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EVALUATING THE POTENTIAL IMPACT OF NOISE ANNOYANCE FROM OFFSHORE WIND TURBINES IN IRELAND

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ABSTRACT

This paper presents a preliminary investigation into the potential for noise annoyance from offshore wind turbines in Ireland. The study compares the use of ISO 9613 and CNOSSOS-EU to estimate the impact of noise from the wind turbines on coastal communities. Over 40 sites of proposed offshore development in Ireland were initially considered, with two sites selected for further investigation. Preliminary results suggest that under certain conditions, the noise from the wind turbines may be audible to coastal communities. The results of this study highlight the importance of considering the potential impact of noise from offshore wind turbines during the planning and development stages of such projects. It also suggests that further research is required to fully understand the potential impacts from offshore wind turbines on coastal communities. Such research would aid in the development of appropriate noise mitigation strategies, which could help to reduce the potential negative impact of offshore wind turbine projects on coastal communities.

Keywords: *noise, annoyance, offshore, sound propagation.*

1. INTRODUCTION

Ireland's position on the edge of the Atlantic places it in an ideal position to harness energy from renewable sources, particularly from offshore wind power. Ireland's National Mitigation Plan (2017) recognises that Ireland has one of the best offshore renewable energy (wind, wave, and tidal) resources in the world, and there is very significant potential in utilising these resources to generate carbon-free renewable electricity. This is recognised in the current programme for government, setting an ambition of at least 5GW of offshore wind power by 2030, as well as taking advantage of the potential for at least another 30GW of offshore floating wind power in the deeper waters in the Atlantic. There are clear targets for Ireland regarding decarbonized energy systems, and there is a greater understanding of the role that offshore wind energy can play in achieving these targets.

While the potential behind offshore wind energy is massive, there are significant concerns over the environmental impact that may arise from widespread adoption, including increased noise levels below the sea, impact on marine life, disturbances to habitats, and potential pollution from the release of contaminants from seabed sediments. However, in general discussions related to developments, the expected noise impact on coastal communities is often reported to be negligible (or in many cases non-existent). Such assertions are often not based on any validated noise propagation modelling.

The collection of wind turbines in farms, as opposed to standalone units, will increase noise generation. Further, with the increasing height of the wind turbine towers, and the increasing size of the offshore wind farms, these environmental impacts are becoming significant [1]. This is particularly important in the case of low frequency noise. Larger turbines have significantly more low frequency noise compared to smaller turbines (<2MW), and the difference can be expressed as a downward shift of the spectrum of approximately one-third of an octave [2].

The impacts associated with noise from offshore wind farms present some challenging issues to developers, as the manner in which sound propagates over water is not completely understood, has not been extensively studied,

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and as such has not been incorporated into any national policy document. It is possible that some offshore wind farms close to the shore will be audible under certain conditions, and this issue warrants further consideration, especially considering the national significance of such developments.

2. MODELLING NOISE PROPAGATION FROM OFFSHORE DEVELOPMENTS

As it currently stands there is no reliable method to ascertain the noise impact of offshore wind turbine developments. A standard simply does not exist, so in the relatively few cases where a noise impact assessment is performed, developers often apply standards that are used for onshore developments. The EIS for the planned Oriel Offshore Windfarm, located off the coast of Co. Louth, used ISO 9613 in its assessment of operational noise [3].

For wind turbines, common prediction methods include either ISO 9613, Nord 2000, or CNOSSOS-EU. These models are generally based on empirical observations (measurements) and, therefore, are only accurate for source and receiver conditions which are similar to those associated with the original dataset. In Ireland, the most common prediction method for onshore wind farm noise modelling is ISO 9613-2 (which is considered in detail in the IoA GPG, and specifically excludes offshore turbine noise [4]). There are significant limitations with using a standard such as ISO 9613-2 when assessing noise propagation over water. For example, ISO 9613-2, actually excludes propagation over water, but it has been used in the absence of alternative methods. The standard considers the water surface as being acoustically hard, but studies have shown that this can lead to under-predictions on some sites where large bodies of water are found between source and receiver [4]. Further, the standard is meant for downwind propagation only and was originally developed to predict noise levels up to 1km from the source [5].

It is clear that the ISO standard is not designed for propagation over water, and its use might not accurately capture the true impact of an offshore development. Propagation over water usually means that the sound will travel over longer distances, especially at lower frequencies. There is little published research or guidance in Ireland or the UK on the propagation of noise over water.

2.1 Noise Limits

In their Environmental Noise Guidelines for the European Region, the WHO consider the issue of noise from wind turbines, and recommends reducing noise levels produced by wind turbines below 45 dB L_{den} [6]. It goes on to state that further research into the health impacts from wind turbine noise is needed so that better-quality evidence can inform any future public health recommendations properly. The Australian Independent Scientific Committee on Wind Turbines suggests that 'annoyance' is the primary measure with which to set wind turbine noise limits, and that the appropriate limit is one that ensures no more than 10% of the population would be highly annoyed when exposed to it. This threshold appears to be between 34–40 dB $L_{Aeq(10min)}$ outside the residence, with a mean value of 37 dB $L_{Aeq(10min)}$ [7].

In Ireland there is currently a draft wind energy development guideline under review [8]. The preferred draft approach described in this document is based on 5 dB(A) above existing background noise with rating penalties to be applied if certain characteristics arise in the noise emanating from a wind energy development. It considers a lower 35 dB(A) limit as a default until the 5 dB above background relative level exceeds this. The relative rated noise limit sets two further limitations on the noise level i) a rating penalty for certain special audible characteristics (tonal noise and amplitude modulation); and ii) A maximum noise level of 43 dB(A).

There are currently no limit values identified specifically for offshore developments.

2.2 Objective

This paper will consider the potential noise impact on coastal communities for two test cases off Ireland's coast. Calculations will be developed according to ISO9613 and CNOSSOS-EU. Results will be discussed in the context of existing limit values, and the potential for noise annoyance, (including audibility) of developments in coastal communities.

3. INITIAL ASSESSMENT

There are currently over 40 offshore developments, at various different stages of development, being proposed/considered around Ireland's coast (Fig 1). It can be seen that much of the development is planned for the east coast, because the Irish Sea off the east coast is much shallower and an easier location for development than the deeper Atlantic Ocean on the west coast. It is worth noting, however, that the harsher weather on the west coast would be ideal for offshore wind structures when the technology has matured, and the risk related to floating turbines has reduced. Of the current planned developments, six are considered 'Phase One/Relevant Projects', including the Arklow Wind Bank Phase 2 (approx. 6km from shore), Oriel Wind Farm (approx. 8km from shore), Sceirde Rocks (approx. 5km from shore), and the Dublin Array (approx. 10km from shore). For this paper we have selected two developments to consider the potential noise impact.

Figure 1. Planned offshore developments off Ireland's coast

3.1 Test Case 1: The Arklow Wind Bank

The first phase of the Arklow Wind Bank is the first and only existing offshore wind site to currently exist off the Irish coast. It is off the Wicklow coast, in the Irish Sea. Its turbines have a fixed bottom, and it has an installed capacity of 25.2MW. The farm has been operational since 2004 and currently has 7 turbines. The proposed second phase of the wind farm is due to be operational by 2028, bringing the total capacity to 825MW, from 69 turbines. The planned area to be covered by this development is approximately 27km x 2.5km.

3.2 Test Case 2: The Dublin Array

The Dublin Array offshore wind farm is a 600MW planned development, to be implemented off the Dublin coast in the Irish Sea. It is planned to contain between 45 and 61 turbines.

3.3 Calculation Details

Calculations are performed using the Predictor-LimA noise modelling software from Softnoise [9]. The ground region is considered as a hard surface when over water, with normal uncompacted surface used for land regions. The terrain type was categorised into 'Ice, Open Sea, Lakes', leading to a roughness factor of 0.001. Temperature was set as 9.8°C, humidity was 78.15%, and air pressure was 101.5kPa, values obtained from averages measured by MET Eireann. Finally, for the proposes of noise calculations, all turbines modelled are assumed to be identical and are of a similar sound power profile to a Vestas V236-15.0 MW turbine. A rotor diameter of 100m was set, and hub height was 150m above sea level. Actual turbine details for the proposed projects are not yet available, although it is worth noting that actual turbines are likely to be significantly larger, with a higher sound power rating.

4. RESULTS

4.1 Test Case 1

Figures 2 and 3 present the noise maps developed for the Arklow Wind Park using the standard implementation of both ISO 9613 and CNOSSOS-EU. Two measurement positions on land were selected for further analysis and results are presents in Table 1.

Table 1. Predicted L_{eq} levels at receiver points

Receiver	Distance to Source	L_{eq} *(ISO)*	L_{eq} *(CNOSSOS-EU)*
Ardmore	6.2 km	28 dB(A)	33 dB(A)
Arklow	11.5 km	19 dB(A)	25 dB(A)

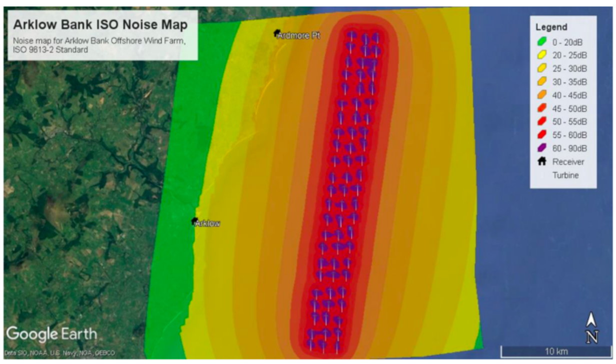

Figure 2. Noise Map for Arklow Wind Bank Test Case calculated according to ISO 9613.

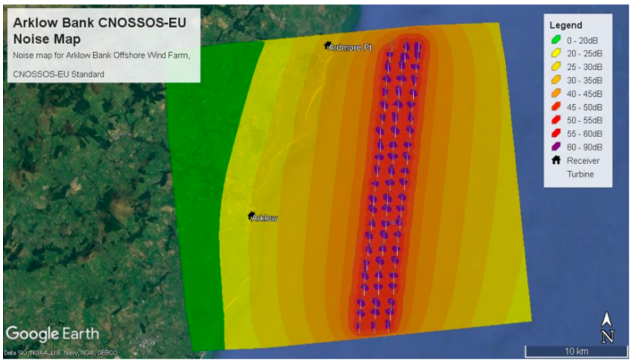

Figure 3. Noise Map for Arklow Wind Bank calculated according to CNOSSOS-EU

4.2 Test Case 2

Calculations were repeated for the Dublin Array (Figures 4 and 5) and noise levels at two land-based receiver points are presented in Table 2.

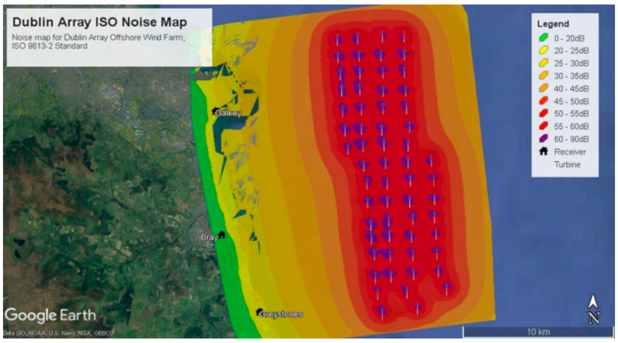

Figure 4. Noise Map for Dublin Array calculated according to ISO 9613

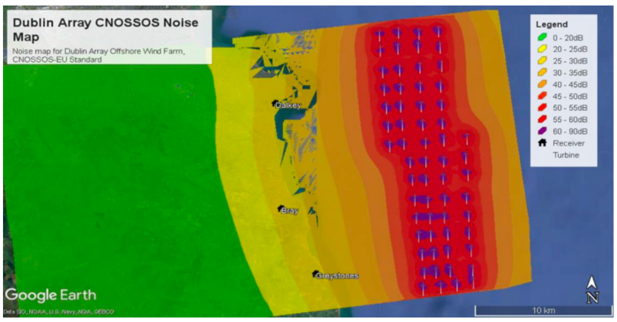

Figure 5. Noise Map for Dublin Array calculated according to CNOSSOS-EU

Table 2. Predicted L_{eq} levels at receiver points

Receiver	Distance to Source	L_{eq} *(ISO)*	L_{eq} *(CNOSSOS-EU)*
Dalkey	8.5 km	22 dB(A)	27 dB(A)
Bray	9.8 km	15 dB(A)	25 dB(A)

4.3 Initial Results

Initial results suggest that CNOSSOS-EU consistently predicts a higher noise level than ISO 9613. In all cases, the predicted noise levels could be considered as being significantly below the WHO guideline value of 45 dB L_{den}. Without a background noise survey at these locations, it is not possible to determine the predicted noise levels compared to background levels (as per the Irish draft guidelines), but it is unlikely that these predicted levels would adversely impact the local community. While these predicted levels are unlikely to lead to noise annoyance, it is worth considering the likely accuracy of these results, and whether or not they represent an accurate estimation of impacts.

5. DISCUSSION

One key consideration in the development of offshore wind farms is to assess whether or not turbines will be audible in coastal communities. It is often assumed that the noise levels will be minimal, and will pose no threat to coastal soundscapes. Given the absence of a validated method to predict sound propagation over water, it is worth considering the veracity of such assumptions.

In 2001, a Swedish report specifically addressed large propagation distances over ground and over water, and assumed a transition from spherical spreading to cylindrical spreading at a distance of 200m [4]. This 200m break point was a function of the sound speed gradient in the atmosphere, which was dependent on the wind speed gradient and the temperature gradient. A separate study conducted over the Baltic sea showed general agreement with the Swedish propagation model, but with a break between spherical and cylindrical spreading at 700 metres rather than the 200 metres [10]. In light of this work, a break of 700m is also recommended by the IOA in their 2014 supplementary guidance note on noise propagation over water for on-shore wind turbines [4]. However, it has been recognized by scholars that more work is needed to properly quantify this effect [11]. In practice, this may mean that when wind turbine noise is propagating over water, there is a 3 dB decrease in sound level for each doubling of distance (cylindrical propagation) instead of the more usual 6 dB (spherical propagation) used for on-shore calculations. This would mean noise over water will be louder over twice the distance compared to propagation over land, suggesting that the results presented in Section 4 may be significantly underpredicted.

While the issue of sound propagation over water needs to be further investigated in itself, the interaction between the water surface and the meteorological conditions at sea is another important issue in need of further research. Meteorological conditions, water surface roughness, and the water/land border are also important to consider, and their effects are not currently well defined. Further, when a sound wave propagating over the sea reaches the shoreline, a variety of changes happen together, such as changes to the wind and temperature gradients as well as the ground impedance. This will alter the sound speed profile and will induce some refraction. Only a few studies have been made of the shoreline effect for acoustical propagation [12], but one study suggests a possible attenuation of only 3dB [13]. The current noise prediction tools commonly used to assess the acoustic impact of wind farm developments are only partially taking these parameters into account. A reliable method to capture the effect of these parameters on noise propagation from offshore is required, as a failure to take these issues into account may result in a significant underprediction of the impact of offshore wind turbines.

5.1 Meteorological Effects

Sound propagation is heavily influenced by meteorological effects. Wind direction, wind speed, temperature, atmospheric pressure, turbulence and the viscosity of air all affect the magnitude of sound attenuation. However, even though meteorological effects can cause deviations of ±20dB, they are widely overlooked in most propagation methods [14].

Wind speed varies with height above the ground, generally increasing with increased height. The change in wind speed leads to wind shear, which influences sound propagation. ETSU-R-97 presents a simple method to correct wind speeds to a height of 10 m using a ground roughness length. However, this method holds significant potential for error. Describing the wind shear in terms of only the surface roughness, and not on atmospheric stability, is not a good predictor for night-time wind profiles [15].

This is further complicated in a marine environment. The marine boundary layer (MABL), the part of the atmosphere in contact with the ocean, is directly influenced by the ocean, and is shallower than the atmospheric boundary layer. Further the MABL is where the ocean and atmosphere exchange large amounts of heat, moisture, and momentum, primarily via turbulent transport. Consequently, wind speeds on sea for a given height are higher, and turbulence intensities are lower, than on land. It is further complicated by the potential presence of low-level jets, which are winds of high speed occurring at a relatively low height and are usually formed by diurnal changes in the thermal stratification of the surface layer.

Further, as sound is propagating from source to receiver, the manner in which it interacts with the ground surface also plays an important role. Some sound energy hits the ground surface and is absorbed or reflected. The spreading of the reflected sound is dependent on the surface roughness of the ground. It is generally assumed that a flat-water surface will totally reflect sound. However, under real conditions on sea, water waves, with different amplitudes and wavelengths, will be present. The effect that water waves have on sound propagation is not fully understood.

5.2 Implications

Taking into account factors such as spherical/cylindrical spreading, low frequency impact, low level jets, the marine boundary layer, etc, it is not unreasonable to assume the results presented in Tables 1 and 2 may be significantly underpredicted, and noises level in excess of 45dB(A) might be experienced on the shore, exceeding the WHO recommended level for (onshore) wind turbines, and well in excess of those limits proposed in Australia. It is impossible to know for sure with today's calculation methodologies, and the issue warrants immediate investigation.

It may be that noise levels will exceed 40-45dB(A) under certain weather conditions. Thus, under certain conditions the developments may be audible at certain times. If this is the case, it is important to highlight this at the development stage, to prevent complaints in the future, and help social acceptance of the developments.

6. DISCUSSION

The development of renewable energy, including both offshore and onshore wind, is central to Ireland's energy policy. For wind farm developments, noise is often a limiting factor and is frequently cited as the most annoying aspect of a development. As it stands, there is currently no accepted methodology for assessing the noise impact of offshore wind turbines in Ireland. If standard prediction methodologies for onshore turbines are simply applied to an offshore setting, there will be significant errors in assessment. It is well established that sound propagation conditions play a vital role in the noise impact from offshore wind farms and ordinary assessment methods can become inaccurate at longer propagation distances over water [16].

In the author's experience, quiet rural areas in Ireland have typical background noise levels of 35 dB(A) during the day, decreasing to 20 dB(A) during the night. Under certain wind conditions, it is possible that offshore developments may be audible in coastal communities. Should noise from offshore wind turbines be audible on the coast, it is highly likely they will be audible above background noise sources. It would be a mistake to just assume any noise will be negligible without a detailed investigation, especially given the national importance of offshore wind energy. If this assumption is found to be incorrect after a development is operational, then it could lead to a sense of mistrust amongst communities, and impede future developments. If this were to happen, future developments would likely be examined intensely and in the event of uncertainty, onerous conditions may be applied at the planning stage.

The time has come to perform a detailed assessment of the acoustic impact of offshore developments. Such assessments should include a detailed analysis of long-range sound propagation over water, under various different meteorological conditions (including thermal inversion). Such analyses are needed in order to avoid unnecessary noise-induced barriers to development in the future, and ensure we can harness the full potential of offshore wind energy.

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