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Offshore Wind Farm Cumulative Effects Assessments – Case Study 2: EIA vs As Built

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PrePARED Report

Offshore Wind Farm Cumulative Effects Assessments – Case Study 2: EIA vs As Built

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Summary

This report identifies substantial differences between Environmental Impact Assessment (EIA) predictions and as-built offshore wind farm (OWF) developments, focusing on parameters influencing cumulative disturbance from pile driving. Analysis of 12 OWFs shows that foundation installation commenced on average 6.5 years after EIA submission, by which time technological developments often meant the original design assumptions at EIA were outdated. On average, only 49% of the number of wind turbine generators (WTGs) and 12% of the number of piles assessed at EIA were ultimately installed, and piling typically occurred later and for shorter durations than predicted. The combination of broad Project Design Envelopes and precautionary worst-case assessment requirements therefore leads to cumulative effects assessments (CEAs) that frequently overestimate disturbance potential. To improve the accuracy and realism of future CEAs, it is recommended that EIAs explicitly report the number of expected piling days (calendar days of activity) for all offshore infrastructure, specify the year(s) in which piling is anticipated, and describe the temporal assumptions used to distribute piling days within the construction period. These refinements would enable more representative cumulative assessments derived from EIA values and improve the robustness of population-level modelling for marine mammals.

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In some instances, data on the actual number of pile driving days were provided by OWF Developers under NDA for this project. For this reason, all OWF have been anonymised in this report. Many thanks to all OWF Developers who contributed their data.

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1. Introduction

To undertake a Cumulative Effects Assessment (CEA) evaluating the potential cumulative disturbance impacts of pile driving across multiple offshore wind farms (OWFs), project-specific data must be compiled for each development included in a CEA. These data are typically sourced from individual OWF Environmental Impact Assessments (EIAs) (where available in the public domain).

Under the Rochdale Envelope approach (where consent is sought for a range of design parameters and installation methodologies), Developers adopt broad Project Design Envelopes (PDEs) at the EIA stage. Consequently, parameters such as the number of wind turbine generators (WTGs), total number of piles, and expected duration or frequency of piling activities can vary substantially between foundation types and relative to the as-built development.

The purpose of this report was to examine the differences between the development scenarios assessed at the EIA stage and the as-built development.

2. Comparison

The data compiled for this report were derived from a combination of sources, including:

- Values presented within publicly available EIA documentation;
- Information reported in publicly accessible Piling Strategy Implementation Reports;
- Data published on project-specific websites; and
- Confidential data provided directly by OWF developers for the purpose of this analysis.

In total, both EIA and as built data were collated for 12 UK OWF that were constructed between 2017 and 2025. The following data were collated for both worst case scenarios presented in EIAs and for as built OWFs: number of WTGs, number of offshore platforms, foundation types, number of piling days, timing of piling, number of piles.

2.1 Time since EIA

The interval between EIA application submission and commencement of WTG foundation installation varies markedly among the 12 OWFs reviewed, ranging from two to eleven years, with a mean duration of approximately 6.5 years across the twelve OWFs examined (Table 2-1). Considering the rapid evolution of offshore wind technology and installation methodologies over such periods, it is unsurprising that the construction details ultimately realised often differ substantially from those anticipated at the EIA stage.

Table 2-1 Interval between EIA application submission year (light green) and the year in which wind turbine generator (WTG) foundation installation commenced (dark green)

OWF	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OWF1	light green							dark green						
OWF2	light green					dark green								
OWF3							light green					dark green		
OWF4							light green			dark green				
OWF5							light green		dark green					
OWF6		light green					dark green							
OWF7				light green					dark green					
OWF8	light green						dark green							
OWF9		light green									dark green			
OWF10		light green										dark green		
OWF11			light green										dark green	
OWF12			light green											dark green

2.2 Construction year(s)

Most EIAs present indicative or "best estimate" timelines for anticipated offshore construction activities. In some cases, these include specific projections for WTG foundation installation (piling) years, whereas others report only the broader offshore construction period. Such estimates are inherently uncertain and are typically dependent upon factors such as the timing of consent determination, confirmation of grid connection, and allocation of Contracts for Difference (CfD).

As illustrated in Table 2-2, the actual WTG foundation installation years for the 12 OWFs examined here showed limited correspondence with those predicted at the EIA stage. Two of the projects (OWF2 and OWF8) did not specify any expected offshore construction timeline or foundation installation schedule in their EIAs, while most others commenced considerably later and over a shorter duration than originally estimated. For instance, the EIA for OWF12 anticipated offshore construction between 2016 and 2021 inclusive, yet WTG foundation piling did not occur until 2025, and then only within a single year.

Consequently, reliance on EIA-derived construction timelines across multiple OWFs is likely to result in substantial overestimation of the piling windows per OWF when used to inform cumulative effects assessments. It is therefore strongly recommended that future EIAs explicitly identify the anticipated year(s) of piling activity rather than only the general offshore construction period. This approach would improve the realism of CEAs by enabling cumulative disturbance analyses to focus on more accurate temporal overlap and duration of piling activities.

Table 2-2 EIA expected WTG foundation installation (green cells) vs real WTG foundation installation years (FI). The cumulative sum of OWFs constructing within a single year is shown for the planned overlap based on EIAs and the final overlap based on as-built years.

OWF	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OWF1					FI	FI					
OWF2			FI								
OWF3									FI	FI	
OWF4							FI				
OWF5						FI	FI	FI	FI		
OWF6				FI	FI						
OWF7						FI	FI				
OWF8				FI	FI						
OWF9								FI	FI		
OWF10									FI	FI	FI
OWF11										FI	FI
OWF12											FI
# OWF piling based on EIAR	1	6	7	7	7	6	6	4	2	0	0
# OWF piling based on reality	0	0	1	2	3	3	3	2	4	3	3

2.3 Number of WTGs

As EIAs are based on a precautionary, worst-case design scenario, the maximum number of WTGs presented at the EIA stage often differs substantially from the final project configuration. Across the 12 OWFs reviewed (Table 2-3), the actual number of WTGs installed represented, on average, 49% of the maximum number assumed within the corresponding EIAs, irrespective of turbine capacity or foundation type. Consequently, any CEAs derived from these maximum design envelopes could have overestimated project-level impacts by approximately a factor of two relative to those associated with the as-built developments.

Table 2-3 Comparison of the maximum number of WTGs expected at EIA stage (irrespective of turbine size or foundation type) compared to the number of WTGs installed

OWF	EIA #WTGs	Real #WTGs	% of EIA
OWF1	339	100	29%
OWF2	277	84	30%
OWF3	85	60	71%
OWF4	150	114	76%
OWF5	54	54	100%
OWF6	332	174	52%
OWF7	360	165	46%
OWF8	325	102	31%
OWF9	300	95	32%
OWF10	300	95	32%
OWF11	200	100	50%
OWF12	200	87	44%
		Minimum	**29%**
		Mean	**49%**
		Maximum	**100%**

2.4 Number of piles

Due to the Rochdale Envelope approach, wide Project Design Envelopes (PDEs) are adopted at the EIA stage, where the expected number of piles can vary drastically between foundation types and compared to what is installed. For example, a fixed foundation OWF with 100 WTGs could be installed on 100 monopiles, or 400 pin piles. There is usually no indication in the EIA as to which is more likely, and therefore when using EIA information to conduct a CEA, decisions must be made as to which scenario to present as the worst case for cumulative impacts. In practice, CEAs often assume the temporal worst-case scenario (that is, the design option associated with the greatest number of piling days, usually corresponding to jacket pin-pile foundations) as this approach aligns with regulatory expectations for precautionary assessment. However, such assumptions may substantially overestimate cumulative disturbance potential.

Many of the EIAs reviewed identified jacket pin-pile foundations as the worst-case scenario for assessment purposes, reflecting the greater number of piles required relative to monopile foundations. In the majority of these cases, however, the as-built OWFs installed WTGs on monopile foundations. As jacket foundations typically comprise three or four pin piles per WTG, the number of piles and associated pile-driving days assessed at the EIA stage were consequently three to four times higher than those realised in practice. For instance, the EIA for OWF7 assessed potential impacts associated with the installation of up to 1,440 WTG pin piles, whereas the constructed OWF used impact piling to install 165 WTGs on monopile foundations, equivalent to approximately 11% of the maximum number of WTG piles considered at EIA. Across the 12 OWFs examined in this study, and including both WTG and offshore platform (OP) foundations, the average number of piles installed using impact pile driving represented only 12% of the maximum numbers presented at EIA (range 0% - 31%) (Figure 2-1, numbers above bars show number of piles).

2.5 Number of piling days

Across many of the OWF EIAs reviewed here (see Figure 2-1 and Table 5-1), the expected number of days on which piling activity could occur was not specified. In several instances, EIAs provided total piling durations by multiplying the number of WTGs by the estimated piling time per foundation. For example, an OWF comprising 100 monopile WTGs with an assumed piling duration of five hours per monopile would be described as requiring 500 hours of piling, equating to 20.8 days when divided by 24 hours per day. However, this figure does not represent the number of *calendar days* on which piling would take place, which is the parameter required for input to population modelling tools such as iPCoD (the interim Population Consequences of Disturbance Model[1]). If one monopile were to be installed per day, the corresponding number of piling days in this example would be 100 not 20.8.

More recent EIAs have included iPCoD population modelling for the project alone, and in some cases, cumulatively with other developments. In such cases, EIAs have typically presented the expected number of piling days, reflecting the model's input requirements. Nevertheless, these EIARs often omit detailed information concerning the temporal distribution of piling days within the overall construction window. This omission constrains the ability to accurately reconstruct piling schedules for use in CEAs of other OWFs. Current practice within UK OWF EIAs generally includes iPCoD-based population modelling of piling-related disturbance impacts, at least for project-alone assessment, as requested by the Regulators and Statutory Nature Conservation Bodies (SNCBs). Consequently, more recent EIAs now tend to provide the finer-scale temporal data necessary for integrating piling activity into cross-project CEAs.

However, even when an EIA specifies the expected number of piling days, these projections frequently diverge from actual construction outcomes. For example, the EIA for OWF3 included iPCoD modelling for both monopile and pin-pile WTG foundations (offshore platforms were excluded). The EIA reported that installation of 85 monopile WTGs would require 87 piling days during the summer period (April 2022 – September 2022), or alternatively, 133 piling days for 85 pin-pile WTGs extending over approximately one year (April 2022 – February 2023). In practice, however, 60 WTG monopiles and two offshore substation (OSP) monopiles were installed over 62 days during the winter period (October 2023 – April 2024).

[1] www.smruconsulting.com/population-consequences-of-disturbance-pcod

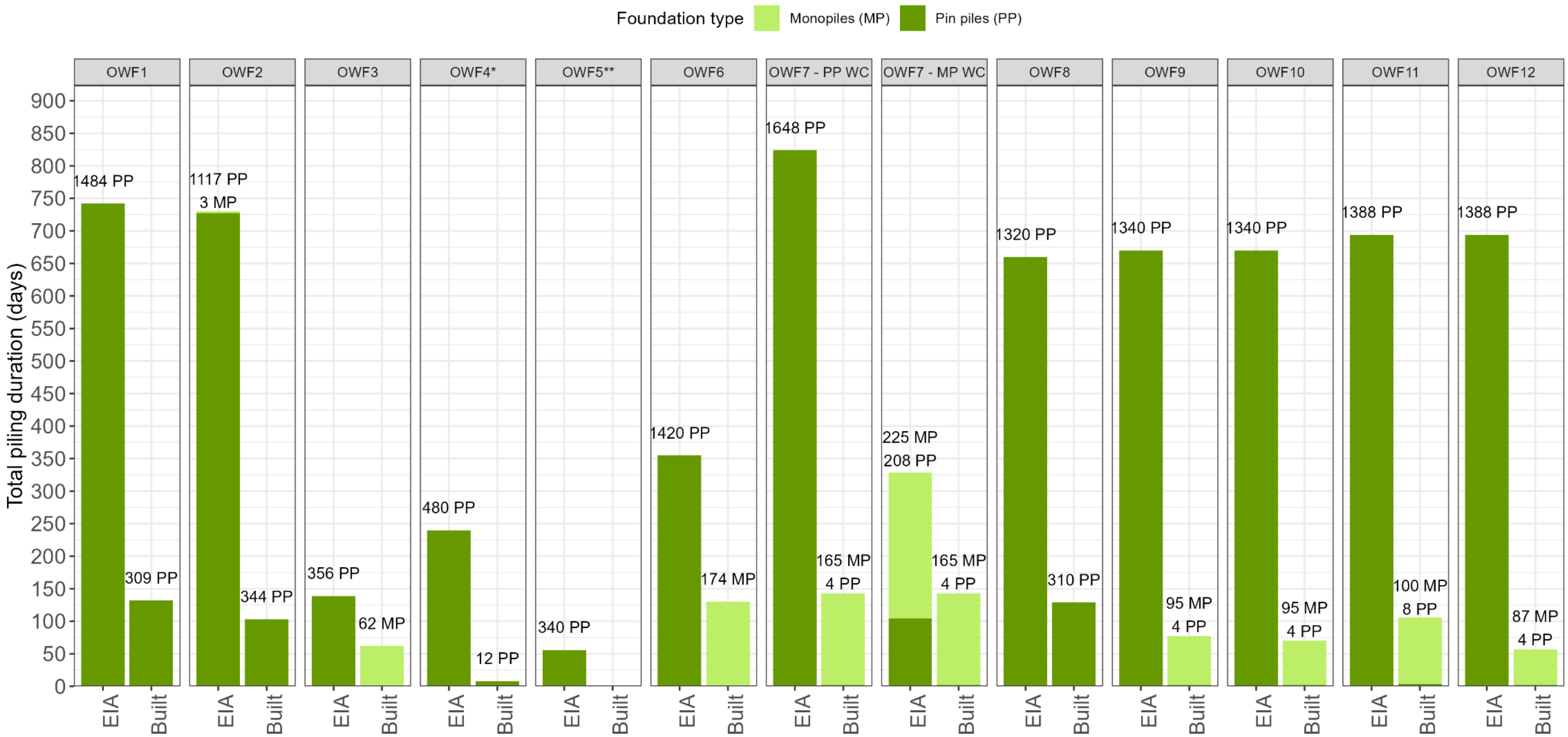

Figure 2-1 Comparison of the total number of piling days in EIA scenarios vs as built construction information for 12 OWFs. Each cell shows the total number of piling days assumed in EIA scenarios and the actual total number of days during which piling happened (Built). The numbers above each bar show the number of foundation piles (planned at EIA or actually piled).

*** OWF4 installed 12 pin piles by impact piling and 114 piles by suction buckets (not displayed). ** OWF5 installed 54 piles by drilling (not displayed). OWF7 shows two scenarios: pin pile worst case scenario assessed in EIA and monopile worst case scenario assessed in EIA.**

3. Summary

This report examines differences between EIA assumptions and as-built OWF developments, focusing on parameters that influence assessments of cumulative disturbance from pile driving. This has shown substantial differences between EIA-stage predictions and as-built OWF developments. The time from EIA submission to foundation installation ranged from 2–11 years (mean 6.5 years), during which technological advancement often meant EIA design assumptions were outdated. On average, only 49% of the maximum number of WTGs modelled at EIA were ultimately installed, on average only 12% of the number of piles assessed at EIA were actually installed with impact pile driving, and foundation installation typically occurred later and for shorter periods than predicted.

Broad PDEs adopted under the Rochdale Envelope approach, combined with worst-case assessment requirements, lead to CEAs that often overestimate disturbance, particularly where multiple foundation options and piling durations are considered.

4. Recommendations

To increase the realism and reliability of future CEAs, it is recommended that:

- EIAs explicitly report the expected number of piling days (calendar days on which piling will occur) for all relevant offshore infrastructure, including WTGs, offshore substations, and ancillary platforms.
- EIAs present the specific year(s) during which piling is anticipated, rather than only the overall offshore construction period.
- EIAs document the temporal assumptions applied in spreading piling days across the piling period (e.g. an even distribution of activity across specific months).

Implementation of these measures would enable more representative assessments of cumulative disturbance potential, support alignment between regulatory expectations and industry practices, and improve the realism of population-level modelling of marine mammal responses to pile driving activities.

5. Appendix

Table 5-1 Summary information for each OWF comparing what was assessed in the EIA vs what was built.

WTG = wind turbine generator, OP = offshore platform, MM = met mast, MP = monopile, PP = pin pile, SBJ = suction bucket jacket, D = drilled. Note, in most EIAs, multiple scenarios were assessed and modelled (different combinations of MP and PP) however not all scenarios are presented here, these are examples only.

OWF		Foundation type		Piling months	Piling		# WTG	# OP//MM	# impact pile driven piles			Total # piling days (associated assumptions)	
		WTG	OP/MM		Start	End			Total	WTG	OP/MM		
OWF1	**EIA**	PP	PP	60	2016	2020	339	8	1484	1,356 WTG PP	128 OP PP	742	NA
	Built	PP	PP	9	May-19	Feb-20	100	3	309	300 WTG PP	9 OP PP	132	NA
OWF2	**EIA**	PP	MM: MP OP: PP	36	Not stated	Not stated	277	6	1120	1,108 WTG PP	3 MM MP 9 OP PP	730	NA
	Built	PP	PP	8	Apr-17	Dec-17	84	2	344	336 WTG PP	8 OP PP	103	NA
OWF3	**EIA**	PP	PP	10	Apr-22	Feb-23	85	2	356	340 WTG PP	16 OP PP	139	NA
	EIA	MP	MP	6	Apr-22	Sep-22	85	2	89	85 WTG MP	4 OP MP	91	NA
	Built	MP	PP	7	Oct-23	Apr-24	60	2	62	60 WTG MP	2 OP MP	62	NA
OWF4	**EIA**	PP	PP	18	2022	2023	120	2	480	480 WTG PP	24 OP PP	240	NA
	Built	SBJ	PP	1	Dec-21	Dec-21	114	1	12	*0 (114 WTG SBJ)*	12 OP PP	8	NA
OWF5	**EIA**	PP	PP	15	Jul-21	Sep-22	54	2	340	324 WTG PP	16 OP PP	56	NA
	Built	D PP	D PP	0	*NA (drilling 20-23)*		54	2	0	*0 (54 WTGs drilled)*	*0 (2 OP drilled)*	0	NA
OWF6	**EIA**	PP	PP	36	2015	2019	322	9	1420	1,328 WTG PP	92 OP PP	355	NA
	Built	MP	PP	12	Jan-18	Apr-19	174	4	174	174 WTG MP	16 OP PP	130	NA
OWF7	**EIA**	PP	PP	60	2017	2022	120	10	1648	1,440 WTG PP	208 OP PP	824	Piling days not stated. Assume 2 PP/day
		MP	PP	60	2017	2022	225	208	433	225 WTG PP	208 OP PP	329	Piling days not stated. Assume 2 PP/day, 1 MP/day
	Built	MP	PP	13	Oct-20	Oct-21	165	1	169	165 WTG MP	4 OP PP	143	NA
OWF8	**EIA**	PP	PP	17	Not stated	Not stated	325	5	1320	1,300 WTG PP	20 OP PP	660	Piling days not stated. Assume 2 PP/day
	Built	PP	PP	10	Apr-18	Jan-19	102	1	310	306 WTG PP	4 OP PP	129	NA
OWF9	**EIA**	PP	PP	72	2016	2021	300	10	1340	1,200 WTG PP	140 OP PP	670	Piling days not stated. Assume 2 PP/day
	Built	MP	PP	15	Jul-22	Nov-23	95	1	99	95 WTG MP	4 OP PP	77	NA
OWF10	**EIA**	PP	PP	72	2016	2021	300	10	1340	1,200 WTG PP	140 OP PP	670	Piling days not stated. Assume 2 PP/day
	Built	MP	PP	25	Apr-23	Apr-25	95	1	99	95 WTG MP	4 OP PP	70	NA
OWF11	**EIA**	PP	PP	72	2016	2021	200	12	1388	1,200 WTG PP	188 OP PP	694	Piling days not stated. Assume 2 PP/day
	Built	MP	PP	15	May-24	Jul-25	100	1	108	100 WTG MP	8 OP PP	106	NA
OWF12	**EIA**	PP	PP	72	2016	2021	200	12	1388	1,200 WTG PP	188 OP PP	694	Piling days not stated. Assume 2 PP/day
	Built	MP	PP	8	Feb-25	Sep-25	87	1	91	87 WTG MP	4 OP PP	**57**	NA