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The Iberian region as a hub for technology development and industrial leadership in the field of floating offshore wind

Summary Report

enzen

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Summary Report

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Address by Javier Sanz

The energy transition is a global-scale initiative targeting the transformation of the energy sector from a fossil-based to a zero-carbon scheme by 2050. The main motivation is the need to decarbonise the global energy sector, which implies the progressive implementation of measures that reduce CO_2 emissions related to energy generation in order to mitigate the effects of climate change. According to IRENA, renewable energy, deep electrification and energy efficiency measures can potentially achieve 90% of the required carbon reductions.

The energy transformation needed to meet these targets is only possible by scaling up wind power generation capacity installations in the coming years. One major step in this direction has been the impressive development of offshore wind technologies, which have become a major contributor to global electricity generation. However, the potential of traditional offshore wind is limited by water depths and seabed conditions.

Floating foundations are potentially a "game-changer" technologies to effectively exploit abundant wind potential in deeper waters, leading the way for rapid future growth in the offshore wind power market and, therefore, to the decarbonization of the energy sector in many countries where deeper waters do not allow the installation of traditional bottom-fixed offshore wind turbines. Increasing economies of scale, more competitive supply chains and further technological improvements will continue to reduce the costs of FOWE.

For instance, 80% of all the offshore wind resource is located in waters 60 m and deeper in European seas, where traditional bottom-fixed offshore wind is not technically viable or economically attractive. The European Union is already at the forefront of this technology as the only region in the world with pre-commercial projects. The EU has historically bet on offshore technologies and has supported its development both institutionally and financially with funding opportunities such as Green Deal Call or the Innovation Fund. Nevertheless, if it wants to secure its global leadership it needs to move fast and increase its investments in floating offshore wind.

Within the EU, Spain and Portugal have sufficient grounds for leading the development of this technology given their existing industrial capabilities, strategic geographical positioning, competitiveness, research centres and academia, etc. Additionally, floating offshore wind energy (FOWE) technology development has attracted players to the region that have leveraged current capabilities from other sectors, what has resulted in Iberia holding a first-mover advantage for the development of certain key elements in remarkable FOWE projects such as WindFloat Atlantic.

The promotion of a technological and industrial activity such as FOWE in the Iberian region will contribute not only to mitigate the climate change through the development of a clean power generation technology, but also will bring a positive macroeconomic impact in the region, derived from the creation of qualified jobs, exports and GDP growth.

This publication summarizes a comprehensive analysis of the main elements to develop the Iberian region as a hub for technology development and industrial leadership in the field of FOWE on the basis of an existing strong combination of infrastructure, industry, research centres and universities.

Even though the Iberian region has already positioned itself as a strong player in FOWE technology and industry development, a tailored action plan, based on creating a long-term policy vision to enable a local demand of projects and attract investment, should be key for leveraging existing capabilities and securing a hub position.

InnoEnergy is confident that this report will guide the technology and industry stakeholders' efforts to turn the Iberian region into a technological and industrial hub in the floating wind and contribute to driving the energy transition.

Javier Sanz
Thematic Leader – Renewable Energies, InnoEnergy

Executive summary

The rationale behind this report is to show that there is a solid basis for the Iberian region to become a technology and industry hub for floating offshore wind energy (FOWE), answering the following questions:

- What is floating offshore wind technology and its market?
- What is the opportunity for the Iberian region to become a hub for technology development and industrial leadership in the field of FOWE?
- How can the Iberian region seize this opportunity?

The main conclusions are based on a review of different developing technologies, a global market outlook, a value chain analysis, the estimation of the potential macroeconomic impact FOWE would have in Iberia, the assessment of the regulatory framework and a set of recommendations to promote the development of FOWE in the region.

Floating offshore wind technology

Based on the analysis of current technologies, semi-submersible floaters and spar-buoys are expected to be the market openers, motivated by their advanced stage of development and their proven performance in oil and gas applications. However other technologies are being developed, being the Iberian region a relevant example of technology development.

Given its applicability, FOWE is expected to be a grid-scale power generation technology rather than a niche technology. However, there are specific applications or niches where FOWE may already have a business case such as blue economy development initiatives, island communities heavily reliant on oil imports for electricity generation or offshore facilities (e.g., Equinor - Hywind Tampen).

Current LCOE levels for FOWE are yet not competitive against other generation technologies; however, significant cost reductions are expected in the coming years which will bring down the LCOE by 66% on average.

The floating offshore wind market

Growth of FOWE will be greater compared to other technologies in the past due to:
The energy transition is already a reality, renewable energy sources are required to meet national-level objectives and the international context is encouraging investment in renewable energies.
FOWE time to maturity is shorter than other renewable technologies were in the past, as it is a combination of different technological elements from other industries (primarily from wind power and offshore oil and gas).
WindEurope estimates 450 GW of offshore wind by 2050 in order to meet 30% of Europe's electricity demand in 2050; between 100 and 150 GW of these are anticipated to be floating. According to this analysis, Iberia could install 22 GW of FOWE, 13 GW in Spain and 9 GW in Portugal.

In the Iberian region there are several FOWE technologies being developed, available capacity and sufficient resource potential; nevertheless, there are no large projects planned in the foreseeable future. Therefore, barriers must be eliminated by supporting professionalization, cooperation in the sector and creating stronger regulatory support; and drivers must be activated.

On the supply-side market, the Iberian region has already taken significant steps; for instance, a Spanish shipyard has constructed the floating structures for some of the most relevant FOWE projects.

Local demand for projects will be required to strengthen existing capabilities, boost the industry and leverage the first-mover advantage the Iberian region already has across the FOWE value chain. This is a requirement to propel Iberia towards a hub position.

Key drivers for boosting FOWE in Iberia in the short-term are a supportive regulatory framework for project development, together with specific finance and support for local technology development.
FOWE development in the medium and long term will be driven by LCOE reduction resulting in increased competitiveness against other RES, the sustainability of a supportive regulatory framework and the establishment of clear national objectives for ocean energy.

The floating offshore wind value chain

The Iberian region is already strong in FOWE technology and has a strong wind power industrial network mainly derived from onshore wind.
FOWE technology development has attracted players to the region that have leveraged current capabilities from other sectors such as shipbuilding industry. This prompt entry of certain players has resulted in Iberia holding a first-mover advantage for the development of certain key FOWE elements such as floaters.

Overall, the Iberian region has strong capabilities across almost the entire FOWE value chain, resulting in a relatively advantageous positioning against other competing regions. The Atlantic coast of the Iberian region (incl. Portugal) concentrates most of the key capabilities for FOWE technology and industrial development. This part of Iberia will therefore benefit from an increasing development of this technology. To end their reliance on expensive fossil fuels for energy generation, the Canary Islands are set to become a key demand area for FOWE in the short-/mid-term.

With current capabilities and supply chain requirements, Iberia's immediate addressable markets will include the EU and the USA's East Coast. In the short- to mid-term, Africa and LATAM will not be addressable markets since their primary focus will be PV; however, there might be an opportunity in the European Islands in the Atlantic Coast of Africa (the Canary Islands, Azores and Madeira).
The value chain analysis shows that Iberia has sufficient grounds to become a technology and industrial hub for several FOWE key elements.

Macroeconomic impact of FOWE in Iberia

The macroeconomic impact analysis of FOWE development is based on two scenarios targeting between 11 and 22 GW of installed capacity in Iberia by 2050. According to these scenarios, annual GDP contribution could reach a value between €4,681 and 7,752 million respectively (direct + indirect contribution). The activity with a higher cumulative GDP contribution in the region would be the manufacturing of FOWE elements (72%) followed by O&M of FOWE farms (17%). The consequent job creation would range between 43,669 and 77,825 jobs (direct + indirect) in 2050, representing between 0,18% and 0.31% of the workforce in Iberia in December 2019. These would be highly skilled industrial jobs.

FOWE contribution to GDP per installed MW is expected to be greater than it was for onshore wind due to FOWE's higher industrial content (and LCOE) and export rates. FOWE shall contribute as a driver for synergistic industries as it touches upon capabilities from numerous sectors that will benefit from increased activities.

Regulation and support framework

Investments in the development of new projects and in the supply chain, require a political perspective to 2030 and beyond.
The establishment of binding technology-specific objectives in NCEPs is considered the most powerful stimulus for investment in renewable energy as this would drive stakeholders to make the required investments for the development of this technology. Given the potential of the Iberian region and the strong existing value chain, both countries should set more ambitious targets for the development of this technology.

Project development for FOWE in Spain and Portugal entails a rather complex process, as it is affected by several regulations from different national-level authorities. Additionally, these regulations are usually outdated and do not reflect the reality of new activities or applications such as FOWE, hindering their development. The two key aspects that will be required to be updated in both countries to enable FOWE development are:

- Establishment of an appropriate maritime spatial planning.
- Streamlining of the related regulation and administrative procedures.

To reach country-level RES targets, governments implement a mix of policy instruments to support the development and deployment of these technologies. The renewable energy sector involves a host of policy tools and regulations and there are no fit-all approaches.
Based on current market trends and following the example of leading countries such as UK and France, the two supporting mechanisms identified as most appropriate for offshore wind development are the so-called contracts for difference (CfD) and auctions.

- Auctions are the most common schemes to allocate support in a competitive bidding process for renewable generation in which prices are determined by the market and not by the government.
- CfDs are an innovative supporting mechanism which is gaining relevance as the most appropriate for offshore wind development since they are more cost-effective for the government, better aligned with the market (CfDs are indexed with the electricity market price) and the off-take risk is shared between generators and governments.

The maximum annual cost for governments of implementing CfDs in Iberia would be between €259 and 606 million depending on the scenario, which would only represent between 8% and 11% of the estimated GDP contribution of FOWE in the same year.

Recommendations and Action Plan

Based on the existing business case, the final part of this report develops a tailored Action Plan seeking to boost the development of FOWE technology and the Iberian industry, leveraging the existing strengths and mitigating weakness and threats. This Action Plan is structured across seven (7) lines of action which include seventeen (17) specific measures to be implemented in the Iberian region.

Figure 1. Summary of measures in the Action Plan.

	Measure
A. Long-term vision	1. Define a strategy for the development of offshore energy 2. Create a joint working group in the Iberian region (based on the Atlantic super-cluster)
B. Maritime spatial planning	3. Include in the MSPs specific areas for the development of FOWE
C. Regulation and support schemes	4. Update the regulatory framework for permitting and grid connection 5. Establish a remuneration framework with specific mechanisms for offshore energy 6. Establish a calendar for auctions according to offshore generation targets
D. Electricity grid	7. Develop T&D grid planning according to offshore generation targets and reserved maritime areas
E. R&D	8. Definition of an integrated R&D and innovation programme 9. Establish specific remuneration mechanisms for pilot projects or demonstrators 10. Engagement of port authorities for the development of FOW projects 11. Development of a flagship pilot project with support from the government 12. Promote Canary Islands as a development site
F. Training and education	13. Preparation of a guide for administrative processing for offshore energy projects 14. Include FOW-related topics in education curricula in the Iberian region
G. Promotion campaign to targeted groups	15. Social awareness campaigns for offshore energy 16. Sectoral cooperation and training campaigns 17. Organization of international FOW events in Iberia

Source: Enzen analysis, EIT InnoEnergy.

Introduction

The global energy transition objectives highlight the importance of wind power as a key contributor to the decarbonization of the energy sector. After years of development, onshore wind power is currently struggling with limitations regarding resource availability, space limitations and turbine size constraints. This has sparked the development of offshore wind technologies, which have become a major contributor to global electricity generation in the last decade. However, the potential of traditional offshore wind is limited by water depths and seabed conditions.

Floating offshore wind is potentially a "game-changing" technology to effectively unlock the abundant wind potential in deeper waters, leading the way for rapid future growth in the offshore wind power market. A floating wind turbine is mounted on a floating structure that allows power generation in water depths where bottom-fixed turbines are not feasible.

While FOWE technology was previously confined to R&D, it has now developed to such an extent that several demonstration projects are currently in operation. Even though there is still some technological development to be done, FOWE technology is ready to roll out and scale-up.

The key advantages of FOWE include the following:

- Integration of the most powerful wind turbines (8 MW and above).
- Deployment in waters of up to 300 metres in depth or even more, allowing access to stronger and more reliable winds, reducing visual impact as they are far from shore, and reducing the impact on other sea activities such as fishing, coastal navigation, and recreation.
- Simplified, flexible deployment as FOWE structures can be assembled in quaysides and then towed to sites, reducing installation costs associated with heavy-lift vessels.
- Access to diverse industrial capabilities as floating structures can be manufactured using both steel and/or concrete, depending on local availability.

Figure 2. Turbine installed in Portugal (WindFloat Atlantic project).

Floating offshore wind technology

As a consequence of its recent development, different FOWE concepts are currently under development in different regions (Figure 3); with Europe, Japan and the USA positioned as innovation leaders. Spain is the country with the most technologies identified in the study as currently under development.

Figure 3. Geographical distribution of FOWE concepts under development (Total=34)[1].

UPC (WindCrete)
Nautilus Floating Sol. (Nautilus)
Cobra ACS (FLOCAN[2])
Iberdrola (TLPWind)
Esteyco (TELWIND)
X1 Wind (X1 Wind)
Saitec Offshore Tech. (SATH)
EnerOcean (W2POWER)

TetraFloat Ltd (TetraFloat)

Naval Energies (Sea Reed)
CETEAL (XCF)
Ideol (Damping Pool)

GustoMSC (TriFloater)
Blue H Engineering (Blue H)
SBM Offshore (SBM Windfloater)

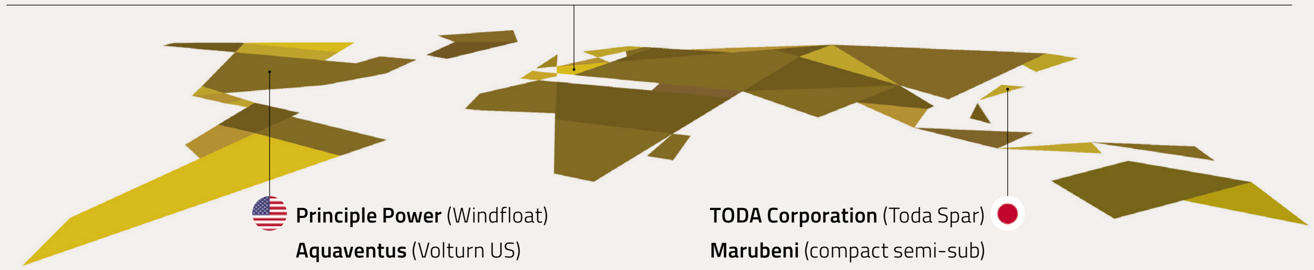
Equinor (Hywind)
Dr. Techn. Olav Olsen (OO-STAR)
SWAY A/S (SWAY)

Aerodyn Engineering (SCDnezzy2)
Gicon (GICON-SOF)

Saipem (Hexafloat)

Stiesdal Offshore Techs. (Tetraspar)

Hexicon (HEXICON G2)



Principle Power (Windfloat)
Aquaventus (Volturn US)
Glosten (PelaStar)
DBD Systems LLC (Eco TLP)

TODA Corporation (Toda Spar)
Marubeni (compact semi-sub)
Marubeni (V-shape semi-sub)
Marubeni (Advance Spar)

Notes
1. Low TRL (3 or lower) and vertical axis concepts have not been identified.
2. FLOCAN concept was developed by Cobra but they has already decided not to implement it.

Source: Enzen analysis, EIT InnoEnergy.

To analyse the wide spectrum of FOWE concepts/technologies, these have been grouped into six categories according to the design of its floating structure, mooring system and TRL. While some of these FOWE concepts are novel designs, others are based on legacy technologies from offshore rigs used in the oil and gas industry.

The more developed concepts, inherited from the oil and gas industry, are spar buoy, semi-submersibles and TLPs, while some more novel concepts include barges, hybrids and 'game changers':

- Spar buoy technology consists of a cylinder ballasted to keep the centre of gravity below the centre of buoyancy. The floating structure is kept in position by a catenary or taut spread mooring lines with drag or suction anchors.
- Semi-submersible floaters consist of a number of large columns, which provide hydrostatic stability, linked by connecting bracings/submerged pontoons, which provide additional buoyancy. These platforms achieve static stability by distributing buoyancy widely at the water plane. The floating structure of semi-submersibles is kept in position by catenary or taut spread mooring lines with drag or suction anchors.
- Tension-leg platforms have a central column and arms connected to tension tendons which secure the foundation to the suction/piled anchors. These floaters achieve static stability through the tension in the mooring lines and a submerged buoyancy tank.
- Barge-type structures have a very large pontoon structure and they achieve stability via distributed buoyancy and by taking advantage of the weighted waterplane area for righting moment.
- Hybrids are those which combine elements and properties from the aforementioned categories.
- Game changers are defined as those with the most novel and disruptive concepts.

Different FOWE concepts or technologies may have different characteristics that affect their suitability for different applications. The following characteristics have been assessed for each technology group:

- Floating structure design, where the analysis depends on the simplicity of the substructure, its mass, proven technology, and the simplicity of wind turbine control.
- Draft requirements are analysed based on their suitability for different water depths and port friendliness.
- Mooring system depends on the design simplicity, suitability for seabed conditions and footprint.
- Marine operations are analysed based on their self-stability, simplicity of onshore turbine assembly and use of widely available and low-cost vessels.
- Seakeeping performance analysed depending on their sensitivity to waves and the ability to cope with extreme weather events.
- Lifetime costs which depend on their CAPEX and OPEX.

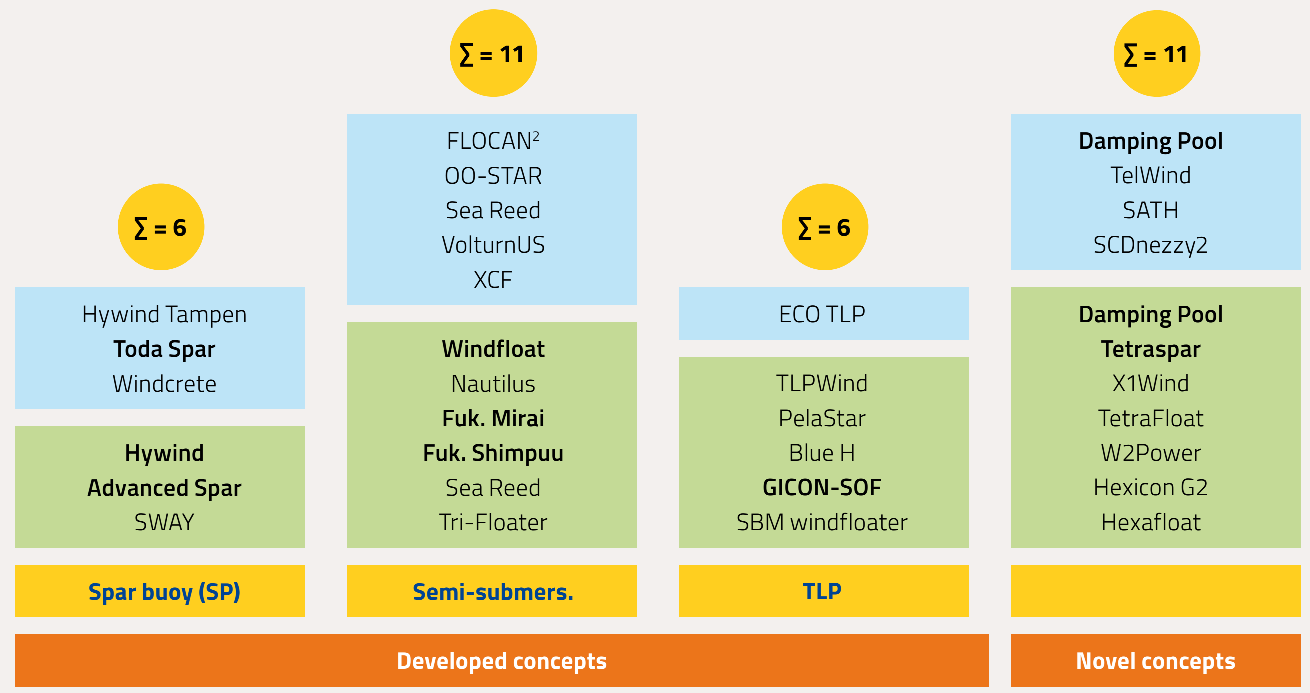
This analysis shows that, in general terms, semi-submersible structures have the most positive assessment, followed by the barge and the spar. However, this is not a definitive conclusion, as the suitability of a technology is strongly dependent on the specific conditions of each project; for example, for a project site with rough sea conditions, a spar-buoy floater will be the most appropriate one. In the case of hybrid concepts and game-changers, a fair assessment is not possible since there are relevant differences between the diverse technology concepts within each group.

FOWE concepts vary not only according to their design, but also according to the material with which they are built. To date, the most developed floating structures (demonstrators and prototypes) have been primarily made of steel, reflecting the dominant trends in the bottom-fixed offshore wind (BFOW) and oil and gas industries; however, there are also concrete concepts, and a clear winner is yet to emerge. Figure 4 shows the classification of the previously identified FOWE concepts according to their construction material, either steel or concrete.

Both steel and concrete structures have their advantages and disadvantages and its suitability will depend on different factors such as the availability of materials, manufacturing infrastructure, etc.

On the one hand, concrete is an inherently durable material. Its constituent materials can easily be tailored to provide different features such as degrees of durability, resistance to marine corrosion, etc. Nevertheless, their offshore longevity for floating applications is yet to be proven in the long-term. The cost of raw materials per ton of concrete is also lower compared to steel and it is not subjected to price volatility. Nevertheless, the initial investment required in quayside facilities for concrete manufacturing is larger than the one needed for steel since the mass and size of the

Figure 4. Classification of FOWE concepts[1] according to construction material (Total=34).



Notes
1. Low TRL (3 or lower) and vertical axis concepts have not been identified.
2. FLOCAN concept was developed by Cobra but they has already decided not to implement it.
*Bold concepts indicate those operating ones at a full-scale demonstration or pre-commercial array stages.

Source: Floating Offshore Wind: A Situational Analysis, Catapult (2018); Enzen research, EIT InnoEnergy.

structures are greater. Concrete manufacturing also unlocks higher local content which not only impacts transportation, which is a key environmental consideration, but it can later bring further benefits such as securing greater support from local governments.

On the other hand, steel's environmental credentials are excellent, being considered the most recycled material in the world. Also, steel has a long history of being used in offshore applications such as shipbuilding, the oil and gas industry and BFOW.

Finally, both steel and concrete structures can be affected by the marine environmental conditions; for example, steel structures are very sensitive to oxygen in the atmosphere due to corrosion, while concrete structures are more sensitive to environmental conditions such as frost and rain during manufacturing. Therefore, the materials used for offshore applications and the manufacturing processes must have higher quality standards than for onshore ones, in order to prevent future failures during useful life.

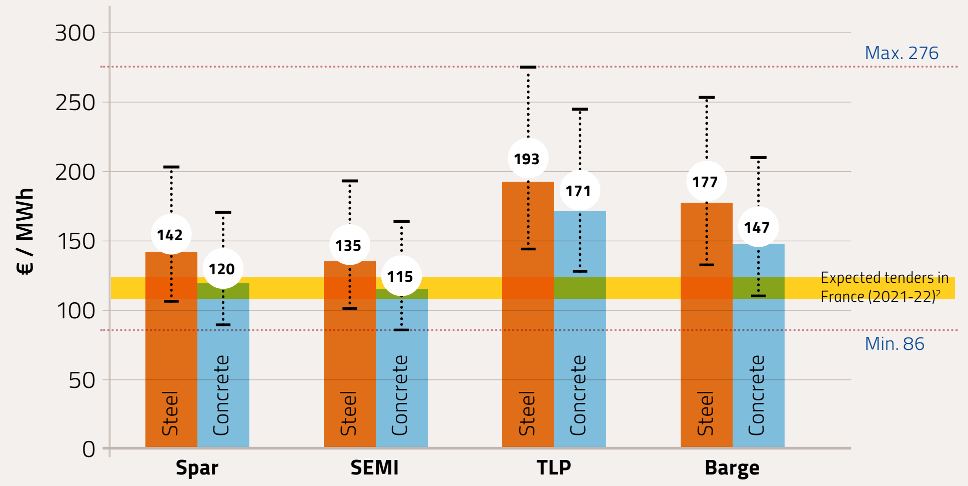
LCOE analysis

The levelized cost of energy (LCOE) is a measure of the average net present cost of electricity generation of an energy plant over its lifetime. It is used to calculate the present value of the total cost of building (CAPEX) and operating (OPEX) a power plant over an assumed time span. This measure allows comparing different power generation technologies when operating in competitive markets.

The LCOE for FOWE has been calculated only for spars, semi-submersibles, TLPs and Barges since the concepts within each group have common characteristics. Calculating the LCOE of hybrids and game-changers would imply a much more detailed analysis of every specific concept within these diverse technology groups. Figure 5 shows the result of the LCOE calculation for the four technology groups analysed. All numbers are in 2019 € throughout this report unless otherwise noted.

These results indicate that semi-submersible and spar-buoy technologies would have lower LCOE values compared to TLP and barge. As the LCOE is strongly dependent on the specific conditions of a project's site, the estimated variation of the LCOE for each technology has also been indicated with a range. The maximum value is reached by a steel TLP and the lowest by a concrete semi-submersible unit. These findings also indicate that concrete structures would have a lower LCOE than steel structures regardless of the technology.

Figure 5. LCOE comparison for FOWE technologies.[1]



Notes
1. Based on current prices
2. Expected target strike prices for a 250 MW project in Brittany (120 €/MWh) and a 250 MW project in the Mediterranean (110 €/MWh); LCOE values do not take into account development costs, therefore they are comparable to the LCOE figures from public tenders in France.

Source: Beiter, P., Musial, W., et al. (2016), A Spatial-Economic Cost-Reduction Pathway Analysis for US Offshore Wind Energy Development from 2015–2030; Myhr A., Bjerkseter C., Ågotnes A. and Nygaard T. (2014), Levelised cost of energy for offshore floating wind turbines in a life cycle perspective; Seaplace analysis; Enzen analysis, EIT InnoEnergy.

As there are no full-scale commercial projects in operation yet, current LCOE for FOWE is still relatively uncertain. Current LCOE estimates are significantly higher than those for other renewable energy sources (RES), but the analysis carried out in this report shows that the LCOE of a 500 MW farm could be close to that of other RES such as BFOW or solar PV. Furthermore, FOWE could already be competitive against diesel power generation in certain isolated regions which are heavily dependent on fuel imports, such as small archipelagos.

As with any other technology in the early stages of development, the LCOE for FOWE is expected to lower over time, increasing its competitiveness against other power generation sources. This future reduction shall be driven by three main levers:

- The first lever is CAPEX reduction, which will depend on the manufacturing costs and the use of new materials for floating structures and mooring and anchors systems. Other factors that will contribute to a reduction in CAPEX values include the reduced use of heavy-lifting units during installation marine operations (quayside assembly of the wind turbine) or the pre-lay of mooring and anchoring systems.
- OPEX reduction is the second lever. The key drivers in this case are the reduction of the fatigue of wind turbine components by improving life cycle performance, the reduction of maintenance costs due to the use of advanced materials and optimized logistics (marine operations for O&M activities).
- The third lever for LCOE reduction is a better power/generation ratio for FOWE units, which will be given by the scalability of the system and its capacity to integrate larger wind turbines.

The impact of this levers for LCOE reduction has been analysed for each FOWE technology group in order to assess the market potential for each of them. The result of this analysis shows that

spars and TLPs have more room for LCOE reduction compared to semi-submersibles or barges. Hybrids and game-changers are the most novel concepts and have a higher potential of CAPEX reduction due to mass production; however, LCOE reduction in these categories will depend on each specific design.

In terms of potential LCOE reduction, spar-buoy is the best ranked because of its potential reduction in manufacturing costs due to standardization and mass production, its potential reduction in the cost of marine operations associated to heavy lifting operations and its scalability to integrate larger wind turbines.

At this point in the report, three different aspects across FOWE technologies have been analysed: the applicability of each technology, the LCOE analysis, and the estimation of the LCOE reduction potential. In accordance with this analysis, spar-buoy and semi-submersible technologies have positioned, as the most promising technologies for future FOWE development, based on currently available information. In terms of applicability, semi-submersible technology is the best ranked given its favourable low draft requirements and self-stability features, allowing onshore turbine assembly, therefore resulting on the lowest total costs (CAPEX and OPEX) across all technologies. However, the main advantages of spar-buoys are its simple structural design and its exceptional seakeeping performance in rough sea conditions, therefore resulting in a similar LCOE as semi-submersibles despite higher total costs. For example, the Hywind Scotland 30 MW farm has achieved an average capacity factor of about 65% during its first year in operation.

Based on this thesis, semi-submersible floating structures are expected to be the most common technology for FOWE applications, except for those sites with rough sea conditions that could significantly reduce its capacity factor, therefore justifying a spar-buoy floater.

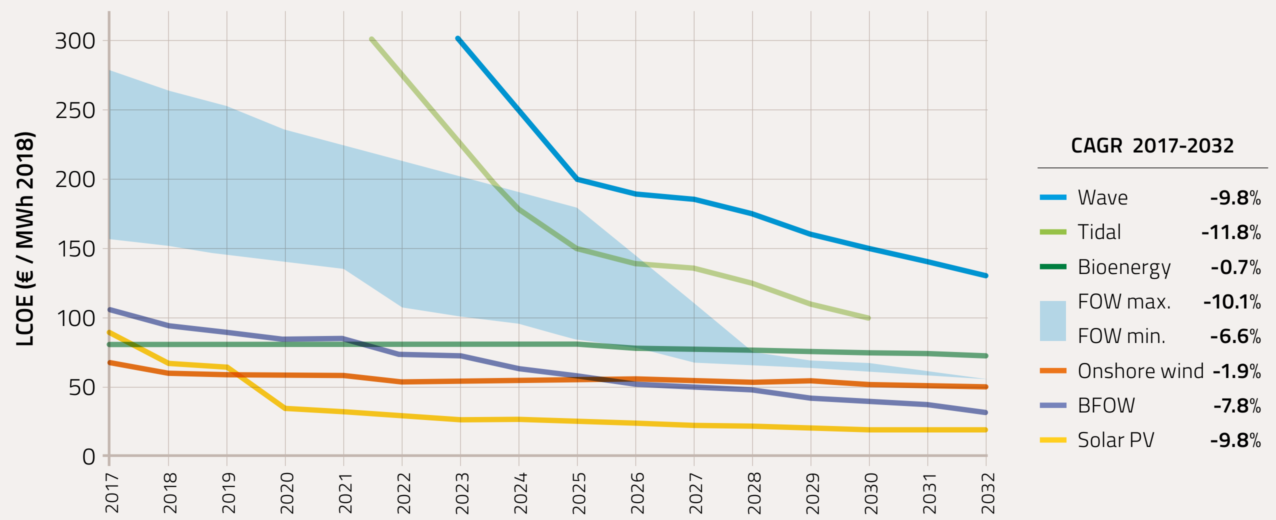
Regardless of the specific technology, FOWE is expected to be a grid-scale power generation technology rather than a niche technology as is the case, for example, with wave and tidal power generation technologies. However, there are specific applications or niches where FOWE may already have a business case, such as blue economy development initiatives, island communities heavily reliant on oil imports for power generation, offshore facilities (e.g., Equinor - Hywind Tampen) or even power-intensive industrial activities (e.g. through the production of green hydrogen).

For FOWE to compete in grid-scale power generation with other renewable generation sources, the LCOE needs to be significantly reduced. Although, there is significant uncertainty regarding the future LCOE of FOWE due to its technological and market immaturity, all estimates foresee very significant reductions.

The cost of FOW in Europe based on current operational projects today is in the order of €180 to 200 per MWh for pre-commercial projects. The industry expects the cost to reach €100 to 80 per MWh for the first commercial-scale projects using existing proven technologies and reaching final investment decision between 2023 and 2025. Likewise, costs are expected to decrease even faster at "mature" commercial scale, reaching €40 to 60 per MWh by 2030 given the right visibility in terms of volumes and industrialization (WindEurope).

There is a consensus in current LCOE projections in pointing at FOWE to become a competitive technology and a viable solution for exploiting ocean energy resources, with the average expected LCOE reduction in the coming years at 66%. When comparing FOWE LCOE projections to those for other renewable technologies (Figure 6), it can be seen that, by 2032, the FOWE LCOE could be lower than bio-power, wave and tidal and, more importantly, similar to onshore wind.

Figure 6. Comparison of the expected evolution of LCOE for FOWE vs other RES (2017-2032).



Source: Offshore Wind Technologies Market Report, United States Department of Energy (2018); NREL; Eolfi, European Commission (2018); WindEurope (2017); Enzen analysis, EIT InnoEnergy.

The floating offshore wind market

The potential of offshore wind, both bottom-fixed and floating, primarily depends on water depths of shores. The global offshore wind gross potential is about 120,000 GW leading to 420,000 TWh of annual generation. This is equivalent to 11 times the global demand in 2014.

Additionally, near 78% of this available resource is located in deep waters (>60m), where FOWE is the only alternative. Therefore, FOWE potential is estimated at 333,000 TWh (95,000 GW) per annum. Europe accounts for 24% of the total FOWE potential, placing it as one of the best-positioned regions to exploit this resource.

According to the current project pipeline (public announcements only), there are 11 countries, including the Iberian peninsula, with FOWE projects under development (Figure 7), with the USA and South Korea accounting for the largest pipeline of FOWE projects. All these regions have the potential to become technology hubs and industry leaders.

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Figure 7. Geographical distribution of current project pipeline.

Total = +220 MW
Canary Islands Equinor, 200 MW (2024)
Saitec, 2 MW (2021)
Saitec, Demo 1:6 (2020)
X1 Wind, Demo 1:6 (2020)
W2Power, Demo 1:6 (2020)
Multiplat2, 10 MW (TBD)
Nautilus/Balea, 8MW (2021)

Total = 25 MW
Windfloat Atlantic, 25 MW (2020)
Windfloat Atlantic, 125 MW (TBD

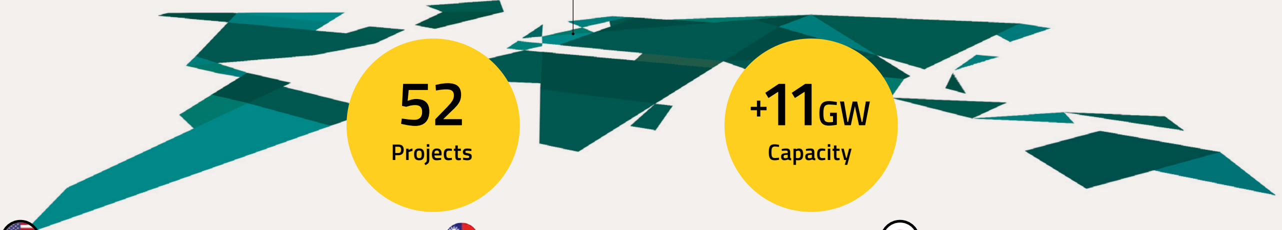
Total = 6 MW
AFLOWT, 6 MW (2022)

Total = +1700 MW
Hywind Scotland, 30 MW (2017)
Kincardine, 50 MW (2020)
Dounreay Tri, 10 MW (2021)
Atlantis Energy pre-commercial, 100 MW (2021)
Atlantis Energy, 1500 MW (TBD)
Naval Energies (Sea Reed)
CETEAL (XCF)
Ideol (Damping Pool)

Total = +600 MW
Floatgen, 2MW (2018)
EFGL, 25 MW (2021)
Groix-Belle-Ile, 24 MW (2021)
PGL Wind Farm, 25 MW (2021)
EolMed (Gruissan), 24.8 MW (2021)
Bretagne Sud, 240 MW (2050)
EolMed Commercial, 500 MW (2028)

Total = 180 MW
Stiesdal Demo, 3.6 MW (2020)
Hywind Tampen, 88 MW (2022)
NOAKA, 88 MW (2023)

Total = 6-8 MW
GICON, 6-8 MW (2022)



Total = +3,400 MW
Castle Wind/Morro Bay, 1000 MW (2027)
Redwood Cost Energy, 150 MW (2025)
Aqua Ventus I, 12 MW (2022)
Aqua Ventus II, 450 MW (2025)
Aqua Ventus III, 450 MW (2029)
Oahu North, 400 MW (2027)
Oahun South, 400 MW (2027)
Progression Wind, 400 MW (2027)
Humbolt, 100-150 MW (2024)

Total = 500 MW
W2 S/N, 500 MW (2030)
Name, 500 MW (2030)

Total = 3,300 MW
Donghae TwinWind, 200 MW (2024)
Donghae KNOC, 200 MW (2024)
White Heron, 200 MW (2027)
Donghae Gray Whale, 200 MW (2025)
Ulsan KFW Wind, 500 MW (2025)
Buscan Techno Park, 2000 MW (TBD)

Total = + 1,000 MW
Fukushima FORWARD I, 2 MW (2013)
Fukushima FORWARD II, 12 MW (2015)
Kitakyushu/Hibiki, 3 MW (2019)
Goto Sakiyama, 2 MW (2016)
Nezzy, 6 MW (2020)
Goto Sakiyama, 22 MW (2021)
Hitachi Zosen, 400 MW (2024)
Acacia, TBD (TBD)

Source: Enzen research, EIT InnoEnergy.

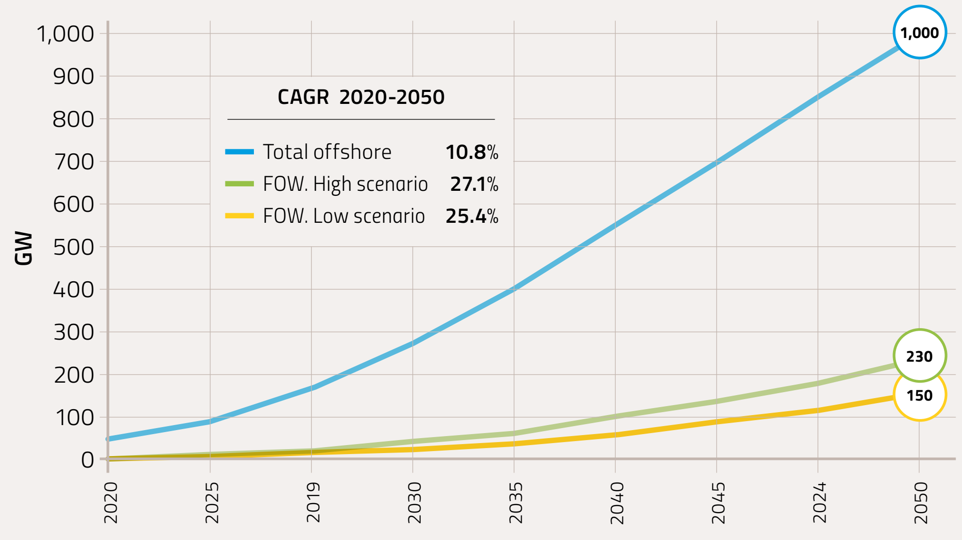
Already commissioned projects
Projects to be commissioned in the near future (2020)
Active countries with project pipeline
Active countries according to current project pipeline

Note. First power indicated by year in brackets; The projects in this pipeline are in different development stages including early planning, financing, construction…

In the Iberian region there are several FOWE technologies being developed, available capacity and sufficient resource potential; nevertheless, there are no specific commercial projects planned in the foreseeable future. This may penalize the future positioning of the region in terms of technological and industrial FOWE development, as other regions may be ahead in terms of leading the promising European market.

WindEurope estimates 450 GW of offshore wind by 2050 in order to meet 30% of Europe's electricity demand in 2050; between 100 and 150 GW of these are anticipated to be floating. Based on those scenarios for the EU and assuming 65% of FOWE capacity will be installed in Europe, global installed capacity by 2050 may reach between 150 and 230 GW.

Figure 8. Global FOW installed capacity scenarios (cum. 2020-2050).



Note: The EC estimates 450 GW of offshore wind by 2050 to meet 30% of Europe's electricity demand in 2050; between 100 and 150 GW of these are anticipated to be floating. *Source: A Clean Planet for All, EC (2018); WindEurope; IRENA; Enzen analysis, EIT InnoEnergy.*

Out of the 65% projected for Europe, WindEurope estimates that the Iberian region could install up to 22 GW of FOWE by 2050, 13 GW in Spain and 9 GW in Portugal; accounting for 10% of the expected global market. The remaining 35% is to be installed between Asia (23%) and USA (12%).

For the purpose of the analysis in this report, two scenarios have been defined for the FOWE installed capacity in the Iberian region:

- The high scenario follows WindEurope estimates of 22 GW by 2050. Resulting values of CAGR (2020-2030) of 61.4% and CAGR (2030-2050) of 10.5%.
- The low scenario, a more conservative one, defines 11 GW of FOWE for the same horizon in the region. Resulting values of CAGR (2020-2030) of 44.6% and CAGR (2030-2050) of 12.7%.

Market drivers for FOWE development

To achieve a future leading position in technology development and later become an industrial hub, it is required to follow the critical path of technology development shown in Figure 9.

The first step in this critical path is the installation of a full-scale FOWE prototype in the region. This will validate the technology and reduce future costs as well as technical risks. The next step is to commission a demonstration park at a pre-commercial or commercial scale, which is the current stage of the WindFloat farm in Portugal. This will allow to validate the value chain and reduce the LCOE.

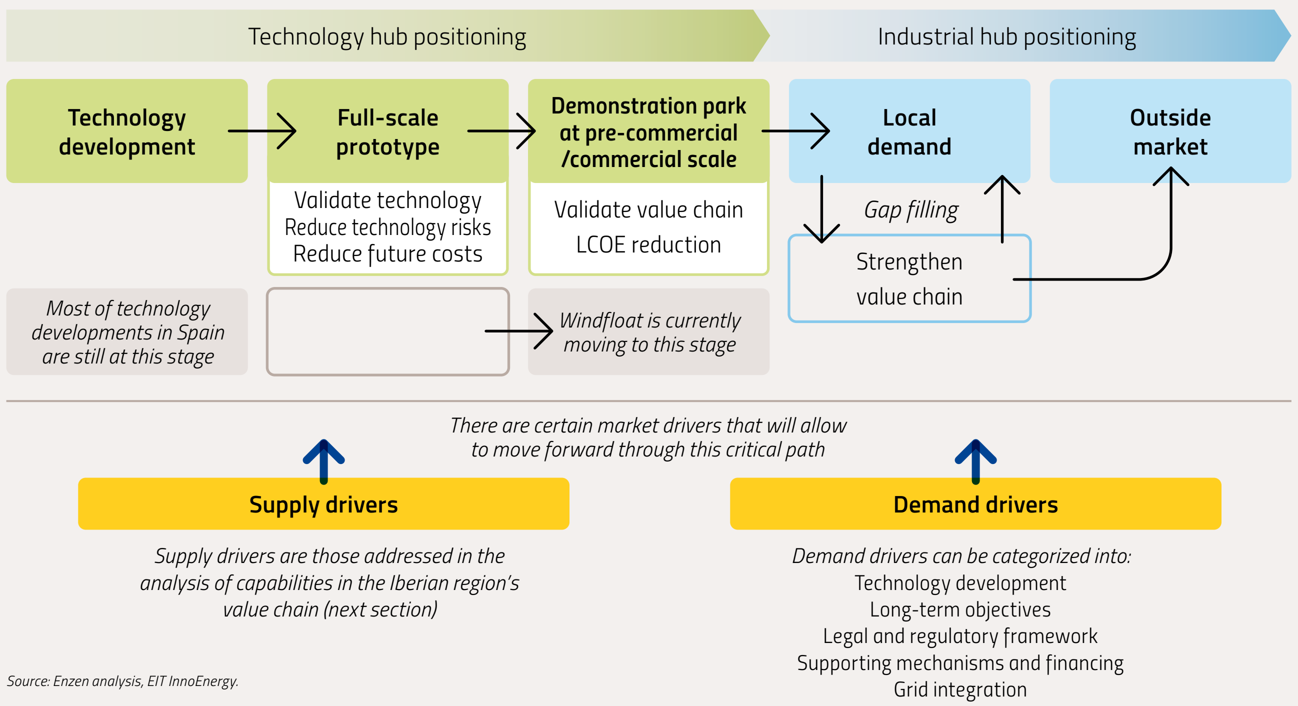
The steps along the technology development value chain are affected by the supply drivers, which will be addressed in the analysis of capabilities of the Iberian region's value chain (next section). These drivers will allow Iberia to move forward in the positioning as a technology hub.

On the supply-side market, the Iberian region has already taken significant steps; for instance, a Spanish shipyard has constructed the floating structures for some of the most relevant FOWE projects. This has resulted in a first-mover advantage of the region in terms of demonstration of its value chain capabilities.

Local demand of projects will be required to strengthen existing capabilities, boost the industry and leverage the first-mover advantage the Iberian region already has. This is a requirement to propel Iberia towards an industrial hub positioning. Additionally, a group of demand drivers have been identified to position Iberia as an industrial hub .

Demand drivers have been classified into five categories: technology development, long-term objectives, regulation, supporting mechanisms and financing and grid integration. An appropriate regulatory framework together with specific finance and support for local technology development are the key drivers to boost FOWE in Iberia in the short-term. In the medium/long-term, the key drivers are LCOE reduction, availability of TRL 9 technologies, acceleration of on-/off-shore grid integration infrastructures and a sustainable regulatory framework.

Figure 9. The critical path to be followed to secure a leading position across the entire value chain.



Source: Enzen analysis, EIT InnoEnergy.

The floating offshore wind value chain

FOWE technology is an innovative technology. However, it integrates technological elements from other industries at different stages of maturity.

- The wind power turbine, tower and blades are at a commercial scale and have a large market size since they come from the already mature industry of onshore wind. However, these elements are still subject to further innovation.
- On the other hand, the floating structure, the moorings and anchoring system and the marine electrical field are elements still under technological development, at a pre-commercial stage and subject to innovation, with new designs and concepts frequently arising.

To carry out the value chain analysis of the main technical elements of FOWE, a generation unit has been divided into four main categories: wind power turbine, which includes the tower, blades and wind turbines (nacelles); floaters, which include both steel and concrete designs; mooring system, which comprises steel chains and synthetic ropes and marine electrical field, which covers offshore cables and offshore substations. Becoming a technology and industrial hub is a phased process requiring the development of different capabilities across the FOWE value chain.

To become a technology hub, Iberia needs to develop strong global capabilities in R&D, project development engineering and procurement. This will allow developing innovative FOWE technological elements which will boost the development of the FOWE market. To support the technology development, a minimum of regional/local industrial capabilities related to procurement, construction, O&M and decommissioning are needed (e.g. construction of prototypes, testing facilities, deployment of demonstration projects, etc.).

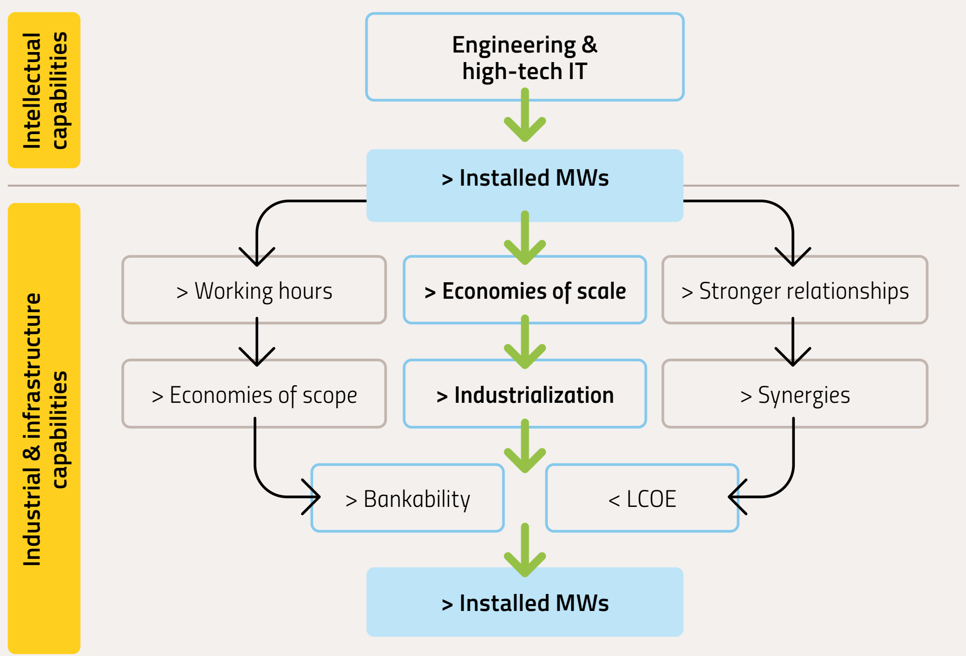
Once Iberia has positioned as a technology hub, the region needs to leverage its existing industrial capabilities for mass production at the lowest cost and cover the widest range of processes across the value chain to scale-up FOWE development. This will generate a virtuous cycle that shall reinforce industrial capabilities for the other FOWE technological elements (e.g., turbine manufacturing, marine operations, etc.) and capabilities for adjacent industries (e.g., automotive industry). At this stage, the already developed global capabilities need to be secured to maintain a technology hub position in Iberia (e.g., maintain a leading position of technology-specific research centres). This will attract the development of additional global capabilities related to other FOWE technological elements (e.g., continuous improvement).

Iberia needs to strengthen existing and proven capabilities and boost its industry to leverage and maintain the first-mover advantage. This first-mover advantage shall be key for establishing the technological and industrial leadership in the Iberian region.

On the one hand, intellectual capabilities are highly replicable, which means intense competition at a global level, demanding constant improvement and aggressive commercial practices to stay ahead. This would be the example of the Spanish REs developers.

Strong intellectual capabilities in engineering and high-tech IT will result in an increased number of MWs installed. On the other hand, industrial capabilities present mid-to-low replicability, requiring sustainable growth and the development of associated infrastructure for local and continental domination. This would be the case of Spanish BFOW jacket manufacturers.

Figure 10. Virtuous cycle of technology and industry development.



Source: Enzen analysis, EIT InnoEnergy.

Therefore, as the number of MWs installed increases, stronger relationships are created which in turn improves synergies with other industries and reduces the LCOE. With more MWs installed, more working hours are required increasing economies of scope and leading to the greater bankability of the project. At the same time, greater economies of scale, as well as industrialization, is achieved by increasing the number of MWs installed. Higher industrialization increases the bankability of the project and reduces the LCOE of the technology.

More financially attractive projects and technologies attract further investment and therefore increases the number of MWs installed. This creates a virtuous cycle which requires strong value chain capabilities and an addressable market in the region. Once established, Iberian manufacturers may export capabilities as partner developers, WTG manufacturers, ITC providers, etc. move to new markets and gain support from trusted suppliers. This is known as the 'pull effect'.

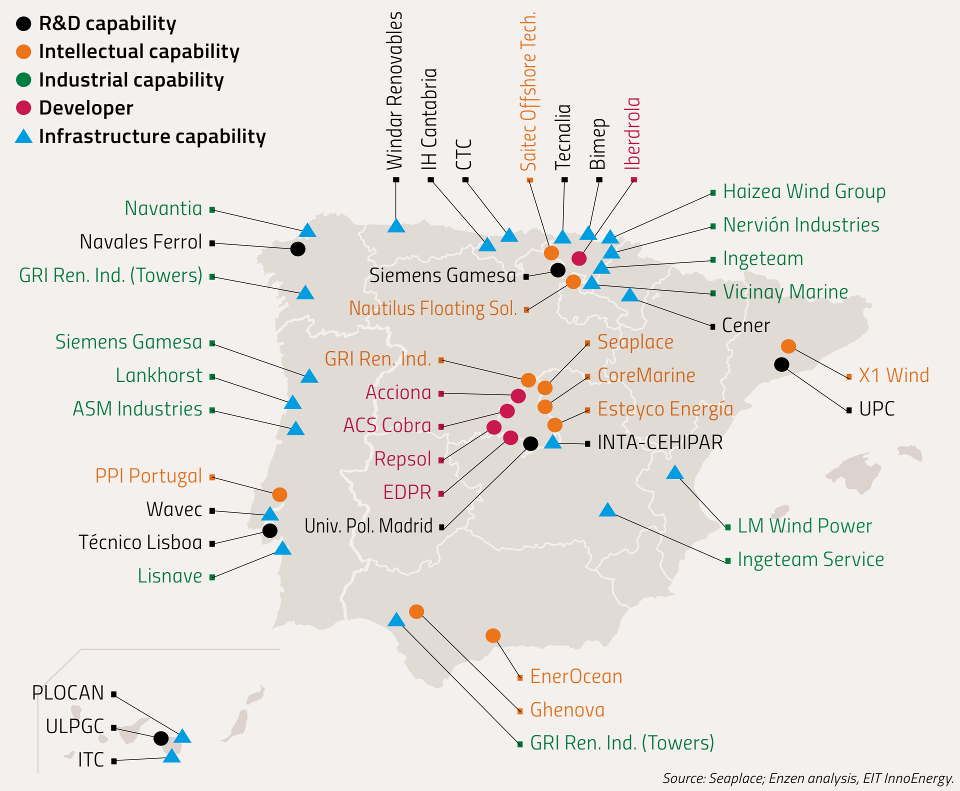
The Iberian value chain for FOWE

The Iberian region is already a strong competitor in FOWE technology and has a strong wind power industrial network mainly derived from onshore wind. As shown in Figure 11 some of the players from the onshore wind industry and new ones from other sectors have already entered the offshore wind market.

This section analyses the current competitive positioning of the Iberian region across the FOWE value chain. This analysis has been made based on the capabilities required for the development of the main elements of a FOWE unit (wind turbine, floaters, mooring systems including anchoring, and marine electrical field). The capabilities analysed have been grouped into four categories:

- R&D, such as testing labs
- Intellectual, such as naval or marine engineering
- Industrial, such as heavy steel manufacturing
- Infrastructure, such as shipyards

Figure 11. Onshore and offshore wind players in the Iberian region.



Source: Seaplace; Enzen analysis, EIT InnoEnergy.

Wind power turbines

The Iberian region has strong capabilities for towers and blades. However, infrastructure and industrial capabilities for offshore wind turbine manufacturers are rather limited.

Offshore blades and towers

The region already has infrastructure and players manufacturing blades and towers for offshore applications. Existing manufacturing facilities may easily adapt for larger elements necessary for FOWE applications as they have the required capabilities and are well located for maritime transportation of produced elements. Intellectual capabilities for blade design may require further strengthening to secure a leading position in Iberia.

Offshore wind turbines (nacelles)

Leading turbine manufacturers have concentrated their offshore activities in Germany, Denmark and France where they have established knowledge and decision-making centres.

Due to the large investment needed to establish a WTG facility and the low replicability of the required capabilities, it is not likely that WTG manufacturing facilities would establish in the Iberian region in the short term. However, players may establish in the mid-/long-term as long as the local demand is enough to attract them back to the region.

Floaters

Given the low replicability and strength of its capabilities, the region is well placed for the development of floaters. With seven concepts under development, the Iberian region is a leading technology developer of floating structures for wind power applications.

Steel structures

The region has already positioned itself in the market since the floating structures currently operating in Europe (Hywind and WindFloat) have been manufactured in Iberia. The region is more competitive than other regions in terms of cost, quality, acquired know-how and manufacturing capacity. The region has some of the most relevant large-scale shipyards and manufacturing facilities capable of producing steel floating structures. Once floating structures' design gets standardized, to increase manufacturing efficiency and capacity of current infrastructure, the region may employ smaller shipyards to manufacture certain parts of the structure and then allocate bigger shipyards for the final assembling of structures.

Concrete structures

Although the region has not manufactured concrete floaters yet, Iberia is highly qualified since it has inherited know-how and strong players from the civil works industry. Moreover, players in the region have a tradition of using floating docks (caisson-vessels) to build concrete structures on-site which is a unique capability to be leveraged.

At the moment only one concrete floater has been constructed in the world (France). Given the great potential of this material many FOWE concepts which are being developed in Iberia are based on concrete structures. The Iberian region could position as a very strong competitor with the capacity to supply national and international demand.

Moorings

Iberia has very strong capabilities for mooring systems specifically in steel chains; yet the development of synthetic ropes for FOWE may require additional strengthening.

Steel chains

The Iberian region has very strong capabilities for the development of steel moorings (from design to manufacturing). Additionally, the global market leader for this kind of mooring systems is established in the region. However, this industry is limited to this player and, therefore, the manufacturing capacity may need to be expanded to meet increasing demand and secure its current leading position.

Synthetic ropes

Iberia has very strong capabilities for the manufacturing of synthetic ropes, with a leading player established in the region. As this element is still at the technology development stage, the region should focus on strengthening R&D and intellectual capabilities to pursue a future leading position based on own developments. Existing players in Iberia could pull the development of this technology motivated by the expected future demand.

Marine electrical field

Existing capabilities and infrastructure allow Iberia to produce floating substations; however, further strengthening is required for subsea cables and HVDC systems.

Offshore substations

Iberia has strong capabilities in power electronics with regional and international players and the region has previous experience in manufacturing offshore substations for BFOW applications. The combination of the above with the strong capabilities in manufacturing floating structures, together with a competitive maritime transport network will allow the Iberian region to develop and produce complete floating substations for FOWE.

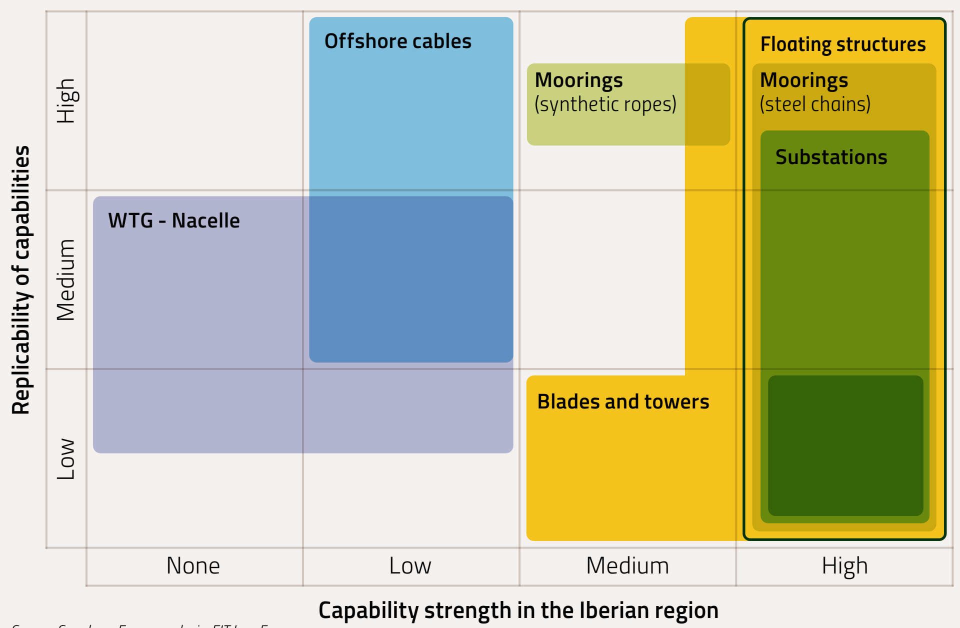
For HVDC applications the region has limited capabilities as the development of this technology is hoarded by fewer players in Northern Europe. Existing players in power electronics may develop this capability attracted by an increasing local demand. However, if the Iberian region does not get to develop this technology, HVDC modules may be integrated into floating substations produced in the region.

Offshore cables

Iberia has limited capabilities in offshore cables and there is still space for innovation in offshore cables (e.g., dynamic cables); therefore, the region should focus on strengthening R&D and intellectual capabilities first. A high local demand for projects may attract offshore cable manufacturers. However, it would be difficult as the region does not have relevant industrial and infrastructure capabilities.

Overall, the Iberian region has strong capabilities across nearly the entire FOWE value chain, showing that Iberia has sufficient grounds to become a technology and industrial hub for several FOWE key elements. As shown in Figure 12, the overlapping strength in floating structures, moorings and substations provides the basis for the Iberian region to become a technology and industrial hub of FOWE.

Figure 12. Positioning of existing key capabilities in the Iberian region for marine electrical field.



Source: Seaplace; Enzen analysis, EIT InnoEnergy.

It is important to remark that there are other activities in the FOWE value chain in which Iberian players could become leaders. These are considered transversal activities:

- Project development: The region has very relevant players in the offshore market that can leverage its experience for floating wind projects (e.g., Iberdrola, EDPR, Acciona or Cobra ACS).
- Installation and decommissioning: There are players with specific know-how for marine operations in Iberia. However, the region lacks players in the offshore wind industry with capabilities for installing offshore substructures and electrical substations.
- Maintenance: The Iberian region has strong capabilities for maintenance of floating structures (e.g. the Canary Islands is a hub for maintenance of oil rigs). However, the region may require specific vessels from other regions in a timely manner.

Additionally, the Iberian region is very strong in some cross-cutting capabilities which have a low replicability, providing a valuable competitive advantage against competitors. These capabilities are transversal and therefore, applicable to every element of the value chain:

- Higher competitiveness than other countries in Europe in terms of manufacturing costs
- Strategic geographical position with a very relevant shore length
- Strong logistics and supply chain capabilities
- Availability of port areas for storage of produced elements (e.g., blades, towers, moorings, etc.)
- Large port sites (quaysides) to locate launched floating elements during outfitting, final turbine assembling, etc.

The value chain analysis shows that Iberia has sufficient grounds for becoming a technology and industry hub due to the following FOWE key elements:

- Activities best placed to become the basis for an industrial hub are project development and operation at a global scale and the development of floating structures, mooring systems and floating substations.
- Activities with a medium probability to reach regional hub-level strength are maintenance of local FOWE farms and the development of blades, towers and offshore cables.
- Activities with a low probability of contributing to a regional Iberian hub in the short-to-mid-term are installation and decommissioning and the development of offshore wind turbines.

The capabilities analysed do not distribute evenly across the Iberian region. For this analysis, the Iberian region has been split into three different sub-regions: (1) Atlantic coast (including Portugal), (2) Mediterranean coast and central Spain and (3) the Atlantic islands:

- The Atlantic coast of the Iberian region (incl. Portugal) concentrates most of the key capabilities for FOWE technology and industrial development. This part of Iberia will benefit more than other sub-regions from the increasing development of this technology.
- The analysis shows that the Atlantic Islands do not concentrate on key industrial capabilities. Nevertheless, this region is expected to be key as the first demand hub for FOWE projects in the Iberian region given the commitment of local authorities for the development of offshore renewable energy and the higher cost of power generation due to dependency of fossil fuels.
- Finally, the Mediterranean and central region primarily ha more R&D and intellectual capabilities, as well as project developers. These capabilities can be leveraged by the rest of Iberia without geographical limitations.

It is also important to compare the positioning of the Iberian region against other active countries in the FOWE industry, as these competitors can also take steps to become a hub for FOWE.

Denmark, France and Germany have a well-stablished bottom fixed industry. Therefore, these countries are clear leaders in offshore nacelles as top offshore manufacturers (Vestas, General Electric and Siemens-Gamesa) have established their main facilities in there. Given the low replicability of the required capabilities for offshore nacelles, it will make it very difficult for the Iberian region to position itself as a leader in offshore wind turbines in the short-to-mid-term. However, this could be an option in the long-term if a local demand for projects in the regions is big enough to attract manufacturers and justify the required investment.

Even though Iberia is not a leader in blades and towers, it has full capabilities for both elements, and it is a relevant manufacturer given its existing onshore wind market. Increasing demand may drive additional manufacturing capabilities leading to better positioning.

Given their first mover advantage, the Iberian region holds a leading position in Europe for steel floaters and mooring chains. This position needs to be secured by increasing the manufacturing capacity and demand. In the case of concrete floaters, the region also has strong capabilities and inherited know-how from the construction industry, which can be easily leveraged to gain a leading position.

For synthetic ropes, Iberia is already a strong player with one of the top global players manufacturing in Portugal. Increasing the volume of production or attracting new players may drive additional development and help secure the position of the region in the future.

When it comes to the marine electrical field, the existing capacities for offshore cables are rather limited and would require much strengthening to achieve better positioning. On the other hand, the region has strong capabilities and experience in offshore substations, inherited from the BFOW industry, which can be leveraged to gain a leading position.

All the capabilities analysed above will allow the Iberian region to reach not only the local market, but also international ones. Analysing the main FOWE markets that Iberia could reach:

- The north-eastern region of North America, around the gulf of Main, has a high potential for FOWE. Due to its relatively good access by sea from the Iberian region, the demand for some FOWE components or activities along the value chain could be covered.
- On the one hand, the Atlantic coast of Europe presents a higher potential for FOWE given its water depths, wind resource availability and EU commitment to developing offshore energy. This market can easily be addressed by the Iberian region. On the other hand, although the Mediterranean region presents a high potential in terms of water depths, wind resource availability is lower compared to the Atlantic coast of Europe. Therefore, slower development is expected in this area.
- The Atlantic coasts of North America and Africa are not expected to have significant FOWE expansion due to higher availability of other renewable resources yet to be exploited.

Therefore, with current capabilities and supply chain requirements, Iberia's immediate addressable markets will be EU and the East coast of the USA.

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Macroeconomic impact of FOWE in Iberia

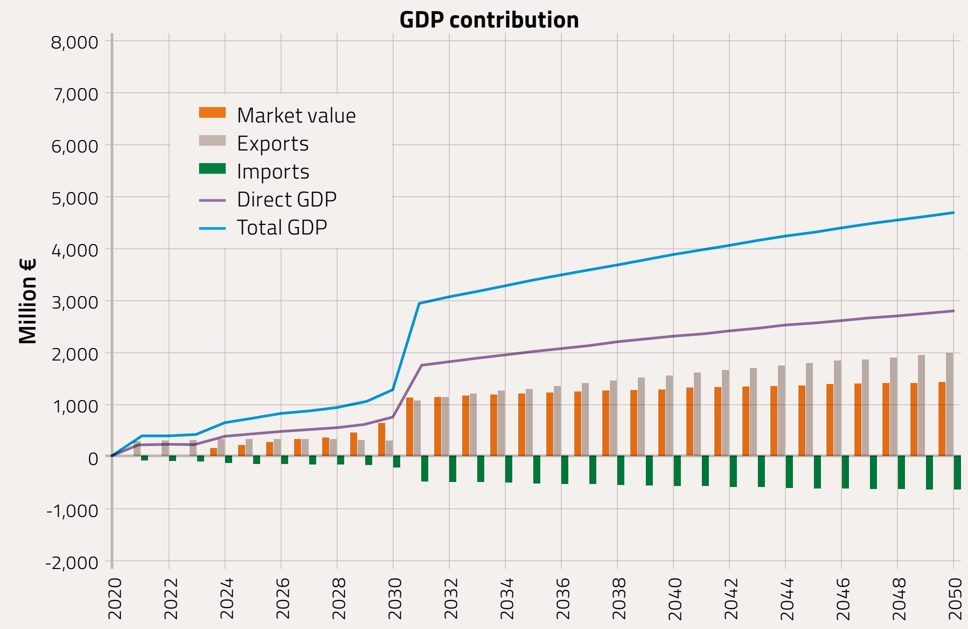
Becoming a technology development and industry hub for FOWE will result in a growth in the related economic activities. This section addresses the socio-economic impact that this will have on the Iberian region.

The macroeconomic impact has been calculated using the value-added methodology. This approach is based on the market value of produced goods and services and the balance of trade for such activities. The macroeconomic impact analysis is based on assumptions made from secondary sources of information and interviews with relevant stakeholders across de FOWE value chain.

The impact assessment is based on market projections analysed in Section 1 of this document, and it considers not only the local demand of projects in Iberia, but also the accessible international markets.

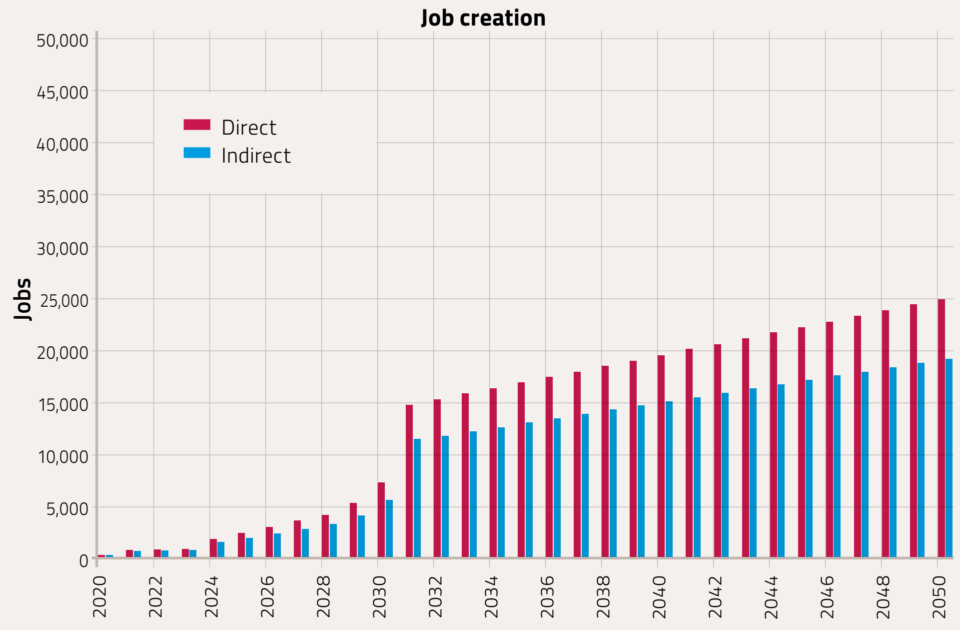
Under the assumptions of the low scenario (Figures 13a and 13b), the annual GDP contribution may reach €4,681 million involving 24,688 direct and 18,981 indirect jobs by 2050 in Iberia.

Figure 13a. Macroeconomic impact analysis (low scenario).



Source: Enzen analysis, EIT InnoEnergy.

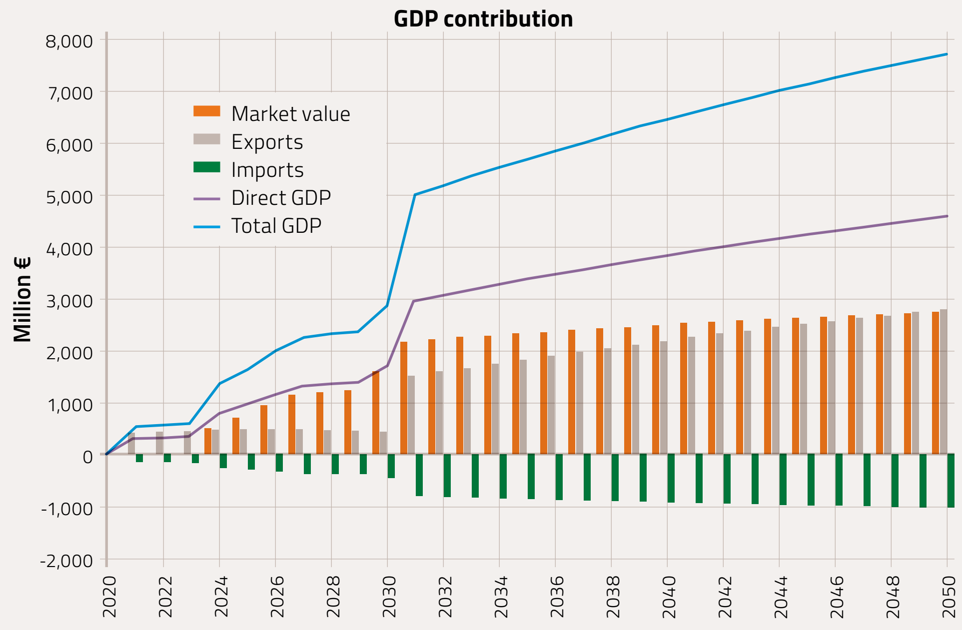
Figure 13b. Macroeconomic impact analysis (low scenario).



Source: Enzen analysis, EIT InnoEnergy.

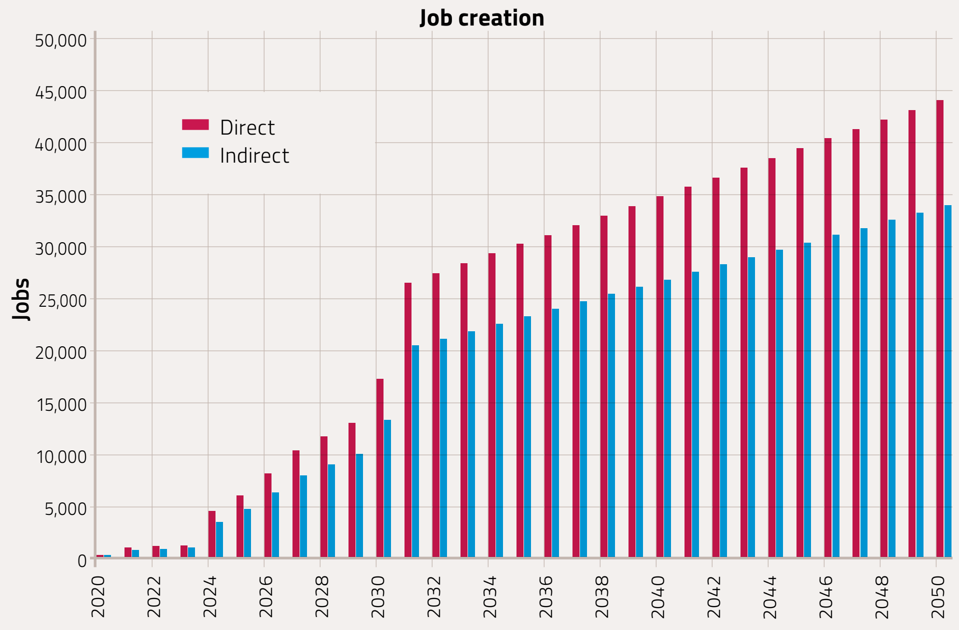
For the high scenario (Figures 14a and 14b), the annual GDP contribution may reach €7,752 million, involving 43,998 direct and 33,828 indirect jobs by 2050 in Iberia.

Figure 14a. Macroeconomic impact analysis (high scenario).



Source: Enzen analysis, EIT InnoEnergy.

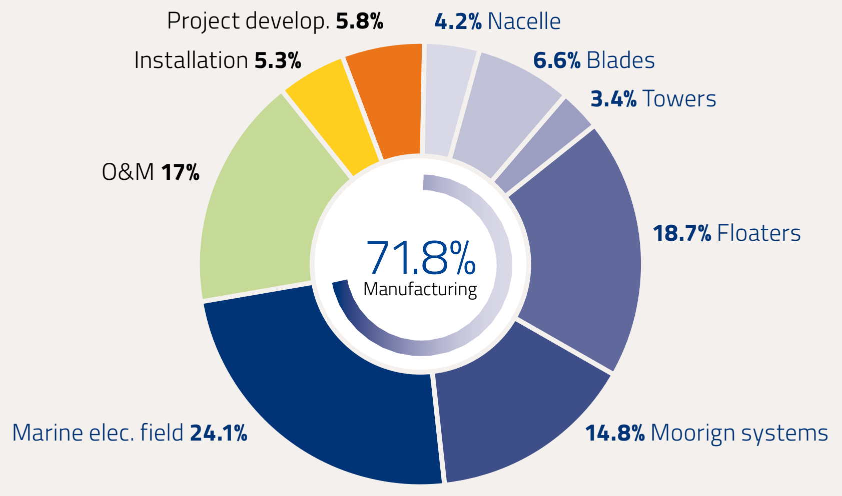
Figure 14b. Macroeconomic impact analysis (high scenario).



Source: Enzen analysis, EIT InnoEnergy.

Based on the impact assessment for both scenarios, the activity with a higher GDP contribution in the region would be the manufacturing of FOWE elements (72%) followed by O&M (17%). The breakdown of GDP contribution provides an indication of where value can be created.

Figure 15. GDP contribution by activity (cum. 2020-2050).



Total (cum. 2020-2050)
Low scenario = € 84,843 million
High scenario = € 146,390 million

Note: Jobs are measured in FTEs
Source: Enzen analysis, EIT InnoEnergy.

When it comes to job creation, manufacturing of FOWE elements represents the 37.2% of total jobs, followed by O&M with 34.5% and installation activities with 25.9%.

In addition to GDP contribution, FOWE will generate renewable energy for the region. At wholesale market prices, this will result in economic value between 2,260 and 4,520 million € depending on the scenario.

Assuming the total electricity consumption in Iberia in 2019 was around 315 TWh in the low scenario, in 2050 FOWE generation may cover up to 13.8% of the final demand, while in the high scenario it may cover up to 27.5%.

Putting into context the result of the macroeconomic impact analysis, it is reasonable to say that the development of the Iberian region as a technology development and industry hub for FOWE will drive significant progress in the region:

- For a total GDP in Iberia €1,457,054 million in 2019:
    - FOWE contribution to GDP in 2050 under the LOW scenario would be equivalent to the 0.32% of 2019 GDP.
    - FOWE contribution to GDP in 2050 under the HIGH scenario would be equivalent to the 0.53% of 2019 GDP.
- For a workforce in Iberia of 24,785,000 workers in 2019:
    - FOWE jobs in 2050 under the LOW scenario would be equivalent to the 0.18% of 2019 workforce.
    - FOWE jobs in 2050 under the HIGH scenario would be equivalent to the 0.31% of 2019 workforce.
- For a total electricity consumption in Iberia of 351 TWh in 2019:
    - FOWE generation in 2050 under the LOW scenario could cover up to 13.8% of the electricity consumption in 2019.
    - FOWE generation in 2050 under the HIGH scenario could cover up to 27.5% of the electricity consumption in 2019.

FOWE having a higher contribution to GDP than it has to employment indicates that FOWE industry would generate highly skilled jobs.

Regulatory and support framework

There are different public benefits which are attributed to REs making it reasonable for the State to support them via regulation. However, this regulation usually needs to be updated in order to adapt to new market trends or innovative technologies such as FOWE. The regulatory analysis in this section is focused on three aspects:

- Country offshore wind objectives to 2030.
- National-level regulation.
- Consenting and administrative procedures.

The European Commission has set decarbonization objectives for 2020-2030-2050. To ensure these goals are achieved several mechanisms have been established. One of them is the development of National Energy and Climate Plans (NECPs). NECPs are the new framework within which EU Member States show, in an integrated manner, their climate and energy objectives, targets, policies and measures to the European Commission. The establishment of binding technology-specific objectives in NCEPs is considered the most powerful stimulus for investment in renewable energy. This would drive stakeholders to make the required investments for the development of this technology.

Spain's NECP does not include specific objectives for offshore wind. Nevertheless, it proposes a series of measures on its NECP from which FOWE may benefit, leaving an open door for the development of this technology.

Portugal, which has already developed the pre-commercial project of WindFloat Atlantic, has set a target of 0.3 GW of offshore wind by 2030. Given the potential of the Iberian region and the strong existing value chain, both countries should set ambitious targets for FOWE development in their NECPs.

Project development for FOWE in Spain and Portugal entails a rather complex process, as it is affected by several regulations from different national-level authorities. Additionally, these regulations are usually outdated and do not reflect the reality of new activities or applications such as FOWE, therefore hindering its development. Examples of these issues are the outdated characterisation of marine areas, unclarity regarding project evaluation criteria or contradictory procedures for call resolution and site reservation and assignation. The regulatory context in Iberia would benefit from the establishment of an appropriate maritime spatial planning and the streamlining of related regulation and administrative procedures.

To reach country-level RES targets, governments implement a mix of policy instruments to support the development and deployment of these technologies. Energy policies set the goals for a country's energy future and create stability in the market, increasing the confidence of investors and thereby allow for energy support to be realised. Therefore, policies play an important role in the future development of (renewable) energy technologies.

The renewable energy sector involves a host of policy tools and regulations and there are no fit-all approaches. The choice of using any of these depends on the context of each country. Moreover, as energy markets and policies become more complex, hybrid schemes are gaining popularity, with countries often having more than one supporting mechanism running in parallel with differences in technology and degree of maturity.

Based on current market trends and following the example of leading countries such as UK and France, the two supporting mechanisms identified as most appropriate for offshore wind development are the so-called contracts for difference (CfD) and auctions.

On the one hand, CfDs are a generation price-based scheme involving a payment per unit of electricity generated. This mechanism is an evolution from the classic PPAs, FiTs and FiPs. CfDs consist of a sub-set of the sliding FiP pioneered by the UK. Generators will still be required to enter into a contract for the sale of its actual power output (in the wholesale market or through a PPA) and, in parallel, the CfD guarantees the generator that it will receive an amount equal to the "strike price" for its power output.

Under CfDs, if the market price is higher a certain "strike price" the premium becomes negative and is deducted from the overall subsidy received by the power plant. This is unlike the FiP model followed in other countries like Germany, where the generator is eligible to keep any gains resulting from high market prices.

Key advantages of CfDs against classic price-based support schemes are:

- CfDs are more cost-effective for the government.
- CfDs are better aligned with the market as CfDs are indexed with the electricity market price.
- The off-take risk is shared between generators and governments, resulting in CfDs being considered a revenue stabilization mechanism.

On the other hand, auctions are the most common schemes to allocate support (supporting mechanisms) in a competitive bidding process for renewable generation in which prices are determined by the market and not by the government. Auctions are flexible mechanisms that allow governments to re-design them every time to pursue different targets. Offshore wind has seen a substantial increase in auctioned volume with 10 GW awarded between 2017 and 2018.

The General elements of auctions for renewable systems are the following:

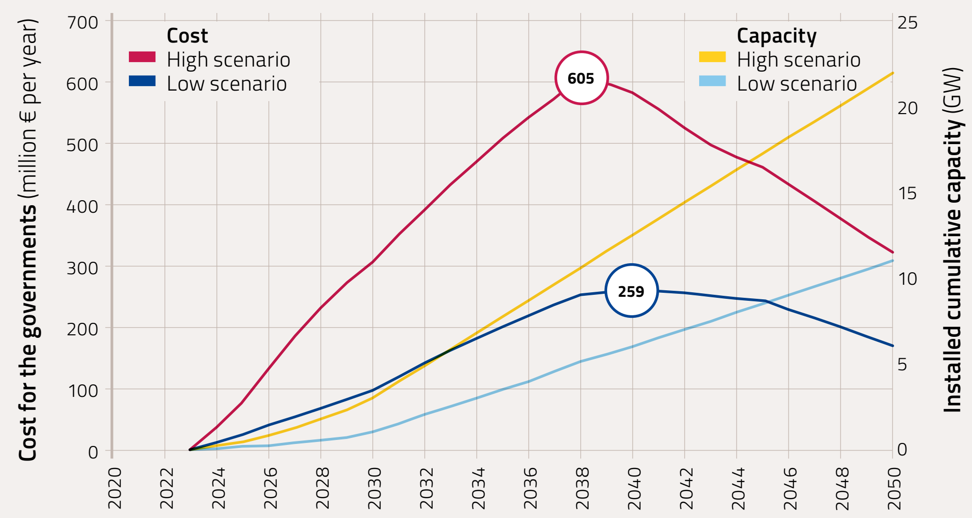
- Auction good and volume. In renewable energy auctions, the auctioned good and its volume is often defined in terms of the power capacity (MW) or energy production (MWh) to be procured and usually depends on the national renewable target.
- Eligible technologies. In this element, one can find: Technology-specific auctions, Technology-neutral auctions and Multi-technology auctions (also known by grouped auctions).
- Multi vs single-item auctions. Bidders compete for one predefined project and the winner gets access to it or bidders to compete for several projects.
- Auction award. It can be grouped in: Investment grants, Long term contracts for a generation (PPAs, FiTs, FiPs or CfDs) and a combination of these two (e.g., Spanish auctions).

The implementation of supporting mechanisms for FOWE in Iberia would have an economic cost for the governments, as specific funds would need to be allocated for it. To measure it, an analysis of the implementation cost of CfDs in Iberia has been made. Figure 16 shows that the maximum annual cost for implementing CfDs in Iberia would be between €259 and 606 million depending on the scenario, which would only represent between 8% and 11% of the estimated GDP contribution of FOWE in the same year.

At a more local/regional level, governments have taken different actions to boost the development of FOWE technology. These initiatives include the creation of local clusters, the promotion of R&D centres, fiscal incentives for certain activities or the utilization of EU specific funding for renewable energy technology development.

At this local/regional level, public energy entities such as FAEN, INEGA and EVE play an important role in the promotion of FOWE. Not only do they support initiatives such as the development of FOWE sites, but they also have direct contact with the government, acting as a liaison with the private sector. For instance, INEGA has carried out the characterization of Spain's North West Coast and has identified six suitable locations for marine energy test sites (e.g., Punta Langosteira site).

Figure 16. Cost for governments vs cumulative installed FOWE capacity in Iberia.



Source: Enzen analysis, EIT InnoEnergy.

The regional energy associations have also promoted the creation of clusters. Examples of these clusters which have become a reference in FOWE are the Canarian Maritime Cluster and the Offshore Wind Energy Basque Country. These clusters have promoted activities such as competitiveness, international projection of Spanish companies, training, technology and innovation, society and image.

All identified regions have promoted the development of R&D related facilities for the different components of FOWE technology. For example, the Canary Islands, with PLOCAN, and the Basque country, with BiMEP, have leading offshore energy testing facilities.

In terms of local development plans, it is remarkable that the Canary Islands have demonstrated an institutional commitment with offshore energy through the development of the local energy plan to 2025 (EECan2025) where a specific target of 310 MW for offshore wind is specified. Although this is not a binding document, setting targets is the most powerful stimulus for investment and support of FOWE projects.

Additionally, the Canary Islands, the Basque Country and Portugal have in place specific financial, legal and tax support to promote FOWE. For instance, EVE provides legal and tax support to Basque companies and in the last decade has allocated over €30 million to aid renewable energy.

All these regional/local initiatives for FOWE technology development may benefit from several funding opportunities as these from the EC, which has specific programmes and funds targeting the energy transition. This funding opportunities usually cover all the technology development chain, from technology innovation to market stabilization.

An example of leveraging EC funds for the development of FOWE is the project Flagship, to be installed in Norway. This project was awarded a grant of around €25 million under the RES19 call (H2020) to an international consortium led by Iberdrola, in which other players from the Iberian region are also partners (CENER, Zabala Innovation Consulting, IH Cantabria and CoreMarine).

The international consortium will design, manufacture, install and operate a floating offshore wind turbine using a +10 MW turbine and a semi-submersible floating concrete structure (OO-Star Wind Floater). According to the planned project schedule, the floating platform is likely to begin being manufactured in Q2 2021 and be installed at sea in Q1 2022. The main objective of the project is to help reduce FOWE's LCOE to a range of between 40-60 €/MWh by 2030, driven by economies of scale, competitive supply chains and a variety of innovations.

This project highlights, once again, the relevant know-how of the Spanish developers and technologists leading this consortium. As a proof of it, Iberdrola is also about to strike an agreement to develop another floating wind power prototype in Spain. This project aims to utilize different technology to that planned in Norway, manufacturing will take place in the Basque Country and the deployment will be in waters around the Canary Islands or in BIMEP (Basque Country).

The Portuguese flagship project WindFloat Atlantic is another example of leveraging and combining different supporting mechanisms for the development of FOWE in a country. Apart from the shareholder's capital, the supporting mechanisms in place for the project were:

- Feed-in tariff equivalent to 168 €/MWh for 20 years.
- €30 million grant to CAPEX and OPEX from NER 300 program.
- €60 million soft loans from the European Investment Bank.
- The export cable was financed, developed, and implemented by the National Grid Operator.

Conclusions, recommendations and Action Plan

The main conclusions of this report have been summarized into a SWOT matrix (see Figure 17), which set the grounds for the definition of the proposed recommendations.

The detailed analysis under this assignment shows that there is a business case for FOW in Iberia and a tailored action plan should be key for leveraging existing capabilities and securing a hub position:

- FOW can be a significant driver supporting the energy transition as it holds the key to an inexhaustible resource potential.
- Given LCOE reductions expected in the coming years and the applicability of this technology, FOW is expected to be a grid-scale power generation technology.
- Iberia is well place to become a technology and industry hub for FOW as there are several technologies being developed in the region, strong industrial capabilities across the entire value chain as well as sufficient offshore wind resource potential. This results in a relatively advantageous positioning against other competing regions.
- Local demand of projects will be required to propel capabilities and mobilise stakeholders in Iberia towards a technological and industrial FOW hub.
- Additionally, the Iberian region would benefit from a significant macroeconomic impact derived from FOW development in terms of GDP contribution and job creation.

Based on the existing business case, the final part of this report develops a tailored Action Plan seeking to boost the development of FOWE technology and the Iberian industry, leveraging the existing strengths and mitigating weakness and threats. This action plan includes seven (7) lines of action:

A. **Long term vision.** The establishment of binding technology-specific objectives is considered the most powerful stimulus for driving stakeholders to invest in renewable energy.
B. **Maritime spatial planning.** Inadequate maritime spatial planning (MSP) may cause uncertainty, project delays and unnecessary costs, hindering the development of offshore projects.
C. **Regulation and support schemes.** Legislation must provide the certainty of a stable regulatory framework. For the foreseeable future, revenues from the power market will not provide sufficient remuneration for investments in floating offshore wind, the stability and reliability of support schemes are of utmost importance.
D. **Electricity grid issues.** Connecting offshore wind plants to the grid is necessary and, in many cases, reinforcement of the onshore T&D grid is needed.
E. **R&D and demonstration.** As it happened with onshore wind, R&D investments at an early stage of development are particularly likely to produce positive results.
F. **Training and education.** The availability of skilled labour can be a significant bottleneck for offshore wind deployment.
G. **Promotion campaign to targeted groups.** Offshore wind has a lower direct impact on people compared to other electricity generation technologies; nevertheless, public acceptance may be an issue in some cases. FOWE may represent an alternative for decarbonization of many other sectors.

Figure 17. SWOT matrix.

	Positive	Negative
Internal	**Strengths** **Iberia has a significant offshore wind resource and given its water depth conditions, FOW is expected to be the appropriate technology for it.** **The Iberian region has strong capabilities across almost the entire FOW value chain, resulting in a relatively advantageous positioning against other competing regions.** Additionally, the Iberian region is very strong in some cross-cutting capabilities which have a low replicability (geographical positioning, supply chain, port infrastructure, manufacturing cost competitiveness, etc.). **First mover advantage:** There are a several FOW technologies being developed in the region, with a pre-commercial project in operation in Portugal (WindFloat). Spanish shipyards have constructed the floating structures for some of the most relevant FOW projects and the region has leading players in offshore moorings.	**Weaknesses** **Although several developers have expressed their interest in implementing this technology in the Iberia, this has not yet materialized into a particular pipeline of projects.** **Currently, NECPs of Spain and Portugal include very low or no specific targets for offshore energy to 2030.** Investments in the development of new projects, and even more so regarding the supply chain, require a long-term political perspective. **Existing regulation requires updating in both countries regarding MSP, streamlining of administrative procedures and the establishment of an appropriate remuneration framework.** **Public investment is needed to promote the development of an internal demand of projects (e.g., supporting mechanisms).**
External	**Opportunities** **Significant cost reductions are expected in the coming years which will bring down the LCOE by a 66% on average.** **The EC estimates 450 GW of offshore wind by 2050; of which 100 and 150 GW are anticipated to be floating.** WindEurope estimates that Iberia could install up to 22 GW of offshore wind by 2050 and this is expected to be mostly floating given water depths. **An internal demand of projects will activate and strengthen the industrial network and value chain, allowing to move to the outside market.** **FOW could have a significant impact for the Iberian economy.** Annual GDP contribution could reach a value between € 4,681 and 7,752 millions. The consequent job creation would range between 43,669 and 77,825 jobs.	**Threats** **Competition with other renewable energy sources.** Current LCOE levels for FOW are yet not competitive against other generation technologies. **Competition with other potential technology and industry hubs.** There are other countries/regions which are well positioned for FOW development and might threaten Iberia's positioning (e.g., France, Poland, UK, etc.).

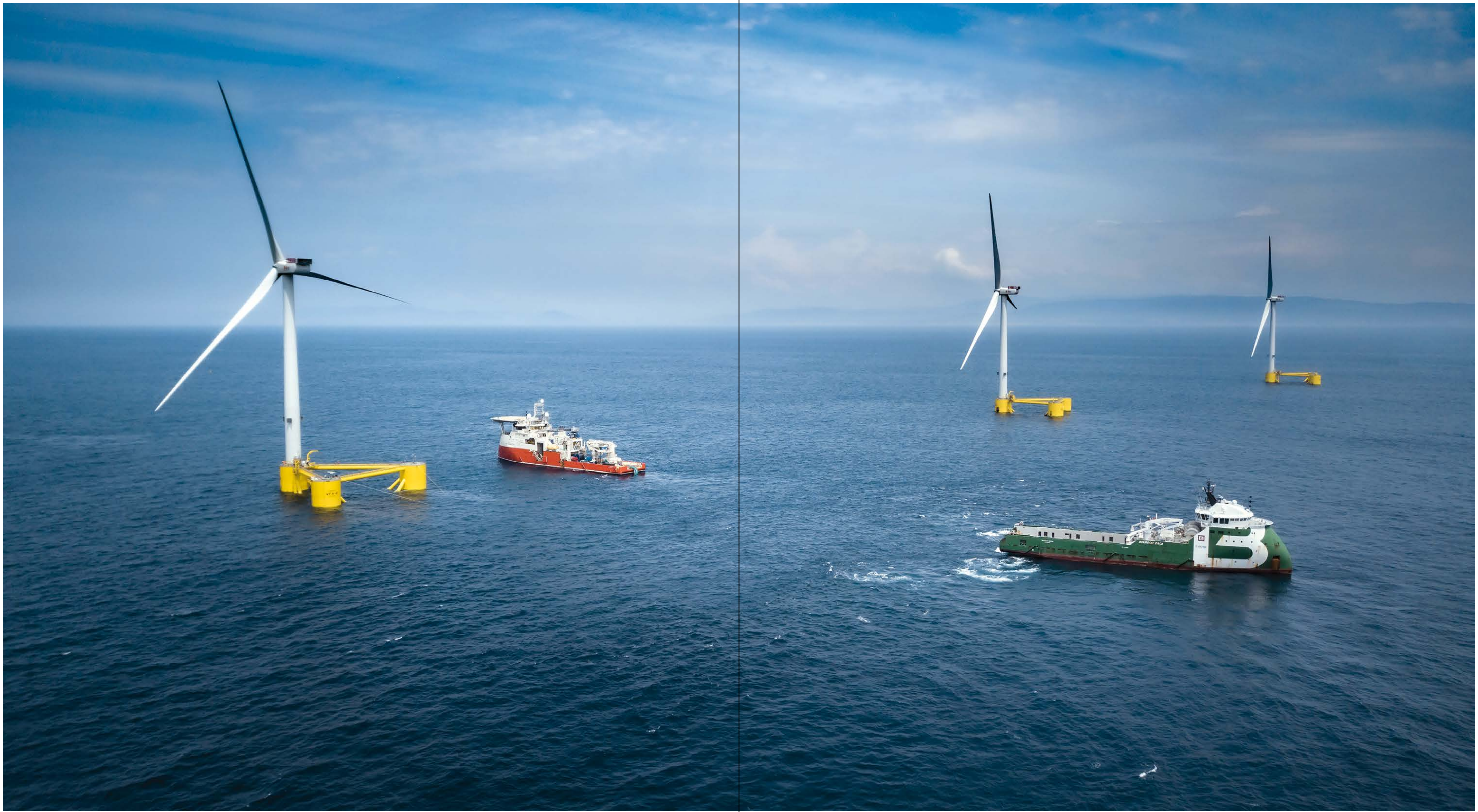
Source: Enzen analysis, EIT InnoEnergy.

Within these seven lines, the Action Plan defines seventeen (17) specific measures to be implemented in the Iberian region.

Figure 18. Summary of measures in the Action Plan.

	Measure
A. Long-term vision	1. Define a strategy for the development of offshore energy 2. Create a joint working group in the Iberian region (based on the Atlantic super-cluster)
B. Maritime spatial planning	3. Include in the MSPs specific areas for the development of FOW
C. Regulation and support schemes	4. Update the regulatory framework for permitting and grid connection 5. Establish a remuneration framework with specific mechanisms for offshore energy 6. Establish a calendar for auctions according to offshore generation targets
D. Electricity grid	7. Develop T&D grid planning according to offshore generation targets and reserved maritime areas
E. R&D	8. Definition of an integrated R&D and innovation programme 9. Establish specific remuneration mechanisms for pilot projects or demonstrators 10. Engagement of port authorities for the development of FOW projects 11. Development of a flagship pilot project with support from the government 12. Promote Canary Islands as a development site
F. Training and education	13. Preparation of a guide for administrative processing for offshore energy projects 14. Include FOW-related topics in education curricula in the Iberian region
G. Promotion campaign to targeted groups	15. Social awareness campaigns for offshore energy 16. Sectoral cooperation and training campaigns 17. Organization of international FOW events in Iberia

Source: Enzen analysis, EIT InnoEnergy.



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