Data Article

Complete Dataset to be used as a workbench to evaluate the profitability of an offshore wind farm

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\section*{A B S T R A C T}

The presented data collection has been used in the paper \textit{Multi-objective optimization of a uniformly distributed offshore wind farm considering both economic factors and visual impact}, but can be used for a realistic evaluation of the annual energy production of an offshore wind farm and/or the calculation of the project investment cost. It contains realistic wind data, a bathymetric map, the definition of the coast shoreline and forbidden zones, as well as the acquisition and installation cost for the most important components influencing the investment and operation costs.

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Specifications Table

| Subject | Environmental Engineering. |
|---|---|
| Specific subject area | Technical and economic evaluation of an offshore wind farm |
| Type of data | Table |
| How the data were acquired | Bathymetry obtained from globalwindatlas.info and [5] and originally obtained from [4,5,6,7]. |
| How the data were acquired | Wind data obtained from a real lattice mast erected in 1999. It has four measurement levels, although only those from 62 meters (the highest one) have been used. The meteorological mast (at Horns Rev) is located approximately 20 km west of Blåvands Huk. |
| How the data were acquired | Characteristics and prices of electrical components from reports, articles, thesis, and catalogues [1]. |
| How the data were acquired | Power and Thrust curve for Vestas V80 from [2]. |
| How the data were acquired | Macro-economic data and energy price recovered from [3]. |
| Data format | Analyzed: Economic data have been obtained from different countries and years, and have been converted into euros at 2017 |
| Data format | Captured: From geographical maps. |
| Description of data collection | In order to convert prices and costs from different countries and years, obtained data from manufacturers or existing projects were converted into euros (with the conversion rate of the publication year) and increased according to the accumulated inflation in the euro zone. |
| Description of data collection | A customized application captured the coordinates from the map of Fig. 2, and create a set of arrays containing the coordinates (in % of width and height) of the vertices defining the coast shore-line, forbidden zones, concession zone and extraction zones. A similar procedure was executed to obtain depth curves. For the forbidden/concession/extraction zones or the coast shoreline, the selected zone is at the right when travelling the curve from the first point to the last one. For the depth chart, increasing depths are at the right when travelling the curve from the first point to the last one. |
| Data source location | Institution: Vattenfall |
| Data source location | Horns Rev 1: |
| Data source location | Denmark: |
| Data source location | Latitude: 55° 29' 9.5"; Longitude: 7° 50' 23.9"; (423974, 6151447) - (429431, 6147543) Depth: -10 m; Distance from shore: 18 km. |
| Data accessibility | Repository name: Mendeley Data [8]. |
| Data accessibility | Data identification number: DOI:10.17632/brtzfbjh49b.1 |
| Data accessibility | Direct URL to data: [9] |
| Related research article | For an article which has been accepted and is in press: Angel G. Gonzalez-Rodriguez, Javier Serrano-Gonzalez, Manuel Burgos-Payan, Jesus Riquelme-Santos, Multi-objective optimization of a uniformly distributed offshore wind farm considering both economic factors and visual impact, Sustainable Energy Technologies and Assessments, In Press. |

Value of the Data

- These data are useful as a complete set of values for the evaluation of technical, economic or environmental issues in a real offshore wind farm. Specifically, bathymetric and wind data are related to Horns Rev 1. Often, searching for coherent values related to the site, or to the costs and characteristics of offshore wind farm components is a tedious and hard task required prior to test any algorithm or method. By using these data, researchers can focus on developing their ideas.
- Researcher working in the areas of layout optimization, macro-siting, electrical infrastructure design, noise reduction, visual impact.
- Results obtained after using these data can be compared the obtained values with those obtained from e.g. [4] or [3].
1. Data Description

Table 1 presents the wind rose (frequency for every wind direction) as well as the mean of the Weibull parameters for every wind direction at Horns Rev. Fig. 1 represents this table, and specifies the probability that corresponds to certain speed intervals. In this figure, only values between cut-in speed and cut-out speed are represented.

Table 1
Values for probability, and Weibull parameters (scale factor A at 62 m and shape factor WeibK) for every sector.

| Sector | N | NNE | NEE | E | EES | ESS | S | SSW | SWW | W | WNW | WNN |
|--------|---|-----|-----|---|-----|-----|---|-----|-----|---|-----|-----|
| freq (%) | 3.8 | 4.3 | 5.5 | 8.3 | 8.7 | 6.7 | 8.4 | 10.5 | 11.4 | 12.2 | 13.9 | 6.1 |
| Weib_A (m/s) | 8.71 | 9.36 | 9.29 | 10.27 | 10.89 | 10.49 | 10.94 | 11.23 | 11.93 | 11.94 | 12.17 | 10.31 |
| Weib_K | 2.08 | 2.22 | 2.41 | 2.37 | 2.51 | 2.75 | 2.61 | 2.51 | 2.33 | 2.35 | 2.58 | 2.01 |

Fig. 1. Wind rose obtained from [2]. Only values between cut-in speed and cut-out speed are represented.
Table 2 shows the power and thrust curve for a wind turbine model Vestas V80.

| Wind speed (m/s) | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Power (kW)       | 0   | 0   | 0   | 66  | 154 | 282 | 460 | 696 | 996 | 1341| 1661| 1866| 1958|
| Thrust coef      | 0   | 0   | 0   | 0.818| 0.806| 0.804| 0.81 | 0.81 | 0.807| 0.793| 0.739| 0.709| 0.409|

| Wind speed (m/s) | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  | 25  |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Power (kW)       | 1988| 1997| 1999| 2000| 2000| 2000| 2000| 2000| 2000| 2000| 2000| 2000|
| Thrust coef      | 0.314| 0.249| 0.202| 0.17 | 0.14 | 0.119| 0.088| 0.077| 0.067| 0.06 | 0.05 |

Table 3 presents required data to calculate the yearly cash flow obtained by selling the produced energy, after subtracting the operation and maintenance costs.

| Concept                          | Cost               |
|----------------------------------|--------------------|
| O&M Costs                        | 15 € /MWh          |
| Increase                         | 5% per year        |
| Surface and insurances           | included in O&M    |
| Price of energy                  | 130 € /MWh         |
| Increase                         | 0% per year        |
| Availability                     | 95%                |
| Life Time                        | 20 years           |
| Interest rate                    | 9.40%              |
| Inflation                        | 1.5%               |

Table 4 contains the main costs in an offshore wind farm, which are the acquisition and installation of turbines and foundations.

| Concept                          | Cost               |
|----------------------------------|--------------------|
| Turbines                         |                    |
| Acquisition                      | 765 k€ /MW         |
| Installation                     | 405 k€ /MW         |

| Foundations                      |                    |
|----------------------------------|--------------------|
| Reference price                  | 450 € /MW at 15 m depth, Zone 1 |
| Increase                         | +2% per metre depth |
| Vessels mob demob                | +30% for zone 2    |
|                                 | +60% for zone 3    |
|                                 | 430 k              |
Table 5 contains the cost of secondary non-electrical components necessary to calculate the investment cost. Table 6 lists price and characteristics for different model of medium-voltage cables, to be used for connecting turbines in a row.

### Table 5
Secondary non electrical items affecting the investment and decommissioning.

| Concept                  | Cost     |
|--------------------------|----------|
| Design and management    | 95 kMW   |
| SCADA                    | 50 k€ /turbine |
| Decommission             | 120 k€ /MW |

### Table 6
Acquisition cost of inner array cables.

| Cross area $mm^2$ | Fixed losses $W/m$ | Variable losses $W/A^2m$ | $I_{max}$ A | Price €/m |
|-------------------|---------------------|--------------------------|------------|-----------|
| A95               | 0                   | 7.14E-4                  | 380        | 128       |
| A150              | 6                   | 4.35E-4                  | 430        | 192       |
| A400              | 24                  | 1.92E-4                  | 680        | 321       |
| A630              | 34                  | 1.23E-4                  | 780        | 481       |
| A800              | 50                  | 8.6E-4                   | 900        | 506       |
| B95               | 0                   | 8.33E-4                  | 260        | 384       |
| B150              | 6                   | 5E-4                     | 360        | 417       |
| B400              | 8                   | 1.72E-4                  | 640        | 514       |
| B630              | 10                  | 1.11E-4                  | 790        | 535       |
| B800              | 12                  | 0.86E-4                  | 900        | 616       |

Additional cable length for connections: 40 m/turbine

### Table 7
Acquisition cost of export and HV onshore cable.

| Voltage (kV) | Section (mm$^2$) | Var.Loss $W/A^2m$ | Export cable Capac. (MVA) | Cost (€/m) | Onshore cable Capac. (MVA) | Cost (€/m) |
|--------------|------------------|------------------|--------------------------|------------|--------------------------|------------|
| 220          | 500              | 6E-5             | 250                      | 843        | 273                      | 233        |
| 220          | 630              | 5E-5             | 273                      | 946        | 297                      | 266        |
| 220          | 800              | 4E-5             | 295                      | 1061       | 314                      | 299        |
| 220          | 1000             | 3E-5             | 314                      | 1214       | 348                      | 367        |
Table 8 presents the remaining components of the electrical infrastructure.

**Table 8**
Electrical items affecting the investment.

| Concept                        | Cost               |
|--------------------------------|--------------------|
| Acq. MV cables                 | see Tab. 6         |
| Installation                   | 120 € /m           |
| Acq. export cables             | see Tab. 7         |
| Installation                   | 170 € /m           |
| Acq. onshore cables            | see Tab. 7         |
| Inst. onshore cables           | 400 € /m           |
| Offshore substation            | 76 k€ /MW          |
| Offshore trafo                 | 19 k€ /MW          |
| Vessels mob demob              | 430 k€             |
| Reactive Compens.              | 128 kMVA           |
| Onshore substation             | 49 k€ /MW          |
| Onshore trafo                  | 11 k€ /MW          |
| Conn. to grid                  | 200 k€ /MW         |
| Shoreline                      | 1.65 M€            |
| OWF Power factor               | 0.85               |

Fig. 2 represents the map site, including depth curves (D1, D2, D3, D4, D5 and D6), forbidden zones (F1, F2, F3), concession area (C1), and coast shoreline. It also includes possible locations for observers in order to evaluate the visual or noise impact.

**Fig. 2.** Site map for Horns Rev I with depth curves (Dx), forbidden zones (Fx), concession area (C1), coast shoreline (S1) and observer positions (ox). Obtained from [8].

Tables 9, 10, and 11 list the sequence of points defining the depth curves, forbidden/concession areas, and coast shoreline, respectively, which are visualized in Fig. 2.

The Excel file in [8] has several sheets with these data:

- Geographic. Size of the workspace, number of sectors for the wind rose, roughness height, reference height, the wind rose, and value of Weibull parameters for each sector.
- Economic. Type of currency, interest rate, inflation, life time, energy price, availability, decommissioning cost, SCADA cost and O&M costs.
- Algorithm. Typical values for a genetic or evolutive algorithm.
- Turbine. Rated capacity, diameter, rotor height, price, installation cost, power curve, thrust curve.
- Foundations. Mobilitation/demobilization cost, foundation cost, cost increment as a function of the depth and the load-bearing capacity.
- Electrical_Data. All data related to cables and electrical infrastructure.
Table 9
Sequence of points defining the depth curves. Coordinates given in percentage (%).

| Depth 15 Symbol in map: D1 |
|--------------------------|
| (2.0, 50.5)-(4.7, 47.5)-(79, 36.3)-(18.7, 23.4)-(19.6, 71.1)-(23.5, 2.0)-(2.0, 2.0)-(2.0, 50.5) |

| Depth 15 Symbol in map: D2 |
|--------------------------|
| (17.9, 96.7)-(18.9, 82.0)-(22.5, 71.8)-(27.7, 67.0)-(27.2, 61.2)-(19.7, 70.6)-(15.8, 78.4)-(15.6, 93.1)-(17.9, 96.7) |

| Depth 15 Symbol in map: D3 |
|--------------------------|
| (33.0, 59.9)-(37.5, 53.3)-(43.1, 49.2)-(41.8, 44.2)-(38.9, 49.7)-(34.3, 49.7)-(30.5, 55.3)-(30.1, 59.9)-(33.0, 59.9) |

| Depth 5 Symbol in map: D4 |
|--------------------------|
| (47.3, 99.8)-(43.2, 83.8)-(43.6, 68.3)-(44.5, 64.7)-(49.4, 65.7)-(57.0, 55.8)-(71.9, 14.0)-(73.4, 0.3)-(0.3, 0.3)-(0.3, 99.8)-(47.3, 99.8) |

| Depth 10 Symbol in map: D5 |
|--------------------------|
| (11.70.1)-(4.3, 73.4)-(5.9, 67.3)-(12.5, 58.6)-(12.1, 44.7)-(18.3, 27.7)-(23.5, 26.9)-(30.1, 30.2)-(38.9, 39.1)-(38.0, 46.7)-(30.7, 47.2)-(26.2, 54.6)-(23.8, 60.7)-(14.4, 72.8)-(8.4, 83.0)-(11.1, 84.5)-(11.1, 70.1) |

| Depth 10 Symbol in map: D6 |
|--------------------------|
| (35.7, 99.0)-(29.0, 88.6)-(24.2, 93.7)-(20.2, 90.9)-(27.4, 72.3)-(36.1, 60.4)-(43.6, 53.3)-(46.7, 53.0)-(57.0, 24.4)- (61.4, 17.0)-(62.6, 1.0)-(1.0, 1.0)-(1.0, 99.0)-(35.7, 99.0) |

Table 10
Sequence of points defining the forbidden zones and the concession area. Coordinates given in percentage (%).

| Forbidden Symbol in map: F1 |
|---------------------------|
| (33.0, 49.0)-(39.0, 49.0)-(39.0, 41.0)-(33.0, 41.0)-(33.0, 49.0) |

| Forbidden Symbol in map: F2 |
|---------------------------|
| (15.0, 35.0)-(15.0, 23.0)-(19.0, 21.0)-(36.0, 21.0)-(36.0, 31.0)-(38.0, 31.0)-(38.0, 37.0)-(27.0, 37.0)-(25.0, 31.0)-(20.0, 31.0)-(15.0, 35.0) |

| Forbidden Symbol in map: F3 |
|---------------------------|
| (9.0, 43.0)-(9.0, 35.0)-(15.0, 35.0)-(15.0, 43.0) |

| Concession Symbol in map: C1 |
|-----------------------------|
| (11.70.1)-(4.3, 73.4)-(5.9, 67.3)-(12.5, 58.6)-(12.1, 44.7)-(18.3, 27.7)-(23.5, 26.9)-(30.1, 30.2)-(38.9, 39.1)-(38.0, 46.7)-(30.7, 47.2)-(26.2, 54.6)-(23.8, 60.7)-(14.4, 72.8)-(8.4, 83.0)-(11.1, 84.5)-(11.1, 77.2)-(11.1, 70.1) |

Table 11
Sequence of points defining the coast shoreline. Coordinates given in percentage (%).

| Coast Symbol in map: S1 |
|------------------------|
| (100.0, 100.0)-(100.0, 0.0)-(79.6, 0.0)-(74.3, 18.3)-(72.7, 23.6)-(73.0, 28.9)-(80.8, 32.2)-(82.4, 18.0)-(84.4, 21.3)-(85.7, 17.0)-(87.3, 4.6)-(86.0, 0.0)-(100.0, 0.0)-(100.0, 27.4)-(86.6, 27.2)-(716, 71.8)-(65.5, 63.7)-(70.5, 48.5)-(70.5, 41.4)-(68.0, 41.1)-(59.1, 61.4)-(51.4, 71.8)-(47.8, 72.8)-(45.4, 78.7)-(49.1, 100.0) |

Depths. Depth curves obtained from the bathymetric charts. Soil. Curves defining the different types of soil as a function of the load-bearing capacity. Forb_Conc. Curves defining the forbidden zones (e.g. too close to the coast or extraction areas) as well as the concession areas. Coast. Curve defining the coast shoreline. Impact. Sensitive positions where impact can be measured, as well as the observation height.

2. Experimental Design, Materials and Methods

The economic and technical data have been obtained from a deep review of technical reports, articles, and thesis. The source of this information is in [1].
Wind data regarding Horns Rev site has been obtained from [2]. This data were obtained from a real square lattice mast erected in 1999 at Horns Rev. It had four measurement levels, although only those from 62 meters (the highest one) have been used. Since this is not the tower height, it is necessary to adjust the scale parameter \( A \) from the measurement height \( (z_{\text{ref}} = 62 \, \text{m}) \) to the hub height \( (z_{\text{hub}} = 70 \, \text{m}) \) due to the wind shear effect. The relationship between scale factors, and in general between wind speeds, at different heights is given by

\[
A = A_{\text{ref}} \frac{\ln(z_{\text{hub}}) - \ln(z_0)}{\ln(z_{\text{ref}}) - \ln(z_0)}
\]

being \( z_0 \) the roughness length for the terrain. Its usual value taken for offshore sites is 0.005, which is also consistent with the wind profiles presented in [2].

The power and thrust curve for Vestas V80 has been obtained from [2].

Bathymetry has been obtained from globalwindatlas.info and [9].

Macro-economic data and energy price recovered from [3], and originally obtained from [4,5,6,7].

Ethics Statements

*The authors comply with the ethical guidelines contained in Data in Brief’s Guide for Authors.*

*This work did not involve human subjects.*

*This work did not involve animal experiments.*

*This work did not involve data collected from social media platforms.*

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Complete Dataset to be used as a workbench to evaluate the profitability of an offshore wind farm (Mendeley Data).

CRediT Author Statement

**Angel G. Gonzalez-Rodriguez:** Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft;
**Javier Serrano-Gonzalez:** Validation, Data curation, Investigation, Writing – review & editing;
**Manuel Burgos-Payan:** Project administration, Funding acquisition, Writing – review & editing;
**Jesus Riquelme-Santos:** Formal analysis, Supervision, Funding acquisition, Writing – review & editing.

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Appendix A. Input Data to the Algorithm

Wind data have been obtained from [2]. The measurement height is 62 m, and roughness height is 0.005.

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