Climatological challenges for the development of offshore wind farms off NW Scotland

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CONTENT

PROBLEM STATEMENT AND AIM OF THE STUDY

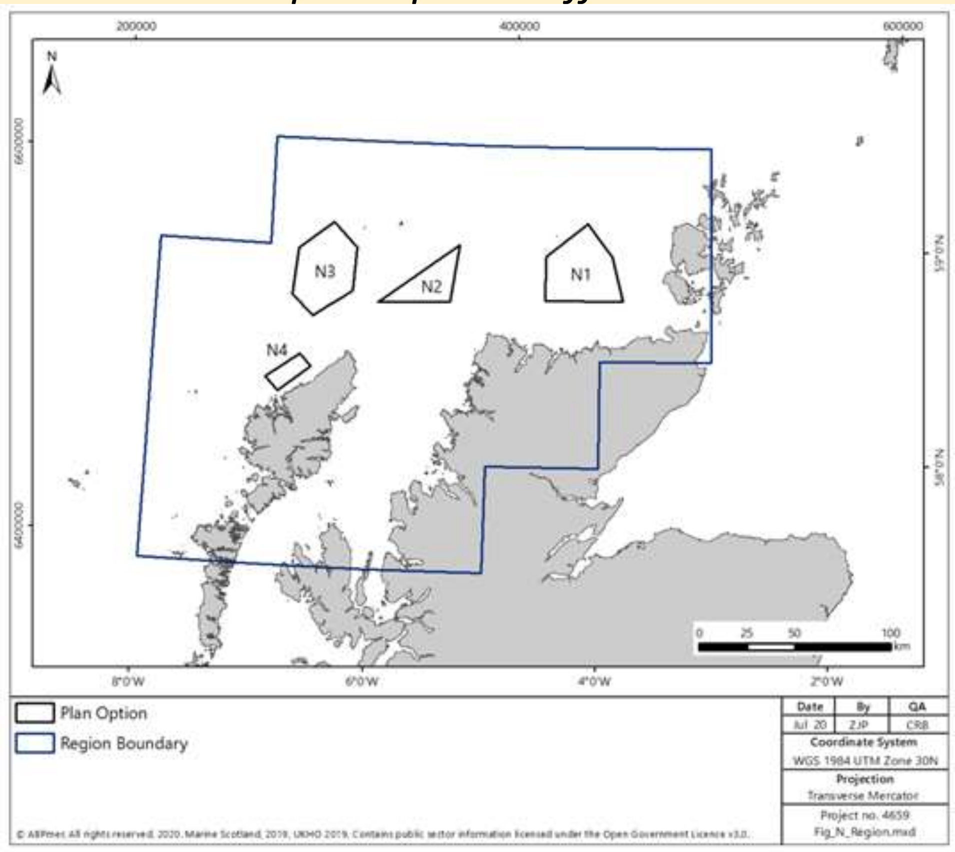
Crown Estate Scotland awarded rights to areas of the seabed for 4 windfarm projects in the NW Scottish waters (“ScotWind”), in conditions dictated by exposure to Atlantic storms and waves.

The climatological parameters in the area represent opportunities to harness the wind resources, pushing for the growth of decarbonized electricity generation in this mature sector.

Plan Option	Area (sq km)	Capacity (MW)	Foundation
N1	657	2000	Fixed
N2	390	1500	Floating
N3	103	495	Mixed
N4	161	840	Fixed

The harsh climate conditions have an impact on the complexity of infrastructure, on the turbine design, performance and deterioration, and on the operation and maintenance (O&M) of the developments, resulting in higher CAPEX and OPEX

ScotWind plan options off NW Scotland



Source: Scottish Government, 2020. Offshore Wind in Scottish Waters.

Through a critical review of the existing literature and the analysis of the metocean data, this study aims to assist developers to make informed decision on the O&M practices, considering the weather-related risk parameters.

STUDY DATA AND OTHER RESOURCES

Existing literature and open-source on-line platforms for

- to review and summarize the O&M activities for wind farms and current trends in the approach to the O&M practices;
- to define the weather-related risks to offshore O&M, the operability thresholds and consequently to define the accessibility criteria for activities by sea and by air.

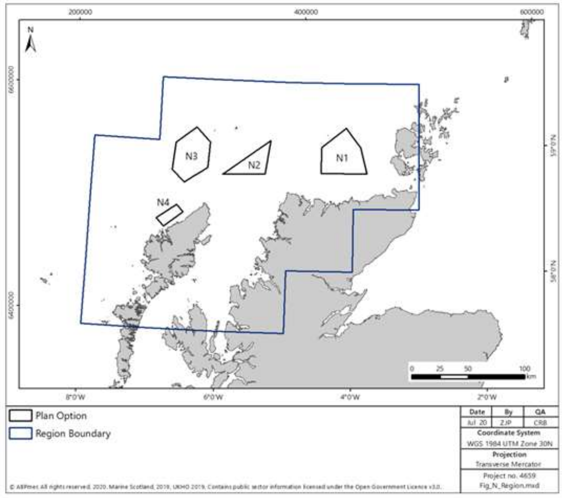
It is noted that current literature and information remain fragmented across the academic literature and the practitioners use-cases and best practices.

8,761 hourly wind observations (speed and direction) at sites between 2018 and 2021 were extracted from NASA's Prediction Of Worldwide Energy Resources (POWER), based on MERRA-2*

236,688 hourly wave data (significant wave height, peak period, mean wave direction) for each of the four ScotWind between 1994 and 2020 were extracted from the ResourceCODE** sea-state hindcast database (courtesy of Dr. Nicolas Raillard from IFREMER, LCSM)

* https://power.larc.nasa.gov/data-access-viewer/
** https://resourcecode.ifremer.fr/explore

WIND RESOURCES AND ELECTRICITY GENERATION



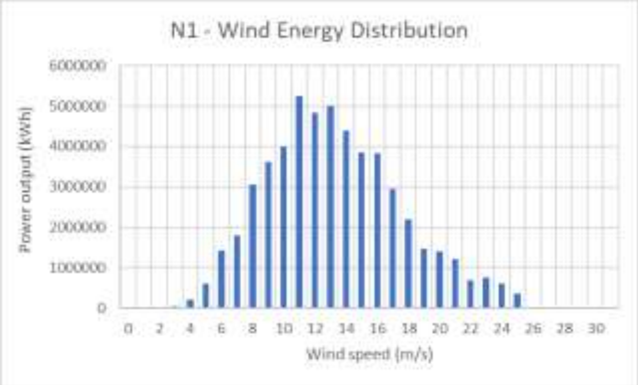
Wind resources represent huge opportunities for renewable electricity generation and new technologies will harness higher resources.

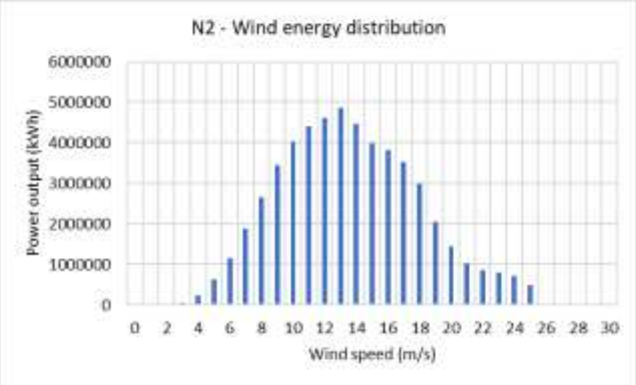
2021 wind speed data were used to calculate the wind energy distribution, the total power output the load factors at the 4 ScotWind sites, using a 9MW wind turbine technology (W2E-215/9.0).

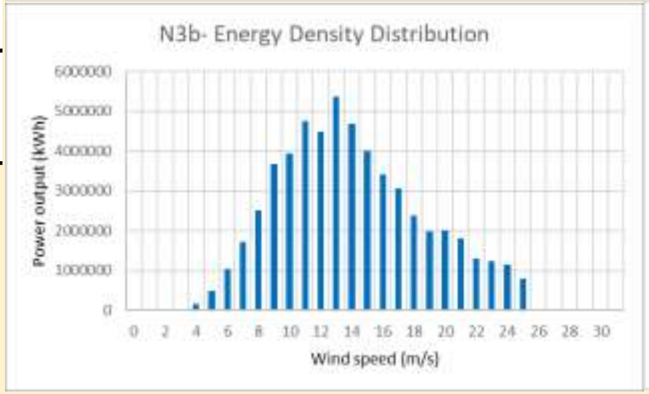
Larger wind turbines with rated power above 15MW will be available for deployment in the new development, and these will be able to harness more wind energy with higher load factors.

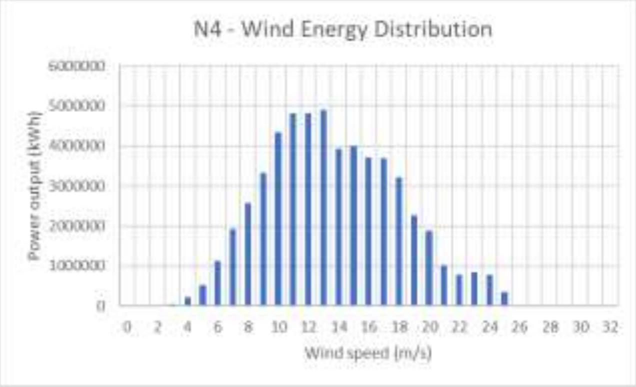
Persistent south-westerly winds with mean speeds around 10 m/s and max speed up to 33 m/s observed in 2018-2021 in the 4 study sites. *(Reference height: 170 m)**

	N1	N2	N3	N4
LOAD FACTOR (%)	68	69	71	70
TOTAL POWER OUTPUT (GWh)	53.6	54.2	56	55









OPERATIONS & MAINTENANCE OF OFFSHORE WINDFARMS

Operations, maintenance and services (O&M) are all those activities related to the offshore windfarm development before and after the commissioning and represent a consistent part of the total cost of energy throughout the windfarm life cycle.

Commercial Operation Date
TEST & COMMISSIONING

Post-consent & construction

Pre-commissioning ops
15% cost of energy

- Transportation and installation of foundation parts, substation, cables at the offshore site.
- Transportation and construction/installation of wind turbine component from fabrication site/marshalling port to offshore site.

Post-commissioning O&M
35% cost of energy

- Turbine maintenance & service (blades, nacelle, transmissions).
- Foundation inspection & repair
- Cable inspection & repair.
- Scour monitoring & management.
- Substation maintenance & service.

Decommissioning

Personnel, machinery and equipment transportation

O&M APPROACHES AND WEATHER SENSITIVITIES

Prescriptive maintenance nowadays has a holistic approach based on real-time monitoring data to make failure prediction together with other input such as recommended actions, prognosis and best O&M planning.

Prescriptive maintenance approach is preferred in offshore windfarms, given that the location of offshore wind farms requiring careful planning of (short-term) operations subject to weather conditions.

The weather sensitivities to offshore windfarm logistics, installation and O&M by sea and by air primarily reported by existing literature are: **wind speed and significant wave height (Hs).**

The access to an offshore site is controlled by an operability limits controlled by the main weather sensitivities, and changing with vessel type, helicopter or unmanned vehicles. See table below for operability limits found in this study.

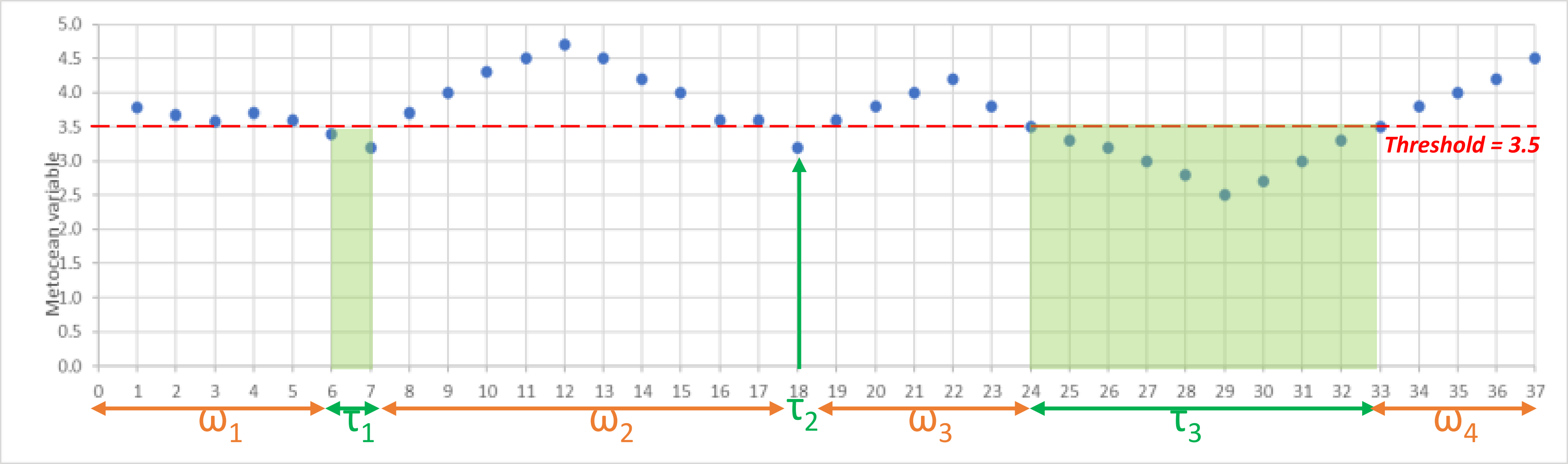
OPERABILITY LIMITS FOR OFFSHORE LOGISTICS, INSTALLATION, OPERATION AND MAINTENANCE FROM THIS STUDY

Vessel type	Significant wave height (Hs) operability limit	Wind speed operability limit
Cable laying vessel	up to 1 m	-
Crew transfer vessel (CTV)	up to 1.8 m	-
Jack-up, floating vessels, diving support vessel, offshore access system	up to 2 m	-
Service operation vessel (SOV)	up to 3.5 m	-
Helicopert	-	up to 20 m/s
Inspection drone	-	up to 10 m/s

ASSESSMENT METHOD OF WEATHER-CONTROLLED SITE ACCESSIBILITY

Accessibility to an offshore site for a specific operation type (vessel type) is defined as follows:

$$\boldsymbol{ACCESSIBILITY} = \frac{\boldsymbol{NUMBER\ OF\ CONSECUTIVE\ APPROACHABLE\ HOURS}}{\boldsymbol{TOTAL\ NUMBER\ OF\ HOURS}}$$



In the example:
Metocean threshold = 3.5 (*e.g.*, 3.5 m Hs)
Total hours = 37
Approachable hrs. = 11
Consecutive approach. hrs. = 10
Accessibility = 10 / 37

The minimum operable time is set at 1 hour, therefore τ_2 *is discarded as approachable weather window.*

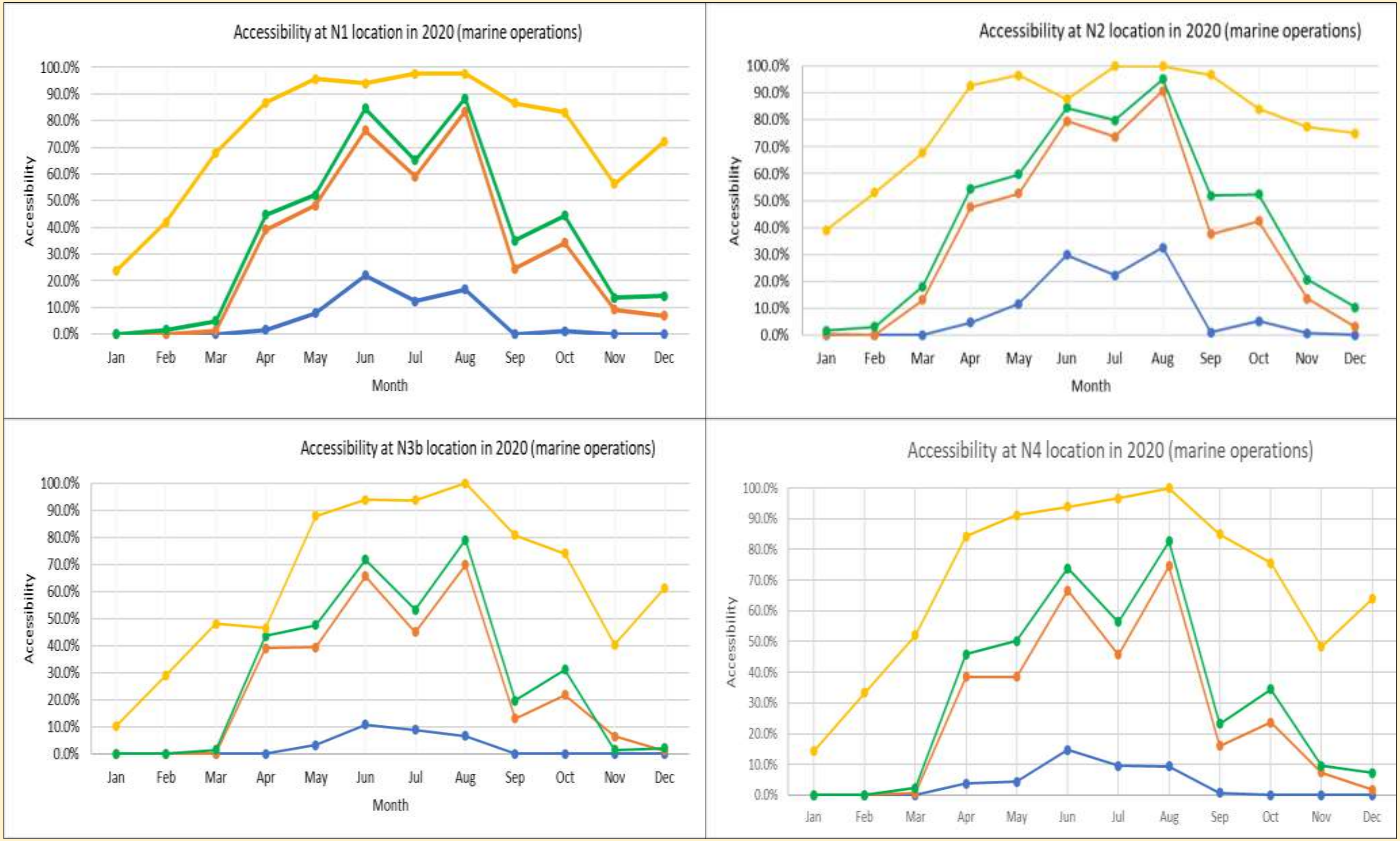
For a specific operation/vessel type, one can define:

- Number of approachable hours = number of hours when the site can be approached as the metocean parameter is below the operability limit.
- τ (weather window) = set of discrete time units (approachable hours) when the metocean parameter is below the operability limit and the site can be approached.
- ω (waiting window) = set of discrete consecutive time units (hours) when the metocean parameter is above the operability limit and the site cannot be approached.

SITE ACCESSIBILITY FOR MARINE OPERATIONS

Hs threshiold limit	Vessel type	O&M key actiities
up to 1 m	Cable laying vessel	Cable laying, cable monitoring and repair
up to 1.8 m	Crew transfer vessel	Crew transfer for all activities. Equipment and material transport.
up to 2 m	Jack-up, Diving support vessel, offshore access system	On-site assembly, installation, access to turbine, foundation, electrical ytransmission system and scouring inspection and repair.
up to 3.5 m	Service operation vessel	Large crew, equipment and material. Farher and longer operations.

SITE ACCESSIBILITY FOR MARINE OPERATIONS



SITE ACCESSIBILITY FOR AERIAL OPERATIONS

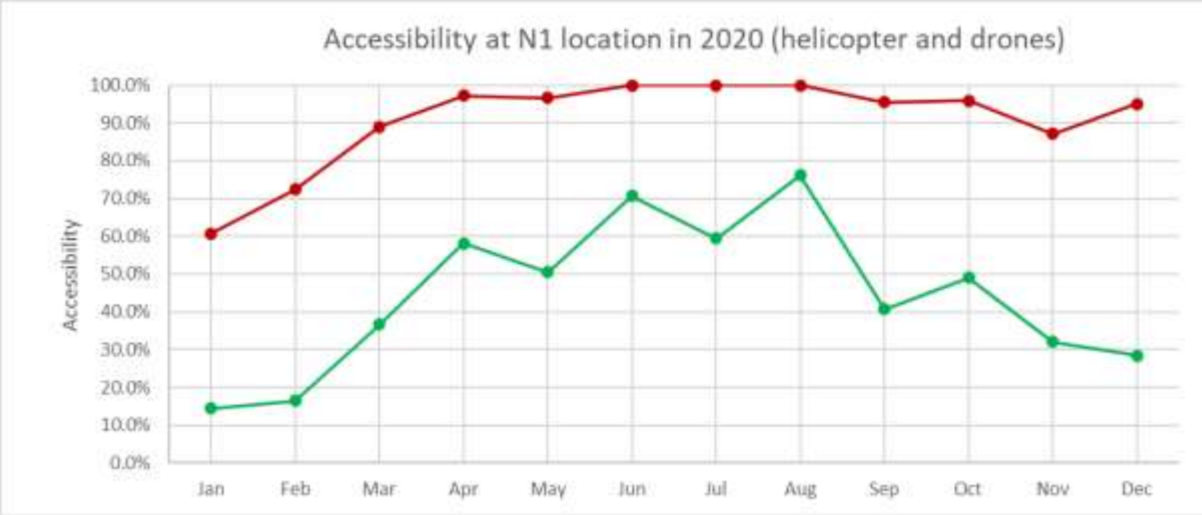
Accessibility is defined by the wind speed (at 170 m height turbine hub) operability limit of helicopter/drone. Data refer to year 2020.

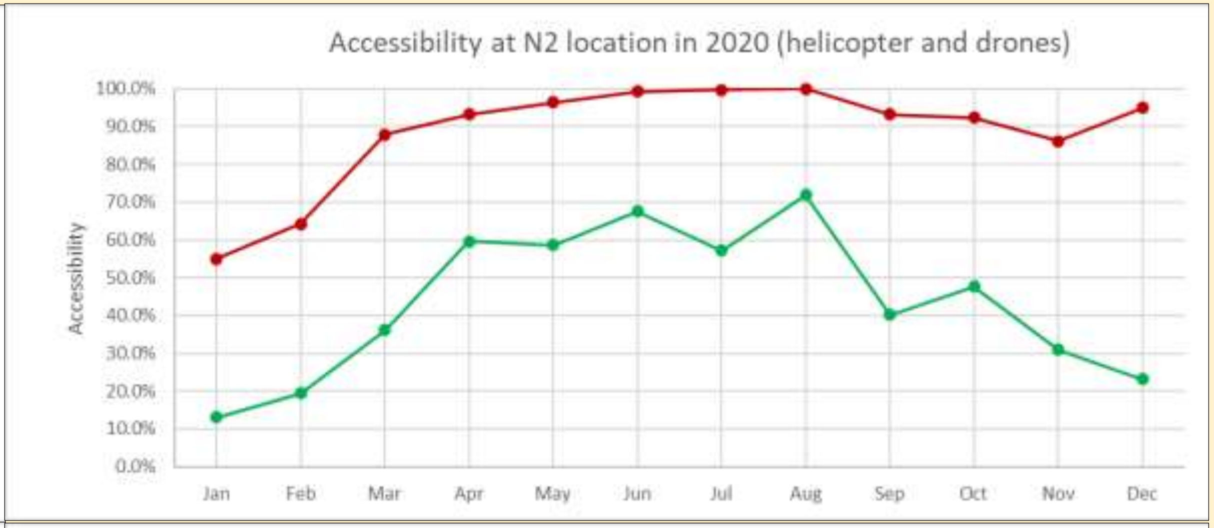
Wind speed threshiold (for wind at 170 m height)	Vessel type	O&M key actiities
up to 20 m/s	Helicopter	Crew transfer from vessel and from onshore, access to turbine hub, equipment transport.
up to 10 m/s	Inspection drone	Turbine inspection

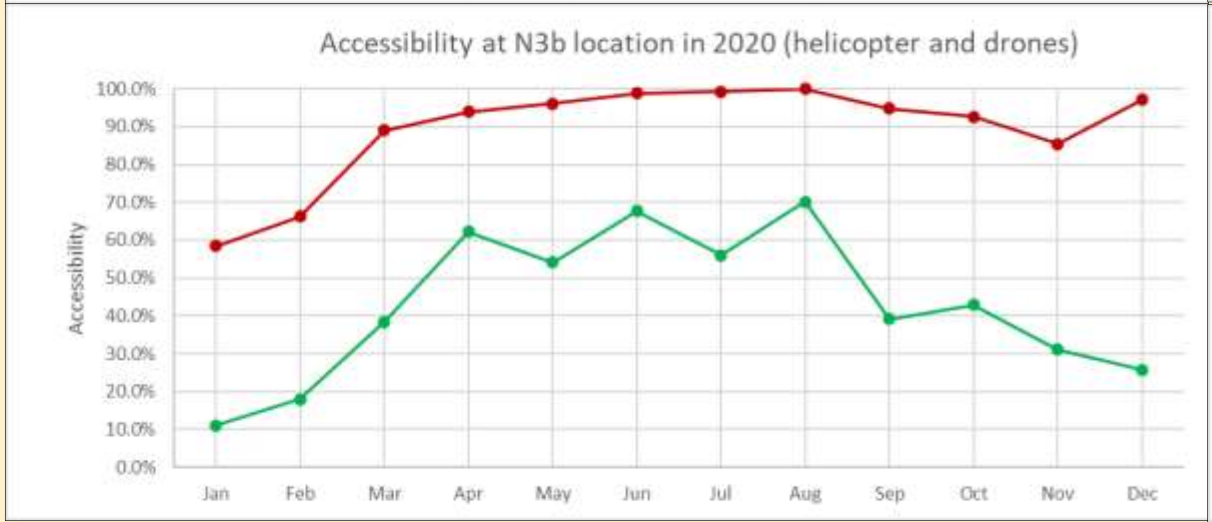
SITE ACCESSIBILITY FOR AERIAL OPERATIONS

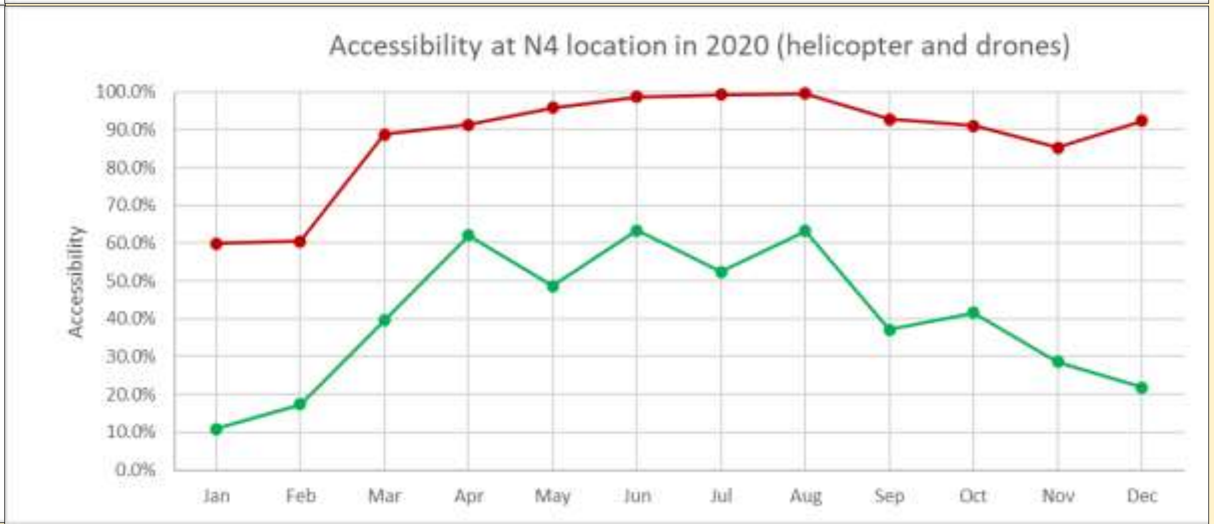
Strong seasonality for accessibility to studied offshore sites for drone inspection, having a lower operability limit (10 m/s)

Operations supported by helicopter ensure higher continuity to turbine throughout the year.









CONCLUSIONS (1/2)

- Offshore site accessibility for air and sea operations is strongly controlled by the metocean variables that define the weather window throughout the year.

- In the studied ScotWind plan areas (N1, N2, N3 and N4) accessibility for marine and aerial operations show the same pattern with marked seasonality, driven by the wind and wave climate, and that does not vary from site to site:
    - April to August with fair weather, lower wind speeds and significant wave heights is the period with the highest accessibility values.
    - November to January are the worst months with stronger winds and higher waves.

- With new emerging technologies (bigger turbines), and siting of windfarms in harsher climates, weather-dependent accessibility assessment for a prescriptive maintenance approach and precise operations' scheduling is crucial to minimize the delay in 1) logistics, 2) inspection and 3) work execution.

CONCLUSIONS (2/2)

- In such challenging offshore environments, practices in prescriptive operation strategies require various expertise from both public and private entities, involving different stakeholders, throughout the life cycle of the wind farm development:
  - Manufacturers.
  - Certifying bodies.
  - Training and service suppliers.
  - Windfarm owner/operator.
  - Vessels' operators.
  - Electricity transmission connection owners.
  - Local and government authorities.
  - Insurance companies.
  - Customers.

- Multidisciplinary research opportunities exist, therefore, to create a systematic and thorough approach to wind farms O&M, and to develop publicly accessible knowledge platform.

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