FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

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FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

NAVIGATIONAL PLANNING AND RISK ASSESSMENT

Summary Report

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In partnership with:

NASH MARITIME

OSPREY CONSULTING SERVICES

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EXECUTIVE SUMMARY

The UK government has a number of ambitious targets to increase electricity generation by renewable energy in order to achieve Net Zero by 2050. The UK is a world leader in the expansion of offshore wind farms (OWF) which is a central component of this energy strategy. To meet these targets, the requirement for new wind farms in deeper waters has led to increasing interest in the opportunities of floating offshore wind (FOW).

Existing UK FOW projects, Hywind and Kincardine, are small scale demonstrator projects. Future commercial scale projects with generation capacity of 1GW could result in novel and more significant impacts on shipping and navigation or aviation receptors. To support the safe and sustainable growth in FOW, it is essential that industry guidance and tools are fit for purpose in identifying potential impacts and ensuring appropriate mitigation measures are in place. Both the maritime and aviation industries were identified as particularly susceptible to these potential impacts and would benefit from improved planning and risk assessment of FOW projects (ORE Catapult and Xodus Group, 2022).

Therefore, the Offshore Renewable Energy (ORE) Catapult Floating Offshore Wind Centre of Excellence (FOW CoE) commissioned a study to review the navigation planning and risk assessment approaches for FOW. The primary objective was to undertake a detailed review of the available guidance and tools for undertaking assessments, establish where gaps exist for floating specific impacts and propose opportunities to address those gaps. This assessment was undertaken by subject matter experts from NASH Maritime and Osprey CSL from the maritime and aviation disciplines, respectively.

A four-stage methodology was undertaken. Firstly, a literature review was used to identify all relevant legislation, guidance, tools, methodologies and lessons learnt relevant for offshore wind. Secondly, lifecycle mapping for a FOW Farm (FOWF) was undertaken with developers and two representative case studies were developed to frame the assessment of potential impacts. Thirdly, a gap analysis was undertaken by comparing the potential impacts with existing guidance and identifying where there were inconsistencies or where potential impacts were not adequately addressed. Finally, opportunities for addressing those gaps were identified and scored given their relative effort and benefit.

The results of this study identified that whilst there are a great number of potential impacts associated with OWFs, the majority were assessed to be either consistent with, or have minor differences, between fixed and floating offshore wind and therefore existing guidance and tools were fit for purpose. There were however some key exceptions where major gaps were identified across both maritime and aviation impact pathways:

- **Management of wet storage sites** – FOW introduces new potential impact areas in coastal waters where turbines might be temporary moored during construction or maintenance. Inshore vessel traffic, ship anchorages, port approaches and coastal aerodromes have not typically been directly impacted by offshore wind farms. The use of wet storage imposes new potential impacts to both maritime and aviation receptors which have not previously been assessed in project applications due to uncertainties on the likely locations of wet storage sites;

- **Assessment of safety of towage operations** – The potential frequent movement of FOW Turbines (FOWTs) introduces new risks both around projects sites and within ports and harbours. There is a greater potential for conflict with vessel traffic and aviation receptors;

- **Changes to site layout** - Maintenance activities may result in temporary removal of FOWTs from the array area, resulting in gaps and changes to geometries which are difficult to manage, change site marking and might increase maritime and aviation risks;
- **Breadth of project design envelope** – The novelty of FOW is likely to result in a wide range of potential design solutions which introduce uncertainties within the assessment and make defining appropriate mitigation measures more challenging;
- **Cumulative impacts** – The significant pipeline of FOW projects is likely to result in greater prominence of cumulative effects, and existing approaches through project specific assessments are perhaps not well suited to regional scale issues.

In addition, several specific gaps were identified to maritime impacts:

- **Management of FOW array construction programme** – FOW construction might result in months between the installation of moorings and the FOWT, increasing risks of snagging;
- **Management of safety and logistics for FOW interface with ports and harbours** – The construction and towage of FOWTs through ports/harbours is likely to increase interactions with other vessels, increasing risks and impacting port capacities;
- **Best practice for certification and marking of floating turbines** – The treatment of FOWTs as either structures or vessels under relevant guidance is unclear and has implications for the use of relevant risk controls;
- **Assessment process for deep sea projects** – Some tools and concepts mandated by key guidance documents are not well suited to deep sea and offshore projects where traffic is less concentrated.

To address these challenges, several opportunities were identified which included development or update of guidance, greater national coordination, undertaking additional studies and technological or design solutions. In particular, it was determined that:

- Improving the planning, risk assessment and management of wet storage sites was a key opportunity to minimising adverse impacts to shipping and navigation. Possible solutions were considered from updating existing guidance, developing new guidance and requiring separate wet storage studies to consolidating and centralising the management of wet storage;
- Preparing for FOW interface with ports and harbours through the development of best practice guidance, supported by industry workshops and additional studies; and
- Promoting the use of regional cumulative assessments to better address concerns around cumulative impacts.

CONTENTS

NOMENCLATURE

Acronym	Description
ADR	Air Defence Radar
ADTI	Advanced Topographic Development and Imaging
AIS	Automatic Identification System
ANO	Air Navigation Order
ATC	Air Traffic Control
AtoN	Aid to Navigation
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CEP	Circular Error Probable
CoE	Centre of Excellence
CTVs	Crew Transfer Vessels
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
ERCOP	Emergency Response and Cooperation Plan
FOW	Floating Offshore Wind
FOWF	Floating Offshore Wind Farm
FOWTs	Floating Offshore Wind Turbines
GW	GigaWatt
HAZID	Hazard Identification
HSE	Health and Safety Executive
IAA	Irish Aviation Authority
IALA	International Association of Lighthouse Authorities
ICAO	International Civil Aviation Organisation
IMO	International Maritime Organization
MCA	Maritime and Coastguard Agency
MGN	Marine Guidance Note
nm	Nautical Miles
NRA	Navigation Risk Assessments
O&G	Oil and Gas
O&M	Operations and Maintenance
ORE	Offshore Renewable Energy
OWF	Offshore Windfarms
PMSC	Port Marine Safety Code
PSR	Primary Surveillance Radar
SAR	Search and Rescue
SHA	Statutory Harbour Authority
VHF	Very High Frequency
WP	Work Package
WTGs	Wind Turbine Generators

1 INTRODUCTION

1.1 Project Context and Objectives

Offshore renewable energy (ORE) and specifically offshore wind is consistently seen as a key contributor to the UK's target of net-zero carbon emissions by 2050 (HM Government, 2021). Due to the requirement for new wind farms in deeper waters, it is projected that the majority of new offshore wind capacity installed in the UK between 2021 and 2031 will be floating rather than fixed (RenewableUK, 2022). Therefore, there is a growing interest in developing the technologies to achieve commercial scale floating offshore wind farms (FOWF).

Key to ensuring the floating offshore wind (FOW) industry in the UK can scale in the rapid and sustainable fashion required, is having an efficient, timely and transparent development and consenting process. FOWFs could pose additional challenges to maritime and aviation stakeholders that must be accounted for within this process. Ensuring that existing guidance, methodologies and tools for navigational planning and risk assessment are fit for purpose is crucial in facilitating the growth in the floating offshore wind industry. This was a key finding of the "Floating Offshore Wind Environmental Interactions Roadmap" June 2022 report (ORE Catapult and Xodus Group, 2022).

The FOW Centre of Excellence (CoE) has therefore established the Floating Offshore Wind – Navigational Planning and Risk Assessment project with the aim of addressing these questions and strengthening the industry's understanding of the role of these tools in informing and optimising the design, permitting, consent and operational decision making of large FOW projects. The project seeks to address the role of navigational planning and risk assessment in respect to both maritime and aviation impacts, focussing on the factors specific to FOW developments.

This report provides a review of the navigational planning and risk assessment tools and approaches that are currently available, identifies those that are likely to be most relevant to FOWF developers and owner/operators, develops guidance regarding their application throughout the lifecycle of FOWFs, and outlines recommendations for relevant follow-on activities. The broader objective of this approach is to provide OWF developers with tailored guidance on the potential for navigational planning and risk assessment to inform and optimise the design, permitting, consent and operational decision making for a large FOW project.

1.2 Project Team

ORE Catapult is the UK's leading technology innovation and research centre for offshore renewable energy. ORE Catapult's vision is to be the world's leading offshore renewable energy technology centre by 2030. ORE Catapult will play a key role in delivering the UK's largest clean growth opportunity, through their mission to accelerate the creation and growth of UK companies in the offshore renewable energy sector. The ORE Catapult use their unique facilities and research and engineering capabilities to bring together industry and academia, and drive innovation in renewable energy.

ORE Catapult has established the FOW CoE. The CoE is a collaborative programme with industry, academic and stakeholder partners. The declared vision is to establish an internationally recognised centre of excellence in floating offshore wind which will work towards reducing the Levelised Cost of Energy from floating wind to a commercially manageable rate, cut back development time for

FOWFs, and develop opportunities for the local supply chain, driving innovation in manufacturing, installation and Operations and Maintenance (O&M) methodologies in floating wind.

NASH Maritime Ltd offer innovative solutions for all aspects of shipping and navigation assessment and risk management for ports, maritime infrastructure, offshore renewable energy and oil and gas (O&G). The multi-disciplinary maritime consultancy expertise integrates practical experience with quantitative analysis and modelling. With extensive experience of undertaking both shipping and navigation studies and Navigation Risk Assessments for OWFs, NASH Maritime are responsible for the delivery of the maritime elements of this scope of work and coordinating the overall project.

Osprey CSL, a tpgroup company, is a specialist technical consultancy, founded in 2006 with the purpose of developing a highly credible, informed and independent consultancy, operating exclusively on civil and military aviation projects. Osprey CSL's services have been developed to apply across the broad spectrum of challenges met by the aviation market: from full system procurements, airspace management and safety cases through to regulatory support, specialist studies and due diligence. An experienced team, many within the company held either an operational aviation role or joined from influential positions within statutory or industry bodies. Osprey is responsible for the delivery of the aviation elements of this scope of work.

The project team are grateful to stakeholders and developers who generously provided their time to describe the project lifecycles and reviewed FOW gaps used within this assessment.

2 METHODOLOGY

2.1 Overview

Figure 1 shows the assessment approach employed in this study, which consists of four key work packages detailed in this section:

- **Work Package 1 (WP1): Literature Review**: To facilitate safely planning and developing OWFs in the UK and to minimise impacts on different receptors, a substantial body of guidance and methodologies has been created to support developers through the consenting process. In addition, international best practice has evolved from the precedents set within the UK. The purpose of WP1 is to provide a systematic literature review of the principal regulation, guidance and methodological tools applicable to OWF navigational planning and risk assessment.

- **Work Package 2 (WP2): Lifecycle Mapping**: To determine where differences might lie between commercial scale FOWF and fixed OWF, project lifecycle mapping and case studies were developed. Firstly, this involved consultation with offshore developers (members of the FOW CoE Focus Group) to explore how a large FOWF might be developed from inception, through consenting to construction, operation and decommissioning. Secondly, two FOW case studies were developed to reflect a nearshore project and an offshore, deep-sea project. The assumptions behind these case studies were discussed with members of the CoE Focus Group to determine whether they were realistic commercial scale projects which might be anticipated within the next ten years.

- **Work Package 3 (WP3): Gap Analysis**: The outputs of the case study and project lifecycle mapping were used to identify the key impacts a FOW project might have upon either shipping and navigation or aviation receptors. A gap analysis was then undertaken to identify whether existing guidance and tools were fit for purpose for the assessment of FOW. Based on a review of the gap significance, key gaps were identified across multiple potential impacts which were then discussed in detail.

- **Work Package 4 (WP4): Opportunities Assessment**: A review of possible opportunities was conducted to address the key gaps identified within WP3. These opportunities included the development or update of guidance, national coordination, undertaking additional studies and technological / design solutions. Each opportunity was then scored based on their potential benefit and their likely effort to be achieved.

2.2 Case Studies

To better facilitate the assessment, two fictional case studies were developed in collaboration with focus group developers to reflect realistic future case FOW projects that might reasonably be expected within UK waters within the next 20 years. This includes:

- **Case study 1:** Near shore - located approximately 20 nautical miles (nm) from shore within the centre of an archipelago; and

- **Case study 2:** Offshore - located in deep water more than 50nm from shore.

The parameters of these projects use the principles of design envelopes to represent the reasonable worst-case constraint on a particular receptor.

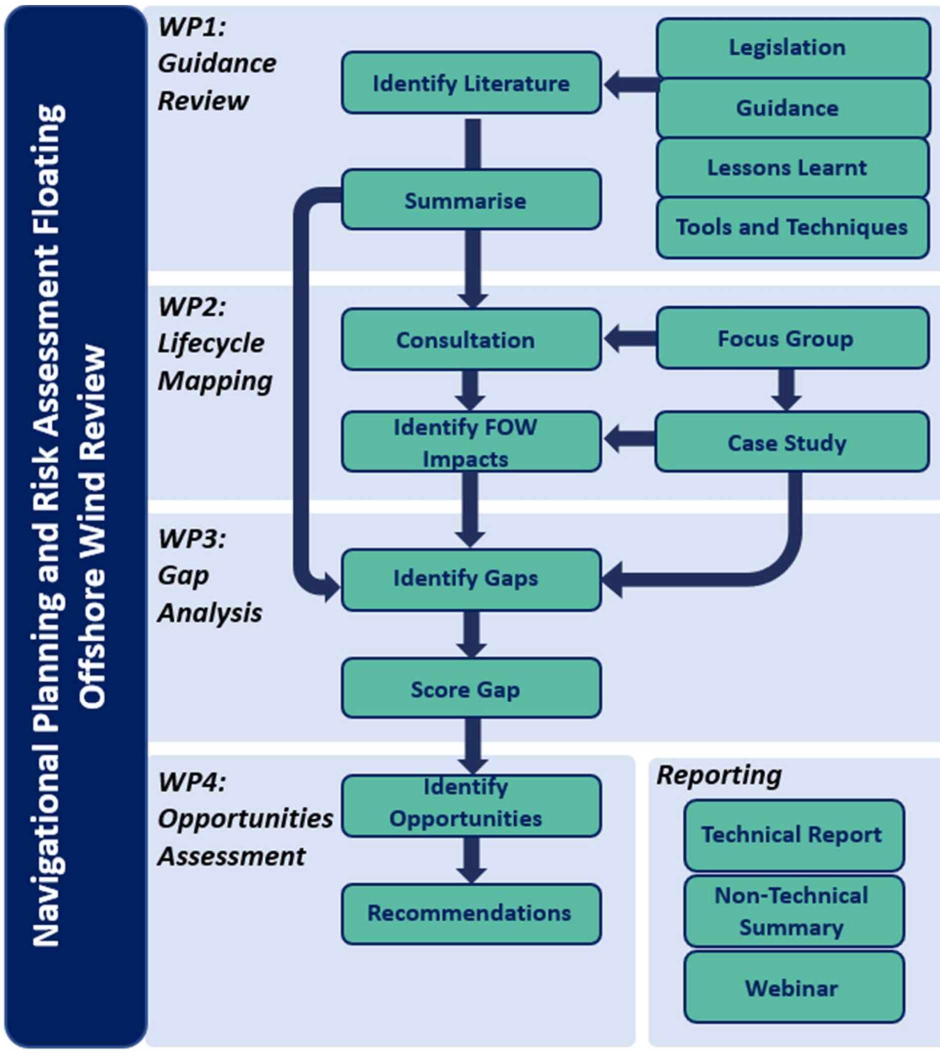

Figure 1: Overview of Methodology.

2.3 Consultation

This assessment has been conducted with support from offshore wind developers and key stakeholders. The following organisations have contributed to the project lifecycle review and gap analysis. All meetings were conducted remotely via teleconference. To ensure a full exchange of ideas, consultation meetings were not recorded and there is no attribution of comments to consultees within this report. The discussions and takeaways from those meetings have shaped the findings of this report.

Figure 2: Key Consultees.

3 OVERVIEW OF RELEVANT LITERATURE

The UK has decades of experience in safely planning and developing OWFs. To facilitate this, a significant body of guidance and methodologies has been created to support developers through the consenting process and to minimise the impacts to different receptors. In addition, international best practice has evolved from the precedents set within the UK. The purpose of WP1 is to provide a systematic review of the principal regulation, guidance and methodological tools applicable to OWF navigational planning and risk assessment.

A summary of the key shipping and navigation, and aviation literature is provided in Table 1 and Table 2 respectively.

Table 1: Summary of Key Shipping and Navigation OWF Literature.

Author	Document
Regulation/Legislation	
United Nations	United Nations Convention on the Law of the Sea 1982
International Maritime Organisation (IMO)	The International Convention for the Safety of Life at Sea 1974
IMO	The International Safety Management Code
IMO	The International Convention on Prevention of Pollution from Ships 1973
IMO	The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers 1995
IMO	The Convention on the International Regulations for Preventing Collisions at Sea 1972
IMO	The General Provisions on Ships' Routeing
HM Government	The Electricity Act 1989
HM Government	The Planning Act 2008
HM Government	The Marine and Coastal Access Act 2009
HM Government	Marine Plans
Scottish Parliament	The Marine Scotland Act 2010
HM Government	The Wales Act 2017
Primary OWF Guidance	
Department for Energy and Climate Change	National Policy Statements
Maritime and Coastguard Agency (MCA)	Marine Guidance Note MGN654: Offshore Renewable Energy Installations (OREI) safety response
IMO	Formal Safety Assessment approach
International Association of Lighthouse Authorities (IALA)	G1162: The Marking of Offshore Man-Made Structures
Secondary OWF Guidance	
PIANC	WG161: Interaction Between Offshore Wind Farms and Maritime Navigation
MCA	MGN372: Guidance to mariners operating in vicinity of UK OREIs
Royal Yachting Association	Position on Offshore Renewable Energy Developments
Nautical Institute	The Shipping Industry and Marine Spatial Planning
Health and Safety Executive (HSE) and MCA	The Regulatory Expectations on Moorings for Floating Wind and Marine Devices

Author	Document
G+	Good Practice for Offshore Renewable Energy Developments
Lessons Learnt	
QinetiQ and MCA	Results of the electromagnetic investigations and assessments of marine radar, communications and positioning systems undertaken at the North Hoyle Wind Farm
British Wind Energy Association	Investigation of Technical and Operational Effects on Marine Radar Close to Kentish Flats Offshore Wind Farm
National Academies	Wind Turbine Generator Impacts to Marine Vessel Radar
MCA	Offshore Wind Farm Helicopter Search and Rescue Trials Undertaken at the North Hoyle Wind Farm
MCA	Report Following Aviation Trials and Exercises in Relation to Offshore Wind Farms
Anatec	Influence on UK Offshore Wind Farm Installation on Commercial Vessel Navigation: A Review of Evidence
Tools and Techniques	
Data Collection and Review	
Vessel Traffic and Incident Analysis	
Future Case Scenario Development	
Consultation	
Risk Matrices and Hazard Workshops	
Constraint Modelling	
Quantitative Modelling Tools	
Ship Simulation	
Modelling of Allision Consequences using Finite Element Modelling	
Wider Risk Assessment Methodologies	

Table 2: Summary of Key Aviation OWF Literature.

Author	Document
Regulation / Legislation	
UN	International Civil Aviation Organisation (ICAO) The Convention on International Civil Aviation.
Civil Aviation Authority (CAA)	Civil Aviation Publication CAP393: The Air Navigation Order (ANO) 2016 (as amended)
Irish Aviation Authority (IAA)	Statutory Instrument 266 Standardised Rules of the Air
Primary OWF Guidance	
ICAO	Document 8168 Ops/611: Procedures for Air Navigation Services Aircraft Operations
ICAO	Annex 14: Aerodromes Design and Operations Standards and Recommended Practices
Eurocontrol	Guidelines for Assessing the Potential Impact of Wind Turbines on Surveillance Sensors
Department for Energy and Climate Change	National Policy Statements
Government of Ireland	Environmental Impact Statement and Natura Impact Statement
CAA	CAP 764: Policy and Guidelines on Wind Turbines
Secondary OWF Guidance	
CAA	CAP 032: UK Integrated Aeronautical Information Package
CAA	CAP 168: Licensing of Aerodromes
CAA	CAP 437: Standards for Offshore Helicopter Landing Areas
CAA	CAP 670: Air Traffic Services Safety Requirements
CAA	CAP 738: Safeguarding of Aerodromes
CAA	CAP 760: Guidance on the Conduct of Hazard Identification and Risk Assessment
CAA	CAP 774: UK Flight Information Services
CAA	CAP 999: Helicopter Search and Rescue (SAR) in the UK National Approval Guidance
Military Aviation Authority	Manual of Military Air Traffic Management

Author	Document
IAA	Integrated Aeronautical Information Package
IAA	SI 215: Obstacles to Aircraft in Flight
IAA	SI 423 : En-route Obstacles to Air Navigation
IAA	Aerodrome Licensing Manual
IALA	Recommendation 0-139, The Marking of Man-Made Offshore Structures
MCA	MGN654: Offshore Renewable Energy Installations (OREI) safety response
Lessons Learnt	
HM Government	Air Defence and Offshore Wind (Policy Paper)
UK AIRPROX Board	Annual Summary Reports (Blue Book)
CAA	CAP 437: Standards for Offshore Helicopter Landing Areas
CAA	Guidance for Specific Approval for Helicopter Offshore Operations (SPA.HOFO)
IAA	Aeronautical Services Advisory Memorandum Number 018 Issue 2
Tools and Techniques	
Data Collection and Review	
Consultation	
Risk Matrices and Hazard Workshop	
Constraint Modelling	

4 IDENTIFICATION OF IMPACTS

Given the case studies and lifecycle mapping exercise undertaken in WP2, a number of potential maritime and aviation impacts have been identified which could occur as a result of the development of an OWF. A total of 19 potential impacts were identified, many of which are consistent with the experiences of previous fixed and floating OWFs. These are summarised in Figure 3 and listed in Table 3.

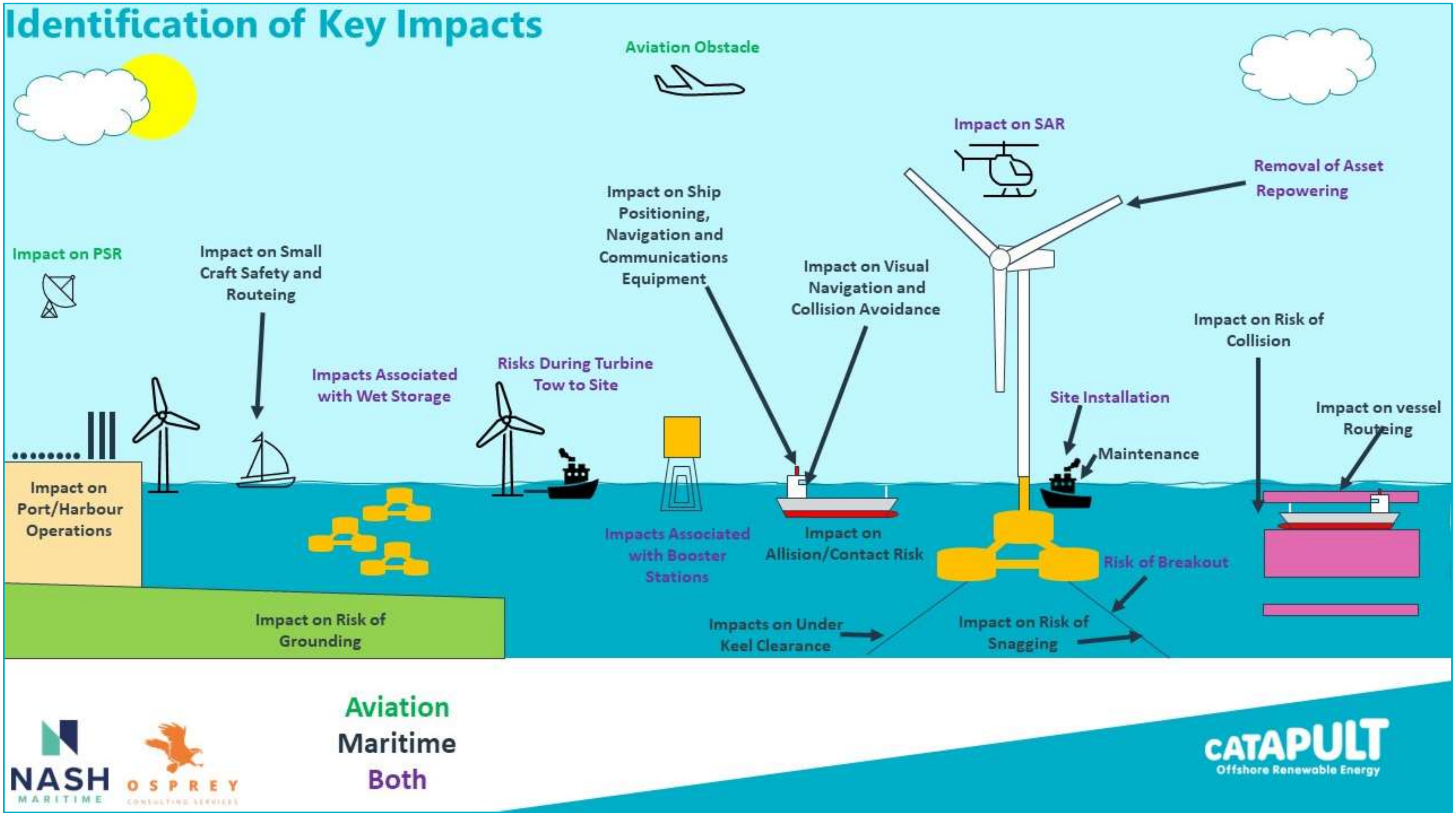

Figure 3:Identification of Key Impacts to Shipping and Navigation and Aviation Receptors.

Table 3: Summary of Potential Impacts of OWF or FOW on Shipping and Navigation and Aviation Receptors.

Potential Impact	Maritime Description	Aviation Description
Impact on Port/Harbour Operations	• Presence of a FOWF could impede the approaches to a port/harbour. • Construction of FOWF places greater demand on facilities in ports/harbours. • Issues associated with the capacity of navigational channels, availability of towage or pilotage assets and impacts on other marine users.	• The presence of above surface infrastructure within a previously unoccupied sea area may cause an obstruction to lower airspace flight operations, reducing the available airspace volume.
Impacts Associated with Wet Storage	• Requirement to temporarily store FOWTs in inshore environments could have a variety of impacts on other marine users. • This could include: ○ Impact on vessel routeing ○ Impact on ports/harbour operations ○ Impact on small craft navigation ○ Impact on SAR ○ Impact on communications, radar and positioning systems ○ Impact on collision risk ○ Impact on allision/contact risk ○ Impact on snagging ○ Impact on grounding ○ Risk of breakout ○ Impact on visual navigation and collision avoidance	• Wind turbine derived radar clutter and wave action (false returns) appearing on Air Traffic Control (ATC) and Air Defence Radar (ADR) displays can adversely affect the surveillance system: ○ Cumulative effect of wind turbine blades rotating and wave action on multiple substructures; ○ 'Wet' construction (and storage) in littoral waters of FOWTs places greater processing demand on ATC and AD systems. • The presence of above surface infrastructure within a previously unoccupied sea area may cause an obstruction to lower airspace flight operations: ○ 'Wet' construction (and storage) of floating wind turbines reduces available airspace volume; ○ Lighting requirements during 'wet' construction and storage.
Risks during Turbine Tow to Site	• Tow of FOWT to site could interact with other vessels increasing collision risk. • Risks of breakout of FOWT during tow. • Impacts/disruption of fishing (static and mobile) during tow of FOWT.	• Negligible effect on Primary Surveillance Radar (PSR) - One or two 'braked' turbines being towed at less than 10kts will be well below the PSR velocity gates designed to remove low speed clutter. • Requirements for both lighting and aeronautical notification of towage. • Risks of breakout of FOWT during tow.
Risks during Site Installation	• Installation of site could increase risk of snagging, allision and collision. • Greater construction vessel movements could increase risk of collision with other navigating vessels.	• Wind turbine derived radar clutter and wave action (false returns) appearing on ATC and ADR displays can adversely affect the surveillance system. • Cumulative effect of wind turbine blades rotating and wave action on multiple substructures in the FOW site. • The presence of above surface infrastructure within a previously unoccupied sea area may cause an obstruction to lower airspace flight operations.

Potential Impact	Maritime Description	Aviation Description
Impact on Vessel Routeing	• Presence of FOWF could result in deviations of shipping routes, increasing transit distance and impacts on operators. • Impacts to lifeline services, ferry operators and other timetabled services may make schedules unviable. • Project could impede access to recognized sea lanes essential to international navigation.	N/A
Impact on Small Craft Safety and Routeing	• Presence of FOWF could cause deviation of recreational and fishing routes. • Increased risks to small craft from wash from Crew Transfer Vessels (CTVs) maintaining FOWF.	N/A
Impact to Risk of Allision/Contact	• The presence of a FOWF in otherwise navigable waters imposes a risk of allision or contact through human error or mechanical failure.	N/A
Impact to Risk of Collision	• The FOWF could increase the risk of collision between navigating vessels, such as through the creation of choke points. • Vessels operating to and from the FOWF interact with other navigating vessels and increase the risk of collision.	N/A
Impact on Risk of Snagging	• The presence of subsurface infrastructure including cables and moorings could pose a risk of snagging from fishing gear and ship anchors.	N/A
Impact on Risk of Grounding	• The presence of the FOWF could deviate shipping routes into areas of shallow water that increases the risk of grounding.	N/A
Impacts Associated with Booster Stations	• The presence of booster stations along the export cable route could increase the risk of allision with navigating vessels or disrupt shipping routes, increasing transit time and imposing collision.	• The presence of booster stations along the export cable route could add to above surface obstacle density. • Negligible effect on PSR.
Impacts on Under Keel Clearance (UKC)	• Subsurface infrastructure, such as moorings and cables, could reduce the navigable depth of water obstructing vessel navigation.	N/A
Risk of Breakout	• The FOWT moorings could fail, causing the FOWT to drift out of the array area which poses a navigational hazard to other vessels.	• The FOWT moorings could fail, causing the FOWT to drift which poses an obstruction or hazard to lower airspace flight operations. • Negligible effect on PSR.
Impact on SAR	• The FOWF could reduce the capability to undertake SAR activities within the array area by reducing access of vessel or helicopter assets.	• The FOWF could reduce the capability of SAR activities within the array area by reducing access of helicopter assets. • Negligible effect on PSR.

Potential Impact	Maritime Description	Aviation Description
Impact on Visual Navigation and Collision Avoidance	• The FOWF could impede the visibility of vessels and other conspicuous landmarks or aids to navigation, reducing the capability of vessels to comply with their obligations under the COLREGs.	N/A
Impact on Ship Positioning, Navigation and Communication Equipment	• The project infrastructure could interfere with shipboard or land-based equipment essential to communications or positioning. These impacts could occur on marine radar, AIS, communications or compasses.	N/A
Maintenance	• Activities associated with the maintenance of FOWTs could impose additional impacts. This could include the removal of the FOWTs from the site or the movement of maintenance vessels.	• Activities associated with the maintenance of FOWTs could impose additional impacts. This could include the removal of the FOWTs from the array site. • Negligible effect on PSR.
Removal of Assets	• The decommissioning of the site and associated vessel movements could interact with other vessel traffic increasing navigational risks. • Some assets may remain in-situ following decommissioning which impose a risk of snagging.	• The decommissioning of the array site may initially introduce additional tall structure obstacles through decommissioning vessels which poses a risk to lower airspace flight operations.
Repowering	• The extension of the project life through repowering could prolong any adverse impacts associated with the FOWF.	• The extension of the project life through repowering could prolong any adverse impacts associated with the FOWF.

5 GAPS ANALYSIS

Based on the key potential impacts discussed above, a gap analysis (summarised in Figure 5) has been conducted using the assessment methodology outlined in Figure 4. This aims to establish the degree of missing guidance, tools and methodologies that occur between fixed OWFs and FOWs for each key potential impact. The gaps identified are detailed in the following tables which outline the potential impacts, describe where differences are present between fixed and floating OWFs and define the degree of gap which is considered to occur based on the literature review of guidance and tools in WP1.

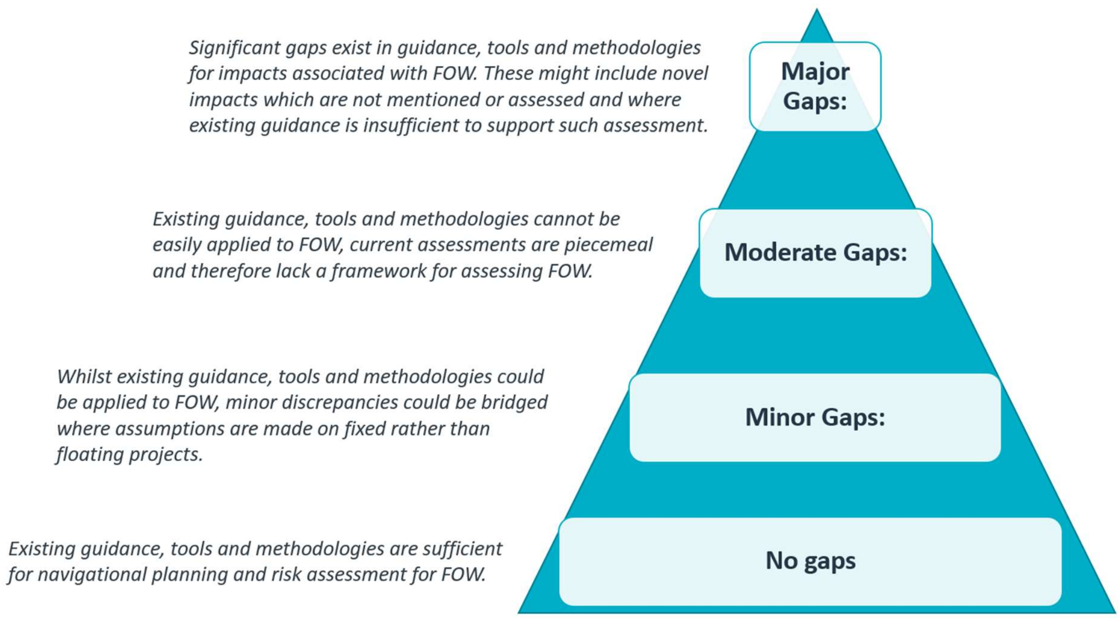

Figure 4: Gap Assessment Methodology.

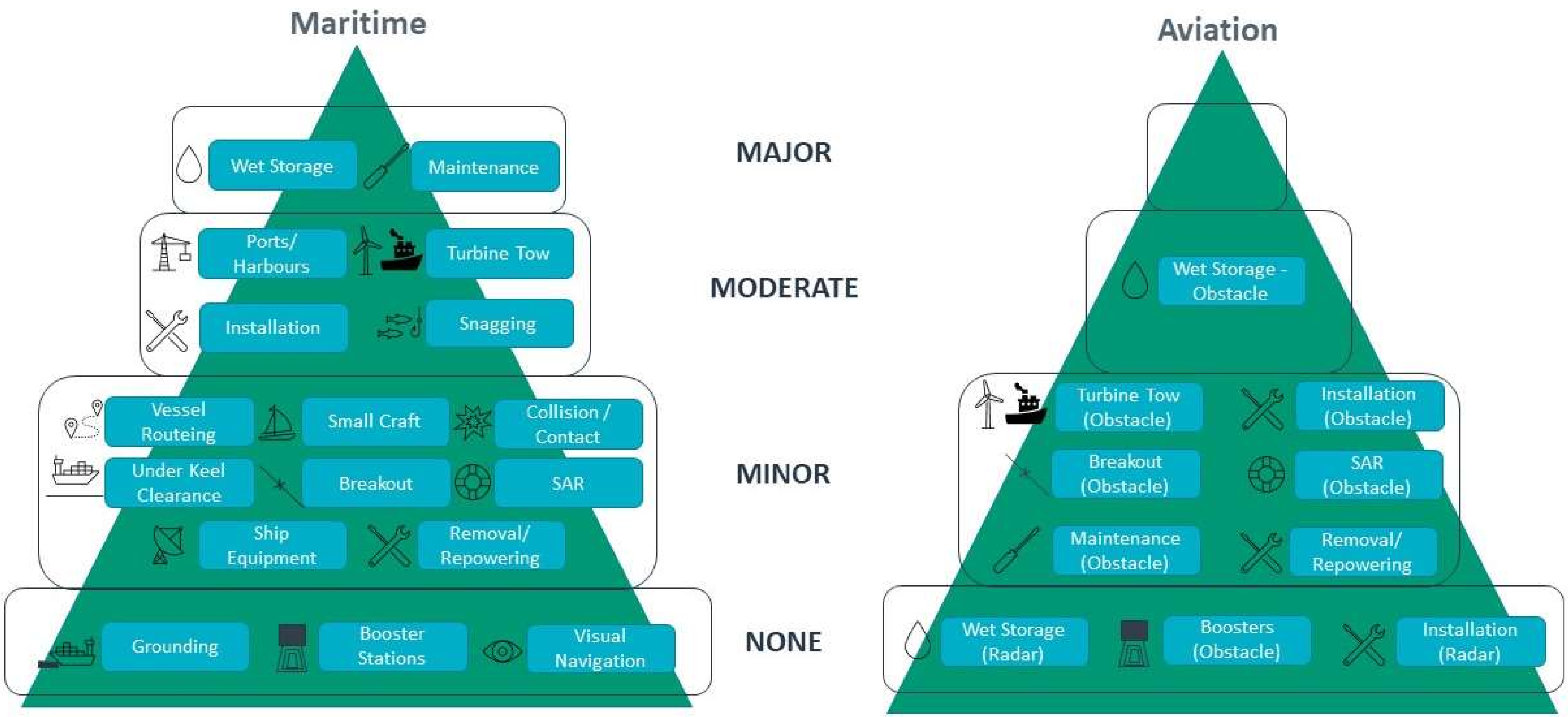

Figure 5: Identification of Key Gaps.

<table>
<tr><th>1</th><th colspan="2">Impacts Associated with Wet Storage Sites</th></tr>
<tr><td>Background</td><td colspan="2">A reoccurring theme during consultation was concerns over wet storage requirements for FOWFs. Environmental Impact Assessments (EIAs) for OWF have typically comprised of three components: the array area, the offshore export cable route and the onshore export cable route to the substation. However, wet storage (which is principally a concept that is useful for construction logistics), involves the temporary storage of either partially or fully constructed FOWTs in port or coastal waters. Whilst developers clearly have aspirations for wet storage, many stakeholders were unaware of this requirement and expressed concerns on the potential impacts to both shipping and navigation and aviation. Some developers expect that as many as 20 substructures may be wet stored simultaneously during the construction of a commercial scale project.
Whilst it is feasible that major maintenance campaigns or even construction could occur at wet storage sites, so called “tow to shore”, the size of FOWTs, depth of water and current capabilities of heavy lift vessels likely make this impractical (Carbon Trust, 2021). Given that wet storage sites are likely to be essential to construction strategies for commercial scale FOWFs, and their potential impacts could be significant, they should be assessed as part of the EIA. However, this assessment of wet storage is constrained by the uncertainties as to where such sites would be located and therefore prevents a full assessment.</td></tr>
<tr><td>Variation to Fixed</td><td colspan="2">• Partially or fully constructed FOWTs will be stored in port or coastal waters temporarily.
• Uncertainty on construction location during EIA limits detail of assessment. This may occur due to constraints on port capacity in a just-in-time supply chain.
• Introduces additional impacts to shipping and navigation receptors outside of array area and aviation receptors for near shore aerodrome Controlled Airspace and Instrument Flight Procedures.
• Greater impacts on near shore small craft such as recreational and fishing activities.
• Congestion and conflict with existing ship anchorages.
• Mooring of FOWTs may have a less regular layout in a wet storage area than in an array (SAR impacts).
• There may be greater constraints on construction weather windows which lengthens the storage period.
• Maintenance may be more restricted to good weather windows and therefore concentrated within specific times of year and as a result, there may be greater cumulative impacts.
• Greater impacts on near shore as within the UK military Low Flying System.</td></tr>
<tr><td rowspan="3">Gap</td><th>Maritime</th><th>Aviation</th></tr>
<tr><td>• MGN654 and other relevant guidance requires assessment of construction impacts which would reasonably include wet storage.
• Uncertainty around the frequency and location of wet storage areas on early floating projects undermines proper assessment.
• Many existing tools and techniques could be used for assessment of impact.
• The marking and lighting requirements for FOWTs in wet storage sites may be different (IALA G1162).
• SAR guidance (MGN654 Annex 5) may require tailoring for wet storage sites.
• Relevant risk controls are not clearly defined for wet storage sites, such as standby towage.
• There is uncertainty as to how wet storage sites should be managed and monitored.
• Potential for wet storage impacts to be greater for future projects than those of the array area.
• Data collection, assessment and consultation requirements not well defined.
• Unclear which consenting process would be required for establishing wet storage and therefore assessment requirements.
• Overlap with Port Marine Safety Code (PMSC) requirements in ports/harbours.</td><td>• Many existing tools and techniques could be used for assessment of impact.
• Uncertainty around the frequency and location of wet storage areas on early floating projects undermines proper assessment.
• The marking and lighting requirements for wind turbines in wet storage sites may be different – CAP764 and the ANO principally considers wind turbines in an array layout.
• Inshore FOWTs may need to be treated as onshore in terms of aeronautical obstruction lighting.
• There may be a requirement to review the marking on charts of moving Wind Turbine Generators (WTGs) to differentiate from fixed.
• Floating wind turbines have the potential to move both about their moorings and vertically in adverse weather conditions There may need to be greater recognition in guidance of the potential for turbine movement.
• No concerns have been raised on potential for the movement and changing aspects for aeronautical obstruction lighting, therefore existing guidance is considered fit for purpose.
• Existing tools could be used to assist impacts on PSR.</td></tr>
<tr><td>MAJOR</td><td>MODERATE</td></tr>
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2	Management of Safety and Logistics for Floating OWF Interface with Ports/Harbours
Background	Ports and harbours are critical to the UK economy as they are necessary for trade, recreation and fishing. Furthermore, many will be required to cater to the offshore wind industry, both construction and ongoing maintenance. The presence of the OWF could impede the approaches and reduce access. Construction/maintenance traffic could create challenges with the capacity of navigation channels, availability of towage or pilotage and may increase the risks to other marine users. A 2022 ORE Catapult report noted that "As it stands, the UK does not have the infrastructure capability, or capacity required to support a number of key large scale floating offshore wind project construction activities including steel substructure manufacture and assembly, concrete substructure construction, FOWT and substructure marshalling, assembly and integration" (ORE Catapult and ARUP, 2022). Therefore, there may also be a requirement for multiple ports to be involved in different stages of FOWF construction.
Variation to Fixed	• Greater quayside requirements for construction of floating turbines. • Marshalling and towing requirements places greater demand on port towage, pilotage and channel capacity. • Just-in-time supply chain places continual pressure on port/harbour during construction. • Uncertainty on construction base location during EIA limits specificity of assessment. • Limitation in number of ports/harbours in UK with necessary infrastructure to serve as construction bases. • Uncertainty around the vessel numbers and construction programme – a challenge similar to fixed projects but to a lesser extent. • Potential impacts may be much more significant than for fixed OWFs. • Construction may be spread across multiple ports/harbours and therefore increases complexity in assessment process.
Gap	**Maritime**
	• MGN654 and other relevant guidance requires assessment of construction impacts. • Many existing tools and techniques could be used for assessment of impact. • Issues of port logistics and capacity are not explicitly mentioned in most OWF guidance. • Uncertainties around construction base, programme and vessel movements makes a site-specific risk assessment challenging. Therefore, it is likely that the NRA will superficially assess impact. It could be argued that an increase in vessel movements falls within competency of port authority and therefore does not require assessment at all within the OWF Application. • Port Marine Safety Code places obligation on port/harbour to risk assess impact. However, this falls outside of EIA consenting process. Impact may therefore require additional assessment outside of conventional consenting process.
	MODERATE

<table>
<tr><th>3</th><th colspan="2">Assessment of Safety of Towage Operations</th></tr>
<tr><td>Background</td><td colspan="2">FOW increases the requirement for towage operations to move FOWTs between ports, wet storage and array areas. Impacts associated with this include increasing the risk of FOWT breakouts, interactions with other vessels increasing collision risk, and disruption to fishing activity (static and mobile). Towage of large structures is routine in many industries and a towage plan/towage risk assessment is developed on a case-by-case basis. There are several requirements which would need to be fulfilled (COREWIND, 2020) in a FOW towage plan/towage risk assessment:
• A suitable weather window, likely with a significant wave height of less than two metres.
• Multiple tugs - whilst one large tug with sufficient bollard pull (up to 100t) might be sufficient for offshore tows, in-port tows or the act of hook up/connection might require multiple tugs.
• Compliance with COLREGs requirements such as lights and navigational shapes.
• Relevant equipment such as Automatic Identification System (AIS), pumps, generators.
• Relevant personnel with suitable kit for a boarding party.
• Relevant authorisations from aviation, maritime authorities, port authorities or insurance.
• Suitable promulgation through Notice to Mariners or Very High Frequency (VHF) broadcasts.</td></tr>
<tr><td>Variation to Fixed</td><td colspan="2">• FOWTs are likely to be constructed and assembled a significant distance from the array and towed to site rather than constructed in-situ. This potentially increases interactions with receptors as FOWTs are towed across them rather than individual vessel movements.
• There may be greater constraints on construction weather windows which lengthens the installation period.
• Tow to site increases impacts to fishermen with loss of gear or gear relocation.
• Mobility of FOWTs may increase desire to use wet storage or tow to port maintenance.</td></tr>
<tr><td rowspan="3">Gap</td><td>Maritime</td><td>Aviation</td></tr>
<tr><td>• There is some overlap between floating wind assessments and existing tidal and wave turbine assessments for tow to site operations.
• Additional risk controls may be required during tow to site operations.
• Considerations of frequent tow to site corridors are not included in existing guidance.
• Methods to assess collision risk during tow to site are not clearly defined, albeit existing methods could be adapted.
• Assessment of routine towage acts on a case-by-case basis is unmanageable and a more systematic approach may be required. This approach is not well developed.
• Towage at slow speed may be disruptive to other operations/activities.
• Requirement for shelter during long distance tows cold result in ad-hoc wet storage.</td><td>• Existing risk controls may not be sufficient for tow to site operations.
• Considerations of frequent tow to site corridors are not included in existing guidance.
• Affect to HMRIs assessment process are not well laid out.
• The marking and lighting requirements for wind turbines in tow may be different – CAP764 and the ANO principally considers wind turbines in an array layout.</td></tr>
<tr><td>MODERATE</td><td>MINOR</td></tr>
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<table>
<tr><th>4</th><th colspan="2">Management of FOWF Array Construction Programme</th></tr>
<tr><td>Background</td><td colspan="2">An OWF would necessitate construction of obstacles in otherwise navigable sea area and increase vessel movements to support construction activities. This poses risks and impacts to other maritime and aviation users including the risk of snagging, allision and collision to maritime users and disruption to aviation activities.</td></tr>
<tr><td>Variation to Fixed</td><td colspan="2">• It is likely that FOWT moorings will be installed prior to the FOWTs themselves. This may result in periods where there is subsurface infrastructure without surface marking which increases snagging risk as opposed to fixed.
• The installation process could have a shorter duration given the reduced requirement for piling operations as opposed to fixed.
• There may be greater constraints on construction weather windows which lengthens the installation period.
• It is likely that many FOW projects will be in deeper water which is further offshore. As a result, some sites would be clear / beyond littoral PSR coverage / horizon.
• There may be greater constraints on construction weather windows which lengthens the installation period.</td></tr>
<tr><td rowspan="3">Gap</td><td>Maritime</td><td>Aviation</td></tr>
<tr><td>• The risks of snagging and obstruction from subsurface hazards are well discussed in relevant guidance as relates to tidal or wave devices.
• The scale of FOW potentially creates greater impacts than previous tidal or wave demonstrator sites.
• Additional risk controls may be required, such as additional monitoring or surface marking.</td><td>• The marking and lighting requirements for wind turbines in array site remains extant – CAP764 and the ANO principally considers wind turbines in an array layout.
• There may be a requirement to review the marking on charts of moving WTGs to differentiate from fixed. A Circular Error Probable (CEP) may need to be allowed in aeronautical recording and charting of individual wind turbines. ICAO Doc 8168 PANSOPS defines this process.
• Existing Advanced Topographic Development Imaging (ATDI) ICS LT tool could be used for assessment of impact.</td></tr>
<tr><td>MODERATE</td><td>MINOR</td></tr>
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<tr><th>5</th><th colspan="2">Best Practice for Major Maintenance and Temporary Removal of Turbines</th></tr>
<tr><td>Background</td><td colspan="2">The 2022 Hazard Identification (HAZID) performed by G+ (2022) noted that offshore heavy lifts for major component exchange is generally seen as undesirable both from a safety and cost-benefit perspective. Jack-up vessels for instance will not be viable due to water depth and larger heavy lift vessels have high costs. Furthermore, a 2021 study determined that many of the existing fleet of heavy lift vessels are unable to lift to the hub height of a 10MW FOWT (Carbon Trust, 2021). Therefore, during major maintenance activities, FOWTs may be removed from the array area and towed to either wet storage areas or into ports to have components changed. The degree to which this might occur is uncertain, but some studies have estimated that there may be a requirement for at least one to two large component exchanges annually (Carbon Trust, 2021). As such, it is possible that there may be frequent changes to the shape and layout of a FOWF project during its lifecycle that may introduce additional risks.</td></tr>
<tr><td>Variation to Fixed</td><td colspan="2">
FOWTs could be maintained in-situ (within the array area), towed to port for maintenance alongside or towed to shore for maintenance in sheltered waters.
There may be a requirement for wet storage (see relevant impact).
There may be a greater impact on ports and harbours (channel and quayside capacity) or anchorages.
Maintenance may be more restricted to good weather windows and therefore concentrated within specific times of year. As a result, there may be greater cumulative impacts.
Maintenance may be less effective due to the motions aboard the FOWT and access is more difficult during adverse weather which might increase wear and tear for FOWTs.
Where FOWTs are towed from the site, moorings may be left in place without surface marking which increases risk of snagging.
Where FOWTs are towed from site, the marking and lighting of the array will be different.
</td></tr>
<tr><td rowspan="3">Gap</td><th>Maritime</th><th>Aviation</th></tr>
<tr><td>
There is uncertainty as to how large-scale floating projects will be maintained, but it is likely that new impacts will arise through the removal of turbines from the site.
The location of the site, depth of water, metocean conditions and availability of suitable infrastructure will all affect how a FOWF will be maintained.
Existing guidance does not specify how this should be assessed or managed.
A recent study by the Floating Wind Joint Industry Programme did not consider that access or effectiveness for maintenance was substantially different between fixed and floating.
There is uncertainty as to the O&M bases used for projects and therefore the level of assessment during consent is limited.
</td><td>
The marking and lighting requirements for wind turbines in array site remains extant – CAP764 and the ANO principally considers wind turbines in an array layout.
There may be a requirement to review the marking on charts of moving WTGs to differentiate from fixed. A Circular Error Probable (CEP) may need to be allowed in aeronautical recording and charting of individual wind turbines. ICAO Doc 8168 PANSOPS defines this process.
Existing ATDI ICS LT tool could be used for assessment of impact.
</td></tr>
<tr><td>MAJOR</td><td>MINOR</td></tr>
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Table 4: Identification of Other Gaps (**Blue: Maritime specific**, **Green: Aviation specific**, **Grey: Both Maritime and Aviation specific**).

Potential Impact	Variation to Fixed	Review of Assessment	Degree of Gap	
			Maritime	Aviation
Impact on Vessel Routeing	• It is likely that many floating projects will be located in deeper water which is further offshore. As a result, some sites would be clear of high-density shipping routes. • Shipping routes may be more dispersed in future sites for floating projects. • Conversely, early fixed projects were located on shallow banks which were already avoided by shipping given the risk of grounding. • Vessels are unlikely to route differently around a fixed or a floating project.	• The need to minimize the impacts on ship routeing are covered in relevant guidance and policy. • The primary assessment approach employed is the use of 90th percentile corridors and route centrelines. • Deep sea projects are likely to have wider 90th percentile corridors than nearshore projects (hundreds of miles as opposed to miles) and there would likely be less scope to completely avoid these corridors. • It is not clear how moorings should be considered in the MGN654 shipping route template.	Minor	N/A
Impact on Small Craft Safety and Routeing	• Where projects are located further offshore and in deeper water, the impacts to small craft navigation are likely to be less. • The potential movement of the FOWTs and additional mooring requirements for some substructures may make some skippers wary of navigating through a floating project. • There may be greater impact on small craft navigation as skippers choose to navigate around the project, increasing interactions with larger shipping. • The temporary mooring in wet storage areas may increase interactions with small craft.	• Existing guidance and policies recognise the need to assess impacts to small craft routeing and safety. • There are relevant tools and methods for undertaking this assessment. • At present, safety zones are not implemented for the operation of floating projects. • There may be a requirement to review the marking on charts of moving FOWTs to differentiate from fixed.	Minor	N/A
Impact to Risk of Allision/Contact	• Existing project designs have excursions of FOWTs of less than 50m in adverse weather. This may result in turbines in less regular layouts than charted which could increase risk of allision. • Some substructures have a greater physical footprint which inherently increases the risk of allision. • Any movement vertically of a FOWT could have impacts on air draught clearance which might increase risk of contact.	• Impacts of allision are not considered to be significantly affected for floating as opposed to fixed. • The movement of FOWTs are limited. Therefore, existing tools and models for allision assessment are fit for purpose in addressing FOWTs. • There may need to be greater recognition in NRAs of the potential for turbine movements and that impact on navigation. • There may be a requirement to review the marking on charts of moving FOWTs to differentiate from fixed.	Minor	N/A
Impact to Risk of Collision	• Sites may be located in deeper water and further from shore where traffic densities are lower (particularly small craft). • Greater use of SOVs as opposed to CTVs (given distance from shore) reduces risk of collision during CTV passages.	• Impacts of collision are not considered to be significantly affected for floating as opposed to fixed. • Commercial shipping would route around a floating project in a similar manner to fixed. Therefore, site selection is the key determining factor of impacts to collision risk as opposed to fixed or floating design. • Existing guidance has considerable reference to models and assessment methods to consider changes in collision risk.	Minor	N/A

Potential Impact	Variation to Fixed	Review of Assessment	Degree of Gap	
			Maritime	Aviation
Impact on Risk of Snagging	• FOWTs may have greater spread of subsurface infrastructure, particularly moorings and cables within the water column. • This increases risk of snagging as opposed to fixed projects. • Substructure designs have large variations in how the catenary slopes – introducing greater uncertainty.	• The risks of snagging and obstruction from seabed export/inter-array/interconnector cables are well discussed in relevant guidance. • Methods to assess risk of snagging of mooring lines and cables are less well defined. • There is often large uncertainty around the mooring spread and catenary which undermines the specificity of any assessment.	Moderate	N/A
Impact on Risk of Grounding	• Sites may be located in deeper water and further from shore where traffic densities are lower (particularly small craft) and therefore the impact on the risk of grounding is potentially lower.	• Existing tools and guidance are fit for purpose in assessing the impact of floating array areas on grounding risk.	No Gap	N/A
Impacts Associated with Booster Stations	• Sites may be located further from shore and therefore there may be greater requirement for booster stations. • Booster stations impose additional risks of allision and collision to vessel traffic.	• Existing tools and guidance are fit for purpose in assessing the impact of booster stations on vessel navigation. • Existing guidance is fit for purpose in assessing the aeronautical obstruction effect of booster stations on aviation.	No Gap	No Gap
Impacts on Under Keel Clearance	• FOWTs may have greater spread of subsurface infrastructure, particularly moorings and cables. • This increases risk of obstruction as opposed to fixed projects. • Substructure designs have large variations in how the catenary slopes – introducing greater uncertainty.	• Existing tools and guidance for assessing the impacts on under keel clearance are clearly defined (such as 5% rule in MGN654). • There is uncertainty as to the catenary of proposed cables and moorings which undermines the assessment of the impacts on navigation. • In general, the engineering solutions proposed to date are such that impacts on under keel clearance are negligible.	Minor	N/A
Risk of Breakout	• FOWTs are secured to the seabed and therefore there is the risk of breakout in adverse weather or due to component fatigue. • Given the size of the structures, wear and tear on the chains and moorings may contribute to breakout. • Floating projects may be further from shore and therefore metocean conditions more severe.	• Guidance is in place for expectations on mooring standards and there is significant overlap with the experiences in the O&G industry (e.g. HSE/MCA expectations document). • Additional monitoring requirements or other risk controls may be required to manage breakout risk for floating projects. • The marking and lighting requirements for wind turbines in wet storage sites may be different – CAP764 and the ANO principally considers wind turbines in an array layout. Additional, or backup, lighting might be required to allow for a 'breakout'.	Minor	No Gap
Impact on SAR	• FOWTs have the potential to move both about their moorings and vertically in adverse weather conditions. • Some substructures for FOWTs have a greater footprint to support helicopter winching operations. • FOWTs may be more hazardous to come alongside and transfer personnel rather than fixed due to their movement which could increase SAR requirements. • Vertical movement is a small percentage of the FOWT's overall height to maximum tip.	• There is a lack of experience in conducting SAR for floating OWFs given the technology's novelty. • Existing guidance regarding lines of orientation and spacing is considered sufficient for floating projects in the context of anticipated movements of FOWTs. • No significant concerns were raised by consultees regarding SAR. • There may need to be greater recognition in guidance of the potential for turbine lateral movement. • A Circular Error Probable (CEP) may need to be allowed in aeronautical recording and charting of individual wind turbines. ICAO Doc 8168 PANSOPS defines this process.	Minor	Minor

Potential Impact	Variation to Fixed	Review of Assessment	Degree of Gap	
			Maritime	Aviation
Impact on Visual Navigation and Collision Avoidance	• Floating projects have greater potential for movement and therefore changing aspects for navigational lights could confuse navigating vessels.	• To date, no concerns have been raised on this impact and therefore existing tools and guidance is considered fit for purpose.	No gap	N/A
Impact on Ship Positioning, Navigation and Communication Equipment	• The potential for cabling within the water column could increase the electromagnetic impacts/fields which might impact ship equipment. • The movement of FOWTs may have greater impacts on shipboard radar clutter that stationary fixed WTGs.	• Existing guidance considers impacts of electromagnetic interference, and these are anticipated to be highly concentrated around the FOWTs and away from most navigating vessels. • There is no available evidence that a FOWTs has a significantly greater radar signature compared with a fixed WTG. This uncertainty could be addressed.	Minor	N/A
Removal of Assets	• Floating projects are likely to have more seabed infrastructure and there may be greater demand for seabed infrastructure to be left in-situ following decommissioning. This has impacts on snagging of fishing gear. • Site array geographic shape may change. • Given the capability to easily replace floating wind turbines, projects may have longer duration as individual wind turbines are replaced with newer and more efficient models.	• The risks of snagging and obstruction from subsurface hazards are well discussed in relevant guidance. • Assessments assume decommissioning and therefore implications for deposit of cables/moorings are not considered. • The marking and lighting requirements for site array wind turbines (CAP764 and the ANO) principally consider wind turbines in an array layout. • Where wind turbines are removed from site, the marking and lighting of the array will be different. • Additional guidance might be required to take account of repetitious asset removal and replacement.	Minor	Minor
Repowering	• Given the capability to easily replace FOWTs, projects may have longer duration as FOWTs are replaced with newer and more efficient models.	• Existing assessments assume decommissioning of projects, cumulative impacts for extended lifespans of projects should be considered.	Minor	Minor

6 OPPORTUNITIES ASSESSMENT

WP4 reviews possible opportunities to assess the key gaps identified within WP3. The project team developed list of opportunities following a review of the literature and consultation with stakeholders. These opportunities were then scored based on their potential benefit and their likely effort to achieve said benefit on a three-point scale:

- The **additional effort** was graded to reflect the cost to implement the opportunity, whether in monetary cost or resource requirements, as well as the likely timescales. Some opportunities can be implemented quickly with low expenditure whilst others are more costly and have longer lead times;
- The **potential benefit** was graded to consider how the opportunity addresses the gap or impact. A measure which addressed a minor gap has a low benefit, whilst those that address a major gap have a greater benefit.

A matrix was developed for comparing the opportunities and provides a grading of the level of opportunity from Low to High (see Figure 6). Therefore, measures which require low resource requirements, can be undertaken quickly and address a major gap have a higher opportunity score than those which are costly, slow and address only minor gaps.

Four themes of opportunities were identified and are described below. These are:

- Addressing Assessment Gaps for Wet Storage;
- Greater coordination;
- Additional study requirements; and
- New technologies or methods.

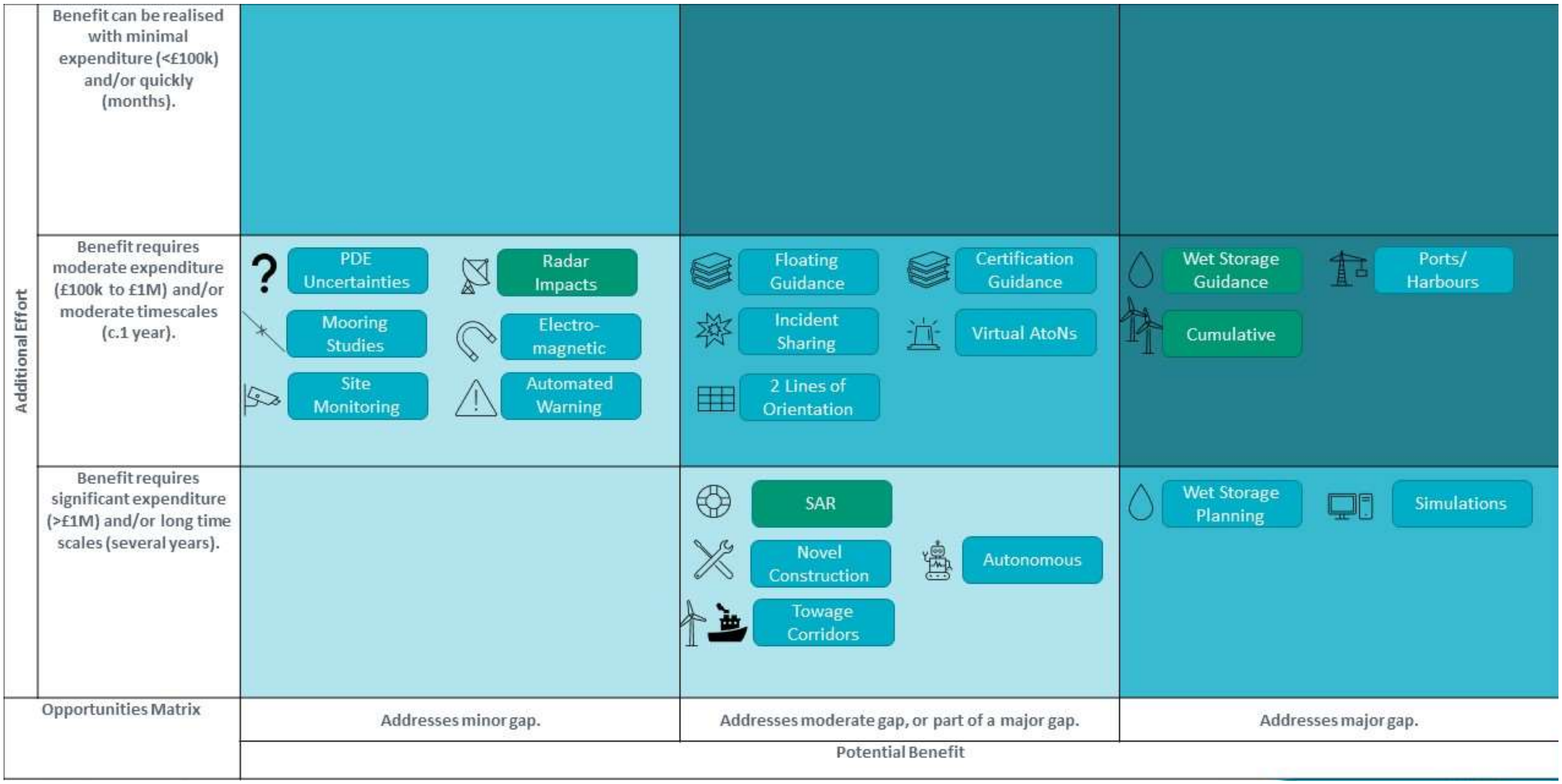

Figure 6: Identification of Key Opportunities.

Addressing Assessment Gaps for Wet Storage		Opportunity
Updating Existing Guidance	Early assessments for FOWFs do not consider the impacts of wet storage locations due to a lack of information. Furthermore, existing guidance has been developed to consider the presence of WTGs in the array area and has not been tested within the context of wet storage requirements. By enshrining wet storage within guidance and educating both stakeholders and regulators, the existing consenting process could be adapted to ensure that relevant impacts are addressed through Applications. Therefore, the same level of due diligence as is required for array areas, would be required for wet storage sites. Such an approach would need to be led by the various regulators responsible for their relevant guidance documents. A key challenge is that such sites are unlikely to be fully realised during the Application process for an individual project and therefore this approach may not be feasible for most developments.	**High**
Establish New Assessment Process	Wet storage could be separated into a distinct assessment which supports a specific marine license (or similar) application. Whilst the process of obtaining consent through a Marine and Coastal Access Act (or devolved equivalents) is clearly laid out, it is not clear whether temporary storage of a FOWT would meet the requirements of "deposit any substance or object". A standalone assessment (such as an NRA) would be required to ensure that all relevant impacts are properly assessed to support the license Application. This may necessitate adaptation of existing guidance (such as MGN654) or development of new wet storage specific guidance. This might include data gathering requirements, consultation, analysis and assessment processes. Conditions could be included in the marine licenses that prevent construction unless wet storage sites have been properly assessed with suitable controls agreed to by statutory consultees. This provides greater flexibility to developers in the circumstance that the locations of wet storage are not known at the time of Application.	
Consolidating and Centralising Assessments	Centralising the management of wet storage rather than on a project-by-project basis could improve the assessment process. Were individual projects to establish their own sites, for example in the Celtic Sea, the suitable areas may become saturated and FOWTs may be stored in sub-optimal locations which have greater risks and impacts. These sites could be shared with consistent risk controls and clear operating procedures including risk assessment, Safety Management System, ERCOP and a Marine Pollution Plan for the site with a defined Project Design Envelope (which covers most foreseeable FOWT designs). These could be reviewed following any incidents and updated on a regular basis to ensure they are fit for purpose. A similar approach is undertaken by the European Marine Energy Centre (EMEC) in the Orkney Islands, which provides the world's first facility for demonstrating and testing tidal and wave energy convertors. EMEC have established the relevant consents for the test sites with site wide EIAs and NRAs. Site wide risk controls are also in place, such as monitoring, management and emergency response plans. There is a potential requirement to manage navigation in a wet storage area to facilitate safety of operations or at a minimum, to control where FOWTs are anchored, however, it is unclear who would be best placed to manage such a site. Currently there would be no powers available to do this if the wet storage is located outside of a Statutory Harbour Authority (SHA) area. There are examples of ports entering into a Memorandum of Understanding with the MCA to use its powers to control vessel traffic (such as Southampton). A statutory regime similar to that of establishing an SHA could be used to place powers and duties on a wet storage operator to allow for management of marine safety.	

Greater Coordination		Opportunity
Cumulative Regional Assessments	A reoccurring concern amongst stakeholders is the significant pipeline of both fixed and floating OWF projects within the UK. This introduces potentially significant cumulative impacts on a variety of activities. The existing tiered approach to assessment is perhaps no longer fit for purpose given adjacency in time and proximity in space at which projects are proposed. There is clear frustration amongst stakeholders that known projects, widely discussed in the media, are not included within cumulative assessments because they have not submitted a Scoping Report. Furthermore, cumulative assessments between different OWFs, undertaken at the same time, could reach entirely different conclusions due to different assumptions and methodologies. Similarly, stakeholders become fatigued through multiple engagements on the same issues by different developers. Therefore, a more coordinated, regional approach to cumulative risk assessments would streamline this process. This could be achieved either through a collaboration between developers or initiated through a statutory body or regulator. The principle would be to undertake regular assessments, with a working group of stakeholders and developers, which account for all proposed projects and identify where key conflicts or navigational concerns might arise. This can enable targeted and effective mitigation which would not necessarily be achievable on a project-by-project basis. There have been some undertakings of strategic assessment to holistically assess impacts on navigation. Two examples are the Forth and Tay Offshore Wind Developers Group undertaken in 2010 and the Irish Sea Cumulative Regional NRA undertaken in 2022. Both of these were cross developer assessments to identify and address wider cumulative impacts than were the assessments undertaken individually. There is no explicit guidance on best practice for undertaking cumulative risk assessments. For example, as the areas under assessment are larger, with more traffic and more structures, the risks are inevitably higher. As a result, the conventional risk matrices used in guidance and assessments may no longer be applicable to the existing baseline risk profile of the area under assessment. Furthermore, there is no guidance on what range or extent of data collection is required to consider multiple sites which are far apart.	**High**
Sharing of Data	Without commercial scale FOWFs there is uncertainty around the risks of operating such sites. Sharing of incident data (navigational, health and safety and engineering failures) between operators will increase the awareness of those risks, their frequency, and encourage work to address those that emerge.	**Medium**

Additional Guidance and Study Requirements		Opportunity
Best Practice for Ports/Harbours	Ports and harbours are preparing to cater for the FOW sector. Handling FOWF operations and impacts on capacity or safety are likely to be challenging. Development of best practice guidelines to support Harbour Authorities in ensuring the relevant impacts are assessed in a consistent and robust manner. These should be consistent with principles within the PMSC. There are several opportunities for further studies to facilitate the development of this guidance. Firstly, developing an industry/regulatory working group to recognise challenges to ports and harbours and identify operational practices which mitigate those potential impacts. Secondly, undertake simulation exercises in full bridge simulators in a range of conditions to test those solutions. Examples include: • Required towage arrangements for different FOWTs. • Suitable safe distances around towed FOWTs from vessels or obstacles. • Separation of FOWTs from navigational channels or ship anchorages. • Required mooring arrangements for FOWTs when alongside at a port. • Emergency response procedures.	High
Certification Requirements	There are uncertainties around the specific regulations of FOWT in the UK. Greater clarity through a guidance document would educate stakeholders and provide assurance to developers on what the expectations were. A similar document was published by the HSE and MCA (2017) on “Regulatory expectations on moorings for floating wind and marine devices.”	Medium
Search and Rescue	Previous studies undertaken by HMCG and the MCA within operational OWFs have been limited to fixed foundations. There may be some differences with FOW and therefore additional trials would test assumptions. Specific operational guidelines for SAR in FOW can be developed for inclusion in MGN654 Annex 5.	Low
FOW Simulations	System wide simulations of FOW operations can be used for navigational planning and risk assessment. Managing the towage operations of large, poorly manoeuvrable FOWTs in constrained navigational channels is likely to be challenging. By undertaking full bridge simulations in a variety of conditions, valuable experience could be disseminated to the wider sector. This will build competence and provide a good evidence-base suitable for informing planning.	Medium
Moorings	Undertake mooring studies for FOWTs alongside quays in ports and harbours to optimize mooring arrangements and minimize breakout from metocean conditions or wash. In addition, modelling of the catenary of moorings within the array area to better understand threat of snagging/under keel clearance.	Low
Radar and Electromagnetic Interference	Previous studies undertaken by the MCA (and others) for the impacts of OWF on radar have noted impacts. It is not clear whether these would be greater or lesser for a FOWF as opposed to fixed OWF. Additional studies to test these impacts, either theoretical or practical, could clarify these assumptions. Previous studies undertaken by the MCA (and others) on the impacts of electromagnetic forces generated by OWF cables have not considered mid-water column cables necessary for FOW. It is not clear whether these would be greater or lesser for a FOWF as opposed to fixed OWF. Additional studies to test these impacts, either theoretical or practical, could clarify these assumptions.	Low
Guidance Review	Projects could be located further from shore which may have different impacts to inshore projects, requiring adaption of existing guidance. For example, data collection requirements under MGN654 may be more difficult to achieve. Sites are larger and radar coverage from a survey vessel would not be sufficient. The 90th percentile concept for characterising shipping routes is less relevant as routes are much more dispersed offshore. It is not clear in guidance whether subsurface infrastructure such as moorings is included in passing distance guidance. Booster stations could benefit from more specific assessment requirements.	Medium

New Technologies or Methods		Opportunity
Virtual/Physical AtoNs	Certain mooring designs may be spread a considerable distance from the FOWT, posing a risk to navigating vessels or fishing vessels. Use of cardinal marks around all FOWFs would provide flexibility for removal of FOWTs without compromising navigational safety. The use of Virtual Aids to Navigation, an established technology to mark the boundary of the site, would provide greater warning to fishermen. Virtual Aids to Navigation (AtoNs) could also be deactivated were a FOWT to become off station.	**Medium**
Site Design	Existing guidance recommends two lines of orientation of FOWT layouts unless a safety case justifies that only a single line of orientation is tolerable. Given the complexities of FOW, requiring two lines of orientation for all commercial scale FOWFs would offer a number of benefits for improving safety and SAR. This would impact upon optimisation of FOWFs.	**Medium**
Construction Methods	The lack of suitable port infrastructure and impacts on shipping and navigation associated with wet storage are key challenges for FOW. Testing of new construction methodologies using Dynamic Positioning, barges and suitable cranes could mitigate these impacts.	**Low**
Site Monitoring	FOWT are tracked by developers to monitor their position and condition. Standardizing the requirement for monitoring could minimise risks. This could be achieved through "geofencing" to notify relevant authorities were a FOWT to move greater than a threshold from its central position.	**Low**
Autonomous Vessels	The distance from shore makes operating within a FOWF more challenging. Greater use of autonomous vessels to survey or monitor the condition of the FOWF could reduce the potential risks, particularly to personnel. Greater use of unmanned aerial/underwater vehicles could improve asset monitoring and support condition-based maintenance. Whilst this has benefits for the industry, benefits to navigation safety are less prominent.	**Low**
Towage Management	Routine towage of FOWTs between the array area and a port/wet storage area could be a reality for FOW. Establishing defined towage corridors as part of the Application would enable these risks to be properly assessed. At present, this may be done ad hoc, for example, fishermen may be asked to remove gear along the towage corridor for a specified window. Relevant stakeholders could be identified, and suitable mitigation strategies put in place.	**Low**
PDE Uncertainties	For complex planning applications, such as OWFs, it is common that not all details of the project are available at the time of submission. Therefore, a Project Defined Envelope (PDE) may be used to address these uncertainties, provide flexibility to the project and ensure that there is a tangible project description for assessment. The Planning Inspectorate's Advice Note Nine (2018) provides guidance to developers as to how this approach should be applied to Development Consent Order projects through the Rochdale Envelope and a Maximum Design Scenario. FOWFs are an emerging technology and have greater uncertainties around project parameters (design/construction) and therefore the Maximum Design Scenario is wide and difficult to assess. Undertaking additional assessment to consider impacts from a range of design options may be beneficial for ensuring suitable risk controls are in place. This would provide greater transparency to stakeholders. Existing PDE approach is well recognised by consultees and changes could make inconsistencies with wider EIA approach.	**Low**
Automated Warning	AIS monitoring of the site could be used to identify potential incursions or drifting vessels which pose a threat to the FOWTs. This would enable immediate action to prevent an incident. Given low historical frequency of large vessel incidents around OWFs, the benefit is likely to be minor.	**Low**

7 CONCLUSIONS

At the time of conducting this study, there was a substantial pipeline of proposed OWFs within the UK and elsewhere in Europe. It is inevitable that as more projects are proposed, there will be increasing conflicts between renewable energy development aspirations and shipping and navigation activities. Shipping and ferries are responsible for 95% of UK trade, fishing is a major industry and there are thousands of recreational craft enjoying the sea. Safeguarding these activities whilst supporting the growth of renewable developments relies on robust and fit for purpose approaches to navigational planning and risk assessment.

This study has identified a range of potential impacts associated with FOW, many of which, such as collision or impacts to vessel routeing, were largely consistent with those identified for fixed OWFs. Therefore, many stakeholders consulted as part of this project were content with applying the existing guidance and tools to FOW projects. FOW specific issues around snagging risks or under keel clearance impacts, for example, are more prominent but have well laid out methodologies and tools for assessment under existing risk assessment guidance documents.

However, it was apparent that the specific construction and O&M methodologies likely to be employed were uncertain to both developers and stakeholders, contributing to a lack of awareness as to what could be potentially significant impacts. The experiences with existing projects such as Hywind and Kincardine, both small in scale with a large proportion of construction being undertaken abroad, have not been a concern to date. Yet, once issues around wet storage, interfacing with ports and towage were discussed, it became clear that significant gaps existed with conventional navigational planning and risk assessment approaches, which was not previously considered.

The rush to commercialise FOW has the potential to leave some of these gaps unanswered. This is exacerbated by the greater pressure on stakeholders and regulators to engage with this process, review documentation, attend meetings and come to a considered opinion on an ever-growing list of projects with a limited number of experts. Therefore, the extent to which these potential impacts and gaps are critical may not become apparent until the first commercial scale FOWF goes through consent and is constructed, by which time it would be too late to learn from experience and reform the planning and risk assessment process to better manage other projects.

This study clearly identified that the use of wet storage may have the greatest potential impact on shipping and navigation receptors, introducing new risks to new user groups in new areas. Without proper management and coordination of wet storage, there is a risk that coastal waters could become inundated by FOWTs causing conflicts with other activities and increasing navigational risks. These potential impacts are the direct result of the construction of the OWF, and they should be assessed under existing guidance. However, as the wet storage sites may not be known at the time of the assessments (as is often the case for construction/O&M bases) it may be deferred. Additionally, as FOWTs in wet storage would be temporarily moored, and not generating electricity, if the project got consent, there would be seemingly limited requirement to undergo a detailed assessment of impacts on maritime risk.

FOWFs also pose potentially much more significant impacts to ports and harbours than conventional fixed bottom OWF. Previously, ports and harbours were only major consultees in risk assessments if the OWFs were proposed in their approaches, with separate commercial discussions regarding construction/O&M base requirements. The need for significant shoreside infrastructure and the inherent additional hazards involving construction, towing and storing FOWTs in port waters is likely to require an expansion of assessments to consider this.

The overarching theme of FOW impacts might be distilled to that of geography. The construction, operation and decommissioning of a FOW project steps beyond the limited scope of risk assessments; array area and cable route. Potential impacts are now spread across multiple ports and harbours, wet storage areas and towage routes. Encapsulating all of these potential impacts with detailed levels of assessment is potentially impractical. Yet, as array areas move further offshore and into deeper water, it may be within these new geographies that the most significant impacts occur, and where the most detailed assessments are required. To meet these challenges, opportunities exist for coordination and collaboration to both minimise impacts to shipping and navigation and aviation, whilst maximising the development potential for offshore renewable energy.

REFERENCES

Carbon Trust (2021). Floating Wind Joint Industry Programme: Phase III Summary Report. Available at: https://www.carbontrust.com/our-work-and-impact/impact-stories/floating-wind-joint-industry-programme-jip/floating-wind-jip-1.

COREWIND (2020). D4.1 Identification of floating wind-specific O&M requirements and monitoring technologies. Available at: https://corewind.eu/wp-content/uploads/files/publications/COREWIND-D4.1-Identification-of-floating-wind-specific-O-and-M-requirements-and-monitoring-technologies.pdf.

G+ (2022). G+ Floating offshore wind hazard identification (HAZID). Available at: https://www.gplusoffshorewind.com/work-programme/workstreams/guidelines.

HSE and MCA (2017). Regulatory Expectations on Moorings for Floating Wind and Marine Devices. Available at: https://www.gov.uk/guidance/offshore-renewable-energy-installations-impact-on-shipping.

IALA (2021). G1162 The Marking of Offshore Man-Made Structures. Available at: https://www.iala-aism.org/product/g1162/.

MCA (2021). Safety of Navigation: Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response. Available at: https://www.gov.uk/guidance/offshore-renewable-energy-installations-impact-on-shipping.

ORE Catapult and ARUP (2022). Strategic Infrastructure and Supply Chain Development. Available at: https://ore.catapult.org.uk/?orecatapultreports=fow-coe-strategic-infrastructure-and-supply-chain-development.

ORE Catapult and Xodus Group (2022). Floating Offshore Wind: Environmental Interactions Roadmap: Public Summary Report. Available at: https://ore.catapult.org.uk/wp-content/uploads/2022/06/FOW-PR31-Environmental-Interactions-Roadmap-Report-May-22-AW_FINAL.pdf.

Planning Inspectorate (2018). Advice Note Nine: Rochdale Envelope. https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/advice-note-nine-rochdale-envelope/

Planning Inspectorate (2019). Advice Note Seventeen: Cumulative Effects Assessment Relevant to Nationally Significant Infrastructure Projects. Available at: https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/advice-note-17/.

RenewableUK (2022). EnergyPulse Insights: Offshore Wind: October 2022. Available at: https://www.renewableuk.com/store/viewproduct.aspx?id=20986359.

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