projects in the Celtic Sea[62]. On networks, the UK is undergoing regulatory restructuring for the GB network to ensure its efficiency and strategic alignment. This initiative involves the launch of the Offshore Transmission Network Review in 2020, aimed at assessing the design and delivery of the offshore transmission network in line with our commitment to achieve net zero emissions by 2050.

A recommended design, called Holistic Network Design, has been published for connecting offshore wind farms within scope until 2030. This design proposes a unified network connecting 23GW of offshore wind projects, marking the initial phase of centralized and strategic network planning. Additionally, a Holistic Network Design Follow-Up Exercise will integrate a further 21GW[63] of offshore wind projects into a single, comprehensive network. Ofgem has also announced its decision to expedite onshore transmission investment, streamlining regulatory and funding approvals. This decision is expected to initially apply to £20 billion of investment.

62 https://www.gov.uk/government/publications/offshore-wind-net-zero-investment-roadmap/offshore-wind-net-zero-investment-roadmap

63 https://www.nationalgrideso.com/future-energy/pathway-2030-holistic-network-design

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Despite the UK Government's initial support for floating offshore wind projects in the CfD allocation round, the key obstacle lies in establishing clear strategies and a regulatory framework to facilitate the commercialisation of floating offshore wind without entering into competition with well-established technologies. The challenges in the development and commercialisation of floating offshore wind projects stem from various regulatory and permitting issues. The lack of clear long-term strategies, slow consenting processes, and the need for attractive investments in the local supply chain, including ports and grid infrastructure, are hindering progress in this sector. To address these challenges, policymakers, regulators, and industry stakeholders can collaborate on several key actions:

- Develop a supportive regulatory framework: Creating clear and supportive regulatory frameworks for floating offshore wind projects can reduce risks and uncertainties for developers, investors, and other stakeholders, facilitating the successful deployment of floating wind farms.
- Streamline permitting processes: Simplifying and coordinating the permitting process across relevant agencies and jurisdictions can help minimize delays, reduce costs, and improve the overall efficiency of project development.
- Enhance stakeholder engagement: Establishing open lines of communication and engaging with local communities, environmental groups, and other stakeholders can help build public support, address concerns, and promote the responsible development of floating wind projects.
- Foster collaboration: Encouraging collaboration between industry stakeholders, policymakers, regulators, and research institutions can help share knowledge, identify best practices, and develop innovative solutions to regulatory and permitting challenges.

7.1.1.2 Cost Competitiveness

The UK's regulatory framework is designed to support economic growth, innovation, and market competition while ensuring compliance with international standards and addressing key policy objectives across various sectors. The current framework is an enabler for the commercialisation of the offshore wind sector but has to evolve to support less mature technologies such as floating offshore wind. For instance, the UK government established:

- The Floating Offshore Wind Manufacturing Investment Scheme (FLOWMIS) was introduced in March 2023 to support critical port infrastructure for floating offshore wind projects[64].
- The government is working on developing the Contracts for Difference (CfD) regime to continue supporting Floating Offshore Wind (FLOW) projects[65]. There is a recognition

[64] https://commonslibrary.parliament.uk/research-briefings/cdp-2023-0208/

[65] https://www.nortonrosefulbright.com/en/knowledge/publications/292a783d/floating-offshore-wind

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of potential ambiguities within the current definition of Floating offshore wind in the CfD, which may restrict projects using innovative foundation designs.

- On standardization aspects: Developers are exploring different FLOW concepts, with over 50 concepts in development, including structures like spar buoys, semi-submersibles, and tension leg platforms

Furthermore, reducing the high upfront costs of floating offshore wind in the UK involves various strategies. These include a combination of approaches: technological innovation, scale-up production, standardisation, supply chain optimisation, government support, reduced installation and O&M costs, public-private partnerships, and market competition. Collaboration and risk-sharing initiatives like the Carbon Trust's Floating Wind Joint Industry Project and MaRINET2's research on Synthetic Mooring Lines further drive down costs and enhance competitiveness.

- Demonstrating successful pilot projects: By showcasing successful pilot or demonstration projects, the industry can provide valuable data on the performance, reliability, and cost-effectiveness of floating wind technology, helping to build investor confidence. Some examples:
    - Hywind project in Scotland, where Equinor developed 5x6 MW turbines mounted on spar-buoy-type floating platforms. Using its experience in offshore oil and gas, Equinor developed a ballasted steel cylinder for stability, achieving a capacity of over 50% in its first two years of operation.
    - WindFloat Atlantic, Portugal: The project uses three 8.4 MW turbines mounted on semi-submersible platforms off the coast of Portugal. The design of the platforms allows them to be fully assembled and commissioned onshore before being towed out to sea, which can significantly reduce installation costs and risks.
- Collaboration and risk-sharing: Collaboration between industry stakeholders, including developers, manufacturers, and investors, can help distribute risks and pool resources. Joint ventures or partnerships can facilitate knowledge sharing and reduce the overall risk exposure for individual investors.
    - Carbon Trust's Floating Wind Joint Industry Project, UK: This initiative is focused on investigating and developing new technologies for floating wind platforms. The project seeks to reduce floating wind energy costs through innovations in platform designs and mooring systems.
    - MaRINET2's Project on Synthetic Mooring Lines: an initiative funded by the European Union, researching synthetic mooring lines. The aim is to develop lighter, more durable, and cost-effective alternatives to traditional chain mooring lines, which could contribute to lowering the overall costs of floating wind technology.

- Government Support and Policy Incentives: Providing financial incentives, such as CfD, tax credits, and loan guarantees, can help mitigate the high upfront costs associated with floating offshore wind projects. Clear and stable government policies that support renewable energy development can also reduce investment risks and attract private sector investment.

Other technological barriers leading to cost reductions are discussed in Deliverable D3.2

Finally, In the UK, there are financial mechanisms and incentives in place to encourage investment in floating offshore wind projects. The government has allocated more than £60 million in public and private investment to support the development of innovative technologies for floating offshore wind. This funding includes over £31 million from the UK government, matched by industry funding, to drive forward plans for placing turbines in deep-sea areas with strong winds, accelerating renewable energy deployment, and maintaining the UK's position as a world leader in offshore wind[66].

Recent developments have seen an increase in financial support for floating offshore wind projects. The maximum strike price for these projects has been raised by 52% to £176 per MWh, aiming to attract more investment and secure the UK's goal of hosting 50GW of offshore wind by 2030[67]. Additionally, a new incentive scheme called the Sustainable Industry Reward (SIR)[68] is being proposed to consider various sustainability factors beyond price, such as local job creation and environmental impact, further encouraging investment in renewable projects.

Tax incentives play a significant role in catalysing decarbonisation projects like floating offshore wind in the UK. Companies can leverage the UK tax system to accelerate such projects, highlighting the government's commitment to supporting green energy initiatives through financial incentives[69]. These combined efforts aim to boost investment in floating offshore wind projects, drive innovation, and contribute to the UK's renewable energy goals.

7.1.1.3 Grid Connection and Integration

The process of integrating floating offshore wind projects into existing onshore grids in the UK is highly complex, requiring solutions to address supply chain limitations, grid connection delays, significant investment demands, technical obstacles, regulatory frameworks, technological advancements, and cost competitiveness. Overcoming these challenges and

[66] https://www.gov.uk/government/news/60-million-boost-for-floating-offshore-wind

[67] https://www.edie.net/uk-boosts-offshore-wind-strike-price-by-two-thirds-after-crisis-talks-with-renewables-industry/

[68] https://energyadvicehub.org/increased-offshore-wind-prices/

[69] https://www.offshore-mag.com/renewable-energy/article/14298758/odfjell-oceanwind-tax-incentives-are-a-catalyst-for-floating-offshore-wind-decarbonization-projects

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seamlessly integrating floating offshore wind projects into the UK's energy infrastructure necessitates close collaboration among stakeholders and a continuous commitment to innovation.

The timelines for connectivity in renewable energy projects are notably prolonged, spanning 10 to 15 years in certain regions of the country. Consultations with the National Grid Electricity System Operator (ESO) and applications for connectivity can only proceed after consenting approval has been secured and seabed leasing has been finalised. Early engagement initiatives are already underway in Wales and Scotland. In some instances, seabed areas are leased without due consideration for connectivity feasibility and without consulting the ESO regarding optimal locations. Recent discussions in Wales highlight ongoing efforts to address these issues and improve the integration process. Some of the key challenges are highlighted below:

- Grid Connection Delays: Delays in grid connection offers for offshore wind projects are hindering the energy transition, with some developers receiving connection offers for the 2030s, slowing down progress. With significant investment required of around £4 billion to establish integrated manufacturing and installation ports for floating offshore wind projects, posing a financial challenge[70].
- Regulatory Frameworks: Streamlined regulatory frameworks are crucial to drive down costs and accelerate market adoption of floating wind farms, emphasizing the need for collaboration between energy developers, grid operators, and policymakers.
- Technological Advancements remain crucial for enhancing the efficiency, durability, and cost-effectiveness of floating wind farms. Continued research and development efforts are necessary to optimize their performance. Floating offshore wind projects encounter technical challenges such as cable procurement, routing, protection, and minimising environmental impacts. These challenges require careful attention to ensure successful project delivery[71].

Furthermore, The UK is undertaking several key strategies to upgrade its grid infrastructure and support the variability and capacity of floating offshore wind farms:

Investment in Port Infrastructure: The government has committed £160 million to upgrade port facilities, aiming to enhance the infrastructure necessary for the development and maintenance of floating offshore wind farms.

[70] https://my.slaughterandmay.com/insights/briefings/a-wake-up-call-for-uk-offshore-wind

[71] https://www.stantec.com/en/ideas/topic/energy-resources/4-challenges-to-overcome-when-transmitting-offshore-wind-power

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Grid Connections: National Grid is working on enabling transmission infrastructure to connect offshore wind farms to the national grid, addressing delays that have been identified as bottlenecks for certain projects.

Integrated Offshore Grids: There's a recognition of the need to develop integrated offshore grids, similar to onshore networks, to efficiently deliver electricity from large-scale renewable projects, including offshore wind farms.

Government Commitment: Both major political parties in the UK have committed to ambitious offshore wind capacity targets, emphasizing the importance of offshore wind in the country's energy transition. The government's focus on creating a conducive regulatory environment and supporting infrastructure development is crucial for the success of floating offshore wind projects.

Transmission Network Holistic Network Design: To support the transmission of electricity generated by renewable energy sources, the UK is implementing a Holistic Network Design of its transmission network and local distribution network.

Grid balancing strategy: While most offshore wind projects are in the North Sea, away from major population centers, strategies to overcome variability include energy storage solutions and co-generation with other offshore technologies like wave, tidal stream energy, and floating solar. The government announced a framework to ease access to funding for co-generation projects, implementing a hybrid metering approach where Contracts for Difference (CfD) will be at the point of generation rather than the BME boundary, allowing both generators to access the CfD.

7.1.1.4 Public Acceptance and Stakeholder Engagement

Environmental concerns: Floating wind farms may raise concerns about potential impacts on marine ecosystems, bird populations, and other wildlife. Transparently communicating the results of environmental impact assessments and demonstrating how potential impacts will be mitigated can help alleviate these concerns and build trust with the public.

Visual impact: Floating wind farms located close to shorelines may generate concerns about visual impacts on coastal landscapes and potential effects on tourism. Selecting appropriate sites with minimal visual impact, considering the use of innovative designs that blend into the environment, and engaging with local communities to address these concerns can help improve public acceptance.

Noise and vibrations: Noise and vibrations from the construction and operation of floating wind farms can be a concern for nearby communities, particularly those near the shore. Implementing noise reduction measures, such as low-noise construction techniques, and

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providing accurate information about the expected noise levels can help address these concerns.

Socio-economic benefits: Highlighting the potential socio-economic benefits of floating offshore wind projects, such as job creation, local economic development, and increased energy security, can help build public support. Engaging with local communities, businesses, and stakeholders to maximise local content and ensure equitable distribution of benefits can further enhance public acceptance.

Raising awareness and understanding of floating offshore wind technology, its benefits, and its potential role in meeting climate and energy goals can help build public support. This can involve organising public information sessions, workshops, and site visits and collaborating with educational institutions to include floating wind topics in their curricula.

7.1.1.5 Supply Chain and Local Content

A systematic approach to developing a supply chain extending to port infrastructure and grid reinforcement: As well as nationally, enabling international standards, certification and policy steps required, the supply chain cannot be tackled in silos. As a critical enabler for the commercialisation and industrialisation of floating offshore wind, enabling investment in the local supply chain is key to driving the creation of advanced materials, manufacturing methods, and components.

Ports are integral to successfully deploying floating offshore wind farms as the interface between maritime developments and the land. Their strategic position creates an opportunity to develop them as multifunctional hubs for offshore wind projects, reducing local and global supply chain constraints. In this role, ports extend beyond logistical services and act as manufacturing and assembly hubs, distributors for specialist spare parts, and providers of technical workforce and ancillary services relating to floating offshore wind.

To strengthen the floating offshore wind industry in the UK and boost local content and manufacturing, several strategies are proposed:

Establishing Local Content Targets: setting specific targets for local content in floating offshore wind projects can incentivise the participation of local manufacturers and suppliers.

Policy Implementation: The development of enacting policies that encourage and support local manufacturing is essential. This includes fostering the growth of domestic manufacturing capabilities for key components such as floaters. Regarding policies, there is also a need to assess their impact on goods and services entering the market, focusing on aspects like procurement conditions and tariffs to ensure a conducive environment for local manufacturing and content.

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To address current challenges in UK manufacturing capacity for offshore wind deployment, the focus is on improving job skills and manufacturing processes. Future opportunities involve integrating domestic content criteria into agreements like Contracts for Difference (CfD). The achievement of a 60% local content target in the 2019 Offshore Wind (OSW) deal was noted as a significant milestone. Manufacturing capabilities and competitiveness rely on strategic long-term market planning and product pipeline management, as well as assessing factors like land and labor costs to maintain competitiveness.

7.1.1.6 Environmental impact and permitting

To obtain permits for floating offshore wind projects in the UK, several environmental challenges need to be addressed. These challenges include a changing regulatory environment, complex permitting processes, assessments becoming more challenging due to the industry's nascency, the need for emergency response plans, and the importance of considering sensitive marine habitats and undersea archaeology.

These environmental impacts are crucial during their planning, construction, and operation phases. While these floating offshore wind farms can help reduce greenhouse gas emissions by producing clean energy, it is essential to identify and mitigate potential adverse effects on the environment. Key environmental impacts to consider include:

Marine Ecosystems: Floating wind farms may impact marine ecosystems through construction noise, potentially disturbing marine mammals, and fish. Additionally, the installation may create artificial habitats, altering local biodiversity. Comprehensive environmental assessments, careful site and design selection, and adaptive management during operation are crucial to mitigate these impacts. Ongoing research projects contribute to reducing the environmental footprint of offshore wind farms[72].

Birds and Avian Species: Floating wind farms pose risks to birds and avian species, including collision with turbine blades and disturbance of nesting or feeding areas. Mitigating these impacts requires careful site selection, monitoring, and proper management. Pre-construction studies, bird-friendly turbine designs, and ongoing research into bird behavior and deterrent systems contribute to effective mitigation strategies.

Benthic Habitats: The installation of mooring and anchoring systems for floating wind farms can disrupt benthic habitats and seabed, causing localised changes to the seafloor and benthic communities. To minimise these impacts, efforts include optimising mooring designs, selecting appropriate anchoring systems, and conducting thorough environmental

[72] Trannum, K., Bakken, T., Alver, O., Axelsen, K.E., Buhl-Mortensen, R., Buhl-Mortensen, P., Jakobsen, J.B., Johnsen, G., Rinde, A.H. and Sandvik, J., 2020. Environmental effects of the deep-water floating wind farm concept - the DEPLOY project. Marine Environmental Research, 160.

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assessments. Preserving benthic habitats involves minimising the physical footprint through careful site selection, innovative mooring designs, sensitive construction scheduling, and optimised cable routing. Ongoing research explores advanced technologies and strategies to reduce these impacts further.

Noise Impacts: Floating offshore wind farms can affect coastal communities and marine users visually and acoustically. However, these impacts are generally less significant than those from nearshore bottom-fixed wind farms. Addressing these issues in planning and design involves implementing sound dampening techniques. Ongoing research aims to enhance turbine designs and layouts to minimise visual impacts and develop effective noise reduction methods for protecting marine life and coastal communities[73].

Electromagnetic Fields (EMF): Subsea power cables generate electromagnetic fields (EMF), potentially impacting marine species, especially those relying on natural geomagnetic fields for navigation, such as sharks and rays. Minimising these effects involves proper cable routing, shielding, and burial. Effective mitigation strategies, including improved understanding and research, are being explored to ensure minimal disturbance to marine life.14

Cumulative Impacts: In regions where multiple offshore wind projects are planned or already in operation, it is essential to consider the cumulative environmental impacts, as they may be more significant than those from a single project.

To mitigate environmental impacts, the taken measures in the UK include:

Thorough environmental impact assessments: Conducting comprehensive environmental impact assessments (EIAs) is vital to identify, evaluate, and mitigate potential environmental risks associated with floating offshore wind farms. EIAs inform the decision-making process, helping to minimise adverse impacts and ensure compliance with environmental regulations.

Site selection: Careful site selection can help avoid or minimise impacts on sensitive habitats, marine protected areas, or important bird areas, reducing potential environmental risks.

Monitoring and adaptive management: Implementing monitoring programs during construction and operation can help identify potential impacts and inform adaptive management strategies, allowing for adjustments to minimise environmental risks.

[73] Cole, L.H., Sleeter, B.D. and Cameron, D.R., 2020. Assessing the impacts of deploying a fleet of utility-scale floating offshore wind farms in California. Ocean & Coastal Management, 184.

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Stakeholder engagement: Engaging with local communities, regulators, and other stakeholders is essential to address concerns, share information, and develop collaborative solutions to mitigate environmental impacts.

Best practices and guidelines: Following established practices and guidelines for the design, construction, and operation of floating offshore wind farms can help minimise environmental impacts and promote the responsible development of this renewable energy source.

7.1.1.7 Technology Development and Standardization

Additional Research and Development efforts to mitigate engineering complexities and challenges associated with integrating floating offshore wind components. With its 6 degrees of freedom, the floating offshore wind turbine introduces uncertainties in the interactions among turbine components and the interface between the turbine and the substructure. Essential data for a more comprehensive understanding of the engineering interface can be collected through pilot projects and collaborative initiatives between manufacturers and developers.

Various floating platform designs, such as spar buoy, semi-submersible, and tension leg platforms, are being explored and tested. R&D efforts in this area focus on optimising these designs for stability, efficiency, and cost-effectiveness while considering specific site conditions, water depths, and environmental factors.

Dynamic electrical infrastructure required for FOWT- including dynamic cables, specialised connectors, protectors, and additional ancillary equipment. Unlike the existing offshore electrical infrastructure employed in fixed-bottom wind and the oil and gas industries, which lack these components and have established Technology Readiness Levels (TRLs), such elements are essential for floating offshore wind projects. They serve as potential single points of failure for individual turbines in the event of faults in the inter-array cabling. Moreover, they play a critical role in the overall wind farm, particularly in the case of export cable failures.

Incorporating cutting-edge technologies and unconventional materials in mooring systems, such as mooring springs, dampeners, synthetic mooring lines, and innovative anchoring systems like mechanical anchors, can extend the system's lifespan, mitigate tension fatigue, and contribute to cost reduction.

Promoting collaboration and data sharing between developers will accelerate the advancement of floating wind innovation. While engineering solutions for technical challenges already exist, optimising these designs relies on efficient feedback loops and mechanisms for sharing data. The improvement of existing designs can be achieved through a shared knowledge interface between projects, though implementing such collaboration may

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necessitate financial incentivisation guided by policies.

Continued support for in-situ research and pilot projects is essential for acquiring insight beyond the scope of numerical modelling simulation or lab-scale experiments. The scale and intricacy of floating offshore wind structures, the complexities of the broader marine ecosystem, and limited historical data render certain design aspects challenging to model or replicate accurately on a smaller scale in a laboratory setting. Financial support for pilot projects is paramount in bridging this knowledge gap and developing effective solutions.

Numerical modelling and multi-body hydrodynamic analysis offer additional insights that complement those obtained from operational scenarios. These models have the capacity to simulate extreme stresses on the system, revealing information that is not present in the dataset—specifically, extremes in environmental conditions induced by severe weather.

7.1.1.8 Weather and operational challenges

Harsh weather conditions, including storms and extreme waves, present significant operational difficulties for floating offshore wind farms in the UK. These challenges include several key areas:

Structural Integrity: Floating offshore wind turbines must endure high winds, waves, and storms while maintaining stability and integrity. This includes mooring systems needing to withstand strong currents and turbulent waves to anchor the turbines securely.

Maintenance and Repair: Accessing wind turbines during harsh weather is challenging, potentially causing delays and increased downtime for maintenance tasks.

Safety of Personnel: Operating in rough seas poses risks to personnel involved in maintenance and operation, necessitating specialised safety protocols and equipment. *Energy Production Variability:* Extreme weather events can disrupt turbine operation, leading to temporary reductions in energy production.

Transportation and Logistics: Storms and adverse weather conditions complicate equipment, components, and personnel transportation, affecting project schedules and costs.

Despite these challenges, advancements in technology and thorough risk assessment can help mitigate the impact of harsh weather. Ongoing research focuses on improving resilience and performance in extreme marine environments[74]. Addressing operational challenges is crucial for the successful integration and growth of the sector, considering risks related to lease availability, grid connectivity, consenting, and revenue contracts. Additionally, meeting the UK's target of 5GW of floating offshore wind by 2030 is hindered by supply chain issues,

[74] Celtic Sea Power (2023), https://celticseapower.co.uk/industrialized-floating-offshore-wind-is-risky-an-opportunity-for-the-uk/

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logistical complexity, and cost pressures[75]. Despite these hurdles, scaling up renewable energy capacity, including floating offshore wind, remains essential for the global energy transition. Industry developments and initiatives like the upcoming CfD auction aim to address pricing issues and enhance the sector's commercial viability[76].

To enhance the resilience and operational efficiency of floating offshore wind projects in adverse weather conditions, various measures are putting in place in the UK:

Strategic planning of specialist vessels to maximise the installation and O&M activities during the most suitable weather conditions through strategic planning of specialist vessels ensures efficient project execution.

Optimised design of components for ease of assembly and disassembly will reduce assembly and maintenance time. Quick-release cables, for instance, facilitate rapid decoupling and minimise downtime. Innovative anchoring systems that can provide stability to floating offshore wind turbines, ensuring structural integrity, efficiency, and longevity.

Leveraging accurate metocean data is crucial for predicting weather windows and scheduling operations effectively. In addition to the development and use of advanced simulation models: that can support in designing resilient floating offshore wind turbines. These models can optimize designs, assess structural integrity under different environmental conditions, and develop risk mitigation strategies.

Incorporating sustainable materials in offshore engineering solutions to improve wind turbine design, enhancing resilience and operational efficiency while contributing to sustainability.

Enhance industry collaborations and knowledge sharing to advance simulation models and ensure project resilience.

7.1.1.9 Interplay with other energy sources

In the UK, there is an increase in initiatives focusing on co-location and hybridisation of offshore wind projects with other technologies. These projects aim to achieve various objectives such as enhancing energy efficiency, providing grid stability, optimising the seabed space, and contributing to achieving UK Net Zero targets. Some examples are highlighted below:

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75 A wake-up call for UK offshore Wind (2023), https://my.slaughterandmay.com/insights/briefings/a-wake-up-call-for-uk-offshore-wind

76 OffshoreWIND.biz (2023), https://www.offshorewind.biz/2023/01/27/overcoming-floating-wind-challenges-is-key-to-global-energy-transition-houlder/

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Project Colocate[77], funded by The Crown Estate and Crown Estate Scotland, is to investigate the viability of the area on the seabed for colocation of Carbon Capture and Storage (CCS) and offshore wind, with bespoke monitoring plans for each area.

HOWaT project[78], Strathclyde University, still at the conceptual stage; this project uses a hybrid device with two turbines for wind (NREL 5MW) and tidal (Atlantis SeaGEN-S 2MW) generation.

Hybrid offshore renewable energy projects in the UK encounter challenges related to technology, regulation, and innovation but also offer significant opportunities for growth, sustainability, and the achievement of clean energy objectives outlined by strategic initiatives like the EU's offshore renewable energy strategy. Efforts to address these challenges and leverage the opportunities can lead to a more efficient and interconnected offshore renewable energy network, as highlighted across multiple sources:

Challenges:

1. **Technical Hurdles**: Implementing hybrid offshore networks involves overcoming technical barriers, such as developing interoperable high-voltage, direct-current (HVDC) transmission systems to connect wind farms efficiently.
2. **Regulatory and Political Complexities**: Establishing international offshore wind farm networks requires navigating intricate political and regulatory landscapes to ensure the effective implementation of cross-border energy projects.
3. **Technological Innovation**: Developing technological solutions today that anticipate future energy system requirements poses a significant challenge for stakeholders involved in offshore wind expansion.

Opportunities:

1. Growth Potential: Hybrid offshore wind and wave power systems offer substantial growth potential in the renewable energy sector, providing opportunities for sustainable energy generation.
2. EU Strategy: The European Commission's strategy on offshore renewable energy sets ambitious targets for installed capacities of offshore wind and ocean energy by 2030 and 2050, fostering investment and development opportunities in this sector.

77 https://www.offshorewind.biz/2023/11/28/uk-offshore-wind-and-ccs-colocation-projects-kick-off/

78 https://www.esru.strath.ac.uk/EandE/Web_sites/16-17/WindAndTidal/concept.html

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3. Technological Advancements: Advances in technology, such as floating offshore wind turbines, are creating new possibilities for harnessing renewable energy from the seas, driving innovation and deployment of hybrid assets in offshore regions.

7.1.1.10 International Collaboration and Standardization

International collaboration can be fostered by implementing collaborative approaches across various sectors and stakeholders, European (and global) countries can effectively share best practices, align standards, and collectively address common challenges in the energy sector.

Collaboration between financing institutions, state-owned energy companies, and private entities are key to drive the sector forward; partnerships in aspects such as developing port infrastructure are essential, considering factors such as grid reinforcements and manufacturing policies, among other considerations, to capitalise on future opportunities.

These collaborations, at the European or global level, will support the development of infrastructure, aligning standards, and addressing common challenges. Additionally, They will drive progress on innovative technologies, strategic partnerships, data sharing, and industry-scientific community collaboration in the sector. Effective development of energy basins is mutually beneficial.

In the UK, there are opportunities for joint research and development initiatives to drive innovation in floating offshore wind in:

Innovative Technologies: Demonstrating high-potential innovative technologies like quick connectors and crane concepts can enhance the assembly of wind turbine generators (WTG) on floating offshore wind (FOW) platforms. However, there is a need for collaboration between Original Equipment Manufacturers (OEMs), FOW project developers, and technology developers to validate and adopt these innovations.

Strategic Partnerships: Collaboration between experienced industrial players, local stakeholders, and the scientific community is essential to drive innovation, reduce costs, improve data sharing, accelerate innovation validation, secure investments, and enhance knowledge in the floating offshore wind sector.

Promoting Data Sharing: Encouraging collaboration and data sharing among developers can accelerate the advancement of floating wind innovation. While engineering solutions exist for technical challenges, optimising designs requires efficient feedback loops and mechanisms for sharing data.

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Industry-Scientific Community Partnership: Promoting collaboration between the industry and the scientific community facilitates tailored innovations in the sector. This partnership is fundamental for overcoming technological limitations and developing state-of-the-art tools in floating wind technology.

Fostering collaboration between component manufacturers, wind farm developers, research institutions, and government agencies can facilitate knowledge sharing, resource pooling, and expertise exchange to accelerate the development and deployment of floating wind technology.

7.2 Portugal

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in Portugal.

7.2.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.2.1.1 Regulatory Framework

There is no dedicated regulatory framework for floating offshore wind in Portugal. The regulatory framework currently applied is the same as established for onshore wind, which is well-defined and supportive. However, there are ongoing efforts to address offshore challenges and seize opportunities in the sector. Offshore wind auctions are being introduced in the country, designed to allocate project licenses and capacity to developers through a competitive bidding process, aiming to ensure the cost-effectiveness and efficiency of energy production.

7.2.1.2 Cost Competitiveness

Anticipated opportunities are on the horizon for floating offshore wind projects, driven by the forthcoming auctions. As these auctions unfold, the regulatory framework is poised to serve as a catalyst, enabling the advancement of such projects. Additionally, it's imperative that inflation concerning commodities and offshore goods is mitigated. This reduction is anticipated to be facilitated by establishing a maximum strike price during the auctions.

7.2.1.3 Grid Connection and Integration

The enhancement of the grid's physical infrastructure entails constructing new transmission lines and substations, alongside upgrading existing ones to support increased power flows. Given the variability of wind power, more sophisticated grid management systems are essential. These systems incorporate advanced forecasting tools to anticipate wind power generation and adjust grid operations accordingly. Furthermore, the integration of demand response programs and energy storage solutions can offer the grid the flexibility required to manage the variable output from wind farms effectively. Additionally, prioritizing the improvement of interconnections with neighboring countries' grids and investing in energy storage technologies are recognized as pivotal strategies.

7.2.1.4 Public Acceptance and Stakeholder Engagement

Offshore wind auction areas have been designated in deeper waters, situated farther from the shore, with a focus on minimizing interference with identified restriction zones. The process has involved ongoing public consultation, with representation from pertinent entities on the advisory committee overseeing the allocation plan. Concerns and suggestions raised during this consultation period are being carefully considered and incorporated into subsequent iterations of the national allocation plan.

7.2.1.5 Supply Chain and Local Content

This is a significant concern, not only within Portugal but throughout Europe. The supply chain within Portugal has yet to fully mature. Moreover, the ambitious targets set by various European countries partially overlap, raising the prospect of potential exhaustion within the regional supply chain. To address this, there is a specific proposal under consideration to require local content as a pre-qualification criterion for offshore wind auctions in Portugal. Establishing partnerships with key stakeholders within established supply chains globally could accelerate the learning curve within Portugal, facilitating rapid progress in this regard.

7.2.1.6 Environmental impact and permitting

Permitting processes in Portugal involve rigorous environmental impact assessments (EIA) and public consultations. Regulatory authorities' main concerns are related with potential impacts on specific wildlife groups about which there are knowledge gaps. These are the following: impacts on marine birds, impacts on bats, water quality, impacts on marine mammals, underwater noise, marine growth on the platforms - biofouling and artificial reef effects.

To minimise environmental footprint and navigate the permitting process effectively the industry should address two main challenges in Portugal:

- Collect baseline data since there is an overall lack of information of the Marine Environment in bathymetries below 30m of depth.
- Willingness to perform a complete Environmental Monitoring Program. Such programs should be designed not only to gather data but also to establish a Reference Situation

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that will serve as the benchmark for evaluating potential environmental impacts.

7.2.1.7 Technology development and standardization

Floating wind technology is less mature than fixed-bottom options, with fewer deployed projects to date, meaning there are fewer standardized designs and practices, making it harder to predict performance and costs accurately. Strong wave climates off the Portuguese west coast may pose a significant engineering challenge, as technologies will have to withstand harsh maritime environments while maintaining efficiency. While there is a need to develop a local supply chain and the necessary infrastructure for large-scale FOW, a considerable challenge per se, technologies will also need to adapt to foreseeable supply chain constraints (e.g. port characteristics). Developing efficient O&M strategies to address increased O&M challenges for FOW farms due to their remote offshore locations and the dynamic nature of floating platforms is critical for ensuring long-term reliability and performance.

Collaboration between academia/research and the industry facilitates the transfer of knowledge and technology. Universities and research institutions can provide cutting-edge research and innovation, while industry partners can offer practical insights and commercialization pathways, ensuring that research outcomes have real-world applications. On the other hand, by partnering with entities in other countries, Portuguese stakeholders can tap into global knowledge, access new markets, and participate in international standard-setting efforts. International collaborations can also open up additional funding opportunities and facilitate the exchange of best practices and technology. Overall, the outcomes of these collaborative efforts will increase market attractiveness, boosting investment opportunities and launching the seeds for a mature innovation-based supply chain.

7.2.1.8 Weather and operational challenges

Metocean conditions in the areas with the most favorable resources in Portugal can present significant challenges, especially concerning extreme waves. Nonetheless, technologies such as the Windfloat (both the demo and the WindFloat Atlantic pre-commercial farm) have already demonstrated their efficacy in these conditions. Moreover, there is evidence indicating a higher frequency of suitable weather windows for installation and O&M activities compared to other exposed coastlines.

To enhance the resilience and operational efficiency of these projects in adverse weather conditions, it is crucial to develop adequate O&M strategies, sub-components and enabling technologies, alongside monitoring systems and routines of critical components (e.g. dynamic power cables).

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7.2.1.9 Interplay with other energy sources

The integration of floating offshore wind projects with other renewable energy sources in Portugal, diversifies the renewable energy portfolio, which helps to mitigate risks associated with overreliance on a single energy source and enhances energy security. It creates complementarity of generation profiles (e.g. solar resource is very attractive in the country), which helps smoothing out fluctuations in energy generation and enhances the overall reliability of the energy supply. It makes it easier to match energy supply with demand, reducing the need for energy storage or backup power plants. It can lead to cost efficiencies, e.g. by sharing transmission infrastructure or maintenance vessels, reducing operational costs and environmental impacts.

Nonetheless, the implementation of hybrid projects should face some challenges in Portugal. The framework in the country may be favorable to the development of hybrid projects, but there are still some concerns cost-wise that need to be addressed.

7.2.1.10 International collaboration and standardization

Portugal has long nurtured a culture of collaborative research and development initiatives as a cornerstone of innovation. The establishment of Technology Free Zones (known as ZLTs in Portuguese), which are physical environments strategically located to facilitate testing and experimentation under the supervision of relevant authorities, exemplifies this commitment.

7.3 Italy

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in Italy.

7.3.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.3.1.1 Regulatory Framework

The current regulatory environment falls short of being supportive. According to Article 23 of DL 199/2021, the Ministry of Environment and Energy Security, in coordination with other authorities, is tasked with consenting responsibilities. However, the process remains unclear, highlighting the need for a streamlined, one-stop-shop approach. Several factors contribute to lengthy procedures: inadequate staffing dedicated to permitting, insufficient information provided to citizens and stakeholders regarding the real benefits, costs, and impacts of

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Floating Offshore Wind (FOW), resulting in strong opposition, and the absence of a comprehensive Maritime Spatial Plan (MSP) integrated into the regulatory framework.

A significant gap lies in the absence of a complete MSP, leading to unidentified areas suitable for offshore wind farm installation, which should be predetermined and auctioned. Consortia must conduct thorough environmental and socio-economic impact assessments before seeking authorization, necessitating considerable time and financial investments. This introduces uncertainties regarding the outcome of the authorization process and requires effective management of opposition from stakeholders and citizens.

7.3.1.2 Cost competitiveness

Italy is defining financial mechanisms or incentives to encourage investment in floating offshore wind projects. Feed-in Tariffs (FiTs), currently applied for onshore wind, will be extended to offshore wind as well (FER2). The anticipated feed-in tariff, which serves as the base auction price for offshore wind, has been set at approximately €185 per megawatt-hour (MWh). Additionally, there are government financing instruments for research and innovation projects within the PNIEC (Integrated National Plan for Energy and Climate).

7.3.1.3 Grid Connection and Integration

The primary technical challenges concerning the connection between Floating Offshore Wind Turbine (FOWT) plants and the onshore grid can be outlined as follows:

- AC/DC array and export dynamic cables are essential but are still undergoing development. Currently, only the 66 kV AC dynamic cable has reached the commercial phase.
- A floating offshore substation (OSS) suitable for deep waters exceeding 60 meters, which are typical of FOWT projects, is required but not yet available. Alternatively, consideration could be given to a fixed OSS for deep waters.
- HVDC solutions become more efficient and cost-effective for distances exceeding approximately 50 km, particularly for wind farms exceeding 1 GW in capacity. However, there is a lack of standardized regulations governing this.

The development plan outlined by TERNA involves allocating over €20 billion in investments[79] over the next decade to expedite the energy transition.

[79] https://www.terna.it/en/electric-system/grid/national-electricity-transmission-grid-development-plan

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7.3.1.4 Public Acceptance and Stakeholder Engagement

Concerns about noise, visual impact, and perceived property value reductions may lead to resistance and legal challenges in Italy. To minimize these challenges, a public consultation of all stakeholders is performed during the procedure for the maritime state-owned property.

7.3.1.5 Supply Chain and Local Content

The promotion of local content and manufacturing to bolster the Floating Offshore Wind Turbine (FOWT) industry in Italy can be achieved through several strategic initiatives. Firstly, forging partnerships with local businesses and academic institutions enables the industry to drive innovation and cultivate expertise tailored to the FOWT sector. By implementing policies that incentivize the utilization of locally sourced materials and services in the construction and maintenance of FOWT projects, domestic manufacturing can be further incentivized. Moreover, investing in training programs geared towards equipping the local workforce with specialized skills necessary for FOWT technologies is imperative. This ensures a continuous supply of qualified personnel to support the industry's growth. Government initiatives offering incentives to companies prioritizing local content in their supply chains can serve as a catalyst for increased domestic participation.

Lastly, public awareness campaigns highlighting the economic and environmental advantages of FOWT can garner community support, fostering a conducive environment for the flourishing of local content and manufacturing. Through these concerted efforts, the FOWT industry can thrive while contributing to the economic and sustainable development of our country.

7.3.1.6 Environmental impact and permitting

The Environmental Impact Assessment (VIA) is a fundamental part of the permitting process in Italy. The legislation establishes the minimum requirements to be met for the environmental impact assessment. Specifically, a preliminary study must be addressed, covering at least the following points:

(a) environmental effects of the project, including cumulative effects, and possible impacts from accidents or malfunctions;

(b) feasibility of technical and economic mitigation measures that can reduce or eliminate adverse environmental effects;

(c) elements not covered in the regulations but deemed necessary by the competent authority;

(d) public consultation concerning the project, i.e., its social acceptance.

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Once the environmental impact analyses are sent to the competent authority (MASE), the applicant must receive the General Minimum Technical Solution or STMG, from TERNA, National Grid Electric Transmission (TSO) company, which defines the criteria for grid connection. In some cases, depending on where the submarine pipelines run, it is necessary to have the Environmental Impact Assessment (VIncA, art. 5 D.P.R. n. 357/97). Finally, it is required to make noise measurements for all site areas before the operation of the wind farm.

7.3.1.7 Technology development and standardization

The biggest challenge in developing and standardising floating offshore wind technologies is related to the many different conditions that characterise different Italian areas in terms of wind and sea conditions, geological conformation and depth of the seabed, distance from the coast, marine flora and fauna, and constraints related to other activities at sea. The development of standards for different conditions is a lengthy process for which there is currently insufficient information. IEA Task 49[80] (Integrated DEsign of floating wind Arrays – IDEA) is working to develop standard arrays for different scenarios.

Within national projects funded by the Ministry of the Environment (National Fund for Electric System Research), joint efforts between research, academia and industries can strongly accelerate the advancement of the technology (the first pilot of FOWT was installed in the Gulf of Naples).

7.3.1.8 Weather and operational challenges

In Italy, harsh weather conditions do not represent a big challenge. However, due to climate change it is important to be able to predict the characteristics of the wind resource in the future. Precise forecasts of possible future extreme events, suitable designs that ensure resilience and safety, remote monitoring systems that provide early warnings and thus timely intervention in the event of an emergency, are the measures that can be implemented to enhance the resilience and operational efficiency of FOW projects.

7.3.1.9 Interplay with other energy sources

The interest in integrating different offshore technologies is demonstrated by some projects under consideration for authorization. Those projects propose hybrid solutions such as integration of wind offshore (both floating and bottom fixed) and floating photovoltaics. Wave energy converter integration has also been investigated.

[80] https://iea-wind.org/task49/

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7.3.1.10 International collaboration and standardization

International collaborations at EU level are already in place, for instance: SET-PLAN, IEA Wind TCP, EERA JP Wind, ETIP WIND. These organizations work in writing strategic documents covering perspectives, needs and objectives to be achieved, implementation plans, reports summarising R&D results achieved, data, and best practices and standards. Additionally, there are several funding opportunities for joint R&D projects in Horizon Europe CL5, Sustainable Blue Economy Partnership, Mission Ocean.

7.4 Greece

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in Greece.

7.4.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.4.1.1 Regulatory Framework

The regulatory framework for offshore wind in Greece was set by the Law 4964/2022 in July 2023. In accordance with Law 4964/2022, the National OWF Development Programme for (NDP-OWF) sets the potential OWF Organized Development Areas (OWFODA), which are areas that could potentially accommodate OWF projects for development in the medium- and long-term. This programme analyses the Greek marine area and identifies the potential OWF Organized Development Areas (potential OWFODA), which are high-confident areas for OWF sitting in the medium- and long-term. The draft NDP-OWF, including the relevant Strategic Environmental Impact Assessment study (SEIA) study, is submitted for approval to competent authorities in order to have legislative validity. In general, the approved NDP-OWF sets the main pillars at national level for the planning, development, siting, installation, and operation of OWF as well as the medium- and long-term goals of installed capacity for OWF projects.

7.4.1.2 Cost competitiveness

The upfront costs of floating offshore wind technology can be reduced in Greece through government financing and participation of citizens in FOWT investments.

7.4.1.3 Grid connection and integration

Currently, Greece has no offshore wind parks installed. The existing infrastructure of the Greek transmission system and the new interconnections envisaged along with the planned internal projects included in the National Energy and Climate plan, and especially those connecting the Aegean islands with the mainland system and the interconnection with Crete, will play an important role in connecting offshore wind to the grid, while contributing to the 2030 and 2050 targets. The critical issue of networks to absorb the power generated by offshore wind is of great concern to investors not only in Greece, but throughout Europe. The offshore transmission infrastructure needed to connect offshore RES may cover up to 54,000 km of routes in European waters.

7.4.1.4 Public acceptance and stakeholder engagement

Currently, there is limited public engagement on FOWT in Greece due to the fact that the process is still at the very early stages. However, there are already difficulties in public acceptance in some specific selected areas in Crete. The major issue in Greece is the numerous touristic areas that depend exclusively from the tourism sector. It is expected that major efforts will be needed to enhance public acceptance by employing stakeholder engagement practices. For example, both the participation of stakeholders in FOWT investments (like in Belgium) as well as regular consultation and information to increase awareness, can take into consideration and address their concerns, resulting in higher support for FOWT development in Greece.

7.4.1.5 Supply chain and local content

There are decommissioned shipyards, harbors and industries in Greece that can be brought into operation and manufacture cheap Greek components for FOWT development. Furthermore, the company Hellenic Cables is one of the biggest cable producers in Europe. Their capacity and expertise can strongly support the development of FOWT in Greece. Finally, there is a large domestic production of steel and cement, which are major components of FOWTs. Their domestic production can reduce FOWTs’ cost and facilitate their development in Greece.

7.4.1.6 Environmental and permitting

The installation of FOWT within environmental protected areas, as they emerge from international conventions (e.g., Ramsar Convention on Wetlands, NATURA 2000 Network) and the National Law (established marine or underwater parks), is subject to restrictions. Considering that, the distance of OWF from the protected areas consists of a major criterion for evaluating the sitting areas in order to ensure the maximum possible limitation of the impacts as a whole on a country scale. In addition, particular risks and obstacles appear to arise for the avifauna and marine fauna. Under this scheme, the requirements to be met for the installation of OWF take into account the possibility of: (i) losses due to crashing, (ii) obstruction and obligation to change course and (iii) formation of obstacles in migratory

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corridors. The potential environmental impacts are assessed through Special Ecological Assessment Studies (SEAS), including Special Ornithological Study. Finally, the installation and operation of OWFs may disturb and affect the behavior or migration routes of marine mammals and other species. Assessment of potential effects on fauna can be conducted through dedicated SEAS. Furthermore, measurements regarding the Sea conductivity, temperature, chlorophyll-A Dissolved O2, Salinity, PH and underwater noises must be taken into account, along with aqua life and birds monitoring (e.g. radar). Regarding marine antiquities, their protection is deemed necessary.

7.4.1.7 Technology development and standardization

Greece has the opportunity to leverage its expertise in marine engineering and renewable energy to contribute to the development of floating offshore wind technology. Research institutions, universities, and private companies can collaborate on R&D projects to improve the efficiency, reliability, and cost-effectiveness of floating wind platforms. This may involve innovations in floating platform design, mooring systems, and turbine technology to withstand the unique challenges of offshore environments. Standardization of floating offshore wind technologies is essential to ensure safety, interoperability, and cost efficiency.

7.4.1.8 Weather and operational challenges

Although harsh weather conditions (storms and extreme waves) create unfriendly environments for developing FOWT, in Greece (particularly in Aegean sea), according to experts, the weather conditions are optimal for the efficient operation of FOWT.

7.4.1.9 Interplay with other energy sources

The integration of floating offshore wind projects into the energy mix will be beneficial for Greece. According to the Greek national plan of 1.9 GW installed offshore wind farms by 2030, there will be a balanced wind-solar-hydroelectric mix which will lead to a smoother distribution of green energy production over the 24-hour period and is in line with the national strategy to make the country an exporter of green energy.

7.4.1.10 International collaboration and standardization

Dedicated international events (capacity building, co-creation, and mutual learning activities) about FOWTs, including stakeholders and experts from the quadruple helix, can play a vital role in sharing knowledge and insights across European countries. The model followed by Greek companies is searching for strategic partnerships between Greek and European companies that have knowledge from past experiences.

There are plenty of joint initiatives between Greek and European companies to explore opportunities for exploration, license granting and development of both bottom-fixed and floating offshore wind technologies. Specifically, there is an agreement between El.PE. Hellenic Petroleum and the German RWE Renewables for claiming license for bottom fixed and floating offshore wind parks. Also, there are agreements between Mytilineos and Copenhagen Offshore Partners, Ocean Winds and TERNA Energy, Motor Oil and Abu Dhabi Future Energy Company, Copelouzos Group and RF Energy, INTRAKAT and Parkwind, as well as FARIA Renewables and DEME.

Beyond the above agreements, there is a huge interest for collaboration between PPC Renewables and Total Eren, while other European companies expressed their interest for the claiming shares in the Greek market, such as Equinor, Iberdrola and Enel. Finally, Greece can participate in international standardization efforts led by organizations such as the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). Additionally, establishing national certification procedures and guidelines can instill confidence in investors and stakeholders.

7.5 Spain

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in Spain.

7.5.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.5.1.1 Regulatory Framework

The current regulatory framework is undergoing public consultation until March 25th. However, its content lacks clarity regarding the delegation of auction definitions and evaluation criteria, which are deferred to future ministerial orders. Moreover, it fails to harmonize bonds with other applicable laws, such as coastal and electrical sector laws. Notably, there are no anticipated auctions for pre-commercial farms. Furthermore, once a project is awarded, it does not possess any rights over the seabed. There is a proposal to suspend any request for proposals until the awarded project secures seabed rights. Under the existing regulatory framework, only prototypes, R&D platforms, and pre-commercial projects can progress to the operational stage. However, there is no mechanism in place to provide them with tariffs to ensure profitability.

Looking ahead, significant gaps exist in areas such as bonds and the reimbursement model. Concerning bonds, while the total amount is capped at 5%, there is no clear coordination on how it will be distributed across different bonds as required by related laws. Additionally, there is a lack of clarity on decommissioning bonds, potentially hindering social acceptance. Regarding the reimbursement model, concerns revolve around the lower number of reimbursable hours compared to offshore wind, absence of indexation, and the limited duration of Contracts for Difference (CfD) lasting no more than 20 years.

7.5.1.2 Cost Competitiveness

The existing regulatory framework in Spain, marked by a state of moratorium and perceived procedural sluggishness, stands as a significant barrier to the commercialization of Floating Offshore Wind Technology (FOWT). While the commencement of a public consultation for future auctions in March 2023 may offer a chance for regulatory adjustments, the current pace engenders uncertainty, impeding industry momentum and potentially compromising cost competitiveness. Streamlining the regulatory process through proactive stakeholder engagement, transparent communication, and expeditious auction developments is imperative to transition the regulatory framework from an impediment to an enabler for FOWT commercialization in Spain. However, the current draft still breeds considerable uncertainties, including the absence of a tentative pipeline of projects, which poses a barrier for prospective investors.

To alleviate the high initial costs associated with floating offshore wind technology in Spain, various technical measures can be implemented. While the Government's prioritization of FOWTs through the Maritime Spatial Management Plans (POEM) is commendable, bureaucratic delays in paperwork and auction processes must be minimized to expedite project timelines. Leveraging technical advancements, such as utilizing government-funded LiDAR-equipped buoys for wind resource assessment, holds promise in significantly reducing costs. These buoys furnish accurate, real-time data on wind conditions at potential project sites, facilitating optimized turbine design and placement. Furthermore, fostering collaborative research endeavors aimed at enhancing technology efficiency, reducing manufacturing costs, and fostering public-private partnerships can collectively contribute to gaining a competitive edge for FOWT in the Spanish energy landscape. Notably, Spanish companies are actively involved in developing 14 out of approximately 50 floating foundations patents currently underway worldwide. Developing solutions that slash costs and enable industrialization and scalability for commercial offshore wind farms will be pivotal in driving down floating offshore wind expenses. Transitioning towards a centralized grid model, where the Transmission System Operator (TSO) assumes responsibility for executing the primary portion of the evacuation line, and enhancing projects to connect to the grid at sea rather than offshore can further lower project costs.

In Spain, the recognized financial mechanisms for floating offshore wind projects predominantly

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originate from European sources, with no specific Spanish mechanisms or incentives formally documented. For instance, initiatives like Renmarinas demos aim to facilitate the execution of new prototypes for floating foundations. The anticipated financial mechanism involves a Contracts for Difference (CFD) model. However, as presently defined, it may fail to effectively incentivize investment. In fact, if implemented as currently outlined, it could potentially result in higher costs than anticipated by the government.

7.5.1.3 Grid Connection and Integration

Currently, the onshore electricity infrastructure in Spain is ill-equipped to manage the energy generated offshore. Plans for reinforcement of Spain's national grid system by 2030 align with the anticipated construction of the first offshore wind farms. However, this endeavor is complicated by the overarching issue of outdated grid infrastructure, inadequately prepared for the rapid surge in renewable energy production. The congestion within the existing grid, exacerbated by the proliferation of renewable energy sources, raises significant concerns regarding the seamless integration of floating offshore wind projects.

Presently, it is anticipated that projects will connect to onshore grid connection points. However, discussions are underway to potentially transition to a centralized model where projects connect directly to the grid at sea. If implemented, this shift poses the challenge of ensuring readiness of the new network to accommodate future project connections.

Addressing these challenges necessitates substantial public investment devoid of commercial interests, driven solely by the imperative to minimize losses from offshore power generation. Given the constraints of the current grid infrastructure and the rapid expansion of renewable energy, a comprehensive strategy is imperative. This strategy should involve substantial public investment, streamlined regulatory processes, and the development of a technologically advanced grid to effectively meet Spain's escalating energy demands. In the northern region of Spain, there is ongoing discussion about reinforcing the current connection to France through sea interconnection, facilitated by offshore wind farms evacuation infrastructure.

7.5.1.4 Public Acceptance and Stakeholder Engagement

Currently, there is a widespread NIMBY (Not In My Backyard) sentiment prevalent in Spain. While people acknowledge the necessity of renewable energies, they are resistant to having renewable energy projects located near their immediate surroundings, even if they do not contribute to renewable energy production in their area. The primary concern among communities is not necessarily about noise or visual impact, but rather a fear of potential negative effects on the marine environment.

To address this challenge, a novel initiative is being developed within a project in Spain. It involves citizen participation through investment of their own funds in the project, utilizing

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crowdfunding models. Should the project emerge as the successful bidder, citizens living in proximity to the project site are encouraged to invest in it. This approach aligns with the interests of local residents, as they are invested in the success of the project and stand to benefit financially from their investment.

7.5.1.5 Supply Chain and Local Content

The lack of a robust European supply chain for floating offshore wind (FOW) components poses significant challenges to project development and competitiveness. This issue becomes particularly pronounced in permitting processes that prioritize local content and European products. Dependence on Asian suppliers introduces the risk of delays due to long-distance sea transport. Addressing these challenges necessitates strategic investments aimed at bolstering the European supply chain, reducing reliance on international markets, and enhancing project efficiency.

Even though Spain has a relevant supply chain related to some of the main components of FOW projects, and several Spanish ports have a good potential for FOWT execution, investing in the enhancement of existing infrastructure is paramount to supporting the FOW industry. Repurposing disused ship workshops located near major roadways offers a strategic opportunity for revitalizing and localizing manufacturing activities. This entails directing funds toward the modernization of these facilities, transforming them into specialized hubs for manufacturing FOW components. Collaborative efforts between industry stakeholders and government entities can streamline this process, fostering local content and revitalizing local economies. This approach not only promotes sustainable growth within the FOW industry but also creates a mutually beneficial scenario.

Furthermore, supporting supply chain and port authorities through clear pipelines, targeted investment, and efficient permitting processes will facilitate the expansion of manufacturing capacity and, consequently, the growth of local content within the FOW industry.

7.5.1.6 Environmental impact and permitting

In Spain, permitting floating offshore wind projects involves environmental challenges that require assessment. Environmental impact assessment, together with geological and geophysical surveys, is essential. However, a major challenge arises from the unclear nature of the environmental permits outlined by the ministry. This ambiguity adds complexity to the permitting process, so it is crucial that developers take a proactive role in designing projects that conform to potential permitting requirements. As the regulatory landscape becomes clearer, collaboration between developers and regulatory authorities will be essential to address specific environmental impacts on marine ecosystems and wildlife, ensuring the sustainable development of floating offshore wind projects in Spain.

In order to minimize the environmental footprint and effectively navigate the permitting process in the context of marine ecosystems in our country, it is imperative to address specific challenges related to the implementation of offshore wind energy. Notably, concerns surround the emerging technology of floating offshore wind, marked by limited pilot projects and the limited knowledge regarding its environmental impact in the deployment areas. Issues pertaining to the interaction between offshore wind and fishing activities include direct impacts on marine resources, species, and habitats, requiring attention to noise, collision, and habitat modification. Additionally, conflicts arise with protected areas like Natura 2000, aligning with biodiversity conservation goals set for 2030.

To address these challenges, corrective measures are proposed. First and foremost, offshore wind deployment should be prioritized as a key component of the energy transition. Clear regulations and designated areas for fishing activities should be established, ensuring legal frameworks for coexistence. Comprehensive studies on the environmental impacts of offshore wind, particularly regarding noise and habitat modifications, should be conducted before project construction. After project construction and during decommissioning transparent monitoring of the environmental aspects must be mandatory. Pilot projects can serve to gather environmental data and study specific marine areas. Adopting principles of Ecosystem-Based Management (EBM) is recommended, focusing on ecological integrity, uncertainty management, and social integration. Ensuring compatibility with biodiversity and local communities is crucial, involving the exclusion of wind farm locations from Marine Protected Areas. Additionally, proposing biodiversity recovery plans within offshore wind parks, including initiatives like creating artificial reefs, can contribute to a more sustainable integration of offshore wind energy.

7.5.1.7 Technology development and standardization

Developing and standardizing floating offshore wind technologies to ensure reliability and performance presents inherent challenges. The complexities arise at the outset, particularly in achieving compatibility between turbine developers and floating structures. The lack of standardization related to floating foundations brings uncertainty around the development of port infrastructure in Spain. Depending on the kind of material or the specific solution, the needs of the line of quay, surface of esplanade, bearing capacity of the different elements change.

Collaborative research and development efforts in Spain play a pivotal role in accelerating the advancement of floating offshore wind technologies. Firstly, fostering a collaborative ecosystem among turbine developers, float manufacturers, and other stakeholders is essential. This collaboration facilitates knowledge sharing, encourages interdisciplinary perspectives, and streamlines the integration process. Establishing research consortia and partnerships that involve academia, industry players, and government agencies can pool resources and expertise, leading to more comprehensive studies and innovative solutions.

To further accelerate technological advancements, a coordinated approach to research and development should be undertaken. This involves setting common research goals, sharing data, and promoting open communication channels. Government support through funding initiatives and incentives for collaborative projects can significantly boost these efforts. Additionally, creating a regulatory framework that encourages collaboration while ensuring safety and environmental standards is crucial.

7.5.1.8 Weather and operation challenges

In Spain, the operational challenges posed by harsh weather conditions vary significantly between the Atlantic Ocean and the Mediterranean Sea. The Atlantic coast, characterized by more frequent storms and higher waves, demands a robust design that can withstand these extreme events. Conversely, the Mediterranean Sea, with its distinct weather patterns, presents challenges such as calmer seas but also encounters specific regional conditions. The operational requirements for floating wind farms must therefore be finely tuned to the unique characteristics of each region, acknowledging the diversity of weather conditions along Spain's coasts.

To enhance the resilience and operational efficiency of floating offshore wind projects in Spain, it is imperative to tailor designs based on precise regional data. For the Atlantic coast, where storms and high waves are more prevalent, employing advanced materials and construction techniques capable of withstanding extreme conditions is crucial. In the Mediterranean, where tides and wave dynamics differ, a nuanced approach to technology design is required. Implementing real-time meteorological monitoring systems specific to each region enables anticipatory adjustments during adverse conditions. Additionally, incorporating adaptive operational strategies considering the varying tides and weather patterns in the Atlantic and the Mediterranean ensures optimal project performance. Ongoing research initiatives should focus on understanding and mitigating the specific challenges posed by the diverse weather conditions along Spain's coasts. By tailoring solutions to regional characteristics, the floating offshore wind industry in Spain can effectively navigate the unique challenges presented by the Atlantic Ocean and the Mediterranean Sea, ensuring resilient and efficient project operations.

7.5.1.9 Interplay with other energy sources

The integration of floating offshore wind projects can significantly complement other renewable energy sources, such as solar or conventional offshore wind, to establish a balanced and reliable energy mix in Spain. While solar power excels in meeting peak daytime consumption, the continuous and substantial nature of onshore and offshore wind power generation ensures a more consistent energy mix. This constant energy production, particularly when combined with floating offshore wind projects, has the potential to mitigate the necessity for extensive energy storage solutions. By synergizing these diverse renewable sources, a more resilient and stable energy grid can be achieved, addressing fluctuations in energy supply and demand and promoting a sustainable and reliable energy future for any country.

The integration of floating offshore wind projects enhances the consistency of the Spanish energy mix, complementing peak daytime solar generation. Considering hybrid projects combining different offshore renewables, challenges and opportunities exist. While globally, these concepts are advanced, Spain is in an early stage of offshore wind development, with no offshore wind auction held to date. Exploring hybrid projects, especially for green hydrogen, faces challenges due to Spain's current technological immaturity in offshore wind. As Spain progresses in offshore wind, hybrid project exploration holds promise but requires careful study.

7.5.1.10 International collaboration and standardization

Significant opportunities for joint research and development initiatives exist in Spain to drive innovation in floating offshore wind. Many Floating Substructure System (FSS) developers in Spain have dedicated research teams that played a pivotal role in conceiving their respective concepts. Furthermore, the MarineWind project, funded by the European Union, aims to enhance knowledge in the marine wind sector, particularly in the field of floating wind. However, there is a recognized need for more research in Spain on this topic. It is anticipated that this research will gain momentum in the coming years, aligning with the increasing deployment of offshore wind projects in the country.

7.6 Belgium

We are performing the financial analysis on all the MARINEWIND partner countries, even those, such as Belgium, where we don't have labs just yet.

This section includes extensive information of how different aspects, such as regulatory framework, cost competitiveness, grid connection and integration, public acceptance and stakeholder engagement, supply chain and local content, environmental impact and permitting, technology development and standardization, weather and operational challenges, interplay with other energy sources, and international collaboration, affects the commercialisation and the market of floating offshore wind turbines in Belgium.

7.6.1 Commercialisation of Floating Offshore Wind Turbines (FOWT)

7.6.1.1 Regulatory Framework

The federal government has established a dedicated offshore wind zone and is developing a second zone to encourage offshore wind energy production. Competitive bidding procedures are being developed to ensure cost-effective deployment in these zones. Belgium's transmission system operator (TSO) has developed a modular offshore grid to connect offshore wind projects to the onshore grid, with plans for further expansion.

7.6.1.2 Cost Competitiveness

Similarly to other geographies, cost reduction can be achieved through innovation and technology development, economies of scale, as well as government policies and incentives. On the one hand, Belgium will benefit from an optimized supply chain, shared infrastructure, and the learning from bottom fixed offshore wind. On the other hand, FOW will face the competition of the already established BFOW and will likely strive to match it in maturity and cost wise. As an EU member, Belgium benefits from the broader EU initiatives designed to support the development and deployment of renewable energy projects, including floating offshore wind.

7.6.1.3 Grid Connection and Integration

Belgium's transmission system operator (TSO) has devised a modular offshore grid to link offshore wind projects to the onshore grid, with additional expansion endeavors in progress. Strategies for enhancement may encompass bolstering grid flexibility utilizing technologies such as energy storage systems to manage variability, upgrading transmission lines to accommodate heightened capacity, and integrating smart grid technologies to optimize demand response and distribution efficiency. Furthermore, improvements in regional grid interconnections may be pursued to facilitate seamless energy exchange and balance across borders, thereby optimizing the utilization of renewable energy sources and ensuring stability and reliability in the energy supply.

7.6.1.4 Public Acceptance and Stakeholder Engagement

We lack specific insights into public perception studies conducted in Belgium. Competitive bidding procedures (tenders) overseen by the federal government aim to expand offshore wind capacity in a manner that minimizes social costs and aligns with European and Paris Climate Agreement objectives. Public consultation should be integral throughout this process.

7.6.1.5 Supply chain and local content

Belgium has a well-established bottom-fixed offshore wind (BFOW) sector. Exploring overlaps and synergies with floating offshore wind (FOW) could streamline the process of establishing a dedicated supply chain for FOW. Leveraging existing OFW infrastructure and expertise may expedite the integration of FOW into the country's renewable energy portfolio. Industry can collaborate with local manufacturers, incentivize investment, fund research and development, train local talent, enforce local content requirements, and establish industry clusters.

7.6.1.6 Environmental impact and permitting

The FOW sector might face the same environmental challenges as the BFOW has been facing in the past decades and no specific challenges have been identified for the FOW industry.

7.6.1.7 Technology development and standardization

The efforts that can potentiate Belgium's advantageous position as a BFOW experienced market to make it a key player in advancing floating offshore wind tech globally are: pooling resources, fostering innovation ecosystems, leveraging strategic partnerships, focusing on niche areas for global leadership, ensuring robust government support and policy frameworks, integrating education and workforce training, and adopting international collaboration for shared knowledge and standards.

7.6.1.8 Weather and operational challenges

The North Sea experiences fewer extreme events on average compared to other exposed water markets. Challenges are already well-understood based on BFOW experience. Measures that can be implemented to enhance the resilience and operational efficiency of these projects in adverse weather conditions are creating effective strategies for operations and maintenance (O&M), including sub-components, enabling technologies, and monitoring systems for critical components like dynamic power cables.

7.6.1.9 Interplay with other energy sources

Integrating FOW with other renewables and conventional offshore wind enhances Belgium's energy mix by balancing generation profiles, ensuring grid stability, and leveraging existing infrastructure for cost efficiency and rapid deployment. This diversified approach mitigates weather-related variability, providing reliable and continuous energy supply. However, solar energy is not expected to be a prominent energy resource in the country.

Hybrid projects raise concerns cost-wise. However, there is potential in the region for multi-source offshore parks, as demonstrated by the Horizon Europe EU-SCORES project.

7.6.1.10 International collaboration and standardization

International collaborations are a valuable instrument for steeper learning that will be fostered by relevant players. This may create the opportunity to place Belgium as a major

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global FOW technology exporter.

Belgium offers significant opportunities for joint R&D initiatives in floating offshore wind, focusing on innovation, cost reduction, and technology advancement, such as cross-sector partnerships between universities, industry, and government.

8. CONCLUSIONS

The Financial Key Performance Indicators (KPIs) outlined for MARINEWIND are crucial for evaluating the financial health and success of floating offshore wind turbine (FOWT) projects. These KPIs, spanning from cumulative investments to Return on Investment (ROI) and Debt-service Coverage Ratio (DSCR), provide a comprehensive framework for stakeholders to assess the sustainability and profitability of the initiatives throughout their lifecycle. Regular monitoring and analysis of these KPIs will enable informed decision-making, contributing to the long-term success of MARINEWIND projects.

The barriers and enablers to floating offshore wind farms present a comprehensive overview of challenges and opportunities. Financial barriers, including funding shortages and communication issues, hinder project development, while enablers like government support and collaboration with the oil and gas sector can enhance project viability. Overcoming financial hurdles requires strategic interventions, collaboration, and government support to unlock the vast potential of floating offshore wind as a sustainable and competitive energy source. The EU Commission's Wind Energy Action Plan demonstrates a strategic approach to address challenges in financing the wind sector. Actions 7 to 10 focus on fostering innovation, leveraging financial instruments, and engaging with stakeholders. The plan provides a conducive environment for growth, investment, and sustainable technologies, aligning with the EU's clean energy objectives.

In the context of the socioeconomic impact of offshore wind farms on fisheries, the issue is complex with both positive and negative outcomes. The study by Gill et al. (2020) identifies various effects, from artificial reef benefits to fisheries exclusion and ecological consequences. The conflicts between wind farming and fisheries require proactive measures such as Maritime Spatial Planning to address potential damage, disturbance of species, and economic and socio-cultural conflicts. A holistic and collaborative approach is essential for the coexistence of offshore wind farms and fisheries, considering ecological, economic, and socio-cultural dimensions.

Market factors assume differentiated classifications across European countries, from market enablers to barriers, from opportunities to challenges. Cost competitiveness and environmental impact & permitting have been identified as two of the main challenges for the commercialization of FOW. Several of the identified factors, such as regulatory framework & government incentives and supply chain & local content, can either present a barrier or an enabler, depending on the geographies and the market reality. Pre-existing activity, notably BFOW, is a relevant factor to facilitate market penetration, although it can create the reverse effect of enclosing FOW in a competitive environment.

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Most of the risks to FOWT commercialisation that have been identified were classified as ‘medium’ or ‘very important’ level. The main concerns revolve around financial risks, both concerning high capital costs and financing uncertainty, as well as risks associated with the volatility in commodities prices, particularly exposed by recent global events. On the other hand, weather and operational risks, represented by extreme weather events and operational challenges, seem not to be a major concern for the MARINEWIND LABs.

The European FOW markets exhibit significant diversity, with some countries possessing mature supply chains, grid adaptations, port infrastructure enhancements and regulatory frameworks inherited from preexisting bottom-fixed offshore wind, while others are still in early stages of development. This diversity offers opportunities for collaboration and the exploration of complementarities, enabling mature markets to support less developed ones through knowledge exchange and resource sharing. By pooling expertise and resources, stakeholders can address common challenges, foster innovation, and accelerate the growth of the FOW sector across Europe.

Overall, this conclusion highlights the importance of financial metrics, strategic interventions, and collaborative efforts in ensuring the success and sustainability of floating offshore wind projects and addressing the multifaceted challenges associated with the integration of wind farms and fisheries.

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