Marine Research Programme

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## *Title - International ORE (Offshore Renewable Energy) Design Flexibility*

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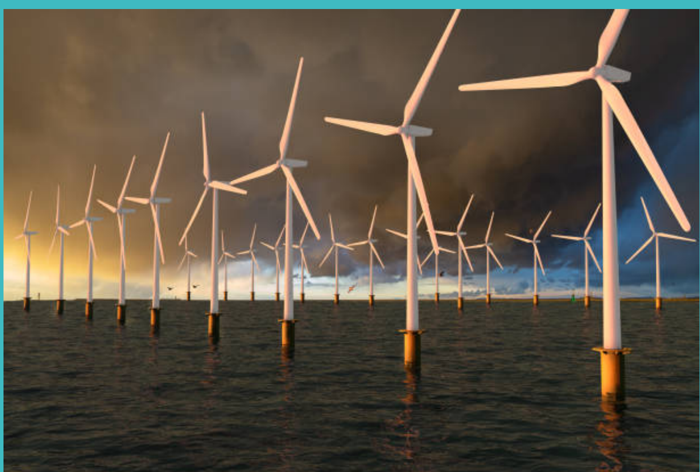

Foras na Mara
Marine Institute

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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

# International ORE Design Flexibility

Final Report

Foras na Mara
Marine Institute

September 2025

MI Project Reference Number RPA/23/03/01

STRUCTURAL & HYDRO-ENVIRONMENTAL DYNAMICS

UNIVERSITY COLLEGE CORK

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# Executive Summary

This report, led by University College Cork, presents a comprehensive assessment of design flexibility in offshore renewable energy (ORE) development, with a focus on informing Ireland's evolving regulatory and planning frameworks. The study integrates international policy analysis, environmental modelling, and stakeholder engagement to support the implementation of the Maritime Area Planning (MAP) Act 2021 and the Strategic Constraint–Designated Marine Area Plan (SC-DMAP).

## Objectives

The project was structured around three core objectives:

Policy Review: Comparative analysis of international consenting frameworks to identify mechanisms that enable design flexibility in offshore wind development.

Environmental Modelling: Scenario-based wave and wake modelling at Site A (Tonn Nua) to inform turbine layout, structural resilience, and optimisation strategies.

Planning Guidance: Recommendations for integrating flexible design provisions into Ireland's regulatory framework, supported by technical evidence and stakeholder feedback.

## Key Findings

Consenting Frameworks: The review highlights significant variation in offshore wind consenting processes across jurisdictions. Lessons from the UK, Denmark, China, and the USA underscore the value of design envelopes and adaptive permitting systems.

Wave Modelling: Using MIKE21 SW FM, the study simulated extreme wave events (e.g., Storm Eowyn) to assess hydrodynamic constraints at Tonn Nua. Results indicate the need for resilience-based design to accommodate storm-driven wave loads.

Wake Effects: Optimisation of turbine arrays using DTU 10 MW and IEA 15 MW models revealed that inter-turbine spacing and seasonal wind variation significantly affect power output and efficiency. The Bastankhah wake model and Pymoo optimisation library were used to refine layouts and minimise wake losses.

Zoning and Spatial Planning: Vessel density, fishing activity, and ecological sensitivities were analysed to inform marine spatial planning. The study supports the designation of SC-DMAP zones and highlights the need for compatibility assessments and exclusion zones.

## Dissemination and Engagement

The project's findings have been disseminated through:

- A stakeholder workshop (Offshore ADAPT, May 2025);
- A sector-wide survey on design flexibility and planning challenges;
- Planned academic publications;

The upcoming Coastal and Offshore Modelling Symposium (Feb 2026), which will serve as a national platform for presenting modelling results and engaging with industry, regulators, and researchers.

## Future Work

Building on this study, the following research areas have been identified:

- High-resolution modelling of wind wake and hydrodynamic impacts;
- Assessment of ecological connectivity and fish transport;
- Investigation of benthic processes and sediment dynamics;
- Modelling of acoustic interference and its effects on marine fauna.

These future directions aim to support a science-based planning framework that balances Ireland's renewable energy targets with environmental protection and stakeholder needs

# 1 Introduction

## 1.1 Background and Policy Context

Ireland's offshore renewable energy (ORE) ambitions are central to achieving national climate targets and energy security. The Maritime Area Planning (MAP) Act 2021 and the National Marine Planning Framework (NMPF) provide the legislative foundation for the development of offshore wind, wave, and tidal energy. However, the consenting process remains complex, with significant variation across jurisdictions in how design flexibility is accommodated.

This report, led by University College Cork, responds to the need for a more adaptive and evidence-based approach to ORE planning. It draws on international best practices and technical modelling to inform the development of Strategic Constraint–Designated Marine Area Plans (SC-DMAP) and support the implementation of the MAP Act

## 1.2 Objectives and Scope

The objectives of this study are threefold:

1. **Policy Review**: To critically examine consenting frameworks in leading offshore wind jurisdictions and identify mechanisms that enable design flexibility.
2. **Environmental Modelling**: To assess wave and wake constraints at Site A (Tonn Nua) using scenario-based modelling to inform turbine layout and structural design.
3. **Future Planning Guidance**: To provide recommendations for integrating flexible design provisions into Ireland's regulatory framework, supported by technical evidence and stakeholder engagement.

The report is structured to move from policy analysis to technical modelling, concluding with actionable insights for future research and regulatory development

## 1.3 Introduction to Consenting framework:

In the context of offshore wind energy, consenting refers to the process of obtaining the necessary approvals, permits, and licenses from relevant authorities and stakeholders to develop and operate an offshore wind farm. The consenting process is a critical and often complex phase of offshore wind project development, as it involves navigating various regulatory and environmental requirements, as well as engaging with local communities and other stakeholders. Under most national and international regulatory regimes, sufficient data needs to be provided by developers in order for regulators to analyse the potential effects of the proposed offshore wind farm. The process of obtaining consent for offshore wind projects varies widely depending on the jurisdiction. This variation is influenced by differences in leasing procedures, regulatory frameworks, environmental priorities, stakeholder engagement practices, energy policies and governmental structures. Thus, a relevant comparison of consenting frameworks in different EU states including USA, Japan, China is made to facilitate the Irish Government, for efficient deployment of offshore wind.

The Department of Climate, Energy and the Environment (DECC), Ireland has identified potential zones in the support of strategic development of offshore renewable energy. The main purpose of the zoning map is to quantify overall resource potential for smooth establishment of phase one offshore wind development in Ireland while providing clarity and certainty.

The Government of Ireland is expected to deliver approximately 3.8GW of offshore wind energy by 2030 while developing Dublin Array with capacity up to 824 MW, North Irish Sea Array with capacity up to 500 MW [1], Arklow wind park 2 up to capacity 800MW and Oriel wind farm with capacity up to 375MW [2] and 900MW capacity from Tonn Nua project. But the timely delivery of these projects remains uncertain in the absence of dedicated robust policy framework. Hence, the need of transparent policy is of paramount importance in accordance with the legislation.

This report reviews international policy implementations and proposes recommendations for integrating flexible design provisions into Ireland's regulatory framework. Drawing on lessons from the UK, China, Denmark, USA, France, Belgium, Germany, Netherlands, Japan, Sweden, and Finland, the report outlines structured approaches to enhance regulatory robustness and accelerate deployment.

## 1.4 Modern wind energy technology advancement

The urgent need to address the climate change and meet the global energy demand, the capacity of offshore wind turbines has continued to evolve (Figure 1-2). Larger capacity of offshore wind infrastructure can be installed offshore due to fewer space limitations, compared to onshore locations where land use may be restricted due to uneven terrain, agriculture and urban development. From the data gathered as part of the literature review, it can be observed that fixed offshore wind turbines can generally be found in water anywhere from 6 to 60 [4] metres in depth, with monopile foundations being used for shallower depths and jacket foundations for larger, typically over 35 metres. Hence, appropriate use of Wind Turbine Generating (WTG) capacity, based on the proposed wind farm location becomes crucial.

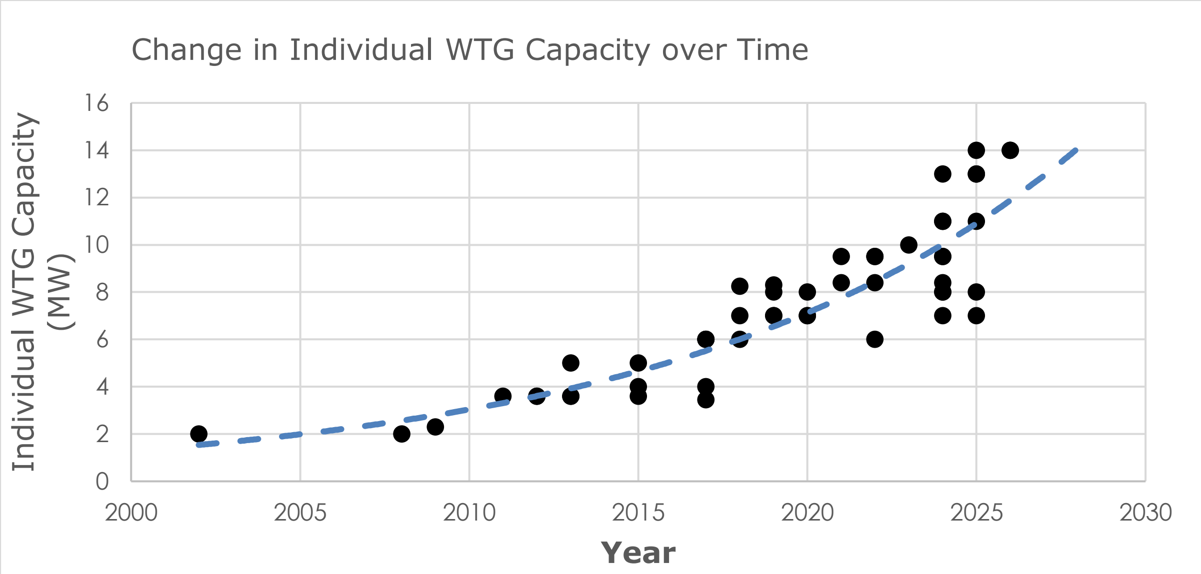



Figure 1. Change in WT capacity

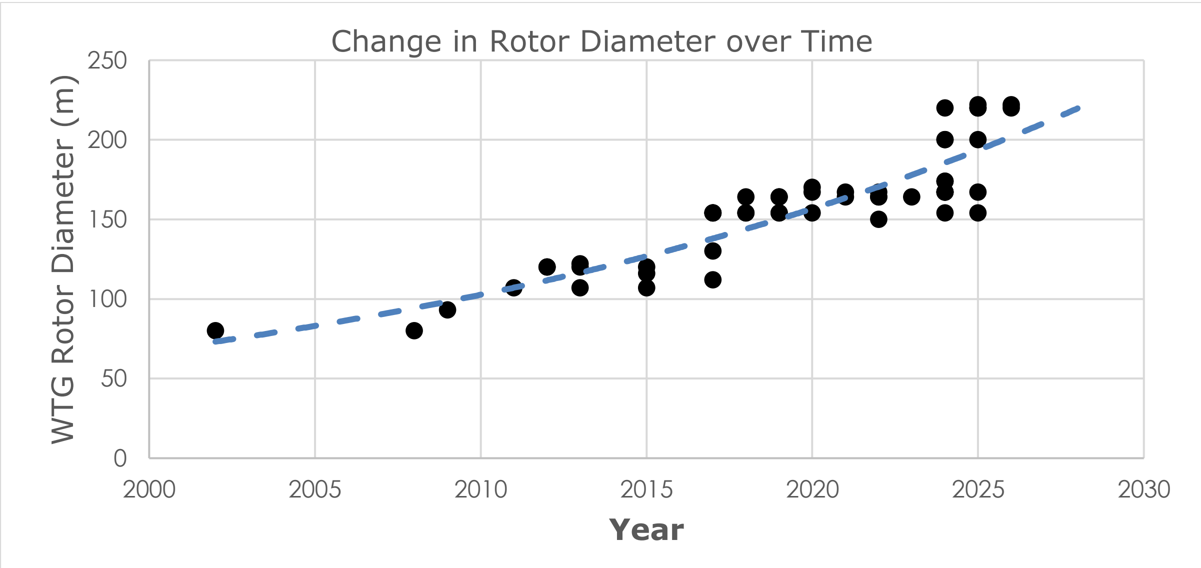



Figure 2 Change in Rotor diameter

The existing planning framework and consenting process for offshore wind farm development sets unique challenges that have contributed to significant project delay. These delays in project timelines, restrict the developer's ability to adopt the new technologies, as a result of which, the developers are often urged to proceed with outdated technology while compromising the standards. Despite these challenges, it must be noted that several strategies are incorporated in different regions of worldwide to deploy offshore wind energy.

This work aims to provide recommendations, how the need for design flexibility can not only speed up the OW development process in Ireland but also provide a better understanding for the developers about the wind farm layout and optimise the hub height through research.

# 2 Need for Irish Offshore Zoning

The water around Ireland have defined zones, which has range of purposes, fishing, aquaculture etc. To manage the exclusive economic zone (EEZ), marine zoning strategies become crucial. Marine zoning is an effective tool to keep balance between economic development and environmental management. The DECC, Ireland has identified potential zones in the support of strategic development of offshore renewable energy. Although OREDP II (Figure-3) [3], identified specific regions for ORE development (wind, wave and tidal), but the constraints to this development other than the complex consenting process are not specifically addressed. The fishery in the Irish water is quite diverse, and according to the Vessel Monitoring Systems, vessel density and fishing activities in the EEZ have no distinct boundaries. Hence, marine zoning exercise is conducted in this task, which is an iterative approach to avoid potential adverse impacts on biodiversity provide.  So, to support the development of ORE while fully utilising the available wind resource, exercise related to geographical area amid OREDP II is prominent. This includes detail assessment of defining the compatibilities- incompatibilities and zero tolerance zones. Additionally, driven by the objectives of NMPF, Climate action plan, Energy security in Ireland, the regions are identified and designated as SC-DMAP.

## 2.1Key parameters

By querying the available dataset, consistent movement of vessels in the proximity of SC DMAP is observed. So, the development of offshore wind farm in the designated area may reduce the space and create choke points for the movement of the shipping vessels. Hence, to assess the maritime risk, and reduce possible conflicts among the vessels, the layout of wind farm must be submitted for approval.

From Figure (4) – (5) substantial movement for passenger vehicle density and fishing activities in the vicinity of S-DMAP is noticed. Based on the available data from SELKIE [5] (Selkie_GISTE), overlapping in priority and permitted area may bring considerable criticism. Importantly determination of necessary safe distance from the wind farm to avoid the collision risk requires further investigation. Intensity of Fishing activities and navigation of the large equipment's certainly triggers the possible conflict. Hence, Minister for Agriculture, food and the marine have planned to ban trawling from the 1st October 2026 . Figure (6), also indicates the dredge fishing activity, which is increasingly a matter of concern, for the target deployment of offshore wind farm.

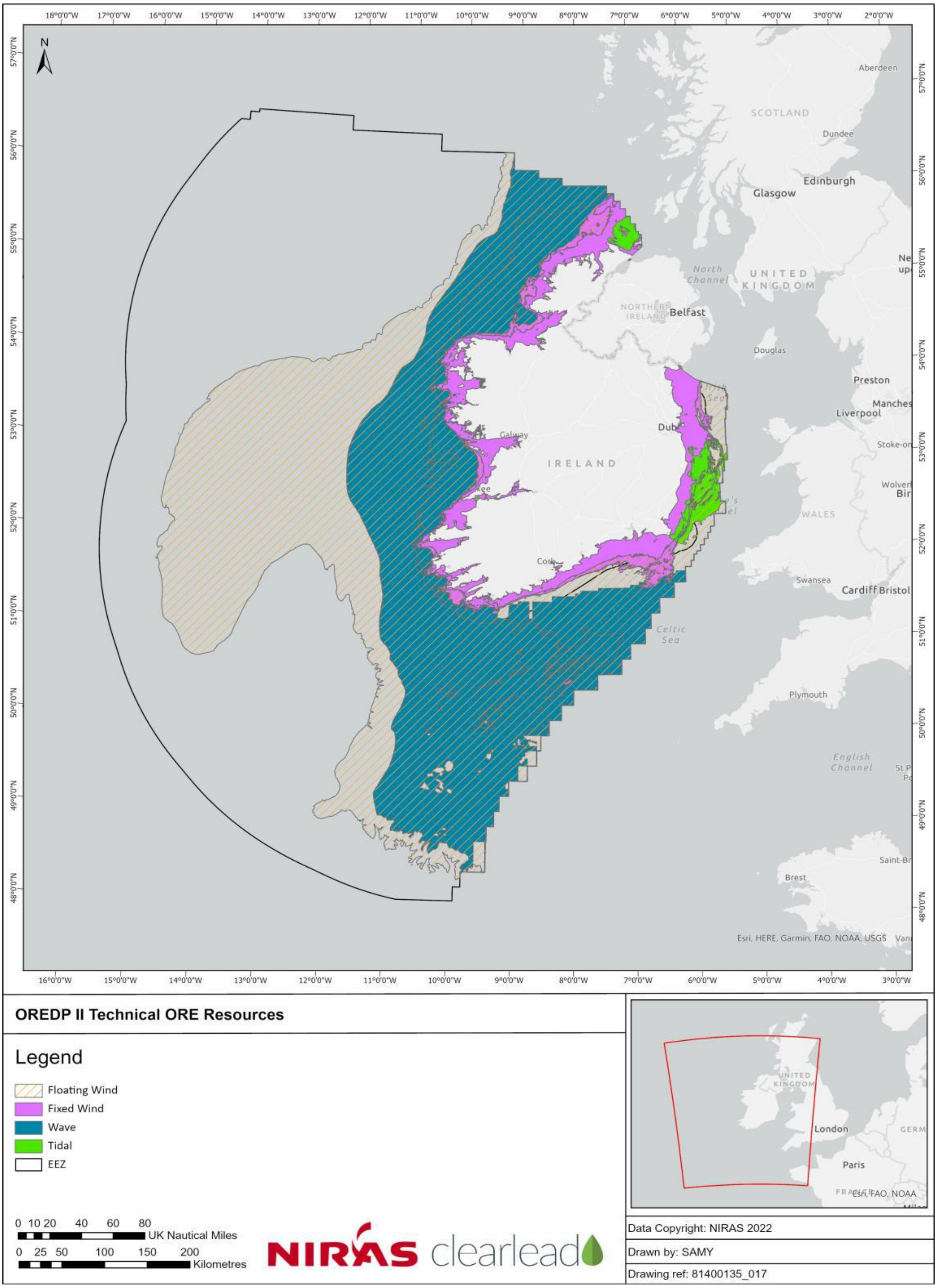



Figure 3. Offshore Renewable Development Plan II.

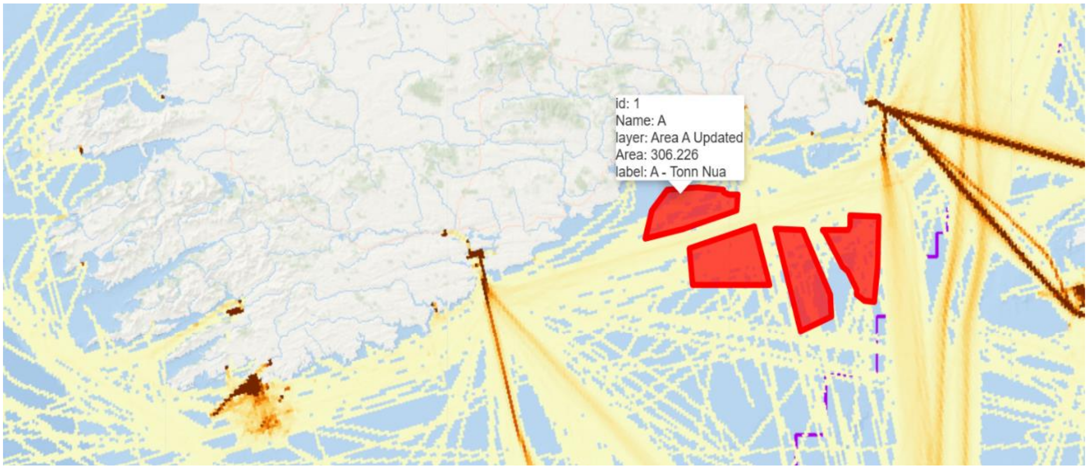



Figure 4. Vessel density Map at the S-DMAP [5, Accessed in Aug 2025]

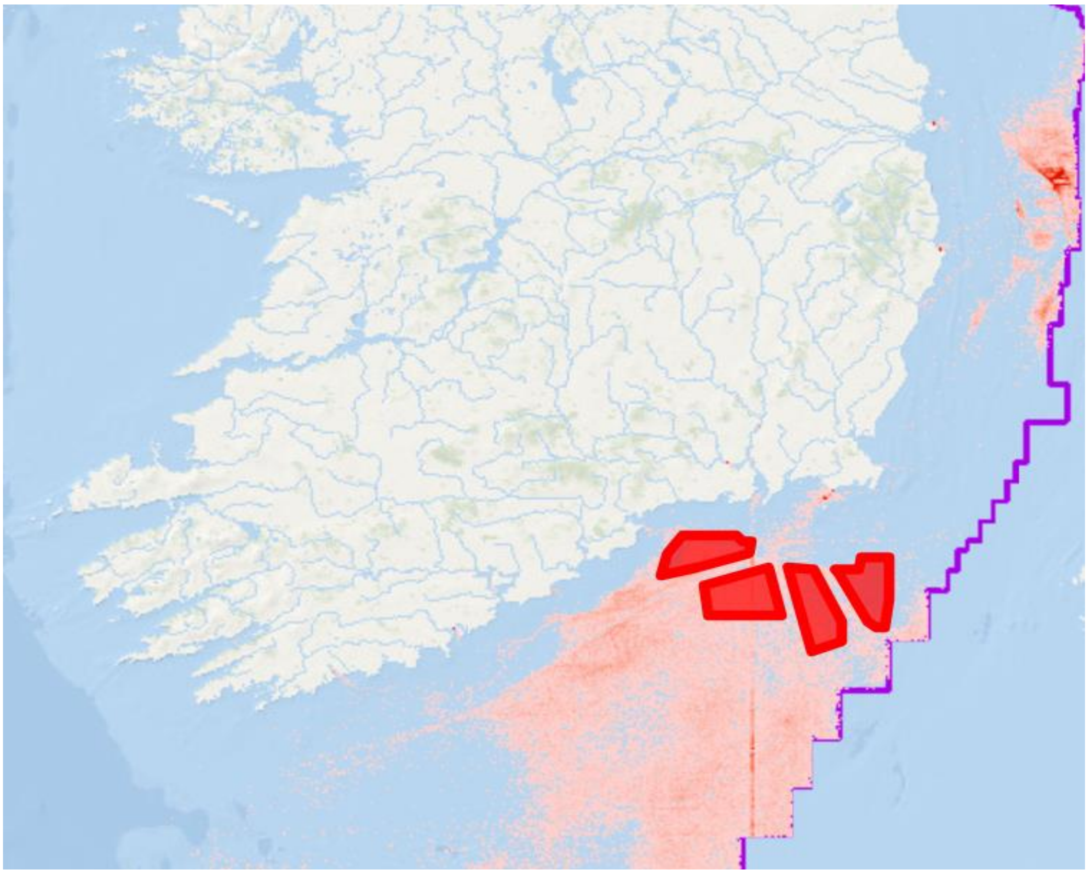


Figure 5. Trawling activity in the Irish sea [5, Accessed in Aug 2025]

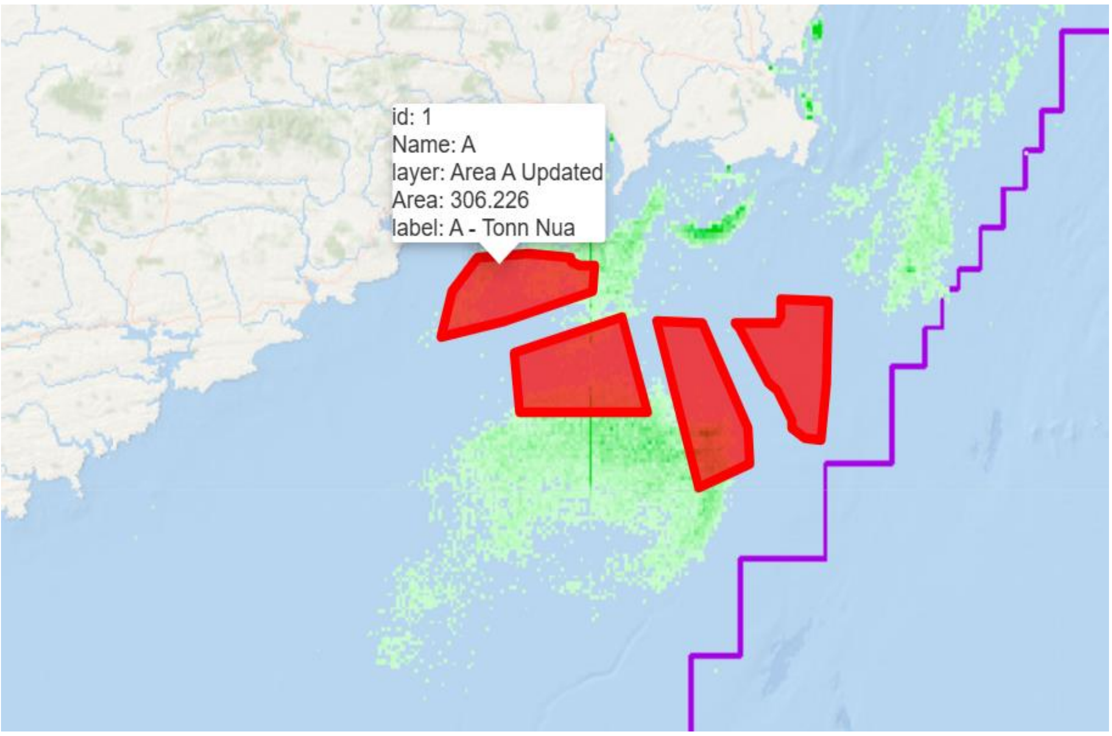



Figure 6 Dredge fishing activity in the Irish sea [5, Accessed in Aug 2025].

# 3 Weather descriptions and Statistical Analysis

In the context of offshore wind development in Ireland, Ireland's Designated Maritime Area Plan(DMAP) aims to specify the Irish coastal areas where offshore renewable energy projects will be developed going forward. At present, only the South coast of Ireland has been selected (referred to as the South Coast DMAP or SC-DMAP) as the geographical area where new offshore renewable energy projects (comprising fixed bottom wind turbines) will be developed. Additional DMAPS will be required at some point on the North, East, West, coasts of Ireland given Ireland's commitments to the development and delivery of offshore wind energy with capacity targets of at least 5 GW by 2030.

As part of the South coast DMAP, four sites off the Wexford and Waterford coasts have been identified for offshore wind development and shown in Figure 4 (red highlighted area). The name and details of the identified locations are listed in Table 1.

Table 1: Summary of Ireland's South Coast DMAP identified locations

| Name | Location | Marine Area Size | Distance to Shore [km] | | Water Depth [m] | | |
|---|---|---|---|---|---|---|---|
| | | $Km^2$ | Western | Northern | Min | Mean | Max |
| Tonn Nua | (A).Co. Waterford | 312.6 | 12.2 | 12.4 | 48 | 57 | 69 |
| Li Ban | (B).Co Waterford | 486 | 49 | 29 | 66 | 71 | 76 |
| Manannan | (C).Co. Wexford | 342 | 52 | 27 | 64 | 69 | 72 |
| Danu | (D).Co. Wexford | 384 | 52 | 27 | 55 | 67 | 78 |

The first site to be developed will be Tonn Nua (Site A) with a proposed capacity of 900 MW. Hence, In this study, Site A (Tonn Nua) has been investigated in terms of

- metocean characterisation and
- modelling of the wake effects of a wind turbine farm.

In terms of metocean characterisation for this Site, a hindcast analysis for both wind and wave data was carried out for Site A. For reference, a hindcast analysis is a method used to estimate both historical wind and wave conditions by utilising past data and numerical models. The hindcast analysis can be used to fill gaps in direct measurements, validate predictive models, assess risks for offshore projects, and study long-term trends, including the impacts of climate change.  By analysing historical data hindcast analyses helps us to improve future forecasts and inform decisions regarding offshore renewable energy development and projects.

Both wind speed and wave data for Site A were analysed for each meteorological season: DJF (December, January, February), MAM (March, April, May), JJA (June, July, August) and SON (September, October, November).

The hindcast analysis of the wind speeds carried out for Site A used the CMEMS [7] and covered the period of 2007 to 2024 (approximately 17 years). This dataset has a spatial and temporal resolution of $0.125° \times 0.125°$ and hourly respectively [8].

For the wind analysis, the temporal wind directions for each site were derived from the wind speed data and subsequently analysed and displayed for each season using wind rose diagrams in Appendix 1. The wind directions used in the analysis are summarised in Table (2)

Table 2 Summary of Ireland's South Coast DMAP locations and their co-ordinates

| Direction | Range [Degrees] |
|---|---|
| N | >=348.75 to <11.25 |
| NNE | >=11.25 to <33.75 |
| NE | >=33.75 to < 56.25 |
| ENE | >=56.25 to <78.75 |
| E | >=78.75 to <101.25 |
| ESE | >=101.25 to <123.75 |
| SE | >=123.75 to <146.25 |
| SSE | >=146.25 to < 168.75 |
| S | >168.75 to <191.25 |
| SSW | >191.25 to <213.75 |
| SW | >=213.75 to <236.25 |
| WSW | >=236.25 to < 258.75 |
| W | >=258.75 to < 281.25 |
| WNW | >=281.25 to < 303.75 |

| | |
|---|---|
| NW | >=303.75 to < 326.25 |
| NWW | >= 326.25 to > 348.75 |

This analysis was carried out for two physical heights (above sea level) namely at 119 m and 150 m, which represent the corresponding hub heights of the two reference wind turbines, DTU 10 MW and IEA15 MW respectively which were used as part of this study.

Similarly, for the wave analysis, a hindcast analysis of the wave data, for a period of 20 years, for Site A was carried out using CMEMS wave data product (https://doi.org/10.48670/moi-00060 [8] which has a spatial resolution of 0.0135° × 0.0303°

Parameters VHM0 [m] (sea surface wave significant height) and VTPK [s] (sea surface wave period at variance spectral density maximum) are similarly analysed and plotted for Site A. The annual and seasonal variability of both significant wave height and wave period are shown in Figure 7 & 8 respectively.

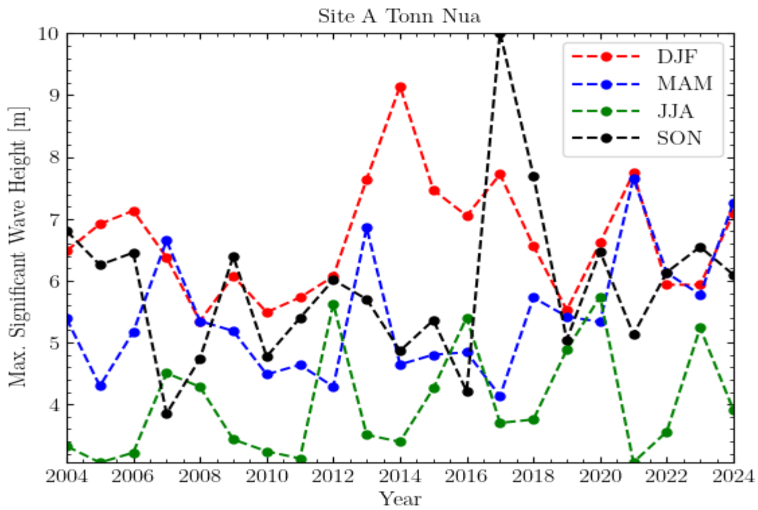



Figure 7 Maximum significant wave height

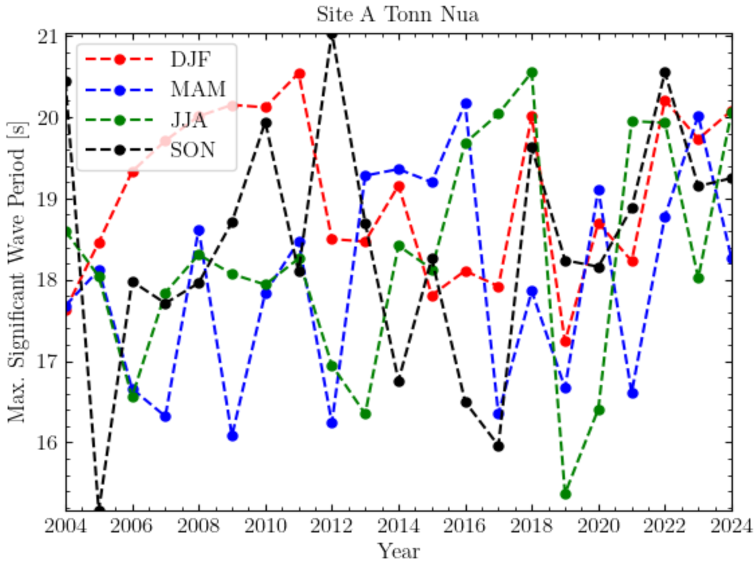



Figure 8 Maximum significant wave period

Subsequently, the joint probability plot of VHM0 and VTPK is shown in Appendix 2.

# 4 Wake and Climate impacts on offshore array

## 4.1 Wake effects

Wake effects are a critical phenomenon associated with wind turbine operation, characterised by a reduction in wind speed that occurs in two primary zones. The first zone is the *immediate upstream area or zone* (often referred to as the *induction* zone) which is the area in front of the wind turbine rotor (also extending a small distance upstream) where the wind speed begins to decrease as it approaches the turbine. This reduction in wind speed is primarily due to the extraction of kinetic energy by the turbine, which converts the wind energy into mechanical energy. As the wind encounters the rotor blades, it experiences turbulence and a drop in velocity, creating a region of lower wind speed just before the rotor.

The second zone is the *downstream area or zone*, and refers to the physical space located behind the turbine, where the air has already passed through the rotor. In this zone, the wind continues to experience a reduction in speed, often referred to as the downstream wind effect. The turbulence generated by the rotor blades can lead to complex flow patterns, which may result in further energy dissipation and a significant decrease in wind speed.

The *induction zone velocity field* describes the characteristics of the wind speed and flow patterns within the induction zone, whereas the wake velocity field describes the flow characteristics within the downstream zone, particularly focussing on the wake velocity profile and turbulence patterns caused by the turbine.

As the distance from the turbine increases, the impact of the wake diminishes. The wind gradually recovers to its freestream conditions, a process known as wake recovery. This recovery occurs as the turbulent eddies dissipate and the airflow stabilises, allowing the wind to reach/return to its original speed. The extent and duration of the wake effects are influenced by multiple factors, including turbine design, wind speed, and atmospheric conditions, making it essential to consider these effects in wind farm planning and layout, in particular inter-turbine spacing to optimise energy production and minimise interference between turbines.

**Study region and wind farm data**

The layout of the wind farm plays a crucial role in determining the extent of blockage losses. Proper consideration of inter-turbine spacing distances is essential to mitigate losses and minimise wake effects and interactions and to optimise energy production.

Predicting wind blockage losses using wake modelling techniques is an important component when analysing the interactions between wind turbines and optimising wind farm layouts. To effectively model wind farm blockage, it is essential to consider using induction and wake models to study both induction and downstream zones respectively. Integrating the induction and wake models can help achieve a better understanding of wind farm blockage.

To understand the impact of wake effects on the power production of proposed offshore wind farm in Site A (the Tonn nua), a wake model is derived. Two reference wind turbine models have been used in this study namely the DTU 10MW [9] and 15MW [10] wind turbines . Hence, the primary details of the wind turbines are listed in Table 3 and 4 and Figure 9 and 10

Table 3. DTU 10 MW wind turbine parameters [9]

| **Parameter** | **Value** | **Units** |
|---|---|---|
| **Name** | DTU 10 MW RWT (v1) | N/A |
| **Rated Power** | 10000 | kW |
| **Rated Wind Speed** | 10.6 | m/s |
| **Cut-in Wind Speed** | 4 | m/s |
| **Cut-out Wind Speed** | 25 | m/s |
| **Rotor Diameter** | 178.3 | m |
| **Hub Height** | 119 | m |
| **Drivetrain** | Geared | N/A |
| **Control** | Pitch Regulation | N/A |
| **IEC Class** | 1A | N/A |

Table 4 : IEA 15 MW   wind turbine parameters [10]

| Parameter | Value | Units |
|---|---|---|
| **Name** | IEA 15 MW RWT | N/A |
| **Rated Power** | 15000 | kW |
| **Rated Wind Speed** | 10.6 | m/s |
| **Cut-in Wind Speed** | 3 | m/s |
| **Cut-out Wind Speed** | 25 | m/s |
| **Rotor Diameter** | 240 | m |
| **Hub Height** | 150 | m |
| **Drivetrain** | Direct Drive | N/A |
| **Control** | Pitch Regulation | N/A |
| **IEC Class** | 1B | N/A |

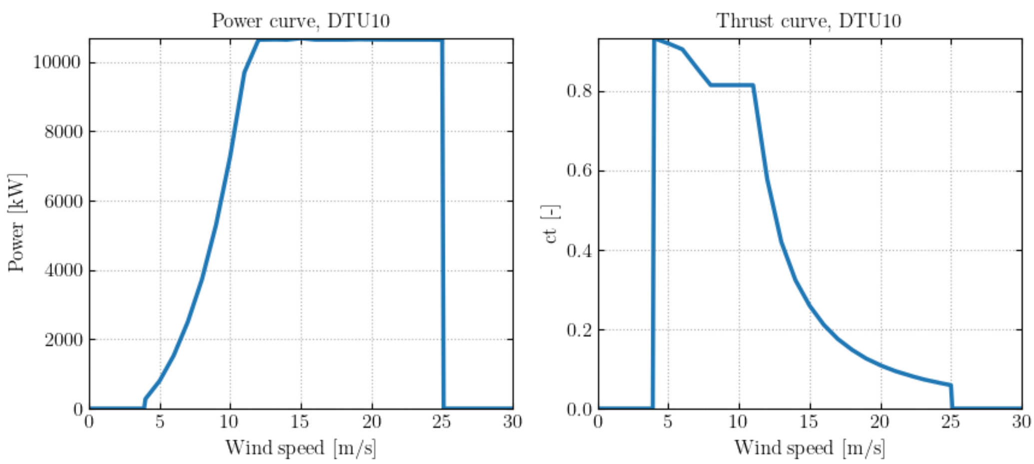



Figure 9. DTU 10 MW RWT wind turbine Power Curve, Thrust Curve

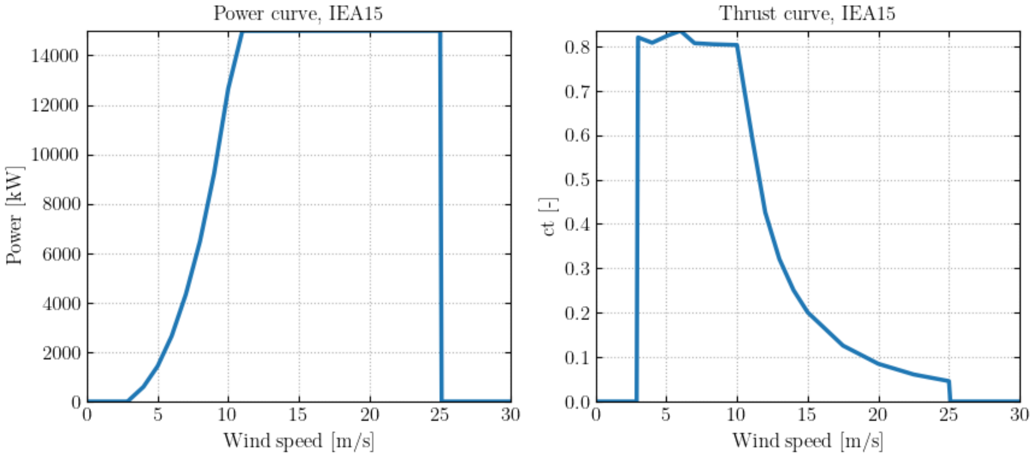



Figure 10. 15 MW RWT wind turbine Power Curve, Thrust Curve

In this study, Foxes (*Farm Optimisation and eXtended yield Evaluation Software, https://github.com/FraunhoferIWES/foxes*), [11]a python based wind farm and wake modelling software is used. Tradionally, wake effects are modelled using either a Jensen wake model or Gaussian wake model. The Jensen model utilises a Gaussian distribution to describe the velocity deficit in the wake. However, it simplifies the representation by assuming a linear expansion of the wake downstream, providing a simplified method to calculating the velocity deficit in the wake of a wind turbine. This approach however may not accurately capture the complexities of the wake characteristics and behaviour being modelled. The Gaussian wake model provides a more comprehensive and accurate framework for simulating wake effects, especially in complex wind farm scenarios. The velocity deficit is modelled using a Gaussian function, therefore providing a more accurate depiction of the wake's shape, characteristics and behaviour. The wake modelling in this study uses an alternative, different model titled the Bastankhah wake model, which offers improvements over the previous two models. Model improvements are achieved by incorporating additional physical phenomena, such as accounting for the effects of turbulence and atmospheric stability on wake behaviour and dynamics. This provides a more accurate representation of wake effects, which is crucial for maximising power output.

In addition, optimisation of the wind farm turbine positions while minimising wake and maximising power output and efficiency is carried out using the Python Pymoo optimisation library (https://pymoo.org/) . A regular grid initial layout with 90, DTU 10MW WIND turbines to generate theoretical power of proposed 900 MW at Site A is shown in Figure 11.

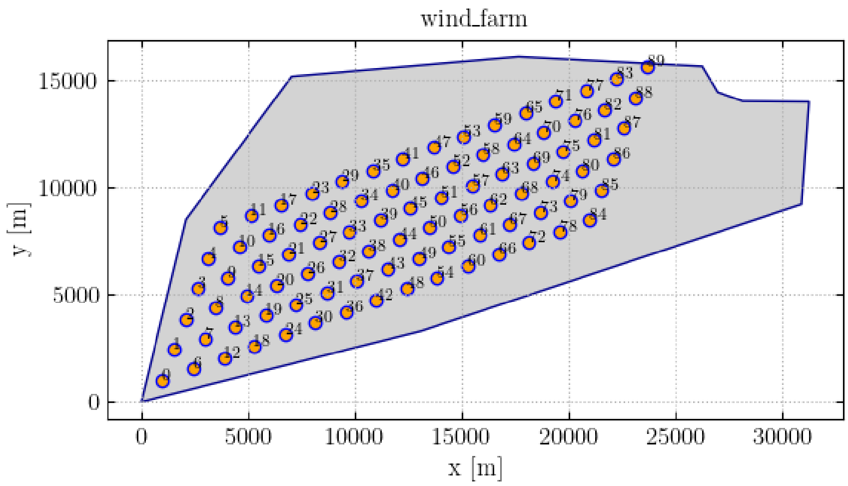



Figure 11. DTU 10MW wind turbine regular array without optimization consisting of 90wind turbines.

Given the physical space available, this poses a significant challenge in terms of optimising the wind turbine locations with such a large number of turbines, while simultaneously trying to maximise the inter-turbine spacing, minimise wake effects and optimise farm power. Using the weighted wind state data for season DJF (which generates the maximum most probable wind speeds) at the hub height of 119 m as presented in the previous section, the model is optimised to maximise the inter-turbine spacing, minimise wake effects and optimise farm power. The Figure 12 shows the optimised wind farm layout while minimising the wake effects. The wake recovery outside the boundary conditions are clearly evident, which is critical.

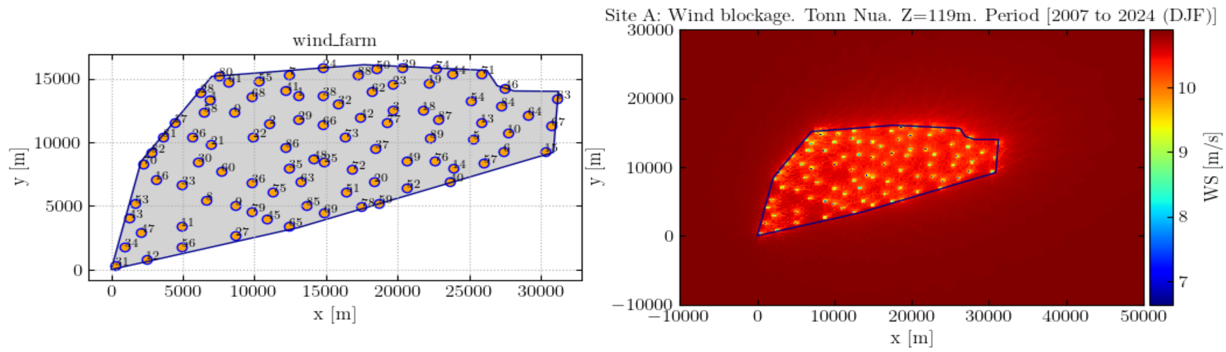



Figure 12.Optimisation of DTU10MW wind farm layout and weighted mean wind speed with wakes.

The results from the optimisation of the ninety (90) DTU10MW [9]wind turbine wind farm are summarised in Table (5) . It is evident that the wind turbine array is not fully optimised in terms inter-turbine spacing, resulting in increased wake losses and lower efficiency, which may be due to a result of having too many wind turbines to be optimised in the available physical boundary space.

Table 5 Efficiency of DTU 10 MW wind farm array at Site A.

| Season/ | Ambient Farm Power [MW] | Farm Power[MW] | Wake Loss [MW] | Efficiency [%] |
|---|---|---|---|---|
| DJF | 771.500 | 638.580 | 132.920 | 82.771 |
| MAM | 313.500 | 248.559 | 64.941 | 79.285 |
| JJA | 310.500 | 245.862 | 64.638 | 79.183 |
| SON | 624.915 | 500.182 | 124.733 | 80.040 |

A similar optimisation using an array comprising sixty (60) IEA15MW wind turbines was carried out, using the weighted wind state data for season DJF (which generates the maximum most probable wind speeds) at the hub height of 150, with a minimum inter-turbine spacing constraint of 6D. The regular grid of IEA15W turbines is showing below in Figure 13.

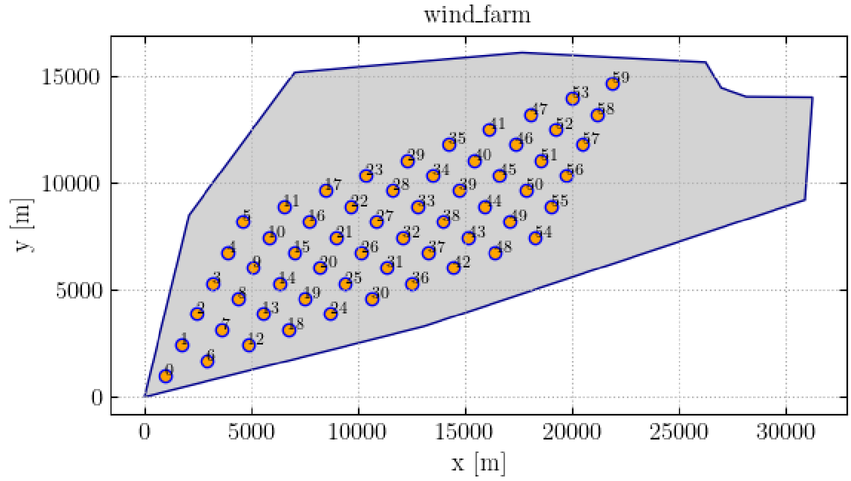



Figure 13. 15MW wind turbine regular array without optimization consisting of 60 wind turbines

The model was optimised to maximise the inter-turbine spacing, minimise wake effects and optimise farm power, the results of which are presented in Figure 14 which again shows both the optimised turbine layout physical positions and the resulting wake effects (weighted mean wind speed with wakes) inside and outside of the boundary for Site A.

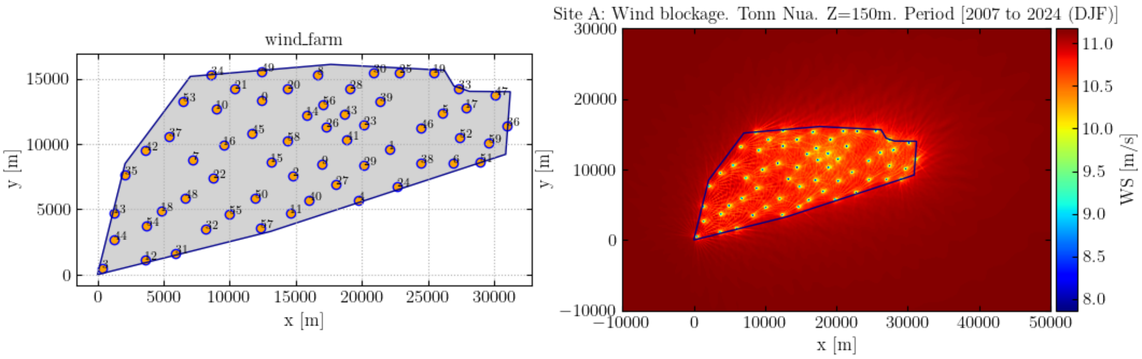



Figure 14. Optimisation of IEA15MW wind farm layout and weighted mean wind speed with wakes

The results from the optimisation of the sixty (60) IEA15MW [10] wind turbine wind farm are summarised in Table 6 below. A larger physical space enabling increased inter-turbine spacing with this layout, potentially results in a reduction in wake losses, higher farm power values and overall higher efficiency.

Table 6. Efficiency of 15 MW wind farm array at Site A.

| **Season/** | **Ambient Farm Power [MW]** | **Farm Power[MW]** | **Wake Loss [MW]** | **Efficiency [%]** |
|---|---|---|---|---|
| DJF | 804.2 | 781.5 | 22.700 | 97.177 |
| MAM | 392.3 | 359.4 | 32.900 | 91.614 |
| JJA | 388.1 | 355.3 | 32.800 | 91.549 |
| SON | 671.9 | 634.2 | 37.700 | 94.389 |

The arrangement of turbines affects how they interact with each other. In the DTU10MW 90 wind turbine array, with more turbines, the wake effects may be more pronounced, leading to reduced efficiency for downstream turbines. Wind turbines in the IEA15MW array can be spaced further apart while still maintaining a high total capacity, resulting in reduced wake effects and corresponding wake losses.

Other differences, between the wind turbine arrays include a larger rotor diameter for the IEA15MW wind turbine which directly translates to higher potential power output (due to the increased swept area), especially in areas with consistent wind flow.

In the current optimisation, the numbers of wind turbines are fixed and their locations optimised to minimise wake effects and maximise farm power output. The next stage in the optimisation model development is to investigate multi-objective optimisation algorithms for determining the optimal number of wind turbines in the wind farm for Site A. The algorithm should dynamically determine the number of turbines based on the optimisation results. The model will target an actual farm power output of 900 MW, within the same constraints that all wind turbines are placed within the defined boundary area and that the required inter-turbine spacing is maintained to minimise wake effects. The model multi-objective optimisation functions will comprise:

- Maximize Power Output: Ensure that the total power output is as close to 900 MW as possible.
- Optimise wind turbine locations: Same constraints of inside boundary and minimum inter-turbine spacing.

- Minimise Wake Effects: Include a term to minimise wake losses, which can be influenced by turbine spacing and arrangement.

Pareto Front Analysis will be conducted after running the optimisation, to identify trade-offs between the objectives. The Pareto front allows us to make informed decisions about which solutions to select based on priorities. It provides a range of optimal solutions, and helps to better understand how changes in one objective affect the others e.g. increasing the number of turbines might improve power output but could also increase costs or wake effects.

# 5 Wave impact Modelling:

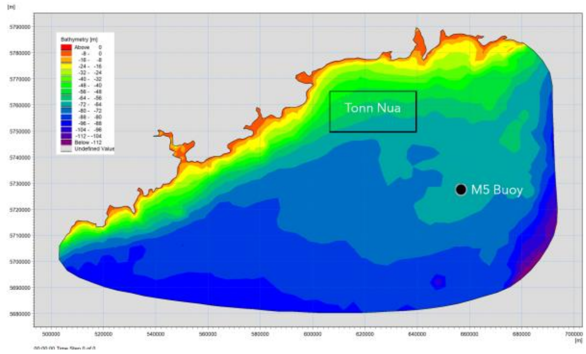
Understanding sea states is fundamental for the effective planning and design of ocean engineering structures. Offshore renewable energy (ORE) systems, particularly structural components in continuous interaction with sea waves, such as wind turbine foundations and semi-submerged support structures, must incorporate adaptability and flexibility at the design stage to ensure long-term sustainability under a wide range of sea states, including extreme conditions. Although evolving sea environments are inherently uncertain, advances in modelling and prediction make it possible to derive proactive benefits, supporting informed design decisions in relation to these constraints. Among the factors influencing design flexibility in ORE systems, sea state predictions are thus an important input that can help connect design requirements with future upgrades, retrofits, and operational optimisations.

In case of offshore wind energy, wave prediction insights for turbine structural resilience to wave dynamics can provide tangible values in highly uncertain marine environments by enabling assessment of how systems are likely to respond to wave loading under extreme weather conditions. To better understand this in the Irish context, a first-order wave model was established across the SDMAP area to develop an initial understanding and insights for a deeper study. This modelling primarily targets the prediction of rare but severe events to which ORE structures may be subjected, creating valuable inputs for refining load cases, optimising structural configurations based on updated environmental data, and informing operational scalability and lifecycle management decisions.

## 5.1 Wave Constraints Modelling in SDMAP:

In the SDMAP [6] area, which is Ireland's designated zone for ocean energy development in the south, a spectral wave (SW) model was developed using the MIKE21 SW FM tool. The model domain covered all four identified ORE sites, with additional buffer zones included to capture potential neighbouring influences on site conditions. For the purposes of results analysis and presentation, this report specifically focuses on 'Site A: Tonn Nua'.

Model bathymetry was constructed using water depth and elevation data obtained from GEBCO , Figure 14. The computational mesh was generated with MIKE's flexible meshing approach: areas of higher importance were assigned a denser mesh with finer spatial resolution, while offshore regions were represented by model-defined mesh sizes, Figure 15. The model was configured with the full spectral formulation.



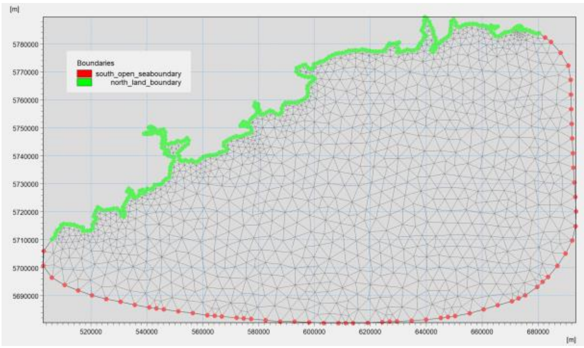




Figure 14 SDMAP bathymetry

Figure 15 SDMAP Model Mesh

The southern open boundary was forced with wind and wave data sourced from CMEMS, while the northern land boundary was defined as closed. Boundary condition inputs varied temporally but were assumed spatially uniform across the domain. This assumption was justified by the offshore placement of the boundary, where spatial variability in wind and wave dynamics is expected to be limited. Initial conditions were specified using standard empirical formulations for SW modelling.

Tonn Nua, the site of interest for wave dynamics assessment in this report, was resolved in the model with a spatial resolution of approximately 5–12 km$^2$ and a temporal resolution of 60 seconds. Model outputs were validated against observed wave data from the Marine Institute's M5 Wave Data Buoy. Subsequently, intensity and propagation of simulated waves across the Tonn Nua site were analysed for insights relevant to informing design flexibility in offshore renewable energy structures.

## 5.2 Scenario Simulation and Results

To evaluate wave intensity and propagation across the Tonn Nua site, the developed wave model was applied to an extreme event scenario. The most recent severe storm, Eowyn (22~27 Jan 2025), was selected for simulation, with wind and wave forcing data from the event period used as model inputs to drive the prediction of waves in the site.

### 5.2.1 Comparison of Waves: Modelled vs. Observed

Recorded data on significant wave height, peak wave period, mean wave direction were obtained from MI's M5 wave data buoy. Modelled wave conditions during the Eowyn event were compared with these observations, a subset of which is presented in Figure 16. The figure illustrates an observed increase in wave height on 24 January 2025. While the model did not reproduce the observed waves with full accuracy rather slightly overestimated, it demonstrated a comparable

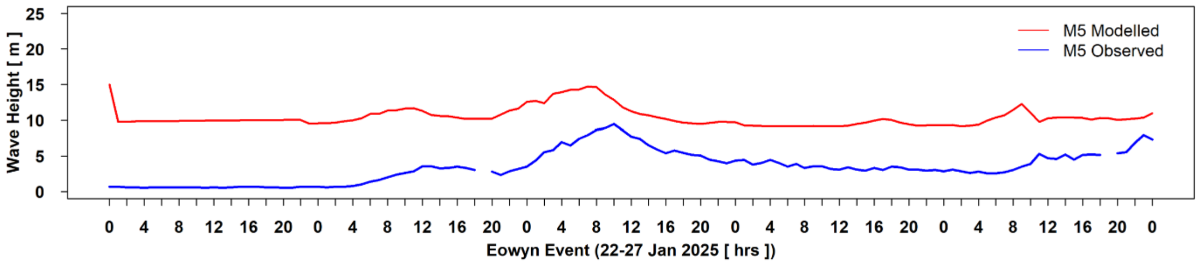



Figure 16 Model vs. Observation

tendency in the rise and fall of wave intensity and wave dynamics phases. As this was a preliminary attempt to predict wave dynamics in the SDMAP area, the present model simulation is used conservatively to examine wave constraints across the zone of interest. Further efforts toward model calibration and refinement are planned for subsequent trials, though these fall outside the scope of the current report.

### 5.2.2 Wave Conditions at Tonn Nua

Tonn Nua is one of the four designated sites for ORE development on the south coast of Ireland and serves as the area of interest in this report for assessing wave conditions during a representative extreme event. Modelled significant wave heights at Tonn Nua are illustrated in Figure 17, which presents four snapshots at 10-hour intervals.

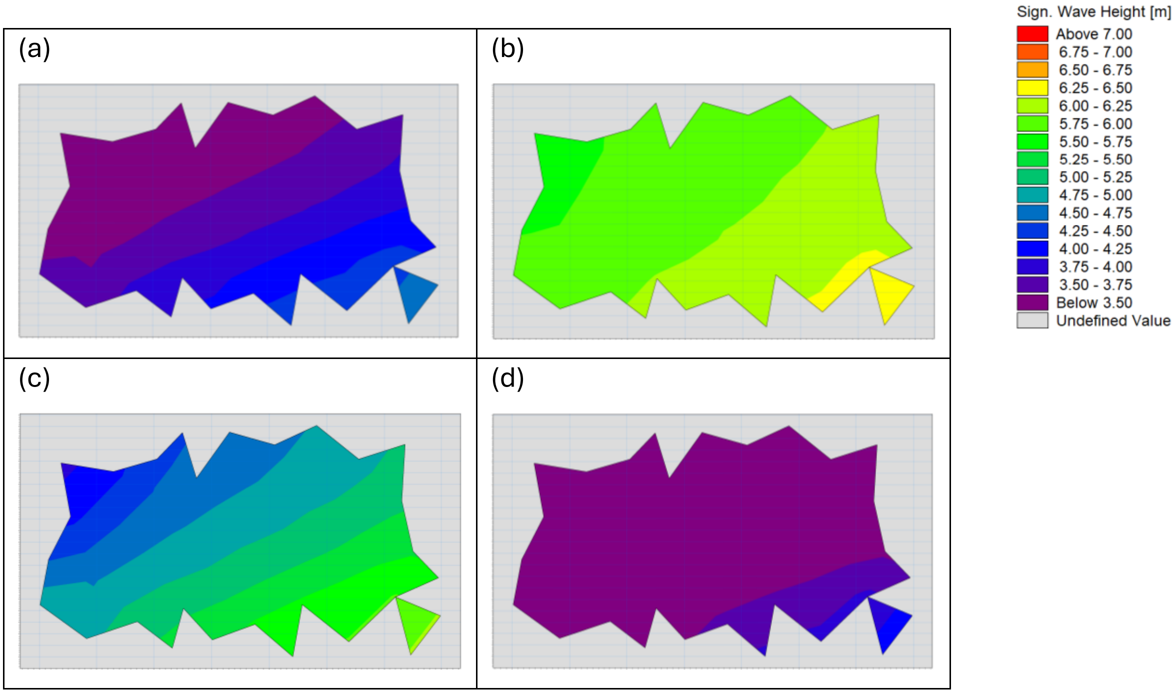


Figure 17 Snapshots of modelled Significant Wave Height (Hm0) across Tonn Nua during the storm Eowyn – (A) 23/01/2025 14:00, (B) 24/01/2025 00:00, (C) 24/01/2025 10:00, and (D) 24/01/2025 20:00

The figure captures wave dynamics during the Eowyn storm, showing higher waves during the peak storm hours and relatively lower wave activity before and after the event. It also indicates increasing wave heights on the offshore side of the site, with wave propagation oriented predominantly northwest–southeast. At storm peaks, significant wave heights show reaching approximately 6.0-6.5 m (Figure 18). These insights provide valuable inputs for developers in supporting design decisions, as well as for policymakers in understanding the constraints imposed by extreme wave conditions.

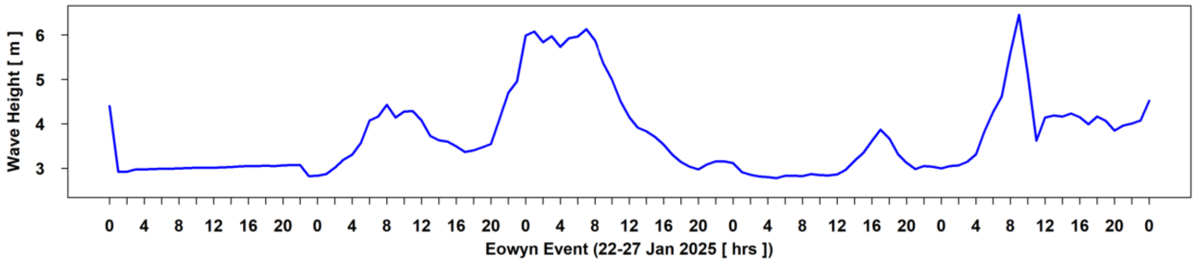



Figure 18 Timeseries of modelled Significant Wave Height (Hm0) at Easting 622452 m Northing 5756782 m located at the centre of Tonn Nua during the storm Eowyn

Wave power density, a key indicator of the forces that waves can exert on submerged or floating structures, has been simulated at Tonn Nua to quantify the amount of power carried by ocean waves per unit width of the wavefront in the area. Figures. 19 and 20 present the simulated wave power outputs. As shown in Figure. 18, during the peak of the storm event, relatively energetic waves within the site were observed on the southeastern offshore side of Tonn Nua, with peak values exceeding 250 kW/m, driven by increased wave heights. The temporal distribution of wave power over the Eowyn storm period (Figure. 13) highlights the escalation from regular background levels to higher intensities under storm conditions. These results are directly relevant for evaluating the robustness of offshore structures, as such waves may impose substantial static, dynamic, and impact forces, including pressure, drag, and lift, that warrant further detailed analysis.

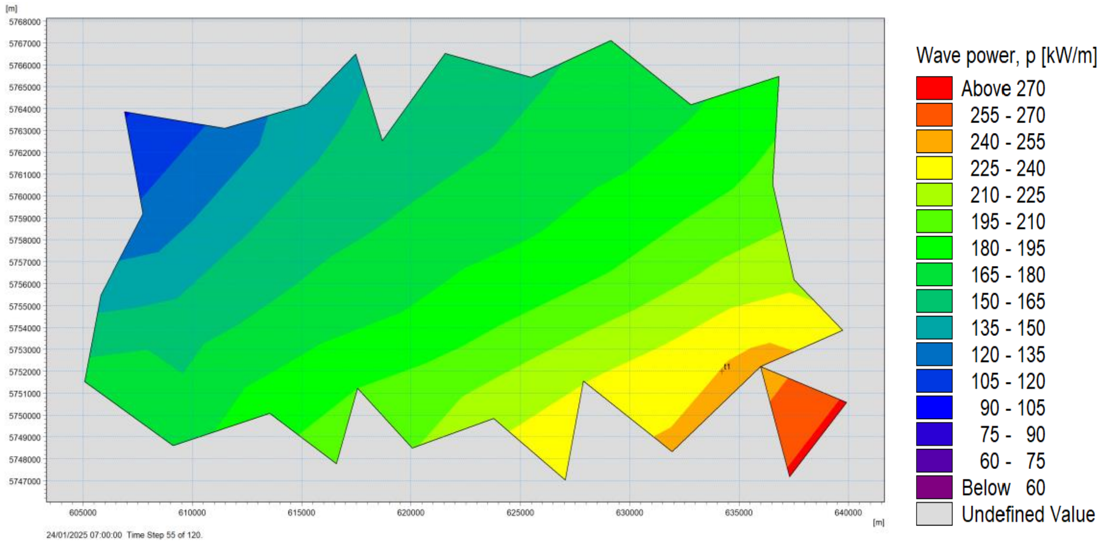



Figure 19. Snapshot of modelled wave power density at Tonn Nua [t1 shows the location for extracting wave power time-series data for the Eowyn event period presented in Figure 18].

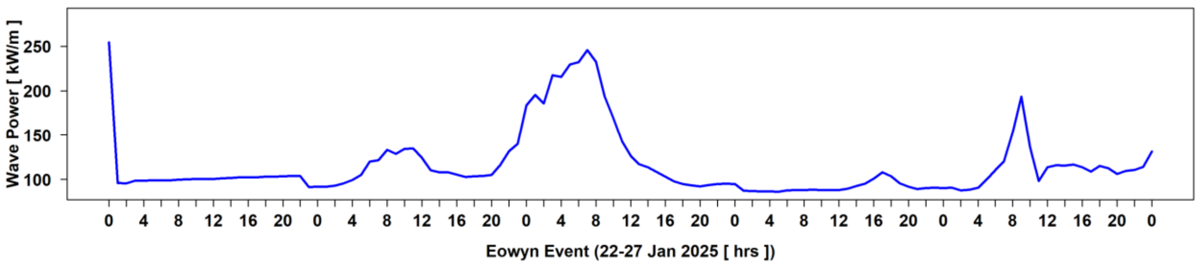



Figure 20 Timeseries of modelled Wave Power at Easting 622452 m Northing 5756782 m located at the SE of Tonn Nua during the storm Eowyn

### 5.2.3 Modelling Wave Effects on OWT Structures

To achieve the target of 900 MW power generation capacity at Tonn Nua, a scenario was implemented within the wave model to extract and getting an impression about hydrodynamic loading effects on OWT structures. As a preliminary effort in this line of investigation, only a single scenario was modelled for the present study and is reported here. The scenario was configured to include an OWT array consisting of 60 turbines placed at Tonn Nua (Figure 21). The model was run to simulate wave conditions following interaction with the turbines for the peak storm period of Eowyn (23/01/2025 20:00hr ~ 24/01/2025 16:00hr). This scenario (Scenario-1: SC1), representing turbine–wave interaction, was compared with a reference scenario (Scenario-2: SC2) without turbines to evaluate potential differences in the generation of wave heights between the two cases.

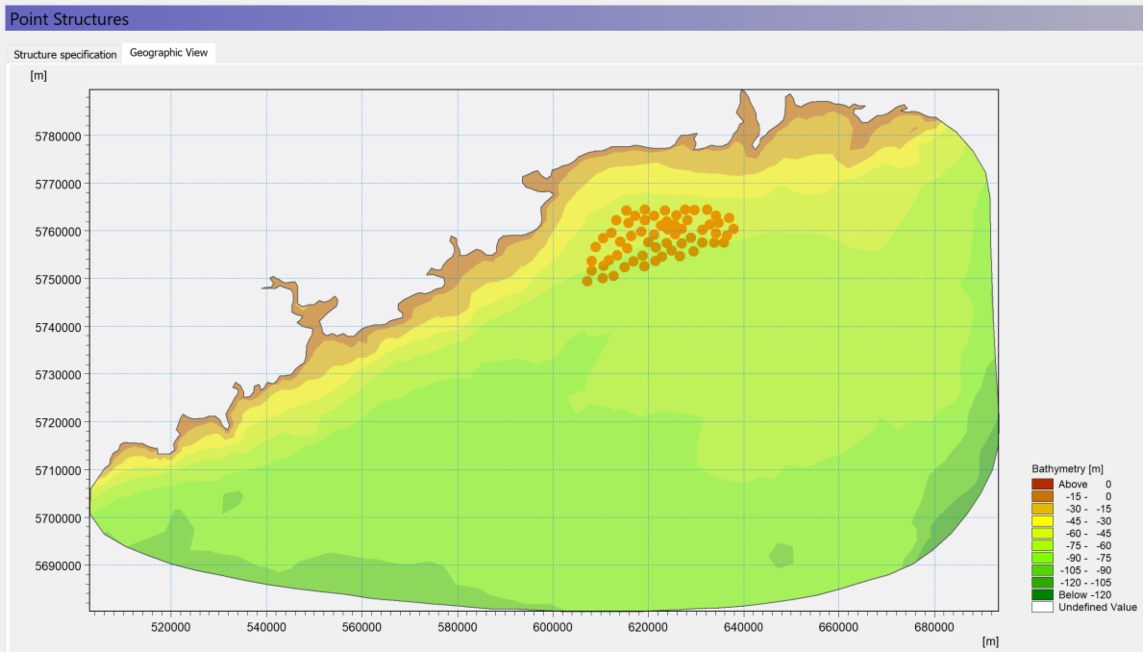



*Figure 21* Wave model domain showing hypothetical Offshore Wind Turbines at Tonn Nua.

The simulation results, specifically significant wave height, were used to compare the two scenarios. The wave height plots over the simulation period indicate consistently higher values in SC1 than in SC2,Figure 22. Several factors can contribute to increased wave heights in SC1. Turbines, especially their foundations, can act as obstacles that reflect and scatter incoming waves. This redirection of wave energy can lead to constructive interference in certain areas, resulting in localised higher wave crests. The presence of the OWT array can alter the wave field, potentially leading to wave focusing effects. This means that wave energy can be concentrated in specific directions or locations due to the interaction with the turbine structures. In some cases, wave energy redistribution can lead to an increase in wave steepness, which can manifest as higher wave crests. Wake effects were not incorporated in this run, and pre-turbine wind conditions were used as model inputs. So, the observed outcome may be influenced by the wind forcing and other aspects of model parameterisation as well.

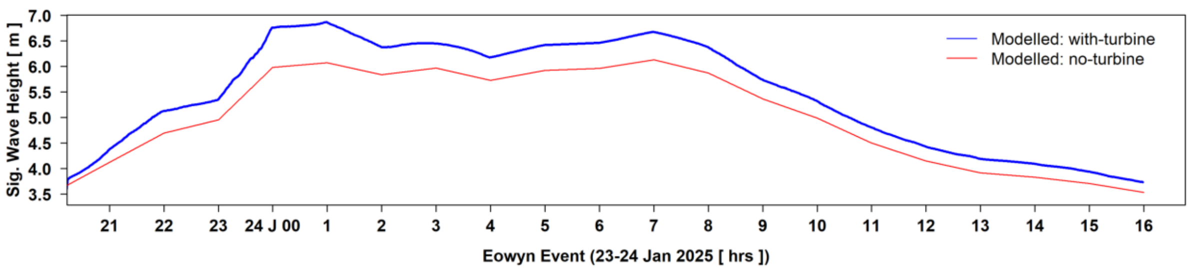



Figure 22 Comparing Significant Wave Heights between with-turbines (SC1) and no-turbine (SC2) scenarios simulated for the peak Eowyn storm period.

A calculated Root Mean Square Error (RMSE) of 0.5034 and a Normalized Root Mean Square Error (NRMSE) of 10.09 % have been obtained through analysis of the model results. On average, the wave height in SC1 differs from the wave height in SC2 by 0.5034 m and this difference is 10.09 % of the typical wave height observed in the simulation. Thus, there is a moderate level of consistent and quantifiable difference between the two scenarios. The analysed results help in understanding Wave-Structure interaction at Tonn Nua, indicating that there might be potential for increased localised wave impact in the area. The turbines might be causing wave energy to concentrate in this area. This could have implications for scour around foundations, fatigue loading on turbine structures, and the impact on surrounding marine life or infrastructure. This finding highlights the need for more detailed wave–structure interaction modelling in future studies.

# 6 Dissemination Activities

This section sets out the details of dissemination activities carried out as strategic priorities of this project.

## 6.1 Academic Publications

Two peer-reviewed manuscripts are currently in preparation, targeting high-impact journals in the fields of marine energy systems and environmental planning. These papers will present:

- A comparative analysis of international consenting frameworks and their implications for design flexibility;
- Technical modelling results from wave and wake simulations at Site A (Tonn Nua), including turbine optimisation and environmental constraint assessments.

The publications will contribute to the academic discourse on adaptive offshore wind planning and provide evidence-based recommendations for regulatory reform in Ireland.

## 6.2 Workshop

A dedicated workshop titled Offshore ADAPT was hosted in collaboration with Wind Energy Ireland and University College Dublin on 27th May 2025, as part of the Wind Energy Ireland Offshore Conference. The event was held at the Clayton Hotel, Burlington Road, Dublin, and attended by over 50 participants from government agencies, industry, academia, and civil society.

Key outcomes from the workshop included:

- Identification of priority areas for regulatory improvement;
- Feedback on the applicability of design envelope approaches;
- Structured roundtable discussions with scientific and policy experts.

The workshop served as a platform for knowledge exchange and helped shape the direction of future research and policy engagement.


Figure 23 Offshore adapt flyer

More than 50 persons from different range of institutions (state, nonstate) attended this event, and suggestions were formulated during the event to prepare structured questions. A separate round table discussion between the scientific community was organised before the end of the event.

## 6.3 Survey Disseminated

To pave the offshore wind development in Ireland, a survey is being implemented jointly by University College Dublin, University College Cork and Wind Energy Ireland. The questions (Appendix 3) are disseminated at different platform (LinkedIn) formally to gain the understanding, if the planning process for ORE development contributes to design flexibility (e.g. turbine overall height, tower height, length of blades, etc.) that will also provide valuable recommendations to the Maritime Area Planning Act 2021 bill.

At the time of writing, more than 40 individuals from different backgrounds such as policy developers, Industry stakeholders have submitted their responses.

## 6.4 Coastal and Offshore Modelling Symposium (Feb 2026)

As a key route for future dissemination, the project team will host the Coastal and Offshore Modelling Symposium on 26 February 2026 at University College Cork (Aula Maxima). This national event, supported by the Marine Institute's Networking & Marine Research Communication Awards, will convene 50–100 participants from academia, industry, and government.

The symposium will provide a platform to:

- Present findings from this project, including wave and wake modelling, turbine optimisation, and spatial planning insights;
- Facilitate cross-sector dialogue on cumulative environmental impacts, sediment transport, and ecological connectivity;
- Showcase modelling tools and decision-support frameworks relevant to offshore wind, marine spatial planning, and coastal resilience.

The event will also support workforce development through technical sessions, early-career researcher presentations, and networking opportunities. Outputs such as proceedings, recorded lectures, and a potential special journal issue will ensure long-term impact and accessibility.

## 6.5 Other Planned Dissemination

Further dissemination activities are planned for the next phase of the project, including:

Presentation of findings at national and international conferences (e.g. SEAI Energy Show, European Wind Energy Association events);

Submission of technical reports to the Department of Environment, Climate and Communications (DECC) and the Maritime Area Regulatory Authority (MARA);

Development of open-access design guidance documents for use by developers, planners, and regulators.

These activities will ensure that the project's outputs are accessible, actionable, and aligned with Ireland's offshore renewable energy goals.

# 7 Conclusions & Further Work

## 7.1 Summary of Key Findings

The key findings of this project carried out by University College Cork, is summarised below:

This study presents a comprehensive review of international consenting frameworks and applies advanced modelling techniques to assess environmental constraints at Site A (Tonn Nua). Key findings include:

- **Policy Analysis**: Comparative review of global consenting regimes highlights the importance of incorporating design flexibility to accommodate evolving technologies and site-specific constraints.
- **Wave Modelling**: Preliminary wave constraint modelling at Tonn Nua demonstrates the value of scenario-based analysis in informing structural design and resilience planning.
- **Wake Effects**: Numerical simulations comparing 10 MW and 15 MW turbine arrays reveal the critical role of seasonal variation and turbine spacing in achieving target capacity and efficiency

## 7.2 Consenting Policy Conclusions

The first phase of the report critically examines the complex consenting frameworks governing offshore wind development in different states. It identifies key regulatory limitations encountered over the past three decades and analyses how different barriers for offshore wind development projects are mitigated over the last 30 years. The pathway of regulatory reforms has been compared with the existing traditional de-centralised planning systems, which provided several learning and potential options to consider the design flexibility in the ORE development. This has led the rationale for introducing robust approach in the Irish context (MAP act 2021) which will allow realistic level of design flexibility.

## 7.3 Hydrodynamic Constraints

In the second part, the wave constraints modelling presented in this report represents a preliminary effort, with the outputs serving as indicative guidance to support offshore renewable energy development at SDMAP in Ireland. These results can assist developers in preparing for unforeseen stressors, such as storm-driven wave events, by integrating resilience and adaptable design criteria into project planning. At the policy level, the findings may inform decisions that enable greater flexibility in regulatory frameworks to support ORE development targets, thereby supporting scalability of offshore projects. Systematic constraint assessment and anticipatory design practices are therefore essential to enable expansion, repowering, and integration of emerging technologies with minimal disruption to existing assets. Ultimately, a comprehensive wave constraints analysis can serve both as a technical safeguard to offshore wind energy development against extreme ocean wave conditions and as a strategic enabler of long-term, cost-effective development, therefore warrant further detailed analysis.

## 7.4 Wind Wake Impacts

The wake effects at Site A (Tonn Nua) are numerically investigated to compare the overall power productions due to 10MW and 15MW wind turbines separately, while optimizing the array spacing. The preliminary results indicate that seasonal variation significantly influence the wind farm's ability to meet the target capacity of 900 MW. Therefore, during the initial planning phase of wind farm, evaluation of the spacing between wind turbines, rotor diameter and height of tower becomes crucial for systematic planning process. As has been highlighted in the report, allowing some degree of design flexibility is valid to build offshore wind farms with available modern technology. While the market in China, operate with 22MW offshore wind farms, the potential options and range for offshore wind turbines to be used in Tonn-Nua, remains unclear at this time.

These results are preliminary and are provided here primarily for visualisation and to offer an initial indication of the scope of forthcoming scenario modelling and analyses. Future work will extend the evaluation of wave dynamics to a range of scenarios, including interactions with offshore wind turbine structures, analysis of extreme values across multiple return periods, and assessments at other designated sites within the SDMAP. Moreover, to support the development of 900 MW offshore wind farm at Site A (Tonn-Nua) along with other ambitious projects at the other identified region in SC-DMAP, an in-depth cumulative impact analysis has attracted the interest to the research team at University College Cork, Ireland. So, in the next round of investigations, the potential conflict between protecting the bio-diversity and the renewable energy generation will be identified. A science-based assessment will be carried out to inform and improve the planning framework to support Ireland's renewable energy targets.

## 7.5 Future Work

Building on the findings of this study, several key research areas have been identified to support the next phase of offshore renewable energy development in Ireland:

- Advanced Modelling of Wind Wake and Hydrodynamic Impacts

Future work will focus on improving the understanding of wake interactions and hydrodynamic responses resulting from large-scale ORE deployments. This includes high-resolution modelling and long-term monitoring to assess cumulative impacts on energy yield, structural loading, and marine conditions.

- Ecological Connectivity and Fish Transport

A targeted assessment will be undertaken to evaluate the impact of offshore wind infrastructure on fish migration patterns and connectivity between onshore and offshore habitats. This includes examining potential barriers to movement and changes in ecological corridors due to turbine placement and cable routing.

- Benthic Processes and Sediment Transport

Offshore wind installations can alter seabed dynamics. Future investigations will model the influence of foundation types and array layouts on sediment transport, erosion, and deposition patterns, with implications for benthic habitat integrity and coastal morphology.

- Acoustic Interference and Marine Fauna

The acoustic footprint of offshore wind farms, including construction and operational noise, will be modelled to assess potential interference with marine species, particularly those sensitive to sound. This includes evaluating cumulative acoustic impacts and proposing mitigation strategies to minimise ecological disruption.

These future research directions will contribute to a science-based planning framework that supports Ireland's renewable energy targets while safeguarding marine biodiversity and ecosystem services. The outputs will also inform regulatory guidance, design standards, and stakeholder engagement strategies for upcoming offshore wind developments.

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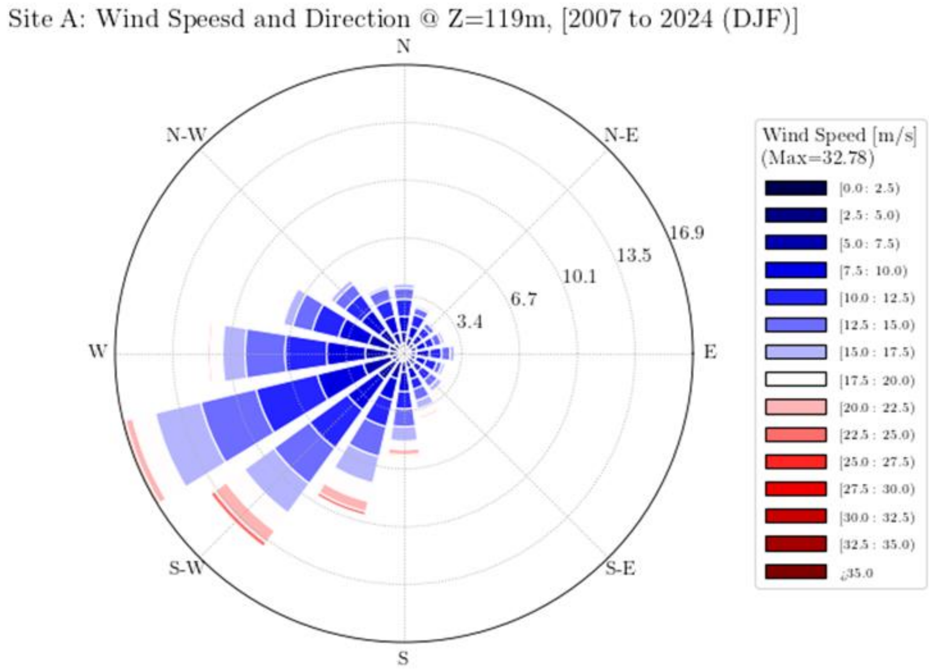
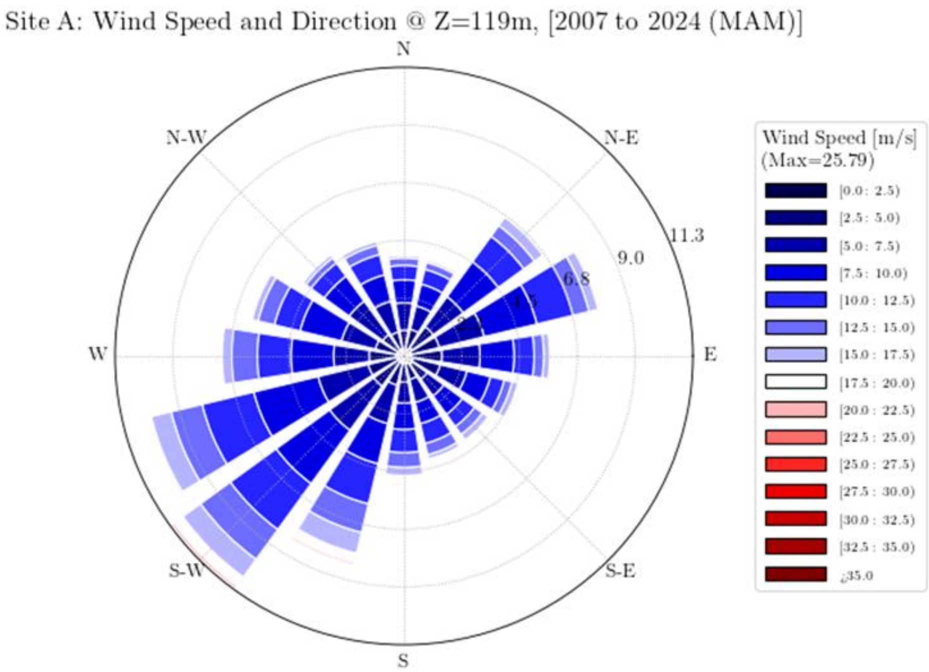
[10] Available: https://nrel.github.io/turbine-models/IEA_15MW_240_RWT.html)

[11] Available: *https://github.com/FraunhoferIWES/foxes*)

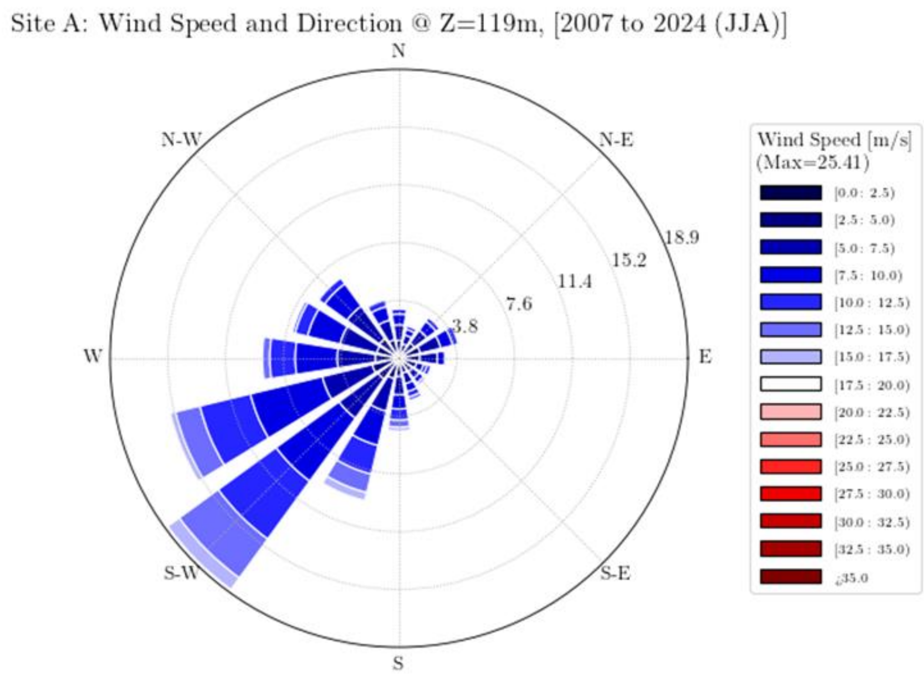
## Appendix 1. Wind Data



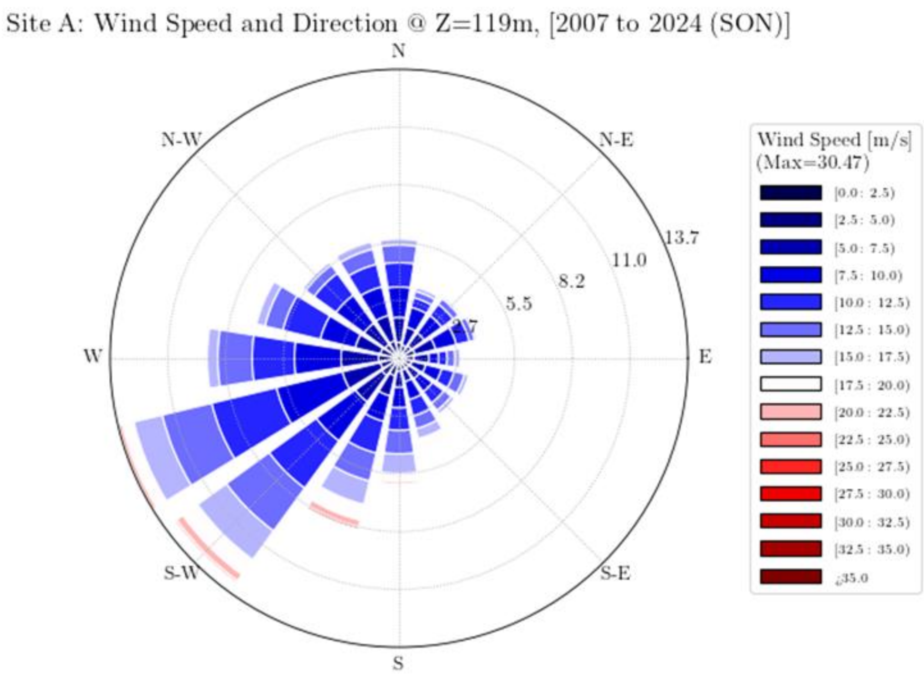

Wind speed distribution and direction for site A at a height of 119m



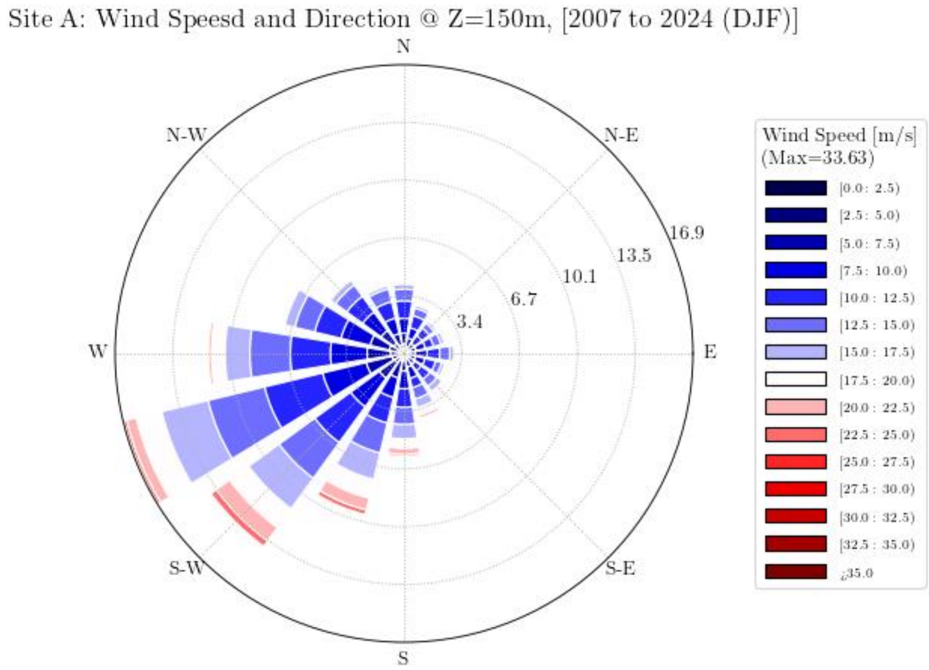

Wind speed distribution and direction for site A at a height of 119m ( MAM, 2007-2024)



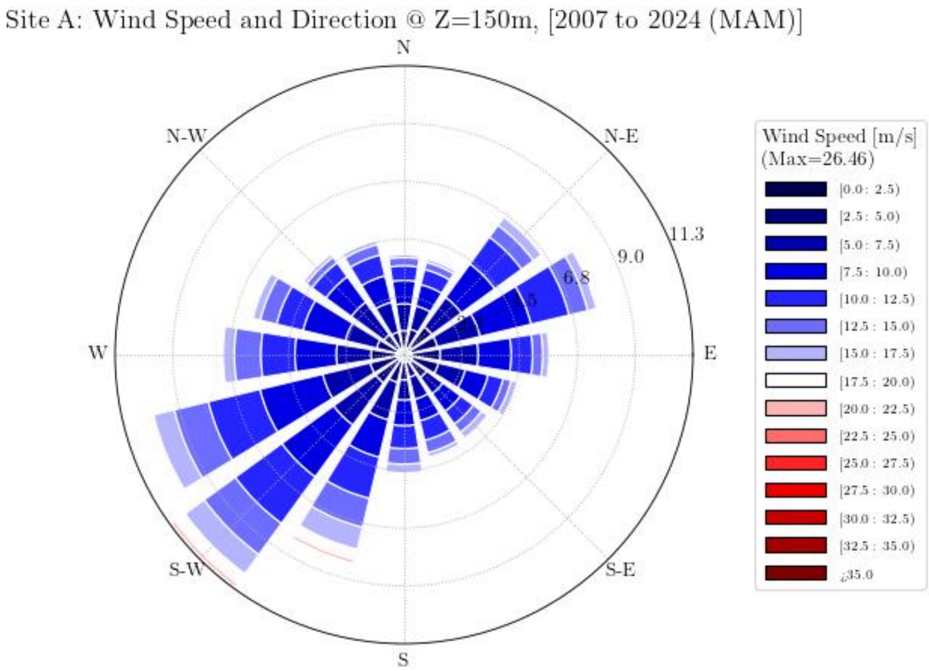

Wind speed distribution and direction for site A at a height of 119m ( JJA,2007-2024)



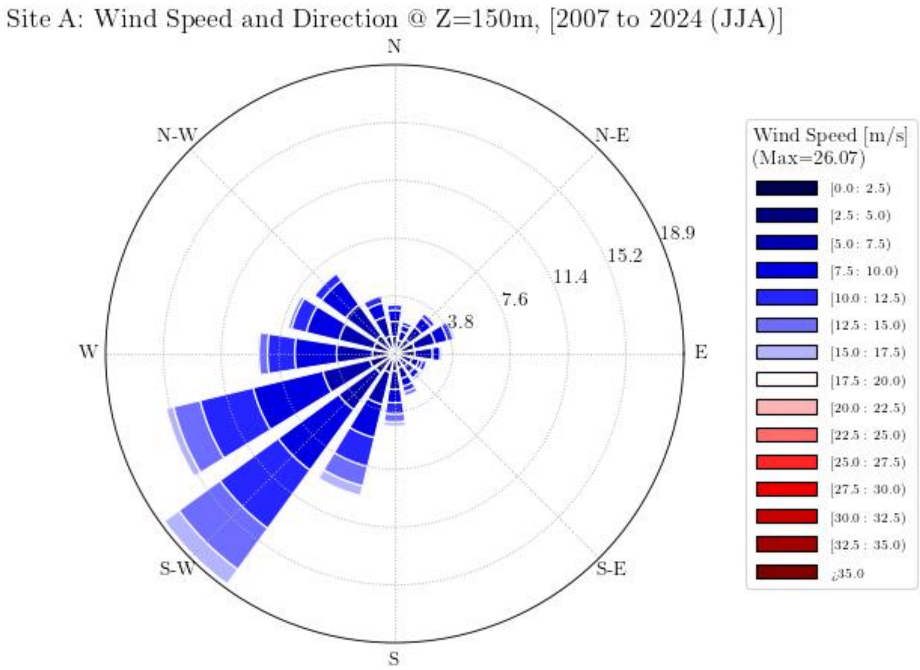

Wind speed distribution and direction for Site A at a height of 119m (SON, 2007-2024)



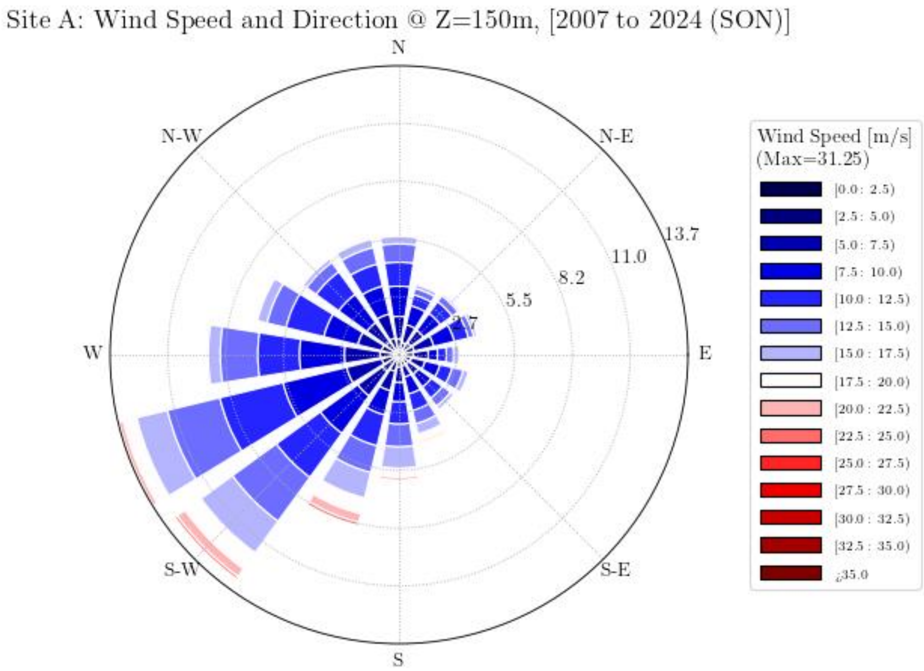

Wind speed distribution and direction for site A at a height of 150m (DJF, 2007-2024)




Wind speed distribution and direction for site A at a height of 150m (MAM, 2007-2024)

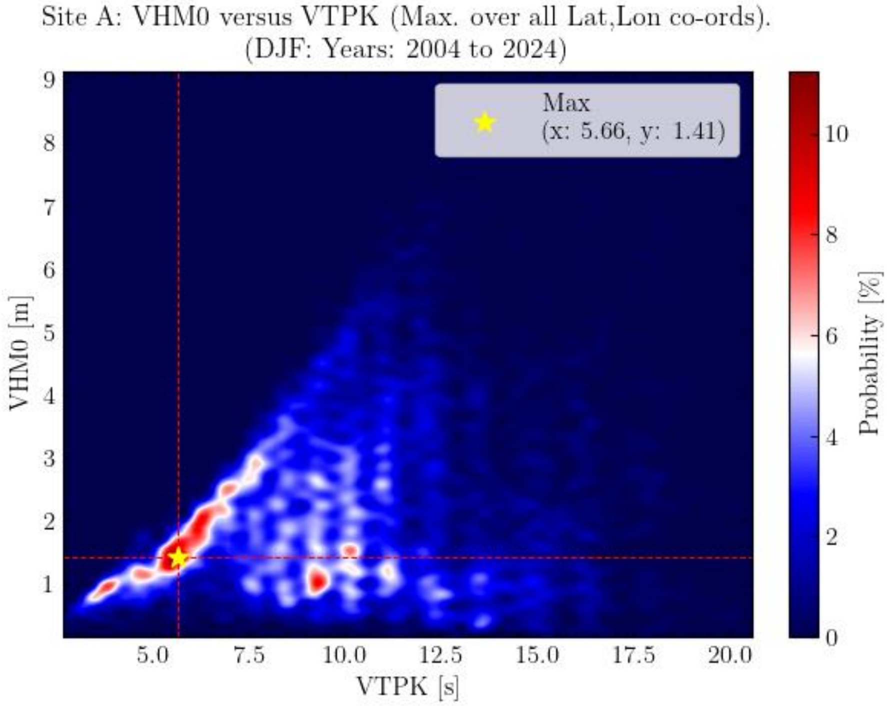



Wind speed distribution and direction for site A at a height of 150m (JJA, 2007-2024)

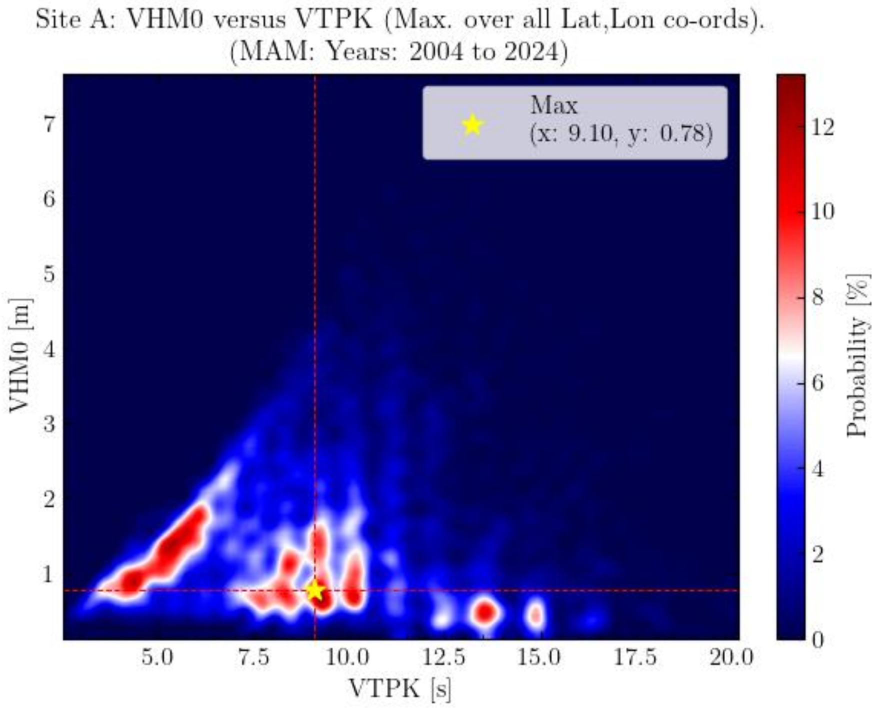



Wind speed distribution and direction for site A at a height of 150m (SON, 2007-2024)

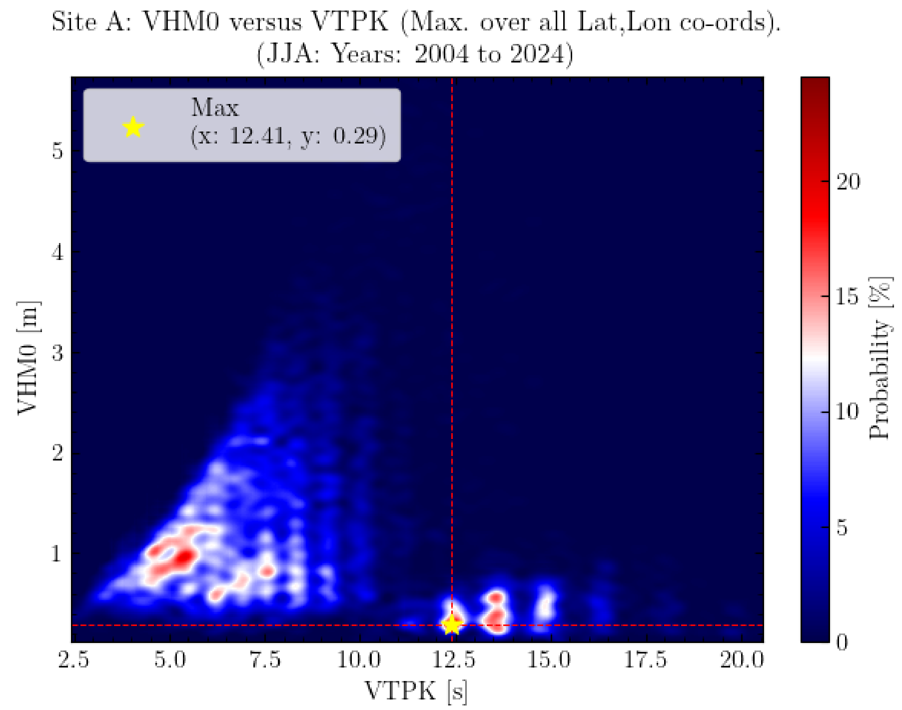
## Appendix 2 Wave JP



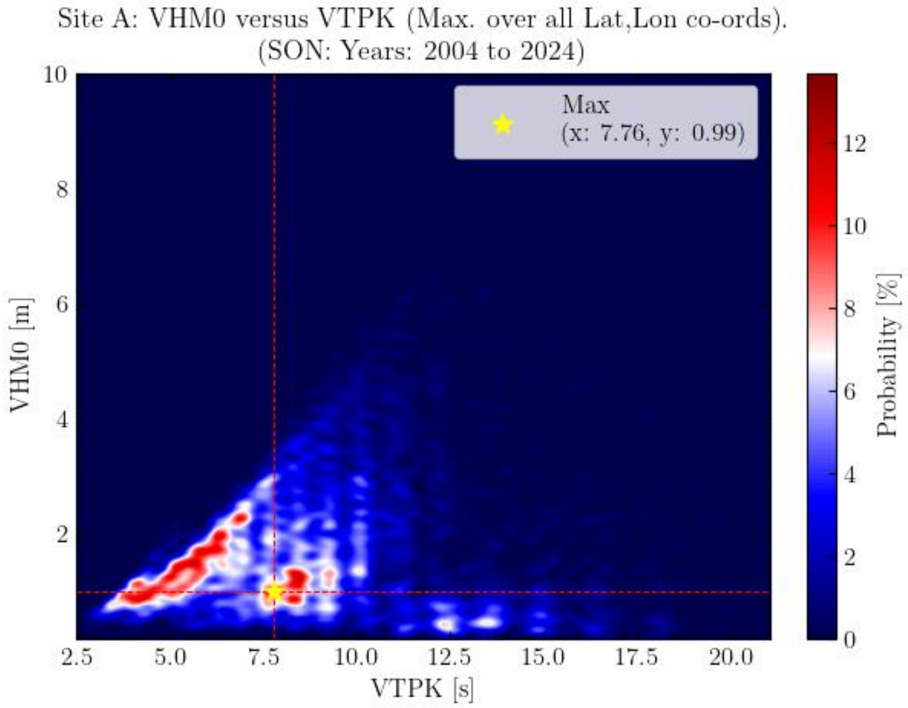

Joint probability of significant wave height and wave period (DJF, 2004-2024)




Joint probability of significant wave height and wave period (MAM, 2004-2024)




Joint probability of significant wave height and wave period (JJA, 2004-2024)




. Joint probability of significant wave height and wave period (SON, 2004-2024)

# Appendix 3 Survey

The set of questions for each section will take approximately 5 minutes to complete. Your time in completing the survey is very much appreciated by the Offshore-ADAPT project team.

All information provided in the survey is anonymous.

***Section 1: Your background***
**Which industry or sector do you work in?**
Offshore wind energy
Onshore wind energy
Oil & gas
Maritime & shipping
Civil engineering & infrastructure
Academia & research
Other (please specify)
**What is your primary role in the industry?**
Engineering (e.g., structural, mechanical, electrical)
Operations & maintenance
Research & development
Project management
Policy & regulation
Other (please specify)
**How many years of experience do you have in your field?**
Less than 1 year
1–3 years
4–7 years
8–12 years
More than 12 years
**Have you worked directly with offshore wind development projects?**
Yes, extensively
Yes, to some extent
No, but I work in a related field
No, but I am interested in offshore wind
***Section 2: Ireland's offshore targets:***
**Do you think Ireland is on track to meet its carbon reduction targets by 2030?**
Yes, Ireland is making sufficient progress
Possibly, but more aggressive policies and actions are needed
Unlikely, due to slow implementation and existing challenges
No, the current pace of change is far too slow
Unsure/I don't have enough information
**Do you think Ireland's target of 5GW offshore wind capacity by 2030 is achievable?**
Yes, it is realistic and achievable
Possibly, but significant challenges remain
Unlikely, due to current barriers
No, it is too ambitious given the current pace of development
**How long do you think it currently takes to develop and commission an offshore wind farm in Ireland, from planning to operation?**
Less than 5 years

5–7 years
8–10 years
More than 10 years
Unsure/I don’t have enough information

**How does Ireland’s offshore wind development timeline compare to leading countries like Denmark or the Netherlands?**

Much slower—Ireland lags significantly behind
Somewhat slower—progress is being made, but still behind
About the same—similar challenges and timelines
Faster—Ireland is catching up or moving ahead
Unsure/I don’t have enough information

***Section 3: The main challenges slowing down offshore wind development projects.***

**What do you think is the biggest challenge slowing offshore wind development in Ireland and the EU?**

Lengthy permitting and regulatory processes
Grid connection and transmission constraints
High capital costs and financing challenges
Supply chain and workforce limitations
Environmental and social acceptance issues
Other (please specify)

**How significant do you think regulatory and permitting delays are in slowing offshore wind deployment?**

Extremely significant
Very significant
Somewhat significant
Not very significant
Not a challenge at all

**What do you believe is the biggest financial barrier to offshore wind development?**

Uncertainty in long-term policy and subsidies
High upfront capital investment
Difficulty in securing power purchase agreements (PPAs)
Inflation and rising material costs
Other (please specify)

**What do you think is the most effective way to accelerate the planning and permitting process for offshore wind projects in Ireland?**

Establishing a single, streamlined regulatory authority
Setting clear and fixed timelines for approval processes
Increasing government resources for faster permit reviews
Enhancing stakeholder coordination and early engagement
Reducing legal challenges and simplifying environmental assessments
Other (please specify)

Do you believe that adoption of open door system along with DMAP (specified site) can speed up offshore wind development in Ireland?

No
Yes
Unsure
May be with reservations

*Section 4: Design Flexibility*

**How would you rate the current level of design flexibility allowed under Maritime Area Planning (MAP) Act 2021?**

Very flexible – allows for easy adaptation to new technology
Somewhat flexible – but with notable restrictions
Not flexible – regulations impose strict design limitations
Not sure / No opinion

**Do you think Ireland's regulatory framework for OWTs should allow more flexibility to accommodate technological advancements (e.g., taller towers, larger blades)?**

Yes – regulations should be more adaptable
No – current regulations provide the right balance
No – regulations should be stricter to minimize environmental impact
Not sure / No opinion

**What do you see as the main challenge of increasing design flexibility in Ireland's OWT regulations?**

Environmental concerns (e.g., impact on marine life, visual impact)
Policy and legal constraints
Public opposition and stakeholder concerns
No significant challenges – flexibility should be easily achievable
Not sure / No opinion

**How do you think Ireland compares to leading offshore wind countries (e.g., Denmark, the Netherlands) in terms of understanding and allowing design flexibility for Offshore Wind Turbines (OWTs)?**

Ireland is ahead – regulations are more adaptable than other leading countries
Ireland is on par – similar level of design flexibility as leading countries
Ireland is behind – regulations are more restrictive and less adaptable
Not sure / No opinion

**What do you think is the most significant benefit of increased design flexibility in offshore renewable energy development in Ireland?**

Faster adoption of new and more efficient technologies
Reduced environmental and acoustic impact on marine ecosystems
Lower costs and increased competitiveness of offshore wind projects
Improved alignment with international best practices and regulations
Not sure / No opinion

**Which component of Offshore Wind Turbines (OWTs) do you think requires the most flexibility in design to support innovation and efficiency?**

Turbine height
Blade length and design
Foundation and support structures
Turbine spacing and layout
Grid connection and infrastructure
Other (please specify)

**To what extent do you think allowing greater design flexibility could speed up offshore wind development in Ireland?**

**0-10%** – Minimal impact, other factors are more significant
**10-30%** – Some improvement, but still many challenges
**30-50%** – Moderate acceleration in development
**50-70%** – Significant boost to project timelines

**70-100%** – Transformational change, greatly reducing delays
Not sure / No opinion

**Do you think using a design envelope (i.e., allowing a range of design parameters rather than fixed specifications) is a good solution for improving flexibility in offshore wind development in Ireland?**

A) Yes – it allows for innovation and adaptation to new technology
B) No – it could lead to uncertainty and regulatory challenges
C) Maybe – it depends on how it is implemented
D) Not sure / No opinion

**Which aspects of Ireland's current planning regulations for offshore wind development do you think need revision to allow greater design flexibility?**

A) Restrictions on turbine height and blade length
B) Fixed turbine layout and spacing requirements
C) Environmental impact assessment (EIA) procedures
D) Grid connection and permitting processes
E) Public consultation and stakeholder engagement rules
F) Other (please specify)
G) No revisions needed – current regulations are sufficient

**Do you believe that strong public protest due to the differences in opinion strongly affecting An Bord pleanála on allowing design flexibility in Ireland?**

Yes
No
Unsure
Other (If any)

**Are you aware of any examples from other countries where design flexibility has been successfully incorporated into offshore wind regulations? If so, please describe the example and its impact.**

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