Offshore Wind Generation Costs - Peer Review

A report for DESNZ

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Executive Summary

Grant Thornton and BVG Associates have undertaken a review of offshore wind costs data, owned and utilised by DESNZ and derived in a project commissioned to Arup in 2024 (Arup 2024). Arup 2024 surveyed offshore wind (OFW) developers to gather OFW costs and technical assumptions, and filtered them to produce low, medium, and high scenarios for each cost and technical assumption category. These scenarios were compared against wider benchmarks.

The design and implementation of the methodology were found to be broadly suitable for purpose. Surveying developers for first-hand, relevant data is found to be the best way to estimate costs and technical assumptions for offshore wind, which are often commercially sensitive. The well understood challenge of persuading developers to disclose commercially sensitive data naturally leads to a limited sample size and hence, to significant uncertainty in the resulting information. This limited sample size could also lead to bias from a higher prevalence of certain project characteristics that could influence the costs and technical assumptions, which is judged as being likely to have occurred in this instance. As a result, several recommendations for change have been made. A greater number of valid responses and resulting data points would alleviate this issue. As highlighted in Arup 2024, there is limited relevant data, partly due to the OFW industry being subjected to significant macroeconomic shifts between 2020 and 2022. Any data prior to 2023 was, therefore, considered out of date and unusable. Assuming we do not see similar shifts in the future, valid data can be gathered over a longer period and for more projects.

We found the filtering process appropriate for refining the data received from survey responses, although disagree with the application of filter sets in a small number of instances. Two of these instances have no effect on the results and only increase their robustness. There was only one instance (regarding decommissioning costs) where we disagreed with the logic in the filter set selection, which does have a significant impact on results.

We found the literature review to be mostly suitable, though we note the limitations of a literature review for OFW cost validation, given the paucity of reliable data in the public domain.

We establish our own set of benchmarks for comparison against Arup 2024 using our extensive data sets obtained from developers and suppliers. We used analysis of the UK OFW pipeline to ensure our benchmarks were representative of upcoming UK projects, which allowed us to assess any potential bias present in the Arup 2024 sample.

We make several recommendations for changes. For the most part, these changes are not due to concerns regarding incorrect assumptions within the Arup 2024 report. The methodology of this report is logical, however, the confidence in the report's results is subject to the representativeness of the data that the survey respondents provided. Grant Thornton and BVGA believe the survey data to be biased towards higher costs due to the high prevalence of projects in the sample that are more costly than a typical UK project.

Table 1 summarises our recommendations across all reviewed cost and technical assumption categories. All costs are in 2023 prices (£ GBP).

Table 1 Summary of review of all categories

Category	Scenario	Arup 2024	Recommendation	Notes on recommendation
Development costs (£/kW)	High	308	231	• Uncertainty from small sample size and bias from projects sample data may be present, evident by maximum result being three times greater than minimum. • BVGA in-house and literature benchmarks consistently lower.
	Medium	216	162	
	Low	104	No change	
Capital costs (£/kW)	High	3,101	No change	• Uncertainty from sample size and bias from high prevalence of deeper-water and higher-distance from shore projects potentially skewing results. • BVGA in-house and relevant literature benchmarks consistently lower.
	Medium	2,823	2,540	
	Low	2,415	2,174	
Infrastructure costs (£/kW)	High	1,029	No change	• Bias arising from high prevalence of higher-distance from shore and HVDC projects in the survey data. • Limited sample size of survey likely means that projects in the UK pipeline with the shortest export distances are not represented. • A very low range in low and high results despite a very large range in project export distances. • BVGA in-house and relevant literature benchmarks consistently lower at lower export distances.
	Medium	937	750	
	Low	802	561	
OMS costs (£/kW/year)	High	64.6	No change	• No change.
	Medium	46.5	No change	
	Low	30.5	No change	
Insurance costs (£/kW/year)	High	9.7	No change	• No change.
	Medium	8.6	No change	
	Low	8.0	No change	
Connection and UoS costs (£/kW/year)	High	132.9	No change	• No change. • Deeper analysis of pipeline and expected grid connection scenarios could provide Use of System costs more representative of average UK project.
	Medium	83.4	No change	
	Low	35.2	No change	
Decommissioning costs (£/kW)	High	140	507	• Significantly increase all scenarios by selecting Filter Set 3.
	Medium	86	255	

Category	Scenario	Arup 2024	Recommendation	Notes on recommendation
	Low	59	110	• We do not believe non-current costs should be included simply because decommissioning is further into the future. • BVGA in-house and literature benchmarks were higher than filtered results.
Capital cost trajectory (cost change after 10/20-year periods)	High	+8% / +5%	-8% / -12%	• BVGA in-house benchmarks and literature review expectations are that OFW will continue to decrease in real terms through increases in turbine size, continued learning-by-doing, and further technological innovation. • Modelled cost reduction using industry standard learning rates projects continued cost reduction over time. • It is our understanding that DESNZ has a process to adjust costs in the event of commodity price shifts.
	Medium	0% / -7%	-12% / -17%	
	Low	-8% / -18%	-15% / -21%	
OMS cost trajectory	Medium	-23% / -35%	-13% / -19%	• Arup 2024 trajectory is representative of approximately a 15-16% learning rate which is significantly higher than industry expectations.
Development period (years)	High	15	No change	• No change to timings, only spend profiles.
	Medium	7	No change	
	Low	7	No change	
Construction period (years)	High	5	No change	• This is supported by BVGA in-house and literature review benchmarks. Small sample size of the survey may have skewed results. • Multiple real-world examples of UK projects being constructed in 2 years. We do not suggest using a value this low as it is not representative of project spend which this technical assumption is ultimately used for. Capital spend will occur prior to the start of offshore construction. • We do suggest change to construction spend profiles.
	Medium	5	3	
	Low	4	2	
Operating period (years)	High	35	No change	• This is supported by BVGA and literature review benchmarks. Small sample size of the survey may have skewed results.
	Medium	35	30	

Category	Scenario	Arup 2024	Recommendation	Notes on recommendation
	Low	35	28	• Given the uncertainty around project lifetimes due to lack of commercial projects reaching end-of-life, it could be naïve to assume such certainty across all scenarios.
Development cost spend profile	High	6.7% each year	Custom profile (Table 2)	• Development spend tends to be weighted towards the end of the development period rather than evenly distributed, especially over very long development periods.
	Medium	14.3% each year	Custom profile (Table 2)	
	Low	15.4% first six years, 7.7% final year	Custom profile (Table 2)	
Capital cost spend profile	High	19% first five years, 4.8% final year	Custom profile (Table 2)	• Capital cost spend tends to be weighted towards the end of the construction period rather than evenly distributed, especially over long construction periods. However, capital spend usually begins before the construction period begins. To align capital spend profiles to construction periods, any spend prior to the beginning of the construction period has been attributed to Year 1 of the construction period.
	Medium	21.6% first four years, 13.5% final year	Custom profile (Table 2)	
	Low	25% each year	Custom profile (Table 2)	

Table 2 Recommendations for development and capital spend profiles

Category	Scenario	Spend in year of period (%)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Development spend profile	High	2	2	2	2	2	5	5	5	5	10	10	10	15	15	10
	Medium	10	10	15	15	20	20	10	-	-	-	-	-	-	-	-
	Low	5	10	10	20	20	20	15	-	-	-	-	-	-	-	-
Capital spend profile	High	10	15	20	25	30	-	-	-	-	-	-	-	-	-	-
	Medium	35	30	35	-	-	-	-	-	-	-	-	-	-	-	-
	Low	60	40	-	-	-	-	-	-	-	-	-	-	-	-	-

Introduction

The Department for Energy Security and Net Zero (DESNZ) requires accurate offshore wind (OFW) generation cost and technical assumptions data that form the basis of its levelised cost of energy (LCOE) calculations. DESNZ uses these generation costs and LCOE calculations for electricity system modelling and to inform future policy. In response to recent macro-economic and market conditions, an update to the OFW cost and technical assumptions was required. In 2024, DESNZ commissioned Arup to develop a methodology for updating the generation costs and technical assumptions (Arup 2024). As part of due process, a peer review is required to give assurance regarding the robustness of the methodology and results.

DESNZ commissioned Grant Thornton and BVG Associates (BVGA) to conduct this peer review and author this report.

Scope

The scope of the peer review was to assess the:

- Overarching methodology,
- Outputs from amalgamated survey data against BVGA in-house benchmarks,
- Filter criteria and filter options selected, and
- Literature review.

The following elements are outside the scope of this review:

- Floating offshore wind costs and technical assumptions,
- The design of the original survey and subsequent analysis of individual responses,
- Gross and net load factors including associated loss factors, and
- DESNZ's LCOE model and calculation methodology.

Review

General review of Arup 2024 methodology

The purpose of this general review is to:

- Summarise the Arup 2024 methodology to provide context for the individual cost and technical assumptions category reviews, and
- Review parts of the Arup 2024 methodology that apply equally to all categories at a high level.

Developer surveys

Generation costs and technical assumptions are derived from responses given by OFW developers to a survey conducted as part of Arup 2024. The surveys asked developers to provide details of their OFW projects. Details included development costs, capital costs, key project timings, technical assumptions, and project characteristics. Arup 2024 states that the surveys were designed to ensure responses were relevant and consistent. Generally, we find this a suitable method for deriving such data, particularly for costs.

Offshore wind is a relatively niche industry and costs are market specific. It is also a rapidly maturing industry that is sensitive to macro-economic conditions. Developers usually do not publish costs and other commercially sensitive project data in the public domain. Locating relevant, reliable, and up to date data in the public domain is therefore difficult. The downside of a survey-based method is that there are few developers available to survey and, furthermore, persuading them to disclose sensitive data can be a challenge. The small sample size of data in Arup 2024 likely reflects this. This small sample size introduces uncertainty and bias, as outlier data points will hold significant weight, and the characteristics of the projects surveyed may not be representative of the wider UK OFW market.

We discuss where we believe this bias could factor into the results in the subsequent category sections. Further bias could be introduced by developers providing inaccurate data, where doing so might influence policy decisions in a way that benefits them. It is not feasible to assess if this is the case, especially with limited visibility of survey data and project characteristics, so no recommendations are made on this basis.

Responses for each cost and technical assumption category were passed through a filter which is explained further below. The mean of the filtered responses generally provided the mid-case output, and the maximum and minimum of the filtered results were used to establish high and low cases (either absolute maximum/minimum or 5th/95th percentiles depending on the category).

Due to non-disclosure agreements with survey respondents, Grant Thornton and BVGA did not have access to the raw survey response data. As agreed with DESNZ, the response data could not, therefore, be individually reviewed, nor tied to site characteristics that may have a significant impact on costs, such as water depth. We were only able to access the amalgamated results for all filter sets in each category. Some project-level data could be inferred from the source report and the filtered results and this insight was then used in our assessment.

Filters and filter criteria

To analyse the data, six filter sets, each with a selection of filter criteria, were created and the survey response data was passed through. These filter sets are shown in Table 3 (published in Arup 2024).

Table 3 Filter criteria and filter sets

Filter criteria	Filter set 1	Filter set 2	Filter set 3	Filter set 4	Filter set 5	Filter set 6
Non-zero response	X	X	X	X	X	X
Technology specific	X	X	X	X	X	X
Non-duplicate	X	X	X	X	X	X
Reasonability test		X	X	X	X	X
Current costs			X	X	X	
Arup 2024 benchmarks				X		X
Literature review benchmark					X	

The first three criteria ensure all data points are unique, non-zero, and for OFW. The reasonability test allows for responses to be more subjectively assessed and included or excluded if there is sufficient justification. The current costs criteria excludes data from 2022 and any prior years. This eliminates out of date data that is not representative of current market conditions. The two final criteria provide more objective benchmarks with which to compare the survey responses.

The filtering choice for most categories aligned with either Filter Set 2 or 3. All but one cost category uses a filter set of 3 or stricter, ensuring results are current. This is important as it was primarily costs that were affected by macroeconomic shifts between 2020 and 2022 and hence, cost data from before 2023 can be considered out of date. Other technical assumptions, such as project timings, should not be affected by such market shifts so older data can reasonably be considered relevant.

Generally, we found the filter criteria and resultant filter sets logical and suitable. We have raised a challenge regarding the application of certain filter sets in two instances, which we discuss in the relevant cost and technical assumptions sections.

Literature review

A literature review was conducted in the Arup 2024 report to give additional insights into OFW developments.

Literature review benchmarks were included as a filter criterion for Filter Set 5, although this filter set was not used. From what is presented in the Arup 2024 report and accompanying model, the literature review did not directly inform any of the costs or technical assumptions used. Instead, the literature review appears to qualitatively validate costs, cost trends, and resultant LCOEs.

Generally, the selection of reports reviewed was suitable. We found that:

- The reports were from well-regarded organisations.
- The reports were all published in 2023 or 2024, implying that they reflect the dynamic market conditions OFW has been subjected to in recent years and the impact of this going forward. Despite the reports being recent, they do not detail how they arrive at

their costs and thus we cannot be sure that the costs they present are representative of costs “locked-in” during 2023 or 2024.

- Some of the literature sources were not specific to the UK market or were tailored for the US market which faces significantly different challenges and costs than the UK market.

We acknowledge that a literature review of offshore wind costs and technical assumptions is difficult as relevant and recent data is commercially sensitive, meaning that what is available in the public domain is limited and broadly unreliable for a study of this nature.

Comments on literature review specifics are included in the following cost and technical assumption sections. Arup 2024 also used the reviewed literature to set hurdle rates for its LCOE estimates but these are not considered in this peer review as agreed with DESNZ.

List of literature and documents referenced in this report

1	IRENA’s *Renewable Power Generation Costs* (2023) (IRENA 2023)
2	IRENA’s *Renewable Power Generation Costs* (2024) (IRENA 2024)
3	Lazard’s *Levelized Cost of Energy +* (2024) (Lazard 2024)
4	Lazard’s *Levelized Cost of Energy +* (2025) (Lazard 2025)
5	NREL’s *Cost of Wind Energy Review: 2024 Edition* (2024) (NREL 2024)
6	National Energy System Operator’s *Five-Year View* (2024) (NESO 2024)
7	OREC’s *End-of-life planning in offshore wind* (2021) (OREC 2021)

Approach to benchmarking and recommendations

BVGA benchmarks

BVGA developed a set of benchmarks with which to test the results for each cost and technical assumption category.

For cost categories, we developed a database of UK fixed - bottom OFW projects we expect to have commercial operation dates ranging from 2028 to 2032. Only one of these projects currently has a Contract for Difference (CfD). This date range aligns with that which Arup 2024 considered “current”. We note that different assumptions on construction period will have an impact on the expected CODs of these projects. However, we expect that this impact is within the margin of uncertainty when dealing with OFW costs, so further adjustments to align lock-in dates, construction periods, and resultant CODs were not made. This selection of projects provides sufficient data points for robust analysis in the short term, ensuring the costs are representative of upcoming projects. This delivered a list of 20 projects. It is not known if any of the projects included in the BVGA data overlapped with those in the Arup 2024 survey responses.

For each project, we gathered project specific characteristics including water depth, capacity, foundation choice, and distance to shore from data sources such as project websites, 4C Offshore, and our own internal data sets. When foundation choice was unknown, we assumed any projects with maximum water depths over 55 m would use jacket foundations, with shallower depths using monopiles. We chose this threshold as it is supported by our cost modelling, where we see a crossover point in cost advantage at this point. Additionally, while projects of this depth (such as Seagreen, at 42-58 m depth, and NNG, at 45-55 m depth) typically use jackets, some deeper water projects plan to use monopiles (Inch Cape, at 34-64 m depth). There is no definitive cutoff for a water depth where a jacket foundation must be used. Local ground conditions, local supply chain, and further technological development of monopiles will mean there is a range of depths where either monopiles or jackets could be feasible.

We modelled costs for the 20 projects using BVGA's internal cost model. The model comprises around 30 sub-models that vary with one or more key project characteristics. The outputs of each sub-model are validated against data supplied to us by developers, other industry benchmarks, and recent industry engagement. We took the median of the modelled data to establish our medium case then used minimum and maximum results to establish low and high scenarios, respectively. This method provides results representative of an upcoming "typical" UK project with the "high" case representing deep-water, distant projects using jacket foundations and "low" case representing shallower, closer sites deploying monopiles. The medium case is approximately representative of a monopile project in 46 m water depths and 75 km from shore with a HVAC export system We believe the data set, on average, to represent less expensive projects that the Arup 2024 sample. For example, only 30% of the projects in our data set have waters depths of 60 m+ whereas these account for half of the projects in the Arup 2024 sample. For TNUoS charges, we established median, minimum, and maximum charges for a UK project based on National Energy System Operator (NESO) published rates for wider and onshore charges, and the range of offshore charges for existing projects[1].

For the technical assumptions we benchmarked, which were limited to project timings in this review, we used two data sets: 4C Offshore's database and a recent project undertaken by BVGA that involved surveying OFW developers regarding timings for UK projects. Again, we took the median of the data to establish our medium scenario and used minimum and maximum results to give us low and high scenarios, respectively.

General approach to recommendations

We make recommendations for changes to costs and technical assumptions.

Recommendations are made when:

- We believe the survey results to be inaccurate due to uncertainty from the small sample size,
- We believe the survey results to be inaccurate due to bias from the selection of surveyed projects, or
- We believe that an incorrect filter set has been selected.

We quantify recommendations using:

- The filtered results from surveys,
- BVGA's internal benchmarks,
- Literature review benchmarks, and
- Results from other filter sets that were not selected.

Arup 2024 results and BVGA's internal benchmarks were given the most weight with literature review benchmarks being used to justify the direction of the change rather than magnitude. A middle ground was sought to reflect this and the uncertainty within any of the data sources. No objective mathematical process was followed to quantify whether changes were required, or their magnitude. Instead, expert opinion was applied on a category-by-category basis, considering how much of an impact bias could have on results, the robustness of our internal benchmarks, and the suitability of the literature benchmarks. Recommendations were rounded to a percentage when the recommendation was between the Arup 2024 value and BVGA benchmarks.

[1] https://www.neso.energy/industry-information/charging/tnuos-charges

Review of costs and technical assumption categories

Pre commercial operation date costs

This section covers:

- **Development costs**: Costs incurred up to the point wind farm construction begins, including technical design, regulatory, licensing, and public consultation costs.
- **Capital costs**: Costs from the start of construction to commercial operation date and include the supply and installation of turbines, foundations and other components. They exclude supply or installation costs of the export system, such as the offshore substation, onshore substation, or export cables.
- **Infrastructure costs**: Costs associated with the power export system, including the supply and installation of the offshore substation, onshore substation, and export cables.

Table 4 Pre commercial operation date costs comparison

Category	Scenario	BVGA benchmark	Arup 2024	Difference
Development costs (2023 £/kW)	High	217	308	+42%
	Medium	144	216	+50%
	Low	110	104	-5%
Capital costs (2023 £/kW)	High	3,063	3,101	+1%
	Medium	2,524	2,823	+12%
	Low	2,148	2,415	+12%
Infrastructure costs (2023 £/kW)	High	1,109	1,029	-7%
	Medium	678	937	+38%
	Low	472	802	+70%

Comparison to BVGA benchmarks

Development costs

Arup 2024 selected Filter Set 3 to filter development costs from surveys, meaning the costs must be current and pass their reasonability test, resulting in five data points.

The filtered Arup 2024 results are significantly higher than BVGA's internal benchmarks, with the medium case being 50% greater and the high case 42% greater. The low case is in reasonable agreement.

There is the possibility of bias impacting the filtered results. A low sample size in the survey data could give weight to outlier responses, and the prevalence of deep-water, distant sites in the survey responses could introduce planning, design, and surveying complexities that are not representative of a typical UK project. We believe the prevalence of such sites in the survey results is disproportionately high compared to the future UK pipeline. Project size can also impact costs, but the average project size in our internal benchmark data set (1,290 MW) is comparable to that of Arup 2024 (1,297 MW) so we do not believe this to have impacted results. The smaller projects in our sample are comparable to that of Arup 2024. The largest project in our sample is reasonably larger than that of Arup 2024 but there is diminishing returns in economies of scale once projects get very large, so we do not believe this to have impacted the cost comparison.

Capital costs

Arup 2024 also selected Filter Set 3 to filter capital costs, resulting in six data points. Filter Set 5, which applies the same criteria as Filter Set 3 with the additional requirement of literature review benchmark range, produces the same results with the same number of data points. Although it has no material effect on the results, we would expect the narrower filter set to be used to demonstrate the results have an additional layer of validity.

The filtered results are reasonably well aligned with BVGA benchmarks; being about 12% higher in the medium and low scenarios, and in close agreement for the high scenario.

The observed discrepancies could again be explained by bias in the sample data, with half of the projects being in 60 m+ water depths and using jacket foundations, whereas BVGA's data has only 40% of projects expected to use jackets and 30% being in at least 60 m water depths. Additionally, about half of the sample size was distant enough to justify the use of HVDC technology while BVGA's data has only 15% of projects further than 70 km from shore, which represents a conservative estimate for HVDC use. We do not believe that project size discrepancies between the two benchmarks sets cause bias one way or another, as project sizes are comparable, as described earlier.

Infrastructure costs

Arup 2024 also selected Filter Set 3 to filter infrastructure costs, resulting in six data points.

While the Arup 2024 results all fall within the range of BVGA's internal benchmarks, the high, medium, and low results do not align. Infrastructure costs are even more dependent on project characteristics than capital costs, being largely determined by offshore and onshore export distance. The Arup 2024 report states a range of 30 to 160 km export distances for the projects surveyed. BVGA's sample range is 20 to 155 km. We therefore expect no bias in the maximum result but should expect the BVGA low benchmark to be lower than that of Arup 2024. Additionally, as above, the sample of projects surveyed were on average more distant than a typical project in the UK pipeline, with half of the sample being distant enough to warrant a HVDC export system. This bias towards more distant projects could justify why the medium case is 38% higher than our internal benchmarks.

What the literature review says

Development costs

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 does not provide development costs directly, but reports that development costs make up 3.5 % of all installed costs. For UK projects, it reports 5th, 50th, and 95th percentile installed costs to be £2,641 /kW, £2,760 /kW, and £2,941 /kW, respectively (after converting to 2023 GBP at rate of 0.8043 GBP = 1 USD). This gives development costs of approximately £92 /kW, £97 /kW, and £103 /kW. However, the report notes a range of 2-9% of total installed cost, signifying the broad range of development costs projects could incur.

Of the reviewed literature in our supplemental review:

- IRENA 2024, which had no significant change in development costs from 2023 estimates.
- NREL 2024*,* which estimates £100 /kW for OFW project development (converting 2023 USD to 2023 GBP at 0.8043 GBP = 1 USD). This report is geared towards the US market which is generally more expensive than the UK due to less experience and a more complex permitting process.

Capital costs

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 reports 5th, 50th, and 95th percentile capital costs to be £2,166 /kW, £2,263 /kW, and £2,411 /kW for UK projects, after removing development and export system costs.
- Lazard 2024 reports a range of £2,929 /kW to £4,491 /kW (converted to 2023 GBP) giving a mid-point of £3,710 /kW. However, this report is heavily geared towards the US market. Our experience is that US projects incur significantly more cost due to risk premiums being applied to components due to the high uncertainty in the market, high-cost local labour, relative inexperience in OFW, tariffs, and transportation costs for imported components. Also, the report does not split out development or export system costs. Therefore, this is not a suitable benchmark for generation costs for UK projects.

Of the reviewed literature in our supplemental review:

- IRENA 2024 had no significant change in capital costs from 2023 estimates.
- NREL 2024 estimates £3,566 /kW for OFW project capital costs (converting 2023 USD to 2023 GBP at 0.8043 GBP = 1 USD). Again, this report is geared towards the US market which is generally more expensive than the UK and not a suitable benchmark for a UK project.
- Lazard 2025 decreased its low estimate by 10% and increased its high estimate by 10% since its 2024 report but faces the same issues that cause the 2024 numbers to be unsuitable benchmarks for UK projects.

Infrastructure costs

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 reports 5th, 50th, and 95th percentile capital costs to be £392 /kW, £410 /kW, and £437 /kW for UK projects using its mid-point estimate of 14.5% for UK projects. The report does not tie these costs to an export distance but suggests a weighted average export distance of 35 km for the European projects included. However, the report highlights the wide range of infrastructure costs, estimating anywhere between 8 to 24% to total CAPEX. Applying these to its low and high UK CAPEX estimates gives a potential range of £649 /kW to £723 /kW.

Of the reviewed literature in our supplemental review:

- IRENA 2024 had no significant change in capital costs from 2023 estimates.
- NREL 2024 estimates £411 /kW for a project with 50 km export distance.

Recommendations

Development costs

For development costs, we recommend a reasonable reduction, informed by:

- Our in-house benchmarks being significantly lower, and
- Literature review benchmarks being significantly lower, including NREL's despite this being geared towards more expensive US projects.
- The small sample size of five data points introducing uncertainty. The maximum results from the survey are about three times greater than the minimum, showing the wide range of results from responses.

It is reasonable to give weight to the survey data as we can be assured it is at least first-hand data from developers that is relevant to UK projects in the desired timeframe. We therefore recommend keeping the low scenario as is and reducing both mid and high scenarios by up to 25%, resulting in minimum low, mid, and high scenarios of £104 /kW, £162 /kW, and £231 /kW, respectively.

Capital costs

For capital costs, we recommend a small reduction, informed by:

- Consistently lower in-house benchmarks.
- Relevant literature review data also substantially lower.
- Potential bias introduced from the site characteristics of the surveyed projects. Half of the survey data set projects being in 60 m+ water depth, using jacket foundations, and being far from shore is potentially representative of a typical UK project going forward. Our in-house benchmarks for such projects are very close to the high scenario results from the survey, suggesting alignment between the costing methodology but misalignment between the underlying project characteristics in the data sets. Distant, deep-water projects are less prevalent in our sample of projects, as previously described, which likely explains the discrepancy between low and mid scenarios.

Again, with the intention to give weight to survey data, we recommend reducing low and mid scenarios by up to 10% while keeping the high scenario as is. This results in minimum low, mid, and high scenarios of £2,174 /kW, £2,540 /kW, and £3,101 /kW, respectively.

Infrastructure costs

For infrastructure costs, we recommend a reduction in the medium and low scenarios, informed by:

- The likelihood of bias arising from the prevalence of distant projects in the surveyed data, increasing the medium result.
- The limited sample size meaning that the lowest export distance of the surveyed projects is not representative of the lowest within the UK pipeline and therefore the low result may be an overestimation. We find the high result to be representative of the upper bound of UK project export distances.
- The relatively low spread of results despite a very large range in surveyed project characteristics. The Arup 2024 report states that the maximum export distance from the survey was 160 km and a minimum of 30 km, yet medium and low results are only 10% and 26% lower when accounting for 5th and 95th percentile adjustments. We would expect a typical UK project, estimated in our pipeline analysis to have an average export distance of about 70 km, to be more than 10% lower than the 160 km estimate, assuming this maximum distance is representative of the maximum

infrastructure cost in the survey results. Additionally, we would expect a project of only 30 km to have infrastructure cost more than 26% lower than a 160 km project.
- The literature being consistently lower for projects with lower export distances (35 km and 50 km).

Again, with the intention to give greater weight to survey data, we recommend reducing low and mid scenarios by up to 30% and 20% respectively, while keeping the high scenario as is. This results in minimum low, mid, and high scenarios of £561 /kW, £750 /kW, and £1,029 /kW, respectively.

Post commercial operation date costs

This section covers:

- Operations, maintenance and servicing (OMS) costs: Costs during the operational n phase of the project, including planned and unplanned maintenance, spares, consumables, and variable OMS costs.
- Insurance: Insurance costs for generation assets during project lifetime.
- Network Use of System (UoS) Charges: Cost for connecting and using transmission and distribution networks.
- Decommissioning costs: Cost to decommission a project.

Table 5 Post commercial operation date costs comparison

Category	Scenario	BVGA benchmark	Arup 2024	Difference
OMS costs (2023 £/kW/year)	High	54.5	64.6	+19%
	Medium	41.0	46.5	+14%
	Low	33.5	30.5	-9%
Insurance costs (2023 £/kW/year)	High	13.1	9.7	-26%
	Medium	9.8	8.6	-13%
	Low	8.0	8.0	-1%
Network UoS charges (2023 £/kW/year)	High	158.7	132.9	-16%
	Medium	51.9	83.4	+61%
	Low	12.5	35.3	+182%
Decommissioning costs (2023 £/kW)	High	396	140	-65%
	Medium	310	86	-71%
	Low	255	59	-77%

Comparison to BVGA in-house benchmarks

OMS costs

Arup 2024 selected Filter Set 4 to filter OMS costs from the surveys, meaning the costs must be current, pass their reasonability test, and be within its benchmark range, resulting in six data points. The filtered results are generally higher than our in-house estimates, with the low scenario being lower. The possibility of bias through project characteristics (depths, distances) seen in capital costs will not be as impactful on OMS, although some cost increase may be expected for distant projects or those with more difficult access due to metocean conditions. Additionally, our in-house benchmarks are supported by relatively few data points in comparison to our sample size for development and capital costs.

Insurance costs

Arup 2024 selected Filter Set 2 to filter insurance costs, resulting in four data points. Despite these not being current data points, Arup 2024 states that they align with the one point that is current. The filtered results are generally lower than BVGA's benchmarks, albeit our benchmarks are made up of few data points.

Network UoS costs

Arup 2024 selected Filter Set 3 to filter Network UoS charges, resulting in five data points. BVGA do not keep benchmark data for UoS charges, instead using charging schedules provided directly by the NESO. The benchmarks provided are therefore somewhat representative of maximum, minimum, and average charges possible for UK OFW projects, noting that exact charges are project specific. The values derived from the survey results all fall within this range.

Decommissioning costs

Arup 2024 selected Filter Set 6 to filter decommissioning costs from surveys meaning the costs must pass their reasonability test and fit with in their benchmark range, resulting in five data points. The filtered results are significantly lower that our in-house estimates. Notably, these are the only results that are not required to be "current" with the logic that cost predictions so far into the future are not relevant to the "current" criteria. We do not agree with this logic. Decommissioning costs are driven by the same factors as installation costs, mainly vessel rates. We have seen vessel costs increase at a rate well ahead of inflation since 2020, and our market engagement suggests that they will not fall back to pre-2020 levels in real terms. Therefore, we expect future decommissioning costs to experience this same shift in costs that installation has faced, which would mean that decommissioning values estimated more than two years ago are effectively out of date and should be excluded. Expected decommissioning costs have increased as a result of macroeconomic shifts, continued increases in vessel charter rates, and likely a better understanding of decommissioning requirements. We suggest that Filter Set 3 is used (reasonability and current filters passed). This increases low, medium, and high results to £110, £255, and £507 /kW which are better aligned with BVGA's benchmarks.

What the literature review says

OMS costs

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 reports total OMS costs of £58 /kW/year for UK projects. However, these figures include operational phase insurance, export system OMS costs, and use of system charges, if applicable, which are separated in this analysis. Using IRENA 2024's estimate of 18% of OMS costs being attributed to insurance and export system OMS gives £47 /kW/year.
- Lazard 2024 estimates fixed OMS costs of £47 to 71 /kW/year, giving a mid-point of £59 /kW/year. This cost includes insurance which, once deducted (18% of total OMS), aligns well with current results (£49 /kW/year).

Of the reviewed literature included in our supplemental review:

- IRENA 2024 provides updated and country-specific OMS costs, although again noted few data points backing up the results. All in OMS costs ranged from £65 /kW/year. Removing insurance and export system O&M reduces this to £54 /kW/year.
- Lazard 2025 does not update OMS cost assumptions.
- NREL 2024 estimates fixed OMS costs of £93 /kW/year (including OMS of the export system).

Insurance costs

Of the reviewed literature in the Arup 2024 report, none specified operational insurance costs specifically.

Of the reviewed literature included in our supplemental review:

- IRENA 2024 estimates that insurance makes up 11% of OMS costs resulting in P5, P50, and P95 estimates of £6.5, £8.8, and £10.4 /kW/year.
- NREL 2024 estimates insurance costs to be £15 /kW/year.

Network UoS costs

Of the literature reviewed in the Arup 2024 report:

- NESO 2024 provides a forecast for UoS charges from 2025-30. Our in-house calculations are based on these estimates.

Given that NESO 2024 provides the most relevant and accurate data available, no other literature was reviewed.

Decommissioning costs

Of the reviewed literature in the Arup 2024 report, none specifically reference decommissioning costs.

Of the reviewed literature in our supplemental review:

- NREL 2024 estimates decommissioning costs of £117 /kW.
- OREC 2021 estimates decommissioning costs of £334 /kW.

Recommendations

OMS costs

For OMS costs, we recommend no change, informed by:

- The current results being less sensitive to bias from a project sample that is representative of a typical UK project and therefore more reliable.
- A lack of relevant or robust data in the literature review. Available cost estimates were either supported buy few data points, did not separate out irrelevant cost items (such as export system OMS), or were more suited to the US market.

Insurance costs

For insurance costs, we recommend no change, for the same reasons as OMS costs.

Network UoS costs

For Network UoS costs, we recommend no change, informed by:

- Results being within NESO 2024 projections (BVGA benchmarks) which are a first-hand forecast of these costs. These projections are more representative of the range of possibilities of UoS charges rather than charges associated with actual projects, thus we don't recommend changing high and low scenarios to align.

However, a more detailed analysis of the UK project pipeline with anticipated grid connection scenarios and weighted average capacities could narrow the expected range of UoS charges. Such an analysis is outside the scope of this review.

Decommissioning costs

For decommissioning costs, we recommend increasing costs, informed by:

- A large increase in results if only "current" costs are included, which we believe should be the case. These updated costs align better with our own benchmarks and the literature review and are consistent with the logic used across other cost categories.

We therefore recommend that Filter Set 3 is selected for decommissioning costs, increasing costs to £110, £255, and £507 /kW for low, medium, and high scenarios, respectively.

Cost trajectories

This section covers:

- Capital cost trajectories: Real term adjustments to capital costs over time, and
- Operational cost trajectories: Real term adjustments to operational costs over time.

Table 6 Cost trajectories comparison.

Category	Scenario	BVGA cost change after 10 years	BVGA cost change after 20 years	Arup 2024 cost change after 10 years	Arup 2024 cost change after 20 years
Capital cost change	High	-8%	-12%	+8%	+5%
	Medium	-12%	-17%	0%	-7%
	Low	-15%	-21%	-8%	-18%
Operations cost change	Medium	-13%	-19%	-23%	-35%

Comparison to BVGA in-house benchmarks

The Arup 2024 results are generally not aligned with our own benchmarks. We expect continued cost decreases over time, driven by turbine rating increases, learning-by-doing, and improvements in efficiency through technology development and standardisation. We have not projected real-term commodity shifts or potential supply chain constraints into the cost trajectories. We apply cost reduction using learning rates and deployment forecasts (rather than through input from developers). We use learning rates of 9%, 7%, and 5% to generate low, medium, and high scenarios, respectively.

Generally, the more mature a market, the less potential there is for further cost reduction. However, in both the medium and high scenarios, there is significantly more cost reduction in later years which we expect is counterintuitive to typical market trends.

For capital costs in our medium case, we expect a 12% and 17% decrease in capital costs over the next 10- and 20-year periods, respectively. Our medium case capital cost reduction aligns closer to the Arup 2024's low/optimistic scenario.

For operational period costs, our projections are considerably more conservative than Arup 2024. In our base case, we expect cost reduction of 13% and 19% by year 10 and year 20, respectively. Arup 2024 projects 23% and 35% cost reduction over these same periods. This cost reduction is not aligned with the Arup 2024 capital cost projections. While future capital costs and operational costs will not necessarily follow the same trajectories, many of the same factors drive both so we should expect reasonable correlation between the two. The cost reduction presented in Arup 2024 suggests a learning rate of 15 to 16%, significantly higher than typical industry estimates of 6 to 11%.[2]

What the literature review says

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 only qualitatively discusses cost reduction through future technology trends, citing increased turbine sizes, improved installation practices, and cost optimisation strategies.

Of the reviewed literature in our supplemental review:

- IRENA 2024 reiterates its expectation that OFW costs will decrease.

[2] https://docs.nrel.gov/docs/fy23osti/81819.pdf

- NREL 2024 estimates learning rates of 6.3%, 8.8%, and 11.2% in its conservative, moderate, and advanced scenarios, respectively, although geared towards the US market where there may be more potential for cost reduction through learning.

Recommendations

For cost trajectories, we recommend increasing the rate of cost reduction across all capital cost scenarios, and decreasing the rate of reduction for the operational cost scenario, informed by:

- Modelling using learning rates within industry standards suggesting more optimistic cost reduction potential.
- Industry expectation that continued increase in turbine rating, learning, and innovation will contribute to some level of cost reduction.

We recommend a capital cost low scenario that has a cost reduction of 15% after 10 years (from cost "lock-in" date[3] of 2023) and 21% after 20. This is reasonably well aligned with Arup 2024, but the change would allow for consistency across all scenarios.

We recommend a capital cost medium scenario that has a cost reduction of 12% after 10 years and 17% after 20 years.

We recommend a capital cost high scenario that has a cost reduction of 8% after 10 years and 12% after 20 years.

We recommend an operations cost scenario that has a cost reduction of 13% after 10 years and 19% after 20 years.

While we would expect a smooth reduction profile that is intersected by these points, a linear interpolation between years 0 and 10, and between years 10 and 20 provides a reasonable approximation. All cost reduction figures are in real terms. These projections do not include the possibility of real term cost changes through commodity price shifts. Real term increases through commodity price spikes are a possibility, but we understand that DESNZ has a process in place for adjusting for commodity price shifts in real time. We have quoted time milestones in terms of years from cost lock-in date rather than from COD, as changes to assumed construction period will change the COD that these costs are relative to.

[3] "Lock-in" date is when developers begin procurement on major components. Approximately 0.5-1 years before construction begins and shortly after a financial investment decision has been made.

Project timings

This section covers:

- Development period and spend profile: period from project inception to the start of construction and distribution of development costs over same period.
- Construction period and spend profile: period from the start of construction to COD and distribution of capital costs over same period.
- Operating period: from COD to decommissioning.

Table 7 Project timings comparisons

Category	Scenario	BVGA period benchmark	BVGA spend profile	Arup 2024 period	Arup 2024 spend profile
Development period	High	11	Custom profile (Table 8)	15	6.7% each year
	Medium	8	Custom profile (Table 8)	7	14.3% each year
	Low	6	Custom profile (Table 8)	6.5	15.4% first six years, 7.7% final year
Construction period	High	5	Custom profile (Table 8)	5.3	19% first five years, 4.8% final year
	Medium	3	Custom profile (Table 8)	4.6	21.6% first four years, 13.5% final year
	Low	2	Custom profile (Table 8)	4	25% each year
Operating period	High	35	Even spend each year	35	Even spend each year
	Medium	30	Even spend each year	35	Even spend each year
	Low	28	Even spend each year	35	Even spend each year

Table 8 BVGA in-house benchmark development and capital spend profiles

		Spend in year of period (%)										
Category	**Scenario**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Development spend profile	High	1.5	1.5	3.2	4.1	4.2	6.5	16.7	18.1	18.5	19.3	6.3
	Medium	5.0	6.8	8.6	17.5	18.1	18.5	19.3	6.3	-		
	Low	8.3	21.3	22.1	22.7	19.3	6.3	-	-	-		
Capital spend profile	High	7.9	13.7	20.5	26.2	31.8	-	-	-	-		
	Medium	38.1	28.2	33.7	-	-	-	-	-	-		
	Low	61.1	38.9	-		-	-	-	-	-		

Comparison to BVGA in-house benchmarks

Development period

Arup 2024 selected Filter Set 2 to filter development period from surveys meaning the results must pass their reasonability test, resulting in three data points. Filter Set 3, which applies the same criteria as Filter Set 2 but must also be current, produces the same results and has the same number of data points. We would expect the stricter filter set to be used to demonstrate the results have an additional layer of validity. We note that in this case it does not make any difference to the results and that project timing data does not need to be as recent as project cost data.

The filtered results are broadly aligned with BVGA's in-house benchmarks with only the high scenarios being significantly different. The two data sets we used (15 data points in BVGA data set, 56 in the 4C data) to establish our benchmarks considered consent submission to beginning of construction while the Arup 2024 data set considered project inception/scoping to construction. To adjust, we added three years to our development timings, accounting for the period between scoping and consent submission and aligning with the Arup 2024 assumptions.

Arup 2024's spend profiles for development period scenarios generally do not align with our benchmarks. Arup 2024's development spend profiles are generally spread evenly across the period. Our benchmark data shows that, especially for longer development periods, spend is generally weighted towards the end of the period.

Construction period

Filter Set 2 was selected to filter construction period, resulting in six data points. The filtered results are generally higher than our benchmarks, but not significantly. The prevalence of deep-water, distant sites could account for this marginal difference between the two data sets. Note we have assumed "construction starts" to mean offshore construction.

Arup 2024's spend profiles for capital spend scenarios generally do not align with our benchmarks. Arup 2024's construction spend profiles are generally spread evenly across the period. Our benchmark data shows that, especially for longer construction periods, spend is generally weighted towards the end of the period. However, we expect capital spend to begin before construction starts. For compatibility with DESNZ's LCOE calculator, we have established capital spend profiles to match construction periods and therefore moved any pre-construction capital spend into the first year of the construction period.

Operational period

Filter Set 2 was selected to filter operational period, resulting in eight data points. The filtered results are generally higher than our in-house benchmarks, notably with all responses expecting a 35-year lifetime for their projects. While we have seen developers expect their projects to last longer as technology matures, our own benchmarks data includes developer estimates from 28 to 35 years. It is possible that the small sample size of the survey resulted in a single estimation of project life.

What the literature review says

Development period

Of the reviewed literature in the Arup 2024 report, none provide development timelines.

Of the reviewed literature in our supplemental review, none specified development periods for UK projects.

Construction period

Of the reviewed literature in the Arup 2024 report:

- IRENA 2023 charts a weighted average construction period of 1.5 years, ranging from approximately 0.5-3 years.
- Lazard 2024 reports a construction period of 3 years.

Of the reviewed literature in our supplemental review:

- IRENA 2024's weighted average construction period remains at 1.5 years, with a reduced range of 0.5-2 years.
- Lazard 2025 makes no change to its 3-year construction period assumption.

Operational period

Of the reviewed literature in the Arup 2024 report:

- Lazard 2024 assumes a 30-year project lifetime.

Of the reviewed literature in our supplemental review:

- Lazard 2025 makes no change to its 30-year lifetime assumption.
- NREL 2024 assumes a project lifetime of 25 years.

Recommendations

Development period

For the development period, we recommend no change, informed by:

- BVGA's in-house benchmarks being broadly in line with results.

We do however recommend an adjustment to spend profiles, weighting more spend towards the end of the development period.

Table 9 Recommended development period spend profiles

	Spend in year of period (%)														
Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
High	2	2	2	2	2	5	5	5	5	10	10	10	15	15	10
Medium	10	10	15	15	20	20	10	-	-	-	-	-	-	-	-
Low	5	10	10	20	20	20	15	-	-	-	-	-	-	-	-

Construction period

For construction period, we recommend a reduction in low and medium scenarios, informed by:

- Our in-house benchmarks being lower in these scenarios. Our benchmarks are informed by two data sets, each of many more data points than that of the survey used. The small sample size could have introduced uncertainty and bias to the results.
- We have seen operational projects such as Seagreen and Hornsea One complete their offshore construction in about 2 years.
- The literature review consistently reporting construction periods of 1.5 to 3 years.

We therefore recommend reducing low and medium scenarios to 2 and 3 years respectively, while keeping high at 5 years. We recommend a small adjustment to construction period spend profiles, shown in Table 10.

Table 10 Recommended construction period spend profiles

	Spend in year of period (%)				
Scenario	**1**	**2**	**3**	**4**	**5**
High	10	15	20	25	30
Medium	35	30	35	-	-
Low	60	40	-	-	-

Operational period

For the operating period, we recommend a reduction in low and medium scenarios, informed by:

- Our in-house benchmarks being lower in these scenarios. Again, our benchmarks are informed by two data sets, each of many more data points than that of the survey used. The small sample size could have introduced uncertainty and bias to the results.
- The literature review consistently reporting construction periods of 25-30 years.

We therefore recommend reducing low and medium scenarios to 28 and 30 years respectively, while keeping high at 35 years.

Appendix A: Detailed cost trajectories

Table 11 Cost trajectories

	Cost reduction after X years																									
Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Capital - high	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.92	0.91	0.91	0.90	0.90	0.90	0.89	0.89	0.89	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87
Capital - medium	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.87	0.86	0.86	0.85	0.85	0.84	0.84	0.83	0.83	0.83	0.82	0.82	0.82	0.81
Capital - low	0.98	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.77	0.77	0.77
OMS - medium	0.98	0.97	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.84	0.83	0.82	0.82	0.82	0.81	0.81	0.80	0.80	0.80	0.79	0.79

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A	Draft	Client discretion	CDB	GGO	NGD	14 August 2025

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