Floating Offshore Wind Innovations Analytical Hierarchy Process Report

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Author(s): Greg Bohan, Ota Dvorak

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This project is closely coordinated with the IEA Wind TCP Task 49 – Integrated Design on floating wind Arrays (IDeA)[1].

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Co-Author(s)	

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

1.0	31/07/2023	Final Report.	Greg Bohan, Ota Dvorak	Fiona Devoy McAuliffe

Executive Summary

This report has been prepared by the Integrated Design of Floating Wind Arrays – Ireland project and is the first of five deliverables for Work Package (WP) 4 of the project.

The IDEA-IRL project commenced in February 2023. Project partners are University College Cork (UCC), Wind Energy Ireland (WEI), and Gavin and Doherty Geosolutions (GDG). The project's goal is to accelerate the sustainable development of Floating Offshore Wind Arrays (FOWA) both domestically and internationally. This will be achieved by building upon key background knowledge and by coordinating and leveraging the international FOWA research effort under the framework of the supported International Energy Agency (IEA) TCP Wind Task 49.

WP4 is focused on Stakeholder Integration and Research Requirement Classification, and will inform the other more technically focused WPs (1-3, 5) within the IDEA-IRL project.

This report will introduce the Analytical Hierarchy Process (AHP) approach that will be used to score and rank a list of floating offshore wind innovations. The proposed methodology discussed in this report will be carried out over Q3 2023, to collate, score and rank a list of floating offshore wind innovations. Results from this exercise will be included in the second deliverable WP4 Deliverable 2 (WP4-D2), due in Month 12.

The report also gives an update on the work undertaken as part of WP4 to date, which has primarily consisted of engagement with floating offshore wind (FLOW) and Marine Spatial Planning (MSP) experts via a survey and interview process. Experts in nine countries have been engaged, with a further list of countries to be interviewed in Q3 2023. Results from this exercise will also be discussed in WP4-D2.

This report also provides updates on recent developments in Irish offshore wind policy as they relate to floating offshore wind, MSP, and WP4. Recent developments (e.g. in relation to Phase One/Phase Two/Phase Three, Offshore Renewable Energy Support Scheme Auctions, Designated Maritime Area Plans, offshore wind targets etc.) show that the landscape in Ireland is changing quickly, and it is important that the IDEA-IRL project team remains aware so that outputs are cutting-edge e.g. policy recommendations, Irish scenario modelling etc.

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Table of Abbreviations / Acronyms

Abbreviation	Explanation
AHP	Analytical Hierarchy Process
CPPA	Corporate Power Purchase Agreement
DHLGH	Department of Housing, Local Government and Heritage
DMAP	Designated Maritime Area Plan
EEZ	Exclusive Economic Zone
FLOW	Floating Offshore Wind
FOWA	Floating Offshore Wind Arrays
GDG	Gavin and Doherty Geosolutions
IDEA-IRL	Integrated Design of Floating Wind Arrays-Ireland
IEA	International Energy Agency
LCoE	Levelised Cost of Electricity
MAC	Maritime Area Consent
MAP 2021	Maritime Area Planning Act 2021
MARA	Maritime Area Regulatory Authority
MSP	Marine Spatial Planning
NISA	North Irish Sea Array
O&M	Operations and Maintenance
ORE	Offshore Renewable Energy
OREDP II	Offshore Renewable Energy Development Plan II
ORESS	Offshore Renewable Energy Support Scheme
OWIH	Offshore Wind Innovation Hub
pNHA	Proposed Natural Heritage Area
R&D	Research and Development
SAC	Special Area of Conservation
SPA	Special Protection Area
TRL	Technolgy Readiness Level
UCC	Univesity College Cork
WEI	Wind Energy Ireland
WP	Work Package

1 Introduction

This report has been prepared by the IDEA-IRL project as the first of five deliverables for WP4 of the project.

The IDEA-IRL project commenced in February 2023. The project is being undertaken by a partnership of UCC, WEI, and GDG. Its goal is to accelerate the sustainable development of Floating Offshore FOWA both domestically and internationally. This will be achieved by building upon key background knowledge and by coordinating and leveraging the international FOWA research effort under the framework of the supported IEA TCP Wind Task 49. Specific objectives across all the work packages include:

1. Deliver a set of fully defined reference sites characteristic of the international global floating wind deployment pipeline including all relevant technical, social, environmental and economic parameters.
2. Deliver a set of fully open source and customisable floating wind array reference designs including key engineering tool input files, cost and environmental impact models.
3. Deliver a Failure Mode, Effects & Criticality Analysis framework for floating wind arrays including for coupled / cascading failures.
4. Engage with the international groups developing innovations for the floating wind energy industry, categorise in terms of multidisciplinary impact and ensure that functionality for their development is included in the reference sites and/or reference farm definitions.
5. Engage with the international agencies responsible for Marine Spatial Planning (MSP) to collect open research questions and concerns. Provide responses directly where possible and otherwise ensure that the reference sites and reference farms are defined in such a manner that they enable the required research.
6. Apply the work of Task 49 in an Irish context and engage with the local supply chain to provide specific policy recommendations and development pathways.
7. Raise the profile of floating wind energy technology, related research and expertise in Ireland through the delivery of a multifaceted communications strategy.

This report will primarily serve to introduce the AHP approach that will be used to score and rank a list of floating offshore wind innovations. A number of these will be selected and modelled as part of the WP2 reference farms and WP5 Irish specific scenarios. An update on recent developments in Irish Offshore Wind policy as they relate to FLOW, MSP, and WP4 is also given, as well as an overview of the work to date as part of WP4.

2 Work Package Overview

WP4 of the project is focused on Stakeholder Integration and Research Requirement Classification. It will be used to ensure the project has the information from stakeholders, providing key input to the other more technically focused WPs (1-3, 5) within the IDEA-IRL project (Figure 2-1)

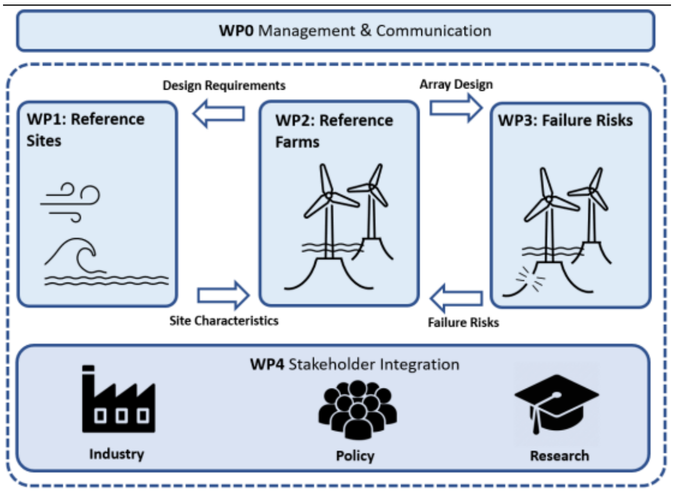

Figure 2-1: Overview of WP0-4, with WP5 - Irish Pathways - also included in this project.

This WP has a few key objectives, including to:

- Assess & facilitate international MSP collaboration for FLOW zoning.
- Identify future development zones for FLOW internationally.
- Align Task work to real world research questions and analysis methods.
- Curate a floating wind innovation register.
- Score for social, economic and environmental benefit.

The five planned deliverables for this WP, to address these key objectives are:

- **WP4-D1:** Analytical hierarchy process report. A report detailing the AHP methodology along with the scored register of innovations. (Month 6)
- **WP4-D2:** MSP Consultation year 1. Report outlining the queries arising from the MSP consultation process along with recommendations or actions taken for their resolution. (Month 12)
- **WP4-D3:** MSP Consultation year 2. (Month 24)
- **WP4-D4:** MSP Consultation year 3. (Month 36)
- **WP4-D5:** Recommendations for future activities (Month 36)

Milestones for the WP are also listed below:

- **WP4-M1:** Initial definitions and functionality recommendations transferred to WP1,2 &3. (Month 12)

- **WP1-M2:** Final definitions and functionality recommendations transferred to WP1, 2 & 3 (Month 24).

WP4 will ultimately look to identify, characterise, and publish the major research questions faced by the industrial, academic and MSP communities in the development of innovations and the strategic planning for FLOW.

Through the deliverables, a feedback loop will be established with WP1, WP2, WP3 and WP5 to ensure that the reference sites and farms being designed contain a sufficient level of detail; are configured in such a manner to address the identified research needs; and any Irish specific context particularly in relation to MSP is considered where necessary.

A register of innovations will also be developed and scored using an AHP approach, to identify innovations with the potential to make the greatest trans-disciplinary impact. A prioritised list will be used to inform the technical developments in WP1-WP3. At least 2 of these innovations will be selected for impact assessment in WP2. This is discussed in more detail in this report.

This WP will also engage with relevant floating wind experts and MSP agencies to understand and categorise the key questions relating to FLOW and MSP. This work will not be related to local planning regulations, but instead focus on cross-cutting topics, for example: viable required port facilities, grid capacity requirements, viable floating farm project capacities, suitable geotechnical / bathymetry, accessibility limits, impacts on marine life, impact on the fishing industry etc. Answers to these questions will be provided where possible and requirements will be passed to the other WPs. For those research questions that cannot be answered, consideration will be given to how these could be addressed, potentially through future projects involving IDEA-IRL and the International Energy Agency (IEA) Task 49 members.

WP4 engagement will also inform the work being carried out to score and rank a floating wind innovation register, with input on these innovations sought from relevant experts.

This engagement is ongoing, and will be reported on in full in WP4-D2 in Month 12 (January 2024).

All aspects of this WP will also look to engage relevant members of the IEA Task 49 of the same name (IDeA) where useful, and leverage the learnings and expertise of this group from experiences in other markets, many of which are more mature than Ireland. One of the key strengths of the IDEA-IRL project is that execution of the plan of work is supported by participation of over 90 international experts in FLOW in the IEA Task 49, which is 19 months into a 48-month programme. GDG is an operating agent of this Task, and the lead for the equivalent WP4.

3 Irish Context – Recent Updates on Offshore Wind, Policy and MSP

Much like most countries active in offshore wind, a significant amount of work has been undertaken in Ireland in the last few years to ensure the necessary frameworks are in place for the development of offshore wind projects here – this will all be relevant to future plans for FLOW, and how these projects are developed.

3.1 Offshore Wind Targets

Several targets for offshore wind in Ireland have been set and increased over the years, through a number of different policies and Government plans. At the time of writing, Ireland has an offshore wind target of 5GW for 2030 (first set in the Programme for Government [1]). There are also plans for an additional 2GW of floating wind to be in development by that stage, with this capacity earmarked for the production of green hydrogen, according to the Policy Statement on the Framework for Phase Two Offshore Wind [2], from May 2023.

Longer term targets of 20GW of installed offshore wind capacity by 2040 and 37GW by 2050 have also been established [2].

This initial 5GW will comprise Phase One and Phase Two Projects, which will be bottom fixed offshore wind projects. The 2GW of floating wind to be in development by 2030 is currently being referred to as Phase Three, with development after this to take place as part of the Enduring Regime.

3.2 Phase One Progress

Phase One projects are those that secured Maritime Area Consents (MACs) in December 2022 [3], and recently took part in Ireland's first Offshore Renewable Energy Support Scheme Auction (ORESS1), namely: Arklow Bank Phase 2, Codling Wind Park, Dublin Array, North Irish Sea Array (NISA), Oriel Wind Farm, and Sceirde Rocks. Codling Wind Park, Dublin Array, NISA, and Sceirde Rocks were successful at this auction, with a combined capacity of 3,074MW [4]. These projects now have a route to market, and can continue to progress their projects through the Irish consenting system, under the MAP 2021. They will now be required to secure development consent for their projects as one of the next major milestones.

The two projects which were not successful at ORESS, Oriel Wind Farm and Arklow Bank Phase 2, can still be developed if they can secure routes to market, most likely through corporate power purchase agreements (CPPAs), before they are required to relinquish their MACs. This time period has not yet been confirmed.

3.3 Phase Two and ORESS2.1

Phase Two Projects will be required to provide the additional capacity needed to reach 5GW for 2030. Exactly how much capacity this will be is unclear at the time of writing. As above, it is unclear as yet if the Arklow Bank Phase 2 and Oriel Wind Farm projects will be developed. These account for a capacity of 1,175MW according to the ORESS1 results.

Attrition of the Phase One projects also needs to be considered. None of these projects have planning consent, so it is possible that they could fail to receive this, or onerous conditions could be attached to their planning consent, which would make the project unviable. Other issues could also cause attrition, given the emerging nature of Ireland's offshore wind industry. Regardless of the above, Phase Two capacity will be needed to reach 5GW.

The first auction for Phase Two - ORESS 2.1 - is planned to launch before the end of 2023 with final results in early 2024 [5], although this timeline is ambitious.

This auction will mark a significant change from the Phase One approach, for several reasons. Some of the primary reasons are listed below:

- ORESS2.1 will auction the right to develop one specific project site identified by the State, rather than being between developer-led projects;
- The capacity of the site will be pre-determined based on available onshore grid capacity, and is expected to be approximately 900MW;
- This site will be within a Designated Maritime Area Plan (DMAP);
- The site will be surveyed by the State in summer 2023, with the resultant data passed to auction participants to inform their bidding;
- Developers will enter the auction without a MAC or Grid Connection Assessment (GCA);
- Offshore infrastructure including substations and export cables will be planned and built by EirGrid.

Little detail is available on ORESS2.2 at the moment, but it is expected to take place in late 2024/early 2025, and involve sites on the east coast in the Irish Sea.

3.4 Transition to a Plan-Led Regime

ORESS2.1 and the proposed approach here continues the planned transition by the State from the 'Developer-Led' model (developers prepare the requirements for consents; select and pre-develop wind farm sites; and develop and build both offshore wind farm transmission assets i.e. offshore substation, export cables, and onshore connection assets), to 'Plan-Led' (a State Body and/or the Transmission System Operator (TSO)/ Transmission Asset owner (TAO) is the responsible party for the complete process of wind farm site selection and predevelopment and offshore grid connection development). This transition to a more Plan-Led model where the State has more control over where and when offshore wind projects are developed is in line with most countries in Europe.

3.5 Ireland and MSP

A Plan-Led approach also makes it easier for efficient MSP to be introduced. The EU MSP Directive of July 2014 provides for the establishment of MSP at EU Member State level, including with regard to the development of Offshore Renewable Energy (ORE), which must take place according to an ecosystem-based approach and include opportunities for public participation.

EU Member States are further required to consider economic, social and environmental aspects to support sustainable development, and to promote the co-existence of relevant activities and uses.

Ireland has transposed the MSP Directive through the MAP 2021 [6]. The National Marine Planning Framework (NMPF) was adopted by Government in May 2021 as Ireland's first statutory maritime spatial plan [7].

Information on Ireland's first DMAP was released by the Department of the Environment, Climate and Communications (DECC) on 14 July 2023 [8]. A DMAP represents a management plan for a specific area of our marine waters and can be used to develop multi-activity area plans; to promote use of specific activities, including ORE; and/or for the purposes of the sustainable use and protection of particular marine environments.

[8] contained the South Coast ORE DMAP Proposal area, shown in Figure 3-1. This area extends to the marine area stretching from High Water Mark on Ireland's south coast to the 80 metre depth contour and/or the edge of the Irish Exclusive Economic Zone (EEZ). The western boundary of the geographical area is based on the location of a military danger and restricted area defined by the Irish Aviation Authority, while the eastern extremity is the demarcation between the Irish Celtic Sea and Irish Sea, classified by the International Hydrographic Office.

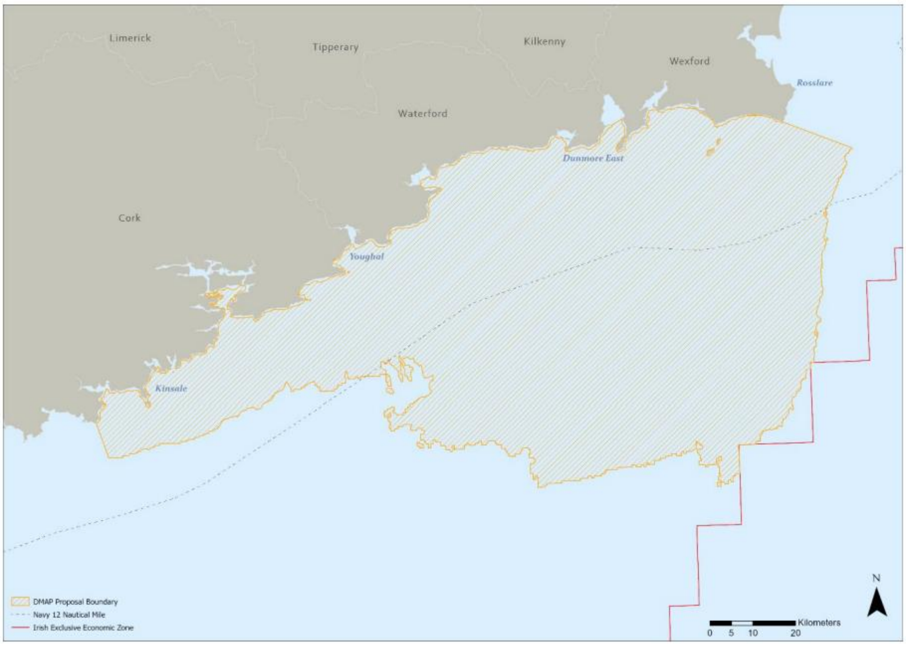

Figure 3-1: South Coast ORE DMAP Proposal Area [8]

The Minister for the Environment, Climate and Communications' intention is to seek the approval of the Minister for Housing and the Oireachtas for a Draft DMAP in late 2023 or early 2024, which will be a more refined version of the DMAP proposal. This objective is contingent on the outcome of the statutory public engagements and environmental assessments that constitute an essential part of the DMAP establishment process. Before being finalised there must be public consultation on the DMAP proposal, before a Draft DMAP can be prepared. There will then be further consultation on this Draft DMAP area, before any updates are made, and the Draft DMAP can go to both Houses of the Oireachtas for approval.

Once the DMAP is approved, ORESS2.1 can begin, which will provide supports for development of a site to cater for up to 900 MW of fixed-bottom offshore wind capacity within the South Coast DMAP. This site is expected to be in depths of approximately 60m or less.

Further programmes of deployment will take place within this DMAP area over the next decade through an orderly, strategic and managed process of development. It is thought that the next proposed DMAP(s) will be off the east coast, subject to grid availability and the progress of the Phase One projects.

3.6 EirGrid and Shaping Our Offshore Energy Future

As noted above, offshore infrastructure including substations and export cables will be planned and built by EirGrid for ORESS2.1. This may not necessarily be the case for further Phase Two auction(s), but is the planned approach for the Enduring Regime.

Plans for this are outlined in Shaping Our Offshore Energy Future [9]. EirGrid will develop an offshore substation off the coast of Waterford or Wexford; an offshore substation off the coast of Cork; a connection between the offshore substations and existing substations onshore; and new substations near to existing substations onshore. The project successful in ORESS2.1 will connect to these offshore substations. The grid infrastructure is expected to accommodate up to 900MW. The study areas EirGrid has outlined for this offshore infrastructure are shown below in Figure 3-2 and Figure 3-3.

EirGrid is currently applying for Marine Licences to undertake marine surveys of these areas, as well as undertaking studies to determine what options are available. This will all inform the location and design of the offshore transmission infrastructure. Extensive stakeholder engagement and consultation will also be carried out as part of this work.

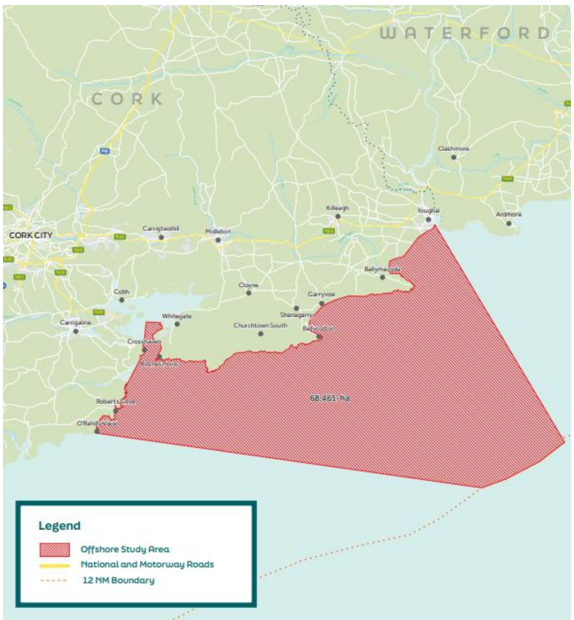

Figure 3-2: EirGrid Cork Offshore Study Area [9]

Figure 3-3: EirGrid Waterford and Wexford Offshore Study Area [9]

3.7 Phase Three and the OREDPII

Significantly, as discussed in the Policy Statement on the Framework for Phase Two Offshore Wind [2], the Irish Government has created a distinct programme of work to provide systems to enable 2GW of floating offshore wind for additional non-grid use to be in development by the end of this decade – Phase Three. This marks Ireland's first official target for FLOW[2]. Phase 3 will be informed by the in-development Offshore Renewable Energy Development Plan II (OREDPII) [10]. This was consulted on from February to April 2023.

OREDPII will be Ireland's new national spatial strategy for our offshore renewable energy future. It will be used to inform Phase Three, and the longer-term Enduring Regime. The OREDP II will provide a high-level framework for the long-term, sustainable and planned development of Ireland's immense wind, wave and tidal renewable energy resources.

The OREDPII draft document focuses on the spatial strategy, proposing how the State will identify the areas best suited for ORE, in line with the principles of good MSP. The document proposes criteria which will be used to identify Broad Areas of Interest for future ORE development within Ireland's maritime area to the outer limit of our EEZ (Figure 3-4), which will then be refined further into smaller geographical areas as part of the DMAP process. Example areas are contained within the draft document.

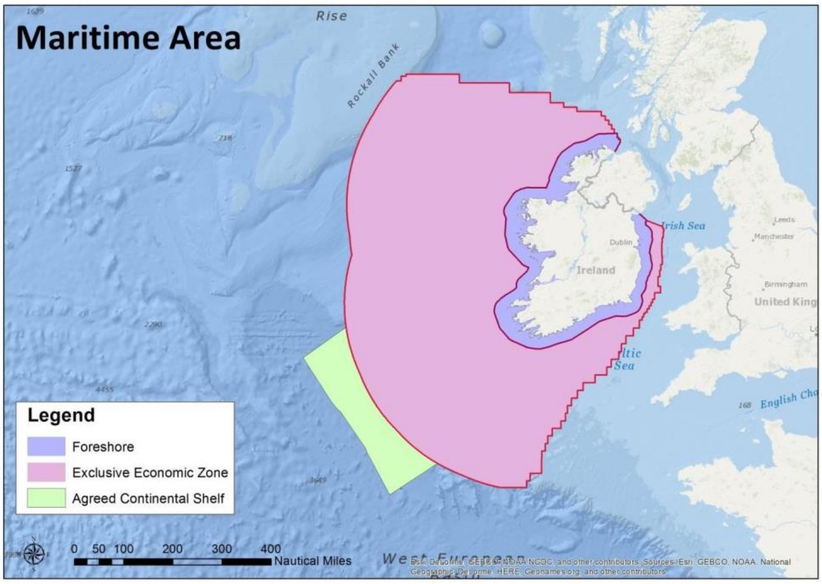

Figure 3-4: Overview of Ireland's Maritime Area [9]

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[2] This target was initially set as part of the 2022 Sectoral Emissions Ceilings negotiations as 2GW of offshore wind, earmarked for the production of renewable hydrogen, to be in development by 2030. The more recent Phase 2 Policy Statement indicates that this will be 2GW floating offshore wind.

To identify these example Broad Areas of Interest, a multiple-criteria analysis of national data was used to map areas suitable for fixed and floating offshore wind, wave and tidal technologies and factors and activities relevant for ORE development. The five criteria used in the multiple-criteria analysis were:

- Technical opportunities
- Exclusions (e.g. Traffic separate schemes, Nearshore anchorage areas, High density shipping routes, Offshore cables and pipelines, Aquaculture etc.)
- Environmental factors (e.g. Proposed Natural Heritage Area (pNHA), Natural Heritage Area, Offshore Special Area of Conservation (SAC), Special Protection Area (SPA), SAC etc.)
- Economic activities (e.g. Shipping and fishing activities)
- Heritage factors (UNESCO world heritage sites)

The example broad areas of interest found are shown below Figure 3-5.

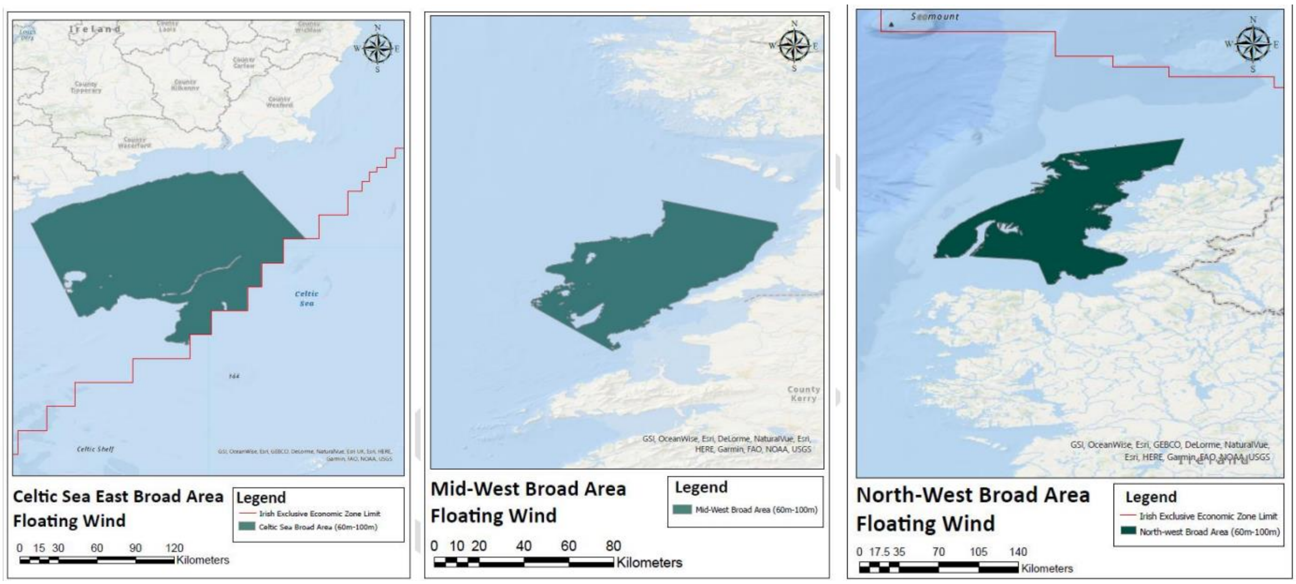

Figure 3-5: Example Broad Areas of Interest as shown in the Draft OREDPII

The report also incudes an assessment of the technical wind resource available in Ireland, for bottom fixed and FLOW, assuming a 15MW turbine and spacing between turbines of seven times the diameter of the turbine (Table 3-1 & Table 3-2). This assessment shows the huge potential for offshore wind, and particularly FLOW, in Ireland. Targets of 20GW by 2040 and 37GW by 2050 could easily be accommodated within our maritime area, based on technical resource capacity.

Table 3-1: Available technical wind resource potential for Bottom Fixed Wind technology from OREDPII

Water Depth	Gross Technical Resource Capacity (GW)	Gross technical resource energy potential [TWh/year]
10-60m	42	170
60-70m	20	83
Total	62	253

Table 3-2: Available technical wind resource potential for Floating Wind Technology

Water Depth	Gross Technical Resource Capacity (GW)	Gross technical resource energy potential [TWh/year]
60-70m	20	83
70-200m	331	1334
200-1000m	246	1065
Total	597	2482

It is not yet entirely clear when areas will be identified for the Phase Three floating wind projects, but they will be informed by the work undertaken as part of the OREDPII. Policy statements for both Phase Three and the Enduring Regime for Offshore Wind are expected to be published in Q1 2024. How this develops will be crucial for the future of floating wind in Ireland.

3.8 The Establishment of the Maritime Area Regulatory Authority (MARA)

Another recent development which will be key to the future development of offshore wind in Ireland was the establishment of the MARA on 17th July 2023 [11]. MARA's functions are set out in the Maritime Area Planning Acts 2021 and 2022, and it will have a key role to play in the new streamlined consenting system for the maritime area, including:

- Assessing MAC applications for the maritime area, which are required by developers before development permission can be granted;
- Granting marine licencing for specified activities;
- Compliance and enforcement of MACs, licences and offshore development consents;
- Investigations and prosecutions;
- Administration of the existing Foreshore consent portfolio;
- Fostering & promoting co-operation between regulators of the maritime area.

MARA is a body under the aegis of the Department of Housing, Local Government and Heritage (DHLGH) and will be located in Wexford.

While this sections serves as an update on developments in Ireland to date, WP4 will also look to get an insight to recent developments in other relevant countries. This is discussed further in Section 4.

4 WP4 – Update on Work to Date

As part of WP4, the IDEA-IRL project has been carrying out stakeholder engagement to inform the work on the innovation list and MSP consultation. The intention of this first round of stakeholder engagement is to speak with two experts from each relevant country (mainly those represented on the IEA Task 49) – one expert in floating offshore wind, and one expert in MSP, ideally working within the MSP organisation of the relevant country.

Table 4-1 below gives an overview of the consultation process – the countries on the list of engagement, and the experts that have been spoken with to date (note that the names/organisations of experts are being kept confidential). Nine countries have been engaged to date, with at least one representative spoken to in these countries. The consultation process will be completed over the course of Q3 2023, to inform WP4-D2.

Table 4-1: List of countries engaged to date as part of WP4

Country	Floating Wind Exert Interviewed?	MSP Expert Interviewed?
USA	✓	✓
France	✓	X
China	X	X
Denmark	X	X
Germany	X	X
Ireland	✓	✓
Italy	X	X
Netherlands	X	X
Norway	✓	✓
South Korea	✓	X
UK	✓	X
Portugal	✓	X
Spain	✓	X
Japan	✓	X
WindEurope Rep.	X	X

Engagement to date has been undertaken via a survey and interview process, where interviews are generally one-on-one via Microsoft Teams, for one hour. Interviewees are sent a survey/questionnaire in advance of the interview (see Appendix A: WP4 Stakeholder Engagement Questionnaire), and then this is answered live on the call, to enable discussion on key areas.

The interviews focus on 5 key areas, as set out below:

1. **MARKET CONTEXT**: Gain an understanding of each countries' floating wind & MSP context and work to date.
2. **CO-EXISTENCE**: Assess the potential for different activities to co-exist with FLOW in each country
3. **SITE ASSESSMENT CRITERIA**: Discuss what criteria stakeholders see as the most important when assessing a site for FLOW potential
4. **RESEARCH & INNOVATION**: Find what stakeholders see as the key areas in need of research and innovation for FLOW
5. **PIPELINE & FUTURE DEVELOPMENT ZONES**: Identify the areas where floating wind is expected to be developed, capacities and timelines

The interview process and results will be discussed in more detail in WP4-D2 – MSP Consultation, once the full round of interviews has taken place.

The focus of this report is on the AHP reporting, which will be completed to score and rank a list of FLOW innovations.

Due to the early stage of the project, and the fact that consultation with key stakeholders is ongoing, this report is used to introduce the methodology that will be followed to identify the list of innovations to be ranked and scored, and how this ranking will be completed (the AHP).

Section 5 below outlines the AHP process that will be conducted in further detail.

5 Scoring and Ranking a List of FLOW Innovations

As part of WP4, the IDEA-IRL project will be looking to identify, score and rank a list of FLOW innovations, based on their social, environmental and economic benefits. The proposed methodology to do this is set out in this section.

This work will be carried out over Q3 and Q4 2023, with results included in WP4 Deliverable 2, due in Month 12 (Jan 2024).

5.1 Methodology - The Analytical Hierarchy Process

When devising any ranking of alternative options, or indeed making any major decision, it is necessary to prevent bias as much as possible to make the decision objective. The decision at hand in this case is which innovative technologies to support to best help growth in the floating offshore wind sector. One method of reaching a decision objectively is the AHP.

5.1.1 Origins and basis

AHP is a theory of measurement which can be applied to multi-criteria decision making. It was developed in 1971 by T. L. Saaty at the University of Pennsylvania. The method is based on mathematics and psychology and uses decomposition, comparative judgement and a synthesis of priorities applied to decision making [12].

Decomposition within AHP means working from the goal, down to criteria, sub criteria and alternatives, where the elements at each level are independent of the lower levels.

Comparative judgement means comparing pairs of elements on one level with respect to a criterion on another level.

Priorities arising from the comparisons are then synthesised from the top down by multiplying the priorities of each element on one level by the priorities of the criteria it effects on the level above and adding these [12].

5.1.2 The method explained with an example

A diagram showing an example of what the hierarchy can look like in practice is shown in Figure 5-1.

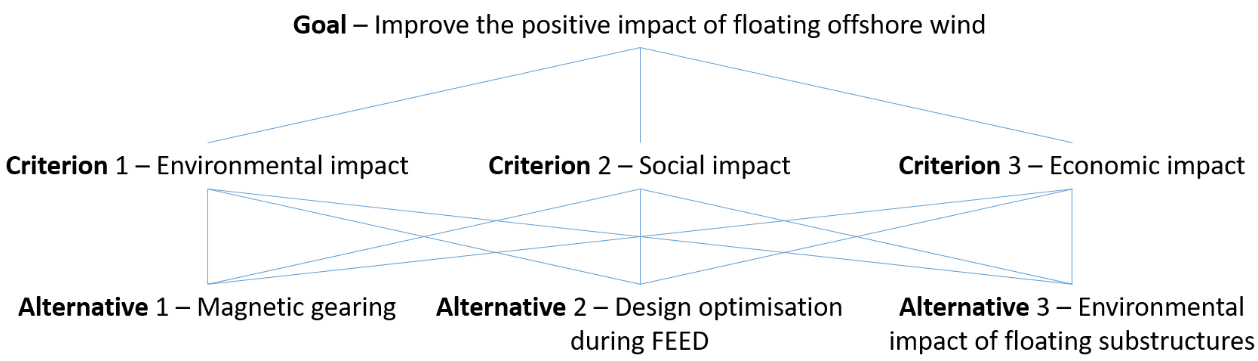

Figure 5-1 - Example of an AHP priorities network, using example innovations

The goal of conducting this AHP method is to collate and impact rank innovations for floating wind arrays to make sure the utility of the technology is maximised. This sets the goal (focus) of the AHP framework.

There are three criteria on which the innovations will be judged – their impact on the environmental, social and economic benefit of floating wind. These criteria represent the first level of decomposition.

The positive impact of floating wind is decomposed into the positive environmental, social and economic impact. These are not necessarily linked! In practice they might be, but AHP treats them as separate things. If the goal was to buy a car, the criteria might be reliability, comfortability and looks – it is easier to see how the criteria are not linked.

The final level is the alternatives – in this case the innovations in the FLOW sector. Three examples of potential innovations are given. Each of these innovations is linked to each of the criteria. The strength of each of the links now must be computed.

The strength of the link is called a priority in AHP. Priority is a number between zero and one such that the sum of all priorities of alternatives with respect to one criterion is unity. The higher the priority number is, the stronger the influence of an alternative on a criterion or of a criterion on the focus point.

The priority number is found based on comparing pairs of alternatives or criteria. The comparison is always done with respect to a criterion if comparing alternatives or with respect to the focus if comparing criteria. A number between one and nine is assigned to the one in the compared pair which is deemed more important than the other. The significance of the number is outlined in Table 5-1. Intermediate numbers can also be used.

Table 5-1 – Pairwise comparison ratings

Intensity	Definition	Explanation
1	Equal Importance	Two elements contribute equally to the objective
3	Moderate Preference	Experience and judgement mildly favour one element over another
5	Strong Preference	Experience and judgement strongly favour one element over another
7	Very Strong Preference	One element is favoured very strongly over another, its dominance is demonstrated in practice
9	Extreme Preference	The evidence favouring one element over another is of the highest possible order of affirmation

This way, the criteria (environmental, social, and economic benefit) can be compared in pairs as shown in Table 5-2. In this example case, it is deemed that the environmental benefits are mildly favoured over the social ones (rating 3 for environmental versus social), while the social ones are strongly preferred over the economic ones. The environmental benefits are very strongly preferred over the economic ones and this dominance is demonstrated in practice. Please note that these are not the actual ratings, just an example of how to use the AHP method.

Table 5-2 – Example of pairwise comparisons of criteria

	Relative importance		
Social	1	3	Environmental
Social	5	1	Economic
Environmental	7	1	Economic

Based on the pairwise ratings, the pairwise rating matrix is constructed. This cross-links the preferences of individual pairs and puts them into more context. Such a matrix is shown in Table 5-3.

Table 5-3 – Criteria pairwise comparison matrix

Criteria matrix	Social	Environmental	Economic
Social	1.000	0.333	5.000
Environmental	3.000	1.000	7.000
Economic	0.200	0.143	1.000

From the matrix in Table 5-3, the priorities are found as the first eigenvector of the pairwise ratings, normalized so that the sum of the eigenvector is unity. If the criteria matrix is A, I is an identity matrix of the same order as A, the first eigenvalue of A is λ_1 and the first eigenvector is v_1, then the corresponding priority vector is p_A such that:

$$(A - \lambda_1 I)v_1 = 0 \qquad \text{Equation 1}$$

$$p_A = v_1 * \frac{1}{\Sigma(v_1)} \rightarrow \begin{bmatrix} p_{A1} \\ p_{A2} \\ p_{A3} \end{bmatrix} = \begin{bmatrix} v_{11} \\ v_{12} \\ v_{13} \end{bmatrix} * \frac{1}{\Sigma(v_1)} \qquad \text{Equation 2}$$

The result is a priority vector like shown in Table 5-4 which shows that the most important criterion is the environmental impact, followed by the social impact and the least important are the economic benefits of FOW. Based on pairwise comparisons of importance, the priority of each criterion with respect to the focus has been established. Presently, the same must be done for the alternatives with respect to each criterion.

Table 5-4 – Priorities calculated from the criteria pairwise comparison matrix

	Priority	Rank
Social	0.279	2
Environmental	0.649	1
Economic	0.072	3

Similarly, to how the criteria were ranked with respect to their contribution to the goal, the alternatives need to be ranked with respect to their contribution to fulfil the given criterion of the goal. In Table 5-5, the three alternative innovations are compared with each other in terms of how much they will contribute to the economic benefits of FLOW. Design optimisation during FEED is mildly favoured over magnetic gearing, there is a strong preference of magnetic gearing over assessing the environmental impact of floating structures and a strong preference of design optimisation during FEED over assessing the environmental impact. Once again, these rankings are not the real ones and are only provided as an example.

Table 5-5 – Pairwise comparisons of alternatives with respect to one criterion

Relative importance with respect to the economic benefits criterion			
Magnetic gearing	1	3	Design optimisation during FEED
Magnetic gearing	5	1	Environmental impact of floating substructures
Environmental impact of floating substructures	1	5	Design optimisation during FEED

A pairwise comparison matrix comparing alternatives with respect to their economic benefit is constructed based on the comparisons shown in Table 5-5 and the priorities of each alternative are calculated the same way – as the normalized first eigenvector of the pairwise comparison matrix (Table 5-5Table 5-6).

Table 5-6 – Pairwise comparison matrix for alternatives with respect to their economic impact

Economic impact	**Magnetic gearing**	**Design optimisation during FEED**	**Environmental impact of floating substructures**	**Priority**	**Rank**
Magnetic gearing	1.000	0.333	5.000	0.297	2
Design optimisation during FEED	3.000	1.000	5.000	0.618	1
Environmental impact of floating substructures	0.200	0.200	1.000	0.086	3

The same procedure is then followed for all alternatives with respect to the other criteria (Table 5-7).

Table 5-7 – Pairwise comparisons for the other two criteria (Social and Environmental Impact)

Social impact	Magnetic gearing	Design optimisation during FEED	Environmental impact of floating substructures	Priority	Rank
Magnetic gearing	1.000	0.333	0.333	0.143	3
Design optimisation during FEED	3.000	1.000	1.000	0.429	1
Environmental impact of floating substructures	3.000	1.000	1.000	0.429	1

Environmental impact	Magnetic gearing	Design optimisation during FEED	Environmental impact of floating substructures	Priority	Rank
Magnetic gearing	1.000	0.333	0.143	0.076	3
Design optimisation during FEED	3.000	1.000	0.143	0.158	2
Environmental impact of floating substructures	7.000	7.000	1.000	0.766	1

All the priority scores are then put into a single table to synthesise the information hidden in them. This table shows the priority rating of each innovation with respect to each criterion as well as the priority of each criterion with respect to the goal.

If the priority of criterion i with respect to the goal is P_{CG_i} and the priority of each innovation j with respect to a criterion i is $P_{IC_{i,j}}$, then the overall priority of the innovation j towards the goal is P_{IG_j} as shown in Equation 3.

$$P_{IG_j} = \sum_1^i P_{CG_i} * P_{IC_{i,j}}$$ Equation 3

Table 5-8 shows the matrix where the priority of each innovation with respect to the goal is calculated. The higher the preference number for an alternative, the more it is preferred over the other ones. Based on the findings of this example of simple AHP, the preferred innovation is "Environmental impact of floating structures". This preference was calculated based on comparisons of pairs of innovations and pairs of criteria. This concludes the methodology of conducting AHP. The method can be expanded to include more levels (sub criteria).

Table 5-8 – Calculation of overall priority of innovations with respect to the goal

	Priority with respect to the given criterion $P_{IC_{i,j}}$			
Criterion	**Magnetic gearing**	**Design optimisation during FEED**	**Environmental impact of floating substructures**	**Criterion priority P_{CG_i}**
Environmental	0.076	0.158	0.766	0.649
Social	0.143	0.429	0.429	0.279
Economic	0.297	0.618	0.086	0.072
Innovation priority P_{IG_j}	0.110	0.266	0.623	
Innovation rank	3	2	1	

5.1.3 Bias considerations

When using AHP, great care must be taken to assign the pairwise comparison ratings on the one to nine scale. Entering the comparison values is one of the few spots in the AHP method where bias can be introduced, so for the method to function properly and return an unbiased value, the comparisons themselves need to be unbiased. Another potential source of bias comes from the selection of the criteria and alternatives themselves, therefore these need to be very carefully selected too.

5.2 The data required

As shown above, the AHP method requires a carefully selected set of criteria and alternatives and an unbiased comparison of pairs of those to provide an answer which can be viewed as objective or unbiased.

The three criteria are pre-defined from the IDEA-IRL task description document, and they are the social, environmental, and economic impacts. What remains to select is the list of innovations.

5.2.1 Selecting the list of innovations

The technology landscape of FLOW is very diverse, with many innovations in the works and without a real technology convergence so far. ORE Catapult's Offshore Wind Innovation Hub (OWIH) published a technology roadmap for FLOW in 2022 [13]. This roadmap can be used to provide the first list of innovations to consider.

The OWIH roadmaps were developed as a tool to identify the innovation requirements of the offshore wind energy sector. They are intended to provide government and industry with validated information on challenges and innovation priorities, identify potential market opportunities and provide demonstration of areas in offshore wind with demand for innovation [14].

OWIH identified five areas of innovation: Turbines, Operation and Maintenance (O&M) and Windfarm Lifecycle, Sub-structures, Electrical Infrastructure, and Floating Wind. The roadmaps build on previous work such as the Cost Reduction Monitoring Framework and are validated by the OWIH Technical Advisor Group, composed of industry and academia experts [14].

In the Floating Wind OWIH roadmap, each innovation has a detailed description, including a brief introduction to the technology, explanation of where the innovation needs to lie, who is likely to enable this innovation, who will benefit from it, Technology Readiness Levels (TRLs), forecasts of timelines, contribution to strategic outcomes, notes on the potential to reduce the Levelised Cost of Electricity (LCoE), notes on the case for intervention and more. The roadmap is accessible as a spreadsheet. It can be found, along with more detailed information directly on the OWIH site. The complete list of innovation areas from the roadmap is provided in Appendix B: Innovation areas from the OWIH 2022 report.

However, this list is too large. To efficiently compare the alternatives, it is not practical to have that many of them, so the list needs to be narrowed down. One such approach would be to select technologies with a current TRL over 3. This eliminates technologies which are too far away in the research and development (R&D) pipeline to be of immediate concern.

The best way to narrow down this list of innovations will be decided amongst the IDEA-IRL group.

Other innovations that have been discussed in interviews to date may also be added to the list of innovations if deemed worthy by the IDEA-IRL project team.

The list of innovations will then be circulated with some key stakeholders including the IEA Task members, to sense check the list and refine it down to a sensible number.

5.2.2 The process of pairwise ranking

Once the list of technologies is complete, the project will create an online questionnaire which will be sent out to survey participants to fill in. In this questionnaire, the participants will be asked to evaluate the relative contributions of individual technologies to a given criterion, just as was shown in Table 5-5.

The form will ask the participants to decide which of the pair of innovations will have a larger impact on the given criterion. A question formulation will look something like “Between the following pairs of technologies, decide which one you think will promote the social benefits of FLOW more.” The participant would then see a grid of ratings like shown in Figure 5-2, where they will be able to click a field based on if they think innovation 1 or 2 will promote the social benefits of FOW more, and by how much. This will then be converted into the numerical scale as shown in Table 5-1. The numerical results will be averaged for each pair based on all responses to the questionnaire following the methodology set out in this report.

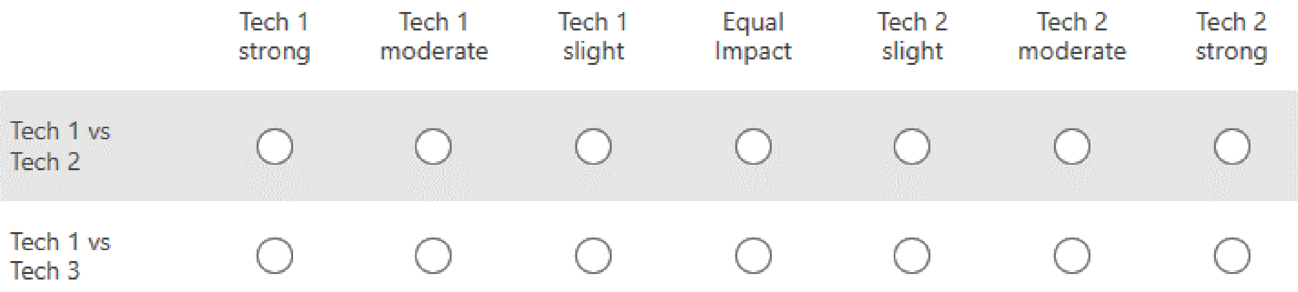

Figure 5-2 – Example of a survey question

5.2.3 Survey participants

The questionnaire will be sent out to as many FLOW stakeholders as possible, keeping in mind the need to ask people from different countries as well as different groups of stakeholders and sea users.

Stakeholders will include IEA Task 49 participants, and IDEA-IRL project contacts gathered via a project mailing list (sign up at http://eepurl.com/iv8X7M) and via WEI contact groups. Picking this group of people will be critical for eliminating as much bias as possible. Based on the responses, the AHP pairwise matrices will be constructed by averaging the responses for each pair of technologies in terms of each criterion. Then the priority calculations can be done within a spreadsheet.

5.3 The output of the AHP method

Once the survey is completed by enough participants, the ratings will be averaged for each pair of innovations and criteria. These average values will then be fed into the pairwise matrices as shown in section Appendix B: Innovation areas from the OWIH 2022 report. The ultimate output of the AHP method is a list of priority ratings of individual innovations with respect to the goal. The magnitude of the priorities can be used to evaluate which innovations should be prioritized in terms of government or NGO interference or extra support, or further research by the IEA Task and IDEA-IRL project.

6 Next Steps

This report has introduced WP4 **(Section 2)** and the work undertaken to date **(Section 4)**, as well as update on recent relevant developments in relation of offshore wind policy and MSP in Ireland **(Section 3)**.

It has also introduced the AHP process that will be used by the WP to score and rank a list of FLOW innovations, and the methodology that will be used to identify and score these innovations **(Section 5)**.

Next steps for the WP are set out below:

- WP4 will continue its ongoing engagement with relevant floating wind and MSP experts over the course of Q3 2023, to complete the first round of MSP consultation and inform WP4 Deliverable 2.
- WP4 will devise a refined long list of innovations to be considered for its work in scoring and ranking FLOW innovations, in line with what has been discussed in 5.2.1 (Q3).
- WP4 will then circulate this long list of innovations with IDEA-IRL project participants and relevant IEA Task 49 member for feedback to help to refine this list of innovations to a reasonable number to conduct the AHP Process (Q3).
- This refined short list of innovations will then be circulated with a wide list of relevant stakeholders via a questionnaire, for them to rank the list of innovations, as discussed in 5.2.2 (Q3).
- Results for the questionnaire will then be used to conduct the AHP process, to establish a final list of scored and ranked innovations (Q3/4).
- Results of this work will be included in WP4 Deliverable 2, as well as a review of the MSP consultation undertaken to date (Jan 2024).
- Work will be undertaken in close collaboration with the other WPs, with results shared to help to inform their work.

References

[1] Department of an Taoiseach, “Programme for Government: Our Shared Future,” June 2020. [Online]. Available: https://assets.gov.ie/130911/fe93e24e-dfe0-40ff-9934-def2b44b7b52.pdf. [Accessed 24 July 2023].

[2] The Department of the Environment, Climate and Communications , “Policy Statement on the Framework for Phase Two Offshore Wind,” 10 March 2023. [Online]. Available: https://www.gov.ie/en/publication/f3bb6-policy-statement-on-the-framework-for-phase-two-offshore-wind/. [Accessed 24 July 2023].

[3] The Department of the Environment, Climate and Communications , “Maritime Area Consent (MAC),” 23 December 2022. [Online]. Available: https://www.gov.ie/en/publication/fab8f-maritime-area-consent-mac/. [Accessed 25 July 2023].

[4] EirGrid, “Renewable Energy Support Scheme - ORESS 1 Final Auction Results,” 14 June 2023. [Online]. Available: https://www.eirgridgroup.com/site-files/library/EirGrid/ORESS-1-Final-Auction-Results-(OR1FAR).pdf. [Accessed 24 July 2023].

[5] Department of the Environment, Climate and Communications , “Consultation on ORESS Auction Design,” 13 July 2023. [Online]. Available: https://assets.gov.ie/263492/f17795f0-ac38-474c-8d43-03d353288830.pdf. [Accessed 24 July 2023].

[6] “Maritime Area Planning Act 2021,” December 2021. [Online]. Available: https://www.irishstatutebook.ie/eli/2021/act/50/enacted/en/html. [Accessed November 2022].

[7] Government of Ireland , “National Marine Planning Framework,” June 2021. [Online]. Available: https://assets.gov.ie/139100/f0984c45-5d63-4378-ab65-d7e8c3c34016.pdf. [Accessed November 2022].

[8] The Department of the Environment, Climate and Communications, “Designated Maritime Area Plan (DMAP) Proposal for Offshore Renewable Energy,” 14 July 2023. [Online]. Available: https://assets.gov.ie/263774/78c79192-470c-45b4-95d8-38e97da44e4b.pdf. [Accessed 24 July 2023].

[9] EirGrid, “Shaping Our Offshore Energy Future,” April 2023. [Online]. Available: https://www.eirgridgroup.com/the-grid/offshore/Shaping-Our-Offshore-Energy-Future-April-2023-Brochure.pdf. [Accessed 24 July 2023].

[10] Department of the Environment, Climate and Communications , “DRAFT Offshore Renewable Energy Development Plan II,” 24 February 2023. [Online]. Available: https://www.gov.ie/pdf/248270/?page=null. [Accessed 24 July 2023].

[11] The Maritime Area Regulatory Authority , “The Maritime Area Regulatory Authority,” 2023. [Online]. Available: https://www.maritimeregulator.ie/. [Accessed 24 July 2023].

[12] R. W. Saaty, “The analytical hierarchy process - what it is and how it is used,” *Mathematical Modelling,* vol. 9, no. 3-5, pp. 161-176, 1987.

[13] C. Wilson, “Offshore Wind Innovation Hub - Floating Wind Technology Roadmap,” 6 October 2022. [Online]. Available: https://offshorewindinnovationhub.com/category/floating-wind/. [Accessed 7 July 2023].

[14] Offshore Wind Innovation Hub, “Coordinating UK offshore wind innovation,” Offshore Renewable Energy Catapult, 2023. [Online]. Available: https://offshorewindinnovationhub.com/about-roadmaps/. [Accessed 20 July 2023].

Appendix A: WP4 Stakeholder Engagement Questionnaire

IEA TASK 49 WP4 WORKSHOP: Q&A TEMPLATE

Part A: Introductory Background questions

Date:

Time: **Attendees:**

1. **Country you are representing and your organisation/role.**

Answer:

Please Categorise your role:

R&D	Policy
Planning and Development	Marine Spatial Planning
Engineering and Design	Environment & the Marine
Operations & Maintenance	Technologist

2. **Current national fixed-bottom offshore wind targets (2030, 2050 etc.) (if any).**

Answer:

3. **Current national floating wind targets (2030, 2035, etc.) (if any).**

Answer:

4. **Please outline the high-level approach to offshore wind development in your country (Plan-led/Developer-led/hybrid)?**

Answer:

5. **What organisation is primarily responsible for MSP in your country?**

Answer:

6. **Is your country currently considering floating wind in its MSP?**

Answer:

7. **Has your country identified zones/sites for floating wind development (through MSP or otherwise)?**

Answer:

When do you expect the first > 500 MW floating farm to be operational in your national waters (pre-2030, 2030-2035, 2035-2040, 2040+)?

Answer:

8. **Please provide a link to/details of the most relevant MSP documents for your country if available.**

Answer:

Part B: Floating Wind and MSP related questions

Quickfire!!

9. Strongly Agree / Agree / Disagree / Strongly Disagree / Neutral Statements

- A 500 MW + floating farm will be operational in my country pre-2030.

Answer:

- A 500 MW + floating farm will be operational in my country pre-2040.

Answer:

- Floating wind will be more acceptable to coastal communities than fixed.

Answer:

- Floating wind will be more acceptable to existing and future users of the marine environment compared to fixed.

Answer:

- Floating wind will be less disruptive to fishing activities within the wind farm site.

Answer:

- Floating wind will have less of an environmental impact than fixed offshore wind.

Answer:

- Floating wind presents a greater opportunity for local content than fixed offshore wind.

Answer:

- Our national supply chain will be ready to support a 500 MW + floating farm pre-2030.

Answer:

- Our national ports will be ready to support a 500 MW + floating farm pre-2030.

Answer:

- Floating wind projects will account for the majority of offshore wind capacity in my country by 2050.

Answer:

- Floating wind will eventually compete with fixed wind for sites with marginal water depths (~70 - 90m).

Answer:

10. Co-Existence:

Which of the below are most and least likely to co-exist with floating wind farms in your region?

Please Rank Top and Bottom 3:

- Small scale / artisanal local fishing -
- Commercial fishing
- Aquaculture
- Shipping
- Hydrogen Production
- Other renewables
- Special Protection Areas / Marine Protected Areas
- Communications networks
- Tourism / Leisure
- Oil and Gas
- Military zones / operations
- Licensed Dumping Areas
- Other (explain)

Answer:

11. Site Assessment Criteria:
What do you view as the Key Criteria when assessing a site for floating wind potential?

Please Rank your Top 5, answering in your capacity as a Floating wind or MSP Expert:

- Resource wind speed
- Metocean conditions (Accessibility)
- Seabed Geotechnical Conditions
- Site Bathymetry
- Socio-ecological factors (marine mammals/birds, migratory patterns, fishing zones, protected areas, other users of the environment)
- Distance to shore
- Proximity to usable port & local supply chain
- Availability of grid connections
- Other developments in the area
- Proximity to demand centres
- Coastal community / population (size and attitudes)
- 'Consentability' of the site
- Subsidy/CfD scheme availability
- Robustness of the Planning and Permitting system
- Any key national consideration not above?

Answer:

1:

2:

3:

4:

5:

Comments:

12. Key Research Areas/Questions to address:
Which Questions/topics do you see as most important or pressing in relation to floating wind and MSP (constraints)?

Please choose your top 3 topics from below and add up to 3 of your choosing not shown.

- What is the most efficient planting density of a site
- Mooring spread and how this varies by technology type
- The impact of mooring lines / anchors on seabed habitats and marine mammals
- The noise impacts of floating offshore wind
- The visual impact associated with floating offshore wind farms
- Skills requirements for developing projects
- Port requirements for commercial scale projects
- Hard technological constraints (e.g seismic activity, wave climate, etc.)
- Lifecycle Carbon Assessment
- How economic farm capacity/size increases with distance from shore
- Power offtake requirements
- Floating platform choice
- Co-existence potential
- How costs can be lowered

Answer:

1:

2:

3:

Additional topics:

1:

2:

3:

Part C: Pipeline and Development Areas

13. Expected Offshore Wind Development:
Please outline the offshore wind capacity you expect to be developed in your country under 2 scenarios:

I. **Expected Capacity – Conservative:** what you see as the best estimate for most realistic values given current pipeline, policy, targets, constraints etc.

II. **Expected Capacity – Ambitious:** what you see as ambitious, but realistic values given the pace of development, political will, resource potential etc.

OW Installed Capacity	2023 (present)		2030		2035		2040		2050	
	GW		GW		GW		GW		GW	
	I	II	I	II	I	II	I	II	I	II
Fixed Bottom										
Floating										
Total										

Discussion:

14. Mapping Exercise

The fun part! Participants will be asked to take control of the screen and mark approximately on a blank map the zones they think will be used to develop floating wind in their country first, before projects from the IEA Task 49 database are shown to see if these overlap with the zones chosen.

Interviewees will be asked to assess which projects/areas would be given the highest confidence rating at the time of interview, and expected timelines for development.

Discussion:

Appendix B: Innovation areas from the OWIH 2022 report

Description	Start TRL	Potential to Reduce LCoE	Case for intervention
Rotors			
Pitch control for floating wind	TRL 6	M	M
New floating WTG configurations	TRL 5	H	M
Powertrain			
Drivetrain design for floating conditions	TRL 2	H	L
Advanced floating WTG controller design	TRL 2	H	M
Testing methodologies for floating wind components (drivetrain)	TRL 2	M	H
Magnetic gearing	TRL 5	M	H
Project Development			
Optimisation of design during FEED	TRL 3	H	L
Environmental impact of floating substructures	TRL 3	L	M
Installation			
Mooring systems connection	TRL 4	M	M
Floating electrical systems connection	TRL 4	M	M
Introduction of turbine assembly strategies for generic harbours	TRL 3	H	L
Offshore floating assembly activities	TRL 4	M	L
Operations and Maintenance			
O&M strategy for dynamic floating conditions	TRL 4	M	M
Balance of plant condition monitoring for floating wind	TRL 4	M	M
Floating substructures lifetime assessment - established methodology and technology	TRL 2	H	H
Optimised O&M major component change strategies	TRL 3	H	H
Access & egress for floating offshore wind	TRL 7	M	L
Electrical Infrastructure			
Improvements in HVAC dynamic cables	TRL 6	H	H
Improvements in HVDC dynamic cables	TRL 3	M	M
Design of electrical components to withstand floating wind conditions	TRL 5	L	M
Design of floating platform substation	TRL 4	L	L
Testing methodologies for electrical floating wind components	TRL 3	M	H
Lead-free dynamic cables	TRL 3	M	M
Substructures			
Manufacturing of current floating wind concepts	TRL 4	H	M
Manufacturing of disruptive floating wind concepts	TRL 2	H	H
Design for whole lifecycle cost reduction	TRL 5	H	M
Floating hybrid energy platforms	TRL 5	H	L
Consolidation in the number of designs	TRL 7	M	M