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Bermuda offshore wind: Annual energy production analysis

For Greenrock

October 2023

BVGAssociates

Document history

Revision	Description	Circulation classification	Authored	Checked	Approved	Date
3	Release	Client discretion	MKN	NGD	NGD	13 Oct 2023

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Executive summary

The purpose of this document is to help Bermuda reach net zero by providing an estimated wind speed and energy production analysis for a 60 MW offshore wind farm off the coast of Bermuda. It was commissioned as follow up to our previous report *Bermuda offshore wind: Key publications review and priority actions,* dated April 2022, which suggested that one of the key uncertainties to address in considering whether offshore wind makes sense for Bermuda related to Levelized Cost of Energy (LCOE).[i] That report noted that uncertainty in LCOE is driven mainly by uncertainty in capital and operational cost (which we addressed in report *Bermuda offshore wind: LCOE assessment*, dated August 2022), but also in uncertainty in wind resource (and hence annual energy production (AEP)).

This document provides an initial calculation of AEP for an offshore windfarm in Bermuda and the methodology for its calculation. It also discusses next steps that should be taken to refine these calculations for the purposes of future project design and financing.

Project assumptions

The AEP was assessed for Site 1 in Figure 0-1. Site 1 was selected for this analysis as it's the most technically viable site with the likely lowest LCOE, and less environmental impact.

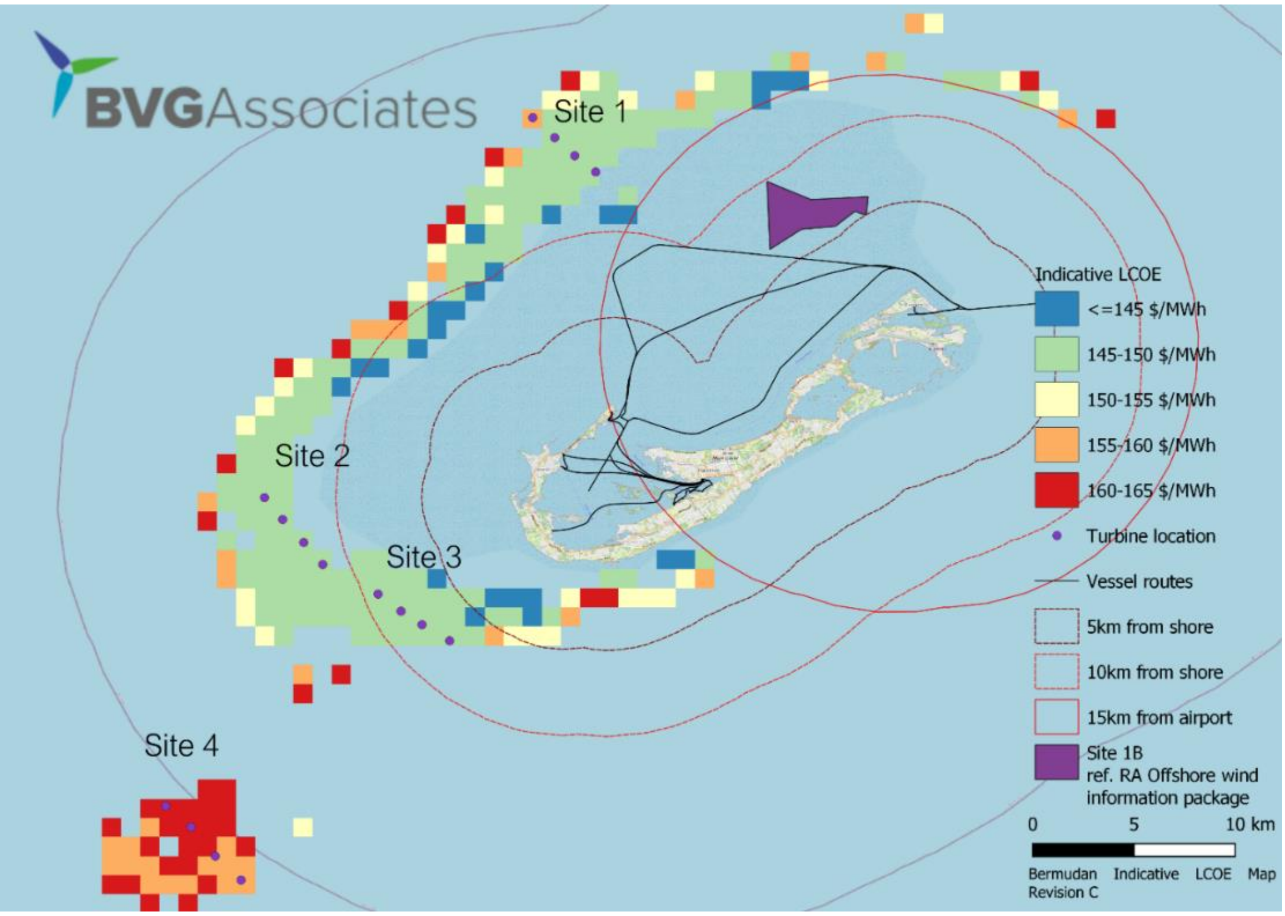

Figure 0-1 Project location – Site 1 has been used in this wind speed assessment.

The project details and turbine characteristics used for analysis of Site 1 are given in Table 0-1.

[i] For an explanation of LCOE, and information of offshore wind technology and processes more generally, see https://guidetoanoffshorewindfarm.com/, including the *Wind farm costs* tab.

Table 0-1 Preliminary key technical parameters.

Parameter	Value	Units
Project capacity	60	MW
Number of turbines	4	-
Turbine rating	15	MW
Rotor diameter	224	m
Turbine hub-height	132.5	m
Mean water depth	18	m
Foundation type	Monopiles	-
Transmission technology	HVAC array cable to shore, no offshore sub-station	-
Distance from O&M port	19	km

Overview of methodology

- The methodology consisted of the following steps: Modelled long term wind resource data was sourced from Vortex , covering the extent of the proposed wind turbine locations at a height of 150 m above sea level
- Summary wind statistics were extracted from the Vortex dataset for each turbine location, including annual mean wind speed and the wind speed distribution (Weibull shape factor), which allows the probability of occurrence of wind for each 1m/s bin to be derived across the operational range of the proposed wind turbine
- A power curve for a representative, generic 15 MW offshore wind turbine was derived based on the performance characteristics of similar wind turbines
- The wind speed distributions and turbine power curve were combined to calculate the gross AEP for the wind farm, before losses
- A range of standard energy losses were applied to derive a net P50 AEP value, which as a 50% probability of being met over the long-term, and
- An uncertainty analysis was performed, taking account of a range of modelling uncertainties and wind variability to derive a P90 net AEP value for any 1 year, any 10 years and the long-term.

Wind farm layout and wind statistics

The project location is centred on 32.45911, -64.86729[ii]. The wind speed and Weibull shape factor are the same for all turbines in the site area.

- Annual mean wind speed at 132.5m ASL: 8.3 m/s
- Weibull shape factor: 1.9

Gross and net energy production

The calculated gross and net P50 AEP values for the wind farm are shown in Table 0-3. The calculated AEP is assumed to apply at an onshore metering location, after export and array system losses.

Table 0-3 Gross and net annual energy production.

Probability of exceedance	Net AEP - Any 1 year (GWh)	Net AEP - Any 10 years (GWh)	Net AEP - Long-term (GWh)
Gross (P50, before all losses)		234.3	
Net (P50, after all assumed losses)		202.1	
P90	165.8	169.2	169.6

In BVGA's previous report *Bermuda offshore wind: LCOE assessment* a net AEP of 3,853 MWh/MW/year for a 60 MW wind farm using 15 MW turbines was calculated. This gives a total net AEP of 231.2 GWh. The value of 202.1 GWh calculated in this report is 12.6 % lower than in the previous analysis. The previous analysis used a generic wind speed distribution and an estimated average wind speed of 9.5 m/s, rather than the more accurate wind speed characteristics modelled for the site location in the present analysis. This difference in wind speed accounts for the difference in the results. The net AEP calculated in this report is more accurate.

Disclaimer

This report uses modelled wind data, modelled wind turbine power curve data, and estimated energy losses to derive a long-term AEP for the proposed project location.

The results of the analysis should be treated as being indicative only, and subject to further work including site specific data collection, long-term wind resource analysis, refined AEP calculation, and detailed loss and uncertainty analysis.

The results of this analysis are suitable for use in high-level technical and economic feasibility studies and should not be relied upon for use in detailed investment appraisals.

[ii] Decimal degrees, map projection WGS 84

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1. Introduction

1.1. Background

Greenrock is seeking to support the decarbonisation of Bermuda's electricity supplies within a timeframe that remains within a 1.5C carbon budget.

Based on previous renewable energy resource and technology assessments, offshore wind has consistently been identified as the most critical mature renewable energy technology to achieve decarbonisation of the electricity sector.

Greenrock has welcomed the progress made by the Bermuda Government to date considering offshore wind as a key potential element of a sustainable, low carbon energy system for Bermuda. It seeks now to help accelerate progress through bringing in global experience of the technology, costs and practicalities of offshore wind, recognising that:

- Offshore wind costs have been falling rapidly and are projected to continue falling, in relative terms compared to traditional forms of electricity generation
- The scale of technology and market continues to grow
- Bermuda has specific characteristics (in terms of size of market, location and available facilities) that need to be addressed, and
- Knowledge about how to progress offshore wind in Bermuda is naturally limited.

Bermuda has a typical power consumption of 30 to 100 megawatts (MW). Historically, Bermuda has used fossil fuels to generate most its electricity but also uses some small-scale renewables with about 13 MW of solar photovoltaic (PV). It does not have the available land area to meet its electricity demand with onshore renewables – there is space for approximately 84 MW of solar PV which would meet a quarter of electricity demand. Offshore wind, however, presents an opportunity for Bermuda to vastly increase its share of renewable energy generation, with a relatively small 60 MW installation able to meet about 40% of electricity demand.

1.2. Purpose

This document provides an estimation of the annual energy production (AEP) for an offshore windfarm in Bermuda and the methodology for its calculation. It also discusses next steps that should be taken to validate these calculations.

Disclaimer

This report uses modelled wind data, modelled wind turbine power curve data, and estimated energy losses to derive a long-term AEP for the proposed project location.

The results of the analysis should be treated as being indicative only, and subject to further work including site specific data collection, long-term wind resource analysis, refined AEP calculation, and detailed loss and uncertainty analysis.

The results of this analysis are suitable for use in high-level technical and economic feasibility studies and should not be relied upon for use in detailed investment appraisals.

2. Methodology

2.1. Overview of methodology

The methodology consisted of the following steps:

- Modelled long term wind resource data was sourced from Vortex[iii] a specialist supplier of modelled long term wind climate data for wind energy applications, covering the extent of the proposed wind turbine locations at a height of 150 m above sea level
- Summary wind statistics were extracted from the Vortex dataset for each turbine location, including annual mean wind speed and the Weibull shape factor, which allows the probability of occurrence of wind for each 1m/s bin to be derived across the operation range of the proposed wind turbine
- A power curve for a representative, generic 15 MW offshore wind turbine was derived based on the performance characteristics of similar wind turbines
- The wind speed distributions and turbine power curve were combined to calculate the gross AEP for the wind farm, before losses
- A range of standard energy losses were applied to derive a net P50 AEP value, which as a 50% probability of being met over the long-term, and
- An uncertainty analysis was performed, taking account of a range of modelling uncertainties and wind variability to derive a P90 net AEP value for any 1 year, any 10 years and the long-term.

[iii] Vortex is a leading independent provider of modelled wind data to the wind energy industry using a widely validated methodology. For more information see https://vortexfdc.com/about-us/

3. Project details

Figure 1 shows the potential project locations assessed by BVGA in a parallel analysis. It was determined that Site 1 was the most technically viable with the likely lowest levelized cost of energy (LCOE), and less environmental impact. The wind speed and energy production analysis presented in this report therefore focusses on this site. Please note that the LCOE values shown in Figure 1 are based on previous analysis and do not incorporate the AEP presented in this report. The project details and turbine characteristics used for analysis of Site 1 are given in Table 1, the values assumed in *Bermuda offshore wind: LCOE assessment*, dated August 2022 are also shown. There are minor differences in water depth and distance to O&M port, however key parameters such as project capacity, turbine rating, and turbine hub-height are consistent.

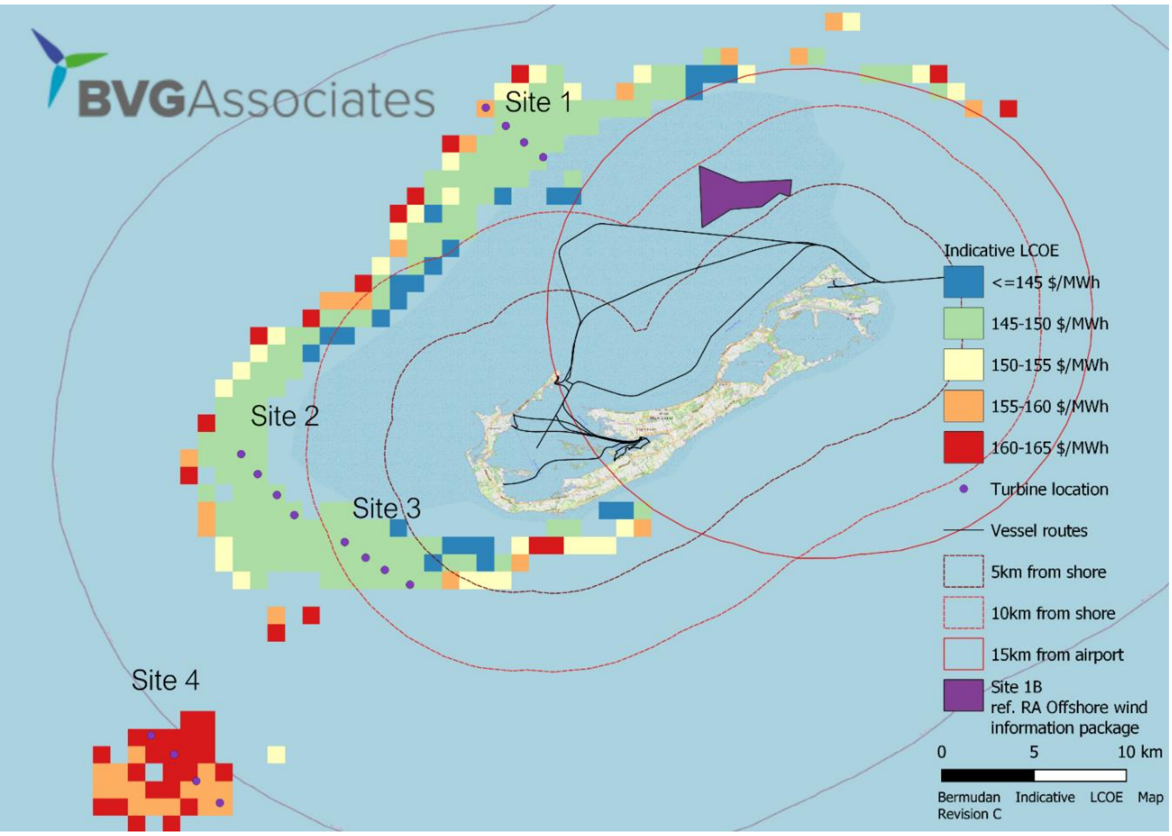

Figure 1 Project location.

Table 1 Preliminary key technical parameters.

Parameter	Value assumed in this study	Value assumed in *Bermuda offshore wind: LCOE assessment*	Units
Project capacity	60	60	MW
Number of turbines	4	4	-
Turbine rating	15	15	MW
Rotor diameter	224	224	m
Turbine hub-height	132.5	132.5	m
Mean water depth	18	20	m
Foundation type	Monopiles	Monopiles	-
Transmission technology	HVAC array cable to shore, no offshore sub-station	HVAC array cable to shore, no offshore sub-station	-
Distance from O&M port	19	20	km

4. Input data and assumptions

4.1. Wind data

The input reference wind data for the analysis was sourced from Vortex. The data run, which was based on the ERA5[iv] mesoscale wind model, represents a period of 20 years and provides wind statistics for each of the 4 turbine locations. Annual mean wind statistics for each of the four turbine locations are presented in Table 2.

The Vortex wind report is presented in Appendix A.

4.2. Wind farm layout and wind statistics

Turbine locations and annual wind characteristics are given in Table 2.

Table 2 Turbine locations and mean annual wind statistics.

Turbine ID	Latitude[v]	Longitude	Annual mean wind speed at 132.5m ASL (m/s)	Weibull shape factor
1	32.48023	-64.87523	8.3	1.9
2	32.46967	-64.86332	8.3	1.9
3	32.46024	-64.85290	8.3	1.9
4	32.45184	-64.84168	8.3	1.9

The general wind speed and wind direction distributions for the project area are shown in Figure 2 and Figure 3.

[iv] ERA5 is an atmospheric reanalysis dataset of the global climate. ERA5 is produced by the Copernicus Climate Change Service at the European Centre for Medium-Range Weather Forecasts. It provides hourly estimates of atmospheric, land and oceanic climate variables, including wind speed and direction.

[v] Decimal degrees, map projection WGS 84

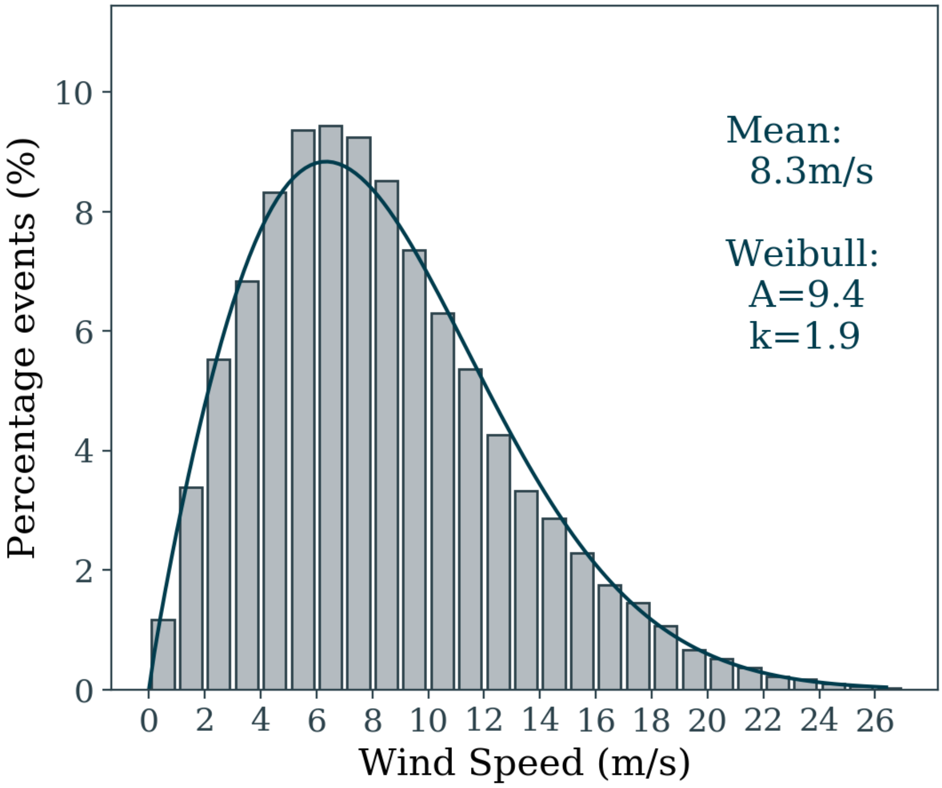

Figure 2 Wind speed distribution for the general project area. (Image from Vortex wind report)

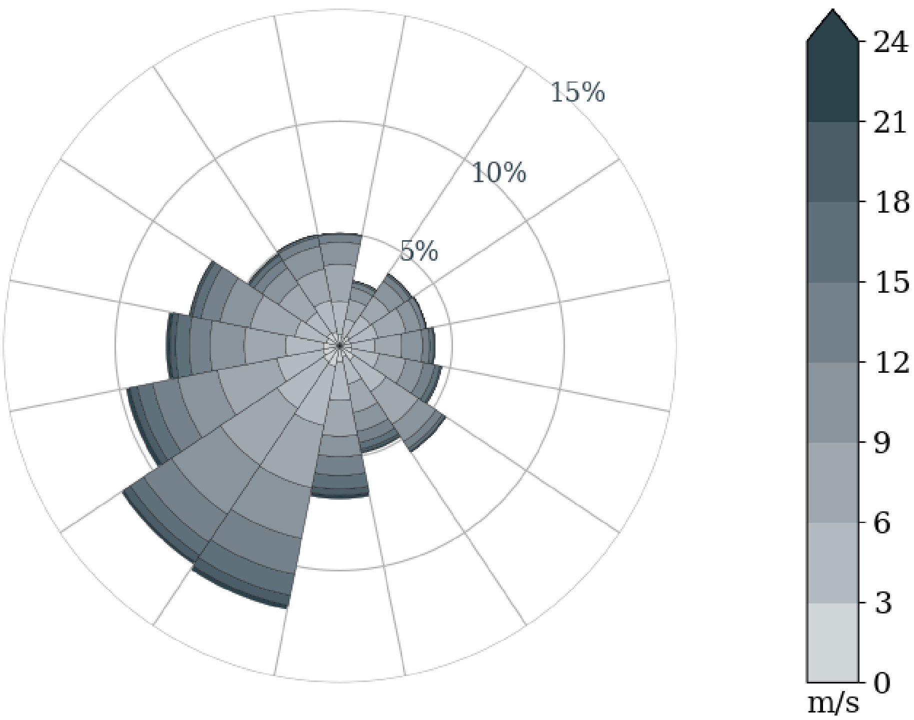

Figure 3 Wind direction distribution for the general project area. North at top. ***(Image from Vortex wind report)***

4.3. Turbine power curve

A power curve for a representative 15 MW wind turbine with a rotor diameter of 224 m was derived, based on performance characteristics for typical offshore wind turbines operating in winds of typical turbulence. A generic power curve was used as the final turbine model has not been determined. The power curve is shown in Figure 4. Wind speeds represent 10 minute means at turbine hub-height.

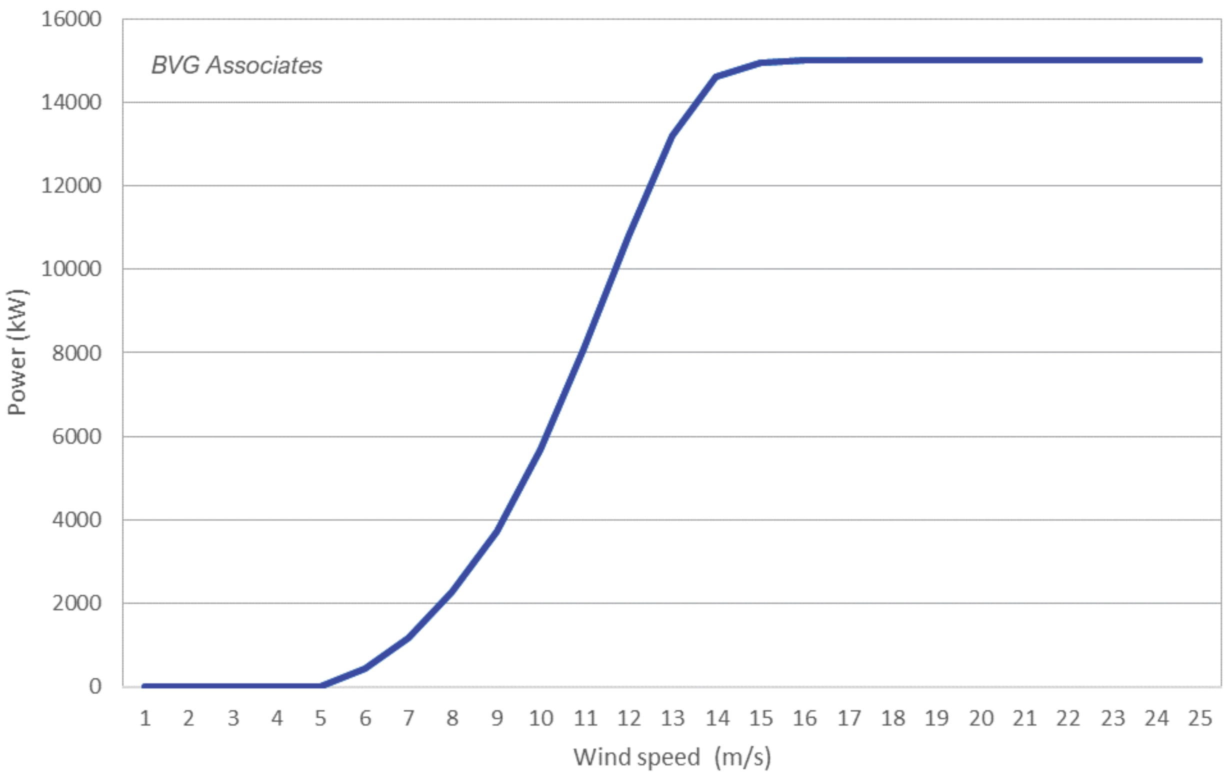

Figure 4 Power curve for a representative 15 MW wind turbine.

4.4. Assumptions

The assumed energy production losses are shown in Table 3.

Table 3 Energy production losses.

Loss category	Energy production loss (%)	Notes
Turbine unavailability	5.0%	Higher than typical value for an offshore wind farm to account for distance from service centre, and availability of large vessels, technicians, and non-standard spares
Inter-turbine wake	3.0%	Lower than typical for a large offshore wind farm due to lower fraction of the time that any turbine is running in the wake of another turbine. Estimated value from BVGA's wake calculation tool, validated against industry models
Electrical	4.0%	Estimated electrical losses in array and export system. Higher than typical offshore wind farm as no offshore sub-station and lower export voltage
Array system availability	0.5%	Estimated losses due to unavailability of array cables

Export system unavailability	1.0%	Estimated losses due to unavailability of export cables
Hysteresis	0.5%	To account for power curve hysteresis (time when the turbine is not running despite being within its operating wind speed range)
Performance degradation	0.5%	To account for turbine performance changes over time due mainly to blade wear
Environmental	0.0%	No environmental losses assumed
Grid curtailment	0.0%	No grid curtailment losses assumed
Total	13.7	When applied on a cumulative basis (rounded)

5. Results

5.1. Gross and net energy production

The calculated gross and net P50 AEP values for the wind farm are shown in Table 4. AEP was calculated for individual turbine locations, accounting for variations in wind speed across the site, and summed to provide the wind farm AEP. The calculated AEP is assumed to apply at an onshore metering location, after export and array system losses.

Table 4 Gross and net annual energy production.

Energy production value	AEP – P50 (GWh)
Gross (P50, before all losses)	234.3
Net (P50, after all assumed losses)	202.1

In BVGA's previous report *Bermuda offshore wind: LCOE assessment* a net AEP of 3,853 MWh/MW/year for a 60 MW wind farm using 15 MW turbines was calculated. This gives a total net AEP of 231.2 GWh. The value of 202.1 GWh calculated in this report is 12.6 % lower than in the previous analysis. The previous analysis used a generic wind speed distribution and an estimated average wind speed of 9.5 m/s, rather than the more accurate wind speed characteristics modelled for the site location in the present analysis. This difference in wind speed accounts for the difference in the results. The net AEP calculated in this report is more accurate and will lead to an increase in the previously reported LCOE values.

5.2. Uncertainty analysis

The net AEP in Table 4 is a P50 value, which represents the AEP that has a 50% probability of being met when averaged over the lifetime of the wind farm.

The assumptions and steps within the AEP analysis methodology are each subject to uncertainties. An uncertainty analysis was performed to calculate the P90 AEP for any one year and any 10 year period, accounting for the following uncertainties:

- Wind speed error: Whilst being a robustly derived and widely applied dataset, the Vortex reference data is subject to errors of both accuracy and long-term consistency. The dataset has not been widely applied to offshore wind locations around Bermuda and has not been validated against robust local wind data. Enquiries with Bermuda Weather Service have established that historical wind data from Bermuda Airport is available for the purposes of local validation. A validation exercise using local data can be included in future refinement of the analysis. An uncertainty of 7.5 % was applied to the mean wind speed, based on Vortex validation data where ERA5 runs have been compared to over 250 wind speed measurement locations[vi].
- Representativeness of the long term wind resource: The methodology assumes that the 20 year period covered by the Vortex data represents the true long-term average wind climate for the project location.

[vi] Vortex SERIES ERA5 Validation.

There is an uncertainty associated with this assumption. Based on the Vortex data, the long-term inter-annual variation in mean annual wind speed at the project location in Bermuda was calculated to be 4.0 %. This is calculated by first calculating the annual mean wind speed for each year in the 20 year Vortex data set and then calculating the standard deviation of the resulting 20 wind speed values. The inter annual variation is the standard deviation as a percentage of the overall average wind speed.

- Future wind variability: The energy production of any given future finite period can be expected to be different from the long-term mean, due to the inherent inter-annual variation in wind speed. Using the inter-annual variation assumptions stated above, the standard error for any future 1 year or 10 year period was calculated. The long-term AEP values assume that future variability is averaged out over the 30 year life-time of the project.
- Errors in loss assumptions: Wake and other losses have been estimated based on industry norms and are not based on site specific modelling, so an uncertainty of 25 % has been included. This is based on an estimation of the potential range of the applied losses and is calculated as a percentage of the aggregated lost energy.

The applied uncertainty values are shown in Table 5. These uncertainties are calculated in both units of wind speed and energy production. Wind speed uncertainties were converted to energy uncertainties by calculating the sensitivity of the energy production to changes to the mean wind speed. Sources of uncertainty are combined on a root mean squared basis to calculate a total standard error as the uncertainties are assumed to be independent of each other.

Table 5 Annual energy production modelling uncertainty values.

Uncertainty	Wind speed uncertainty (%)	Wind speed error (m/s)	Energy uncertainty (%)	Energy production error (GWh)
Wind speed error	7.5	0.62	12	23.88
Long term representativeness	0.9	0.07	1	2.85
Future wind variability – any 1 year	4.0	0.33	6	12.73
Future wind variability – any 10 years	1.3	0.1	2	4.03
Loss assumptions			25	8.04
Overall standard error - any 1 year				28.37
Overall standard error - any 10 years				25.67
Overall standard error – long-term				25.35

The resulting P90 AEP values for any one year, any 10 years and when averaged over the long term are shown in Table 6.

Table 6 Summary of net annual energy production P50 and P90 results.

Probability of exceedance	Net AEP - Any 1 year (GWh)	Net AEP - Any 10 years (GWh)	Net AEP - Long-term (GWh)
P50	202.1		
P90	165.8	169.2	169.6

The net AEP uncertainty values should be interpreted as follows:

- The P50 is the net AEP that has a 50% probability of being met or exceeded, averaged over the lifetime of the project. The P50 is typically used to assess the LCOE of a project, and to model the risk of the equity investment in a wind project. It is also suitable for energy systems modelling purposes.
- The P90 is the AEP that has a 90% probability of being met or exceeded over the period that it is stated for (in this case any 1 year, any 10 years, and the long-term). By way of example, it can be expected that the

P90 – Any 1 year value will be met or exceeded in 9 years out of any 10 year sample (and conversely will not be met in one year out of every 10 year sample). The P90 AEP values are typically used to model the risk of debt investments in a wind project and to calculate debt-service cover ratios. They can also be used to model low-end risk cases in energy system modelling exercises.

6. Further work

The analysis undertaken is based on modelled wind data, a representative power curve and estimated energy losses. Further work will be required to establish an AEP analysis suitable for use in detailed project design and investment decisions, and to inform future turbine selection and classification assessment, including:

- Onsite wind data collection for a period of 24 months, likely collected by a floating lidar
- Undertaking a detailed wind resource measure-correlate-predict (MCP)[vii] analysis to establish a long-term wind climate for the project location, based on site specific lidar wind data and robust long-term reference data[viii].
- Calculating the AEP using measured and validated power curves for specific offshore wind turbine models
- Undertaking a detailed analysis of site energy losses taking account of final turbine selection, electrical design, potential grid and environmental curtailment, and operational strategy
- Updating the uncertainty analysis according to the revised site AEP model, and
- Performing an analysis of site-specific turbulence and extreme wind conditions for the purposes of turbine classification assessment.

6.1. Plan for a lidar campaign and finance-grade annual energy production analysis

The purpose of the floating lidar campaign is to collect accurate wind data from the project site that will be used to:

- Conduct a finance-grade AEP assessment to inform financing and investment decisions
- Inform the final wind farm design and turbine selection, and
- Define the project construction and operational strategies, given the importance of weather downtime at offshore wind farms.

6.1.1 Technical specification for a lidar campaign

To form a finance-grade annual energy production analysis, a 24-month wind data collection campaign should utilise a self-powered, moored floating lidar to be situated within the project site.

Equipment

Floating lidar devices consist of wind lidars installed on a floating platform moored to the seabed. There are several commercially available floating lidar models that can produce wind data within an acceptable level of accuracy. An example of a floating lidar is shown in Figure 5.

[vii] https://www.wind-energy-the-facts.org/analytical-methods-for-the-prediction-of-the-long-term-wind-regime-at-a-site.html

[viii] Enquiries with the Bermuda Weather Service have established that suitable long term historical wind records going back to at least 2007 are available from Bermuda Airport. The instrumentation and data management are of a good standard and likely to be suitable for use in an MCP analysis, providing data collection continues through the lidar campaign period. If upon further detailed analysis these historical datasets should prove to be unsuitable, then the MCP analysis can be performed using modelled time-series reference data with no impact on uncertainty.

Figure 5 Example of a floating lidar device. ***(Image courtesy of EOLOS Floating Lidar Solutions)***

Only floating lidars that have reached stage three compliance defined by the OWA roadmap for the commercial acceptance of floating LiDAR technology (CTC819) [ix] should be used. It is recommended that a validation period is undertaken as described in CTC819 and the 'Offshore Accelerator Recommended Practice for Lidar Systems' (CTC870)[x].

Measurement of wind conditions and other meteorological data should be performed in accordance with IEC 61400-12-1[xi] and follow MEASNET ESSWC[xii] procedures.

Lidar location

The Regulatory Authority of Bermuda (RAB) have proposed a potential offshore wind site as shown in Figure 6. This site is approximately 10km from the Site 1 identified by BVGA and assessed in this report.

A typical large scale offshore wind farm (>1GW) is usually financed on the bases of a lidar campaign in a single location. Wind modelling software is then used to extrapolate this single location to the whole extent of the wind farm. For large projects, this results in turbines being up to 10 km or more from a measurement location.

Based on this industry practice, a lidar located within the RAB site would be suitable for a finance grade analysis at Site 1 (the inverse also being true). It is worth noting that that the wind resource around Bermuda does not vary significantly around the whole island (+/- 0.3m/s at 150m ASL). Extrapolation across this distance and range of wind speeds is well within the capability of state-of-the-art wind flow models and would have no significant impact on overall AEP uncertainty.

Should a lidar be used for a more distant site location (such as using a lidar at RAB's site being used for Site 4), then the uncertainty would be higher, and we would advise locating the lidar closer if possible. Alternatively, a second unit could be installed for a shorter time period of up to 6 months which can be correlated back to the longer-term location.

[ix] https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/roadmap-for-commercial-acceptance-of-floating-lidar

[x] https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/owa-floating-lidar-recommended-practice

[xi] https://webstore.iec.ch/publication/68499

[xii] http://www.measnet.com/wp-content/uploads/2022/09/Measnet_Evaluation-of-Site-Especific-Wind-Conditions_v3-1.pdf

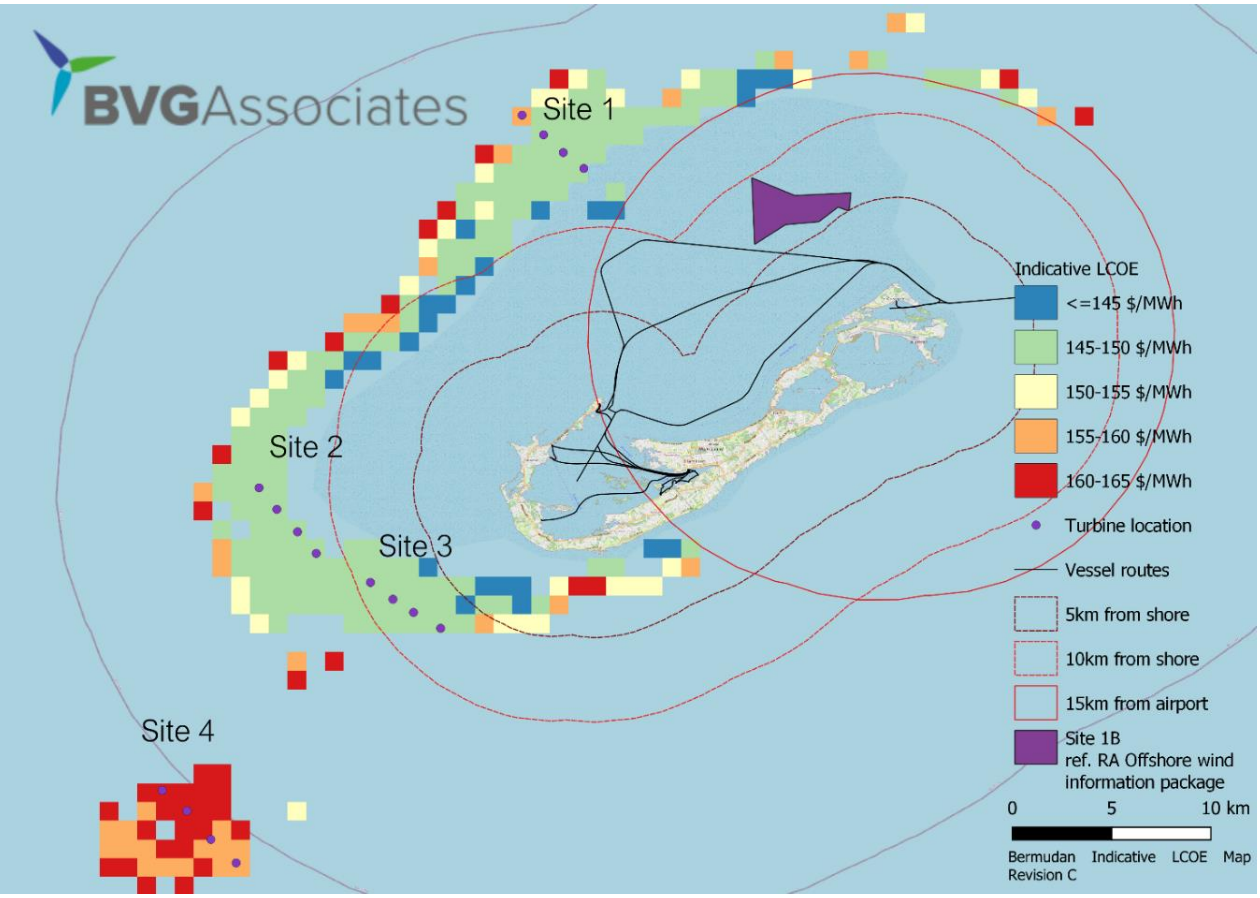

Figure 6 BVGA proposed sites and RAB offshore wind consultation (site 1B).

Data to be collected

Time-series wind data shall be at multiple heights above sea level (ASL) according to good international industry practice (GIIP), including:

- 10-minute average wind speed at five heights from 20m to 244m ASL, to correspond with the top and bottom of the swept rotor diameter and including turbine hub-height of 132.5m
- 10-minute averaged wind direction at five heights from 20m to 244m ASL, to correspond with the top and bottom of the swept rotor diameter and including turbine hub-height of 132.5m
- Turbulence intensity at turbine hub-height, and
- Maximum three second gust at turbine hub-height.

Impact on de-risking

Two years of measured wind data will allow more accurate wind resource and annual energy yield production estimates to be made, which in turn will decrease the uncertainty of LCOE estimates and facilitate the AEP analysis required to secure project financing.

The resulting data will be used to:

- Validate mesoscale wind resource data models, allowing the project developer to make informed decisions regarding project location
- Define a robust wind climate for the purposes of project specific AEP calculations, allowing the project developer to reduce uncertainties in AEP, compared to those resulting from mesoscale models
- Analyse wind characteristics of proposed project, facilitating more certain layout design, turbine selection, and foundation design, and

- Improve Government and investor confidence in the technical and commercial viability of the proposed project.

The use of site data will reduce the uncertainty in the long-term wind speed and AEP predictions. An AEP based on site data typically has a P90 (10 year) AEP about 12% lower than the long-term P50 AEP. For comparison, the P90 (10 year) AEP of the present study is 16.3% below the long-term P50 AEP. The resulting reduction in uncertainty achieved by using site data would equate to the P90 (10 year) AEP increasing from 169.2 GWh to 178 GWh, an increase of about 9 GWh. In project financing terms, assuming a revenue value of $152/MWh, the reduction in uncertainty improves the revenue assumptions of the project by about $1.37 million per annum, or by $43.8million over 32 years, the project length assumed in *Bermuda offshore wind: LCOE assessment*.

Costs

Floating wind lidars are typically procured on a data-as-a-service basis, with specialist providers supplying, installing, managing, and decommissioning the equipment on a turnkey basis.

Typical costs are about $1 million per year. A two-year data collection campaign will cost about $2 million.

Implementation of a lidar campaign and finance- grade AEP annual energy production analysis

To implement a floating lidar campaign the following steps should be followed:

- Finalise the turbine siting and select a lidar deployment location. This should be as close to the centre of the proposed project layout as practicable
- Engage with floating lidar suppliers and request:
  - Preliminary pricing and
  - Technical specifications, particularly with regard to sea-bed anchoring
- Engage with the relevant consenting and regulatory authorities to apply for and secure the permits and consents required to install and operate the lidar. This will include dealing with issues such as environmental impact, fishing, and maritime safety through engagement and dialogue with authorities in Bermuda including:
  - Department of Environment and Natural Resources
  - Department of Marine and Ports Services, and
  - Ministry of Transport
- Undertake a competitive procurement exercise with floating lidar suppliers
- Implement the lidar data collection campaign, and

Procure interim and final finance-grade AEP reports based on the collected data. This should include a measure-correlate-predict (MCP) analysis where the lidar data is correlated with a robust long-term wind speed data set, as discussed above. The floating lidar supplier will be responsible for all data management, downloading, quality control and archiving, and will deliver a robust high-quality dataset through the data-as-a-service arrangement.

The services of a specialist wind resource consultancy should then be procured. This consultancy should hold the necessary accreditations and reputation with lending banks and financial institutions such that the resulting AEP report is of finance-grade and can be relied on in project financing. An interim AEP report should be produced after 18 months of data have been collected, with a final AEP report being prepared after 24 months of data have been collected.

Timeline

An outline timeline for the lidar campaign and AEP reporting is provided in Figure 7. It has been assumed here that the offshore wind farm project location is finalised by the end of 2023.

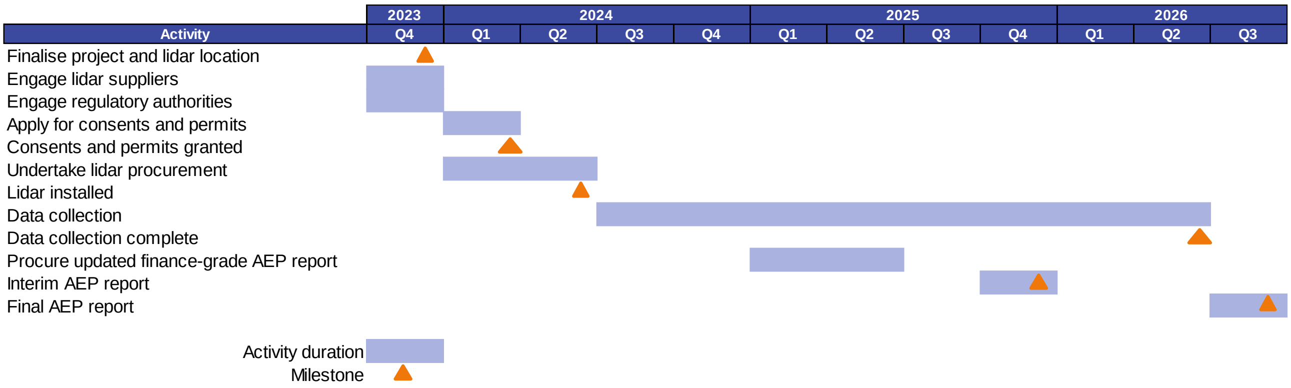

Figure 7 Timeline for lidar campaign and finance-grade annual energy production analysis.

Appendix A Vortex wind resource report

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About BVG Associates

BVG Associates is an independent renewable energy consultancy focussing on wind, wave and tidal, and energy systems. Our clients choose us when they want to do new things, think in new ways and solve tough problems. Our expertise covers the business, economics and technology of renewable energy generation systems. We're dedicated to helping our clients establish renewable energy generation as a major, responsible and cost-effective part of a sustainable global energy mix. Our knowledge, hands-on experience and industry understanding enables us to deliver you excellence in guiding your business and technologies to meet market needs.

- BVG Associates was formed in 2006 at the start of the offshore wind industry.
- We have a global client base, including customers of all sizes in Europe, North America, South America, Asia and Australia.
- Our highly experienced team has an average of over 10 years' experience in renewable energy.
- Most of our work is advising private clients investing in manufacturing, technology and renewable energy projects.
- We've also published many landmark reports on the future of the industry, cost of energy and supply chain.