

Peer Review Report

Review Report on Geoscience solutions for sustainable offshore wind development

Review, Earth Sci. Syst. Soc.

Reviewer: Mark Coughlan

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EVALUATION

Q 1 Please summarize the main theme of the review.

This manuscript reviews the current state-of-the-art with regard to offshore wind development, and how geoscience skills, research and understanding can contribute to its sustainability, both in terms of de-risking construction and integration with the whole energy system.

Q 2 Please highlight the limitations and strengths.

This manuscript is a very timely one given the ongoing attempt at transitioning from fossil fuel-based energy systems to more renewable based ones. Particularly as many countries, like the UK, have developed significant projects to date at "low hanging fruit" sites that are relatively easy to construct, whereas future ones may encounter new technical challenges. Its strengths are that it highlights and discusses the role geoscience can play in this transition, not only in relation to offshore wind development itself, but the wider energy system that supports it (e.g. energy storage, transmission etc). In that regard it is a very holistic review and highlights the many opportunities for geoscience to contribute to a meaningful transition at a time when many graduates in the field may be wondering how geoscience can practically lend itself to the development of renewable energy systems. The manuscript also highlights some of the key areas, still understudied, where geoscience plays an important role, such as seabed evolution over different timescales and sediment mobility. The images are also of good quality and are engaging.

Given the breadth of the subject matter, there is often limited discussion on some of the challenges with no mention of some geohazards like submarine landslides (relevant to floating wind further out on the continental shelf) and earthquakes. There are some relevant existing publications (such as Mellet et al., 2015) that could have been referred to in this regard.

Q 3 Does the review include a balanced, comprehensive and critical view of the research area?

In general, yes.

Q 4 Check List

Is the English language of sufficient quality?

Yes.

Is the quality of the figures and/or tables satisfactory?

Yes.

Does this manuscript refer predominantly to published research? (unpublished or original research is non-standard for a review article, and should be properly contextualised by the author)

Yes.

Does the manuscript cover the topic in an objective and analytical manner

Yes.

Does the reference list cover the relevant literature adequately and in an unbiased manner?

Yes.

Does the manuscript include recent developments?

Yes.

Does the review add new insights to the scholarly literature with respect to previously published reviews?

Yes.

Q 5 Please provide your detailed review report to the editor and authors (including any comments on the Q4 Check List):

The authors should be commended on a timely and engaging paper on how geoscience can support future offshore wind development. Overall it is well-written and well supported by relevant references, covering a number of interesting and relevant issues. The images are of good quality and support/augment the text well. Framing the discussion in the context of the UN SDGs rather than individual country approaches was an interesting choice, and added a different perspective, which worked well. The subject matter is broad, and the manuscript reflects that, but does offer some very good examples of how geoscience is used to address particular problems (e.g. subsurface characterisation for optimal foundation design). The authors rightly highlight sediment mobility and bedform dynamics as an area in need of further research. Below I go into more detail on suggested amendments and comments on the text, but my general comments are:

- 1) whilst a good overview of geoscience challenges and opportunities to offshore wind, some high-level issues like submarine landslides and subsurface morphology & lateral variation (e.g. tunnel valleys) are overlooked. Perhaps a table compiled from sources like Mellet et al (2015) and the Offshore Site Investigation and Geotechnics Committee (OSIG) would summarise some of these in that context, without the need for lengthy discussion. Essentially something to supplement Figure 3, especially at the site evaluation stage.
- 2) I think more mention and reference to active national programmes providing baseline geoscience data to offshore wind development (e.g. INFOMAR in Ireland, Marine Data Portal in the UK) is important here as it's not solely about research and industry collaborating more as government and state agencies also have an important role, especially in a decentralised model of development.

Line 18-19: "...with over 200GW of offshore wind energy generation by 2030", should this be 'planned' or 'targeted' by 2030?

Line 36: "above pre-industrial levels"

Line 44: change 'might' to 'could'.

Line 53: line 51-55 is long, I'd suggest a new sentence starting here with "For example..."

Line 56-62: This sentence is very long, suggest breaking it up into two at least.

Line 76-80: suggested rewording:

In particular, we identify four integration challenges that require input from the geosciences, and geoscientists, to be solved. Namely, the integrating of offshore wind : i) into the environment, ii) into the energy system, iii) with the demands of other users of the marine space, and iv) by maximising of benefits throughout the wind farm lifecycle.

Line 105-107: suggested rewording: An understanding of the site-specific conditions for each offshore wind farm has to be developed to optimise design, (de)construction, low-risk operation and cost-effective maintenance (O&M) (Nielsen and 107 Sørensen, 2011)

Line 123-127: Do Geo-assets have to be "legacy"? You talk later about CAES and pumped hydro, amongst others, which may be new developments

Line 187: should it be "increased stability"? Line 185-189 is a long sentence, I suggest breaking it up to deliver the point more effectively.

Line 252-254: The sentence on mitigating bird risk need to be reworded, maybe start with "Considerations also have to be given to deducing the risks..."

Line 262-266: I think here there's potentially more scope to be added in terms of highlighting how national marine geoscience and seabed mapping programmes lend themselves to site identification and early investigation. For example, the INFOMAR programme (see Guinan, J. et al. (2020) 'Infomar data supports offshore energy development and marine spatial planning in the Irish offshore via the emodnet geology portal', Quarterly Journal of Engineering Geology and Hydrogeology, 54(1). doi: 10.1144/qjegh2020-033.) and work by the BGS (see Mellet, C. et al. (2015) Geology of the seabed and shallow subsurface: The Irish Sea. British Geological Survey Commissioned Report, CR/15/057. 52pp.). Also, the Cameron et al (1992) reference is a little dated There are more recent, related studies that can be referenced (e.g. Bot, S. Le et al. (2005) 'Geological characteristics and geotechnical properties of Eocene and Quaternary deposits on the Belgian continental shelf: synthesis in the context of offshore wind farming', Netherlands Journal of Geosciences, 84(2), pp. 147-160.)

Line 292: suggest removed "trapped" after "shallow gas". "...boulders submerged in sediments"

Line 2.93: '0' at the start of a sentence.

Section 3.1.3: Some references I think you should consider here given their relevance:

1) Van Landeghem and Chiverrell (2020) - a good example of how a thorough understanding of geological history helped identify significant challenges at a site in the Irish Sea (i.e. Celtic Array) (Van Landeghem, K. J. J. and Chiverrell, R. C. (2020) 'Bed erosion during fast ice streaming regulated the retreat dynamics of the Irish Sea Ice Stream', Quaternary Science Reviews, 245, p. 106526. doi: <https://doi.org/10.1016/j.quascirev.2020.106526>.)

2) Le Hue et al (2014) - application of geological and geotechnical undertsanding to foundation selection for an offshore wind farm UK (Le, T. M. H. et al. (2014) 'Geological and geotechnical characterisation for offshore wind turbine foundations: A case study of

the Sheringham Shoal wind farm', Engineering Geology. Elsevier B.V., 177, pp. 40–53. doi: 10.1016/j.enggeo.2014.05.005.)

Line 355–357: This sentence is slightly confusing as depositional bedforms may not migrate, same with erosional ones. I'd suggest rewording to something like: "Bed stresses induced by tidal currents, waves or a combination of both, can induce sediment mobility and bedload transport which can lead to erosion of the seabed, or deposition, resulting in a wide range of bedforms being identified on continental shelves."

Line 367–369: "The patterns of turbulence, wave reflection and diffraction, and breaking waves can cause instability and liquefaction of substrate (soil) leading to increased seabed scour, sediment suspension and transport"

Line 377: change "seabed scours" to either just "scour" or "scour holes". Do this throughout the manuscript.

Suggested rewording of this sentence: "The evolution of seabed scour has been documented through interpretation of monitoring data, highlighting variations between sites with different sediment characteristics in terms of seabed morphology and substrate type"

Lines 402–415: Suggested reference here which may be of use is Raaijmakers et al. (2019) available here: <https://offshorewind.rvo.nl/file/download/53711152/Technical+Note+-+Scour+and+Scour+Mitigation+-+Deltares>

It's a comprehensive review and application of various types of sediment mobility studies (Raaijmakers, T. et al. (2019) Morphodynamics and scour mitigation for Hollanse Kust (zuid) Wind Farm Zone)

Line 487: Do you mean 'halite' instead of 'halide'?

Line 533: space between '79%' and 'of'.

Line 557–558: I don't understand this opening sentence. Suggest rewriting.

Line 614–616: suggested rewording: "The dynamic nature of the present-day seabed is well known, but poorly understood. The modelling and monitoring of sediment mobility over different time- and spatial-scales is an urgently needed input into the lifecycle management of offshore windfarms."

Line 620: suggest amend 'change' to 'evolve'.

Line 623–626: McCarron et al (2019) is a good example of this. I suggest you include it (McCarron, C. J. et al. (2019) 'The hiding-exposure effect revisited: A method to calculate the mobility of bimodal sediment mixtures', Marine Geology. Elsevier, 410(June 2018), pp. 22–31. doi: 10.1016/j.margeo.2018.12.001.)

Line 626–627: I suggest rewording this and adding some references. Suggested rewording: "The influence of stratigraphic architecture on present day sediment mobility, including bedform spatial distribution and migration, is under-investigated.

Some potential references:

Couldrey, A. J. et al. (2020) 'Morphological evolution of a barchan dune migrating past an offshore wind farm foundation', Earth Surface Processes and Landforms, 45(12), pp. 2884–2896. doi: 10.1002/esp.4937.

Section 4.2: As highlighted above, I believe there's scope here to highlight and discuss the role of national geoscience and mapping programmes in the delivery of data relevant to offshore wind development. For example see INFOMAR (A review of the Irish Offshore Renewable Energy (ORE) Sector's data and information requirements in the context of the

INFOMAR Seabed Mapping Programme: <https://www.infomar.ie/sites/default/files/pdfs/GDG%20INFOMAR%20ORE%20Review%20Report.pdf>)

Line 760-761: A very valid point about programmes between academia and industry, but it's also important to highlight the role of government and state agencies in this regard also given that many countries use a model whereby it's the government identifies sites for development and takes much of the early risk in site characterisation and development i.e. a centralised approach (e.g. the UK, Netherlands)

Figure 1: Nice figure, but the bathymetry background may make it confusing for some, especially considering you don't have a scale legend, nor do you mention the source. If the bathymetry is irrelevant here, why not leave it out? Otherwise I think you need to include a working scale, or both topography and bathymetry. Also the country boundaries in black are difficult to see against the greyscale data. A different colour or line dash is needed. The source of the windfarm locations is also needed.

Figure 2: should 'energy storage' be in 'Energy System' and not 'wind farm lifecycle'?

Figure 5: A and B need data legends of some sort, is it bathymetry we're looking at? Also, if you mention sediment plumes in the figure caption, it would be worthwhile labelling them on the map with an arrow, to avoid confusion.

Figure 6 is very cool, good job.

Figure 7 is also a nice visual.

QUALITY ASSESSMENT

Q 6 → Quality of generalization and summary	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Q 7 → Significance to the field	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Q 8 → Interest to a general audience	<input checked="" type="checkbox"/>				
Q 9 → Quality of the writing	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

REVISION LEVEL

Q 10 → what is the level of revision required based on your comments:

Minor revisions.