STANDARDS DOCUMENT

MCS 033: 2025 ISSUE 1.0

**MCS 2025**

# Small Wind Turbine: Pre-Sale Information and System Performance Estimate Standard

To be used in conjunction with the MCS Customer Commitment

This Standard was prepared by the MCS Small Wind Turbines Working Group.

It is published by The MCS Service Company Ltd on behalf of The MCS Charitable Foundation.



The MCS Service Company Ltd welcomes comments of a technical or editorial nature and these should be sent to *meetings@mcscertified.com*



The MCS Service Company Ltd
Violet 3,
Sci-Tech Daresbury,
Keckwick Lane,
Cheshire WA4 4AB

www.mcscertified.com
hello@mcscertified.com
0333 103 8130

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# ABOUT MCS

MCS: Giving everyone confidence in home-grown energy

With energy costs constantly rising and climate change affecting us all – low-carbon technology has a bigger and bigger role to play in the future of UK energy. MCS is here to ensure it's a positive one.

MCS is the UK's quality mark for small-scale renewable energy technologies like solar PV, solar heating, heat pumps, biomass, and battery storage. We have two main roles – setting and maintaining standards, and providing consumer protection.

Our Standards define how certified renewable energy installations should be designed and installed using MCS certified products. They are a benchmark for quality developed in close consultation with industry through independent technical working groups.

The Standards are owned by The MCS Foundation (a charitable trust), but maintained and developed by MCS.

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# CHANGES TO STANDARDS

When MCS Standards are revised, the issue number is also revised to indicate the nature of the changes. This can either be a whole new issue or an amendment to the current issue. Details will be posted online, www.mcscertified.com

Technical or other significant changes which affect the requirements for the approval or certification of the product or service will result in a new issue. Minor or administrative changes (e.g. corrections of spelling and typographical errors, changes to address and copyright details, the addition of notes for clarification etc.) may be made as amendments.

The issue number is given on the left of the decimal point, and the amendment number on the right. For example, issue 3.2 indicates that it is the third significant version of the document which has had two sets of minor amendments.

Users of this Standard should ensure that they are using the latest issue.

**Amendments issued since publication**

| Issue No. | Amendment details | Date |
|---|---|---|
| 1.0 | First publication for MCS:2025 1.0 | 01/01/2025 |
| | | |
| | | |
| | | |

# FOREWORD

Compliance with this Standard is mandatory for MCS Contractors certified to MCS: 2025.

The purpose of this Standard is to specify best practice in achieving high-quality low carbon technology installations. Whilst it is not possible to ensure safety, this Standard provides requirements which should help mitigate potential safety risks associated with the design and installation of this technology.

This document contains references to other documents which may be either normative or informative. At the time of publication any editions of those documents, where indicated, were valid. However, as all documents are subject to revision, any users of this document should apply the most recent editions of those referenced documents (unless a dated version is specified).

*NOTE:*
*This MCS Standard makes use of the terms 'must', 'shall' and 'should' when prescribing certain requirements and procedures. In the context of this document:*

- the term 'must' identifies a requirement by law at the time of publication;
- the term 'shall' prescribes a requirement or procedure that is intended to be complied with in full and without deviation;
- the term 'should' prescribes a requirement or procedure that is intended to be complied with unless reasonable justification can be given.

*Compliance with this MCS Standard does not in itself confer immunity from legal obligations.*

# 1 SCOPE

This Standard describes the method to estimate the amount of renewable energy which might be delivered, by a small wind energy system during a typical year. Two methods are given. One based on the mean windspeed based on the site's grid reference and the other based on site-specific windspeed monitoring. This document is to be used in conjunction with the MCS Customer Commitment. The format in which this shall be presented to the customer is also given along with the technical information to accompany the estimate.

Performance estimates enable customers to compare different systems. The use of this MCS Standard for performance estimates brings a comparable and consistent methodology for different wind turbine configurations.

The estimates are based on the best knowledge of MCS of wind turbine applications.

This Standard and its associated requirements shall be complied with before a contract is awarded to the customer.

*Note: Where site characteristics are unknown, best assumptions shall be made.*

Additional estimates may be provided using alternative methodologies, including proprietary software packages, but:

a) Such estimates shall clearly describe and justify the approach taken and factors used

b) They shall not be given greater prominence than the standard MCS estimate

c) They shall be accompanied by warning text stating that it should be treated with caution if it is significantly better than the result given by the standard method.

# 2 METHOD (MEAN WIND SPEED)

## 2.1 Proposed turbine

Identify:

(a) The hub height ($h_t$) in meters for the proposed turbine above ground.

(b) The turbine Annual Energy Performance Curve for each wind speed band (m/s).

*Note: The Annual Energy Performance Curve is not the Power Curve. Measured Power Curve is a table and graph that represents the measured, corrected and normalised net power output of a wind turbine as a function of measured wind speed, measured under a well-defined measurement procedure. Annual Energy Performance is the estimate of the total energy production of a wind turbine during a one-year period by applying the measured power curve to different reference wind speed frequency distributions a hub height, assuming 100% availability.*

## 2.2 Site evaluation

(c) Identify the category of terrain which best describes the topography surrounding the site for the proposed turbine (see Appendix A, Table 1).

(d) Identify any obstructions that exist upwind and downwind of the location of the proposed turbine.

A significant obstruction is any solid object (such as a building or wall) or semi permeable object (such as tree or bush) that is greater than 0.5m at is widest and reaches a height greater than 0.25 of the hub height of the turbine.

Upwind and downwind: The compass bearing (orientation) of Zones A (upwind) and B (downwind) is defined by prevailing wind direction. The prevailing wind direction for the location should be obtained using the Global Wind Atlas Wind Frequency Rose or other reliable source.

*Note: Use of the Global Wind Atlas is subject to its Terms of Use as given on its website.*

(e) Record the height ($h_o$) of the highest obstruction within those zones

Figure 1 shows that:

- The height of the highest obstruction ($h_o$) shall determine how far Zones A and B extend in the upwind and downwind direction; and
- The height of the turbine ($h_t$) shall determine how far the zones extend perpendicular to the upwind and downwind direction.

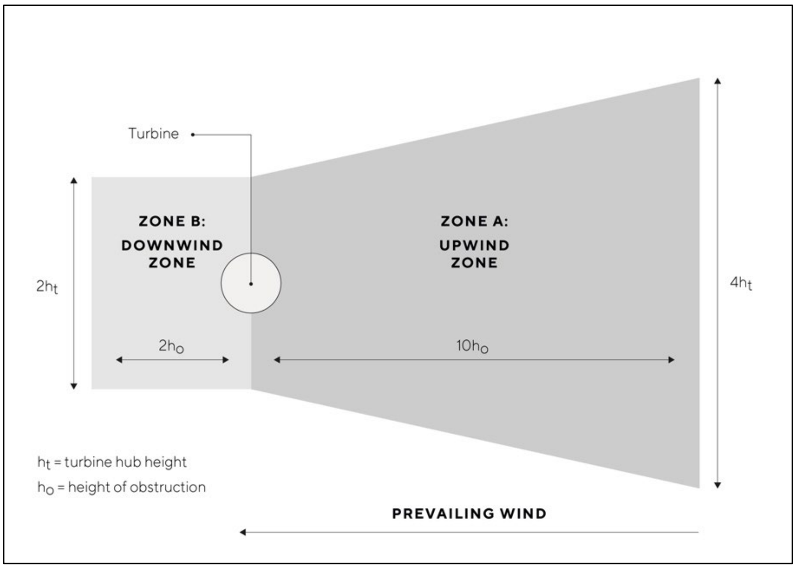


*Figure 1: Obstruction zones*

(f) Calculate a corrected hub height ($h_c$) as follows:

a. Where no significant obstructions then:

$$h_c = h_t$$

b. Where one or more significant obstructions identified in (d) then:

$$h_c = h_t - (0.8 \times h_o)$$

### 2.3 Mean windspeed

(g) Obtain the mean windspeed ($V_{10}$) in m/s using:

- the 10m height option from the Global Wind Atlas (https://globalwindatlas.info/); and
- the exact grid reference of the turbine site location.

(h) Using terrain category from step (c) and the corrected hub height ($h_c$) from step (f) , lookup the correction factor ($C_f$) in Appendix A, Table 2.

(i) Calculate an adjusted mean wind speed ($V_c$) using the formula:

$$V_c = V_{10} \times C_f$$

## 2.4 Estimate of annual energy generation

(j) Identify the annual energy generation for $V_c$ using the Annual Energy Performance Curve for the proposed turbine obtained in step (b).

*Notes:*

*$V_c$ should be rounded to one decimal place and linear interpolation used where necessary to calculate the estimated annual energy generation from the Annual Energy Performance Curve for the proposed turbine..*

*Where $V_c$ is higher or lower than the values given in the Annual Energy Performance Curve, then the turbine manufacturer should be contacted for guidance.*

*Where the Annual Energy Performance Curve is not available then the annual energy can be approximated using the Power Curve and multiplying the power at $V_c$ by 8760. However, this method is likely to be less accurate because it does not account for the frequency distribution of the wind. Therefore, if this method is used, the reduced accuracy should be explained to consumers.*

# 3 PRESENTATION FORMAT (MEAN WIND SPEED)

The results of the preceding calculation shall be given to the customer using the format given below along with the Key Information from Section 6.

A Wind Energy System Performance Estimate (WESPE) tool is published on the MCS website which can be used to undertake the calculations given in this Standard. It also produces an output table in the correct format.

The turbine Annual Energy Performance Curve shall accompany this presentation of the results.

| Wind energy system performance estimate (based on mean wind speed) | | |
|---|---|---|
| Turbine | | |
| Turbine brand & model | | |
| Hub height above ground | | m |
| Swept area | | $m^2$ |
| Power rating (at 11m/s) | | kW |
| Your property / Proposed turbine location | | |
| Location grid reference | | Deg. Latitude |
| | | Deg. Longitude |
| Looked up mean windspeed at 10m height for location | | m/s |
| Terrain description (from Appendix A, Table 1) | | |
| Local Obstructions | | |
| Is there one or more significant obstructions in the upwind or downwind zones of the proposed turbine location? | ☐ Yes | ☐ No |
| Height of obstruction(s) | | m |
| Corrected Mean Wind Speed | | |
| The mean wind speed adjusted to allow for actual hub height, terrain and any local obstruction(s) (where relevant). | | m/s |
| Estimate of Energy Generation | | |
| Estimate of energy generation per annum based on the corrected mean wind speed | | kW |

# 4 METHOD (SITE MONITORING)

## 4.1 Proposed turbine

Identify:

(a) The turbine Swept Area (A) in $m^2$; and

(b) The turbine Power Curve giving the kW ($P_{out}$) against wind speed (m/s).

## 4.2 Wind resource measurement

(c) Using industry best practice for the siting and installation of meteorological masts for wind resource measurement obtain the following measurements:

a. The wind speed (m/s);
b. Air temperature (°C);
c. Air pressure (Pa) (for estimates based on air density see 4.5.3).

Readings shall be recorded at intervals not greater than 10 minutes apart and for a monitoring period not less than six months and preferably one year.

*Notes:*

*For guidance on the siting and installation of meteorological masts see IEC 61400-12. Procedures for calibration, classification and uncertainty assessment of anemometers and other sensing devices are given in IEC 61400-50-1 and IEC 61400-50-2 respectively.*

*Planning permission may be required for the erection of meteorological masts. Check with the planning authority for the proposed site.*

## 4.3 Extrapolated wind speed

(d) Where the height of the anemometer is higher or lower than the hub height of the proposed wind turbine, an estimate of extrapolated wind speed shall be obtained using the following equation:

$$V2 = V1 \times \left(\frac{H2}{H1}\right)^{\alpha}$$

In which the wind speed (V2) at hub height H2 is being calculated using the speed (V1) at the measuring height H1 and α is an exponent representing the friction coefficient for the local terrain selected from Appendix A, Table 3.

### 4.4 Allocate hours to wind speed frequency distribution

(e) Calculate the percentage of datapoints that fall within each wind speed band (m/s).

(f) Convert those percentages to hours in a year for each wind speed band by multiplying by 8760.

For example, if the monitoring found that 10.5% of all wind speed datapoints fell within the 7m/s band, then 10.5% of 8760 hours being 920hrs should be allocated to that wind speed band.

### 4.5 Estimate of annual energy generation

Measured wind data can be processed in different ways to derive estimates of wind generation. This document describes three methods below any of which can be used.

4.5.1 Simple estimate of energy using measured wind speed and power curve

(g) Calculate the energy generated ($E_x$) in kWh for each wind speed band (m/s) by multiplying $P_{out}$ for each wind speed band by the number of hours per year for each wind speed band from step (f).

For example, where a turbine Power Curve indicates an output of 4.41kW at wind speed 7m/s and the wind speed frequency distribution calculated in step (f) at that wind speed was 812 hours, then the estimate of energy generated within that wind speed band is 812(hours) * 4.41(kW) = 3581kWh.

(h) Calculate the estimate of annual energy generation ($E_{total}$) in kWh as the sum of each value of $E_x$ for each wind speed band:

$$E_{total} = \sum (E_1, E_2, E_3 ...)$$

4.5.2 Estimate of energy using the Weibull Distribution

The Wind Speed Frequency Distribution described in 4.4 can be adjusted using Weibull probability density function to describe the site's wind resource and provide a more realistic prediction of the wind speed distribution over multiple years. Various tools and methods are available to calculate the Weibull parameters $\beta$ (shape) and $c$ (scale). The method chosen must conform to good practice using industry-recognised methods.

(i) Where the Weibull distribution is obtained, record:

- the $\beta$ (shape), and
- the $c$ (scale) parameters

(j) Using the above distribution parameters calculate the total number of hours allocated to each wind speed band in m/s – Weibull Distribution

(k) Use the adjusted hours for each wind speed band in step (g) to calculate the estimate of annual energy generation $E_{total}$ in step (h).

4.5.3 Estimate of energy using measured air density

(l) Calculate the air density (ρ) in kg/m$^3$ for each measured datapoint using the following equation:

$$\rho = \frac{P}{R \times T}$$

Where P is the air pressure in Pascals (Pa), R is the specific gas constant for air (287J/kg K), and T is the air temperature in Kelvin (the measured temperature from step (c), plus 273).

(m) Calculate the power density ($P_{in}$) for each measured datapoint for 1m$^2$ of the wind resource using the following equation:

$$P_{in} = \frac{1}{2} \rho 1 V^3$$

Where V is the measured windspeed.

(n) Calculate the maximum potential energy generated ($E_{pot}$) in kWh for each datapoint using the following equation:

$$E_{pot} = P_{in} \times A \times (600 \div 3600000)$$

Where A is the swept area of the proposed turbine identified at step 4.1 (a).

(o) Sum the maximum potential energy calculated in (p) for each datapoint into each wind speed band.

(p) Calculate the turbine Power Coefficient ($C_p$) for each wind speed m/s band as follows:

a. Identify $P_{in}$ for each wind speed band using the turbine swept area:

$$P_{in} = \frac{1}{2} \times 1.225 \times A \times V^3$$

Where 1.225 is the estimate of air density and A is the turbine swept area and V is the wind speed.

b. Divide the Power Curve values in each wind speed band by the corresponding values obtained in a. for each wind speed band. For example, if the $Pin$ for wind speed 5m/s is found to be 6133W and the Power Curve for that wind speed is 1550W then the $Cp$ for that wind speed is 1550÷6133=0.25.

(q) Multiply the potential energy calculated for each wind speed band from (q) and the turbine Power Coefficient for each wind speed band from (r) to calculate the energy generated for each windspeed band ($E_x$):

$$E_x = E_{pot} \times C_p$$

(r) Calculate the estimate of annual energy generation ($E_{total}$) in kWh as the sum of each value of $E_x$ for each wind speed band:

$$E_{total} = \sum (E_1, E_2, E_3 \ldots)$$

For example, if the total potential energy in wind speed band 5m/s is calculated (v) to be 8265kWh and the $C_p$ for that wind speed is 0.25 then the Estimate of Energy using measured Air Density is 8265kWh*0.25=2089kWh. The sum of the results for all wind speed bands gives the total. The results can be extrapolated to a full year.

# 5 PRESENTATION FORMAT (SITE MONITORING)

The results of the preceding calculation shall be given to the customer using the format given below along with the Key Information from Section 6.

A Wind Energy System Performance Estimate (WESPE) tool is published on the MCS website which can be used to undertake the calculations given in this Standard. It also produces an output table in the correct format.

The turbine power curve and raw monitoring data shall accompany this presentation of the results.

| Wind energy system performance estimate (based on monitoring) | | |
|---|---|---|
| Turbine | | |
| Turbine brand & model | | |
| Hub height above ground | | m |
| Swept area | | $m^2$ |
| Power rating (at 11m/s) | | kW |
| Your property / Proposed turbine location | | |
| Location grid reference | | Deg. Latitude |
| | | Deg. Longitude |
| Monitoring period | | Dates from/to |
| *Where the monitoring period is for less than one year, then the results are extrapolated to a full year.* | | |
| Interval period | | Minutes |
| Anemometer height above ground | | m |
| Terrain description (from Appendix A, Table 1) | | |
| Estimate of energy generation (complete at least one) | | |
| Simple method | | kWh |
| Adjusted for Weibull | | kWh |
| Based on air density | | kWh |

# 6 KEY INFORMATION

Important Note: Accurate predictions of energy generation from wind turbines are impossible due to site-specific conditions and the variability of wind speed from year to year. This estimate is based upon the standard MCS procedure and is given as guidance only. It should not be considered as a guarantee of performance. For more certainty, it is recommended that where cost-effective, on-site wind speed monitoring is undertaken for at least a year.

Identifying the uncertainties of performance forecasts for energy generating systems

A range of variables affect how much energy a wind turbine will generate and how efficiently it can deliver that energy. The most important are described below:

Wind speed and the geographical location of the turbine. Generally, the higher the average wind speed at any specific location, the greater the potential power available. The best locations tend to be on higher ground where the prevailing wind is not obstructed or interrupted by, for example, the local topography, trees, or buildings.

There is eight times the potential power available at a site where the average wind speed is 7m/s compared to a site where the average wind speed is 3.5m/s. This occurs because the available power is proportional to the cube of the wind speed which means that apparently small differences in the average wind speed result in dramatic variations in the potential energy. A particular project may be viable where the average annual wind speed is, for example, 6 or 7m/s. Sites below 5m/s at hub height may not be viable. This demonstrates why careful site evaluation is so critical (see below: *Site evaluation and on-site wind speed monitoring).*

Site turbulence. The landscape can have a complicated influence on a turbine's ability to generate energy efficiently. For example, a site can have a high average wind speed, but can also be subject to turbulence: winds that are highly variable in speed and direction. Turbulence can curtail energy generation and the pulses in wind velocity can stress turbine components (which can shorten the life of the whole turbine). Turbulence is caused by obstructions such as trees, the built environment, and topographical features. Some sites may only be viable using turbines that are designed to cope with turbulent conditions.

Weather trends. Differences in the annual average wind speed at any specific location are known as inter-annual variations and these fluctuations can have an impact on the energy generation.

Turbine hub height and local terrain. The wind speed is impacted by the 'surface roughness' of the ground. Areas with lots of buildings, trees, walls, shrubs and other obstructions will cause friction between the wind and the ground curtailing wind speed. Flat areas of grassland or calm water creates the least friction. Average wind speeds increase in direct relation to the height

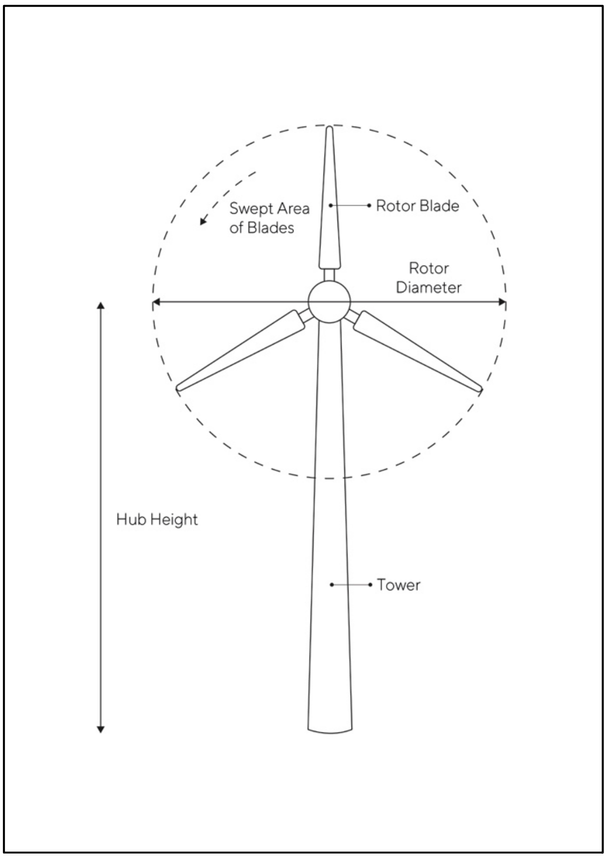

*Figure 2: A typical 3-blade horizontal axis wind turbine*

above ground. Known as 'wind shear' this variation in wind speed usually means that the higher the turbine above ground, the greater the generation is likely to be.

Swept area. The swept area refers to the total surface area of the circle created by the turbine blades as they rotate (*see Figure 2*). Also known as the rotor swept area, the larger the swept area, the greater the generation will be. The swept area is very important because, if you double the swept area, you double the potential energy available for generation.

You only need to increase the radius by a factor of 1.41 to double the swept area. For example, a turbine with a blade length of 3 meters will have a swept area of just over $28m^2$ whilst a blade length of 4.23 will have a swept area of just over $56m^2$.

The turbine's power curve. Wind turbine models have their own characteristic 'power curve': a chart that plots the amount of electricity it will generate as a function of the wind speed. The 'rated' output is the amount of power the turbine can deliver at a wind speed of 11m/s. The wind speed to which the rated output applies will vary from model to model. It is important that the turbine power curve is suitable for the site available.

The power curve will also show:

- The 'cut-in' speed - the wind speed when the turbine starts to generate energy.
- The 'cut-out' speed - the speed when the turbine shuts down to prevent damage.

The power curve alone is not good at estimating the likely energy generation using the average wind speed because the average wind speed does not describe variations in wind speed over time. That wind speed variation is known as the wind speed distribution.

<u>Site evaluation and on-site wind speed monitoring</u>

As noted above, careful site evaluation is critical when deciding whether a specific location is suitable for a planned wind turbine. Any estimate of energy generation depends on a thorough assessment of the wind resource. There are two ways this can be done:

- An assessment of the site based on the mean (average) wind speed obtained from a public database.
- Direct measurement of the site's wind resource (on-site wind speed monitoring).

Both methods have advantages and disadvantages.

### Performance estimates based on mean wind speed

A site can be assessed using estimates for the *average* wind speed for the area where the turbine is to be situated. These averages are obtained from datasets based on global monitoring and modelling.

| Assessments based on mean wind speed models | |
|---|---|
| **Advantages** | **Disadvantages** |
| The process is straightforward. | Estimates of the average wind for a particular area do not consider factors that are site specific. For example, local obstructions and terrain. Instead, those factors are built into the assessment adjusting the calculations to 'model' the way they constrain the wind speed. Inevitably, those adjustments are imprecise. |
| The method is inexpensive.<br>Your installer will provide this estimate to you automatically as part of the pre-sale information you will receive. | Estimates of the average wind speed uses a generic Weibull distribution for the wind speed distribution this can weaken confidence in any estimate of likely energy generation. |
| While the calculations will almost certainly require a site visit, the assessment can be carried out quickly. | |

### Performance estimates based on on-site monitoring

The wind resource can also be assessed by measuring the wind speed over a period at the precise location of the planned turbine. This bespoke information can be used to estimate the likely energy generation of a turbine more accurately.

| Assessments based on on-site monitoring | |
|---|---|
| **Advantages** | **Disadvantages** |
| Because the process measures the wind speed directly, this will include the impact of any local obstructions, the local topography and terrain. | On-site monitoring requires the installation of a meteorological mast (met mast) to carry the instruments necessary to monitor the wind. The cost of the met mast installation and subsequent analysis will need to be factored into the project cost/benefit calculation. |
| The data acquired from on-site monitoring will always include the wind speed *distribution.* | The data is a snapshot in time and does not represent average wind speeds outside of the monitoring period. |

| | |
|---|---|
| Overall, on-site monitoring should provide a more accurate estimate of likely energy generation – especially where the monitoring was carried out for about one year. | The monitoring will delay the wind turbine project development.<br>Met masts in some locations may require planning permission. |

The advantages and disadvantages of both methods should be considered when deciding how the information about the wind resource should be obtained. Whilst on-site monitoring does provide a more accurate assessment, it is unlikely to be viable where small turbines are being planned as the cost of the monitoring relative to the likely energy generation may be prohibitive. On the other hand, where the cost of monitoring is low in relation to the likely energy generation, and it is critical that the turbine installation project achieve a target minimum annual generation, then on-site monitoring should be considered.

### Conclusion

The combined effect of all the factors identified above on the wind turbine system make any performance prediction imprecise although estimates based on on-site monitoring should be significantly more reliable. This potential variability should be considered when making choices based on financial criteria (for example, when 'payback' is being estimated based on capital cost versus net benefits such as energy cost savings).

| Factor | Impact |
|---|---|
| 'Fixed' which include: | |
| Obstructions (in particular – those that are upwind of the proposed turbine site and in the direction of the prevailing wind) | Wind energy input |
| Topography | Wind energy input |
| Local Terrain | Wind energy input |
| 'Variable' which are affected by the system design and include: | |
| Wind turbine model choice (power curves vary) | System efficiency |
| The hub height of the turbine (usually the higher the hub height, the better) | System efficiency |
| The turbine swept area (as described above) | System efficiency |
| 'Random' which cannot be fully anticipated and include: | |

| | |
|---|---|
| Wind Speed (whilst the average wind speed for the local area can be anticipated, it can vary from year to year) (on-site monitoring will provide a more accurate assessment at the precise location of the turbine, but this can also vary from year to year) | Wind energy input |
| Weather (storms and periods of calm weather can constrain the wind energy available in the short term) | Wind energy input |
| Local developments (for example, new building or tree planting that may occur within the vicinity of the turbine) | Wind energy input |
| User behaviour (for example, in following operating instructions and in relation to maintenance) | System efficiency |

Key:
The various factors listed in the table 'impact' the system performance in different ways. Those are identified in the second column and are described below.

Wind energy input:
The wind energy that reaches the turbine.

System efficiency:
The system performance will be directly impacted by these factors. Optimum design will ensure good system efficiency, but other factors are important such as local conditions and user behaviour.

# 7 ACOUSTIC PERFORMANCE ESTIMATE

**7.1** An estimate of the acoustic performance shall be calculated using the procedure detailed in this section.

*Note: Noise from small wind turbines can be categorised in two ways:*

*a) Aerodynamic noise from the rotating blades.*
*b) Mechanical noise from the generator.*

*Whether the noise is intrusive or not will depend on the level of extraneous background sound. Turbine noise increases with operating duty, but background noise is also likely to increase with stronger winds.*

**7.2** The acoustic performance estimate shall be communicated in the prescribed format to the client before the point that the contract is awarded and shall be accompanied by the following text:

*"Important Note: The acoustic performance estimate is based upon a standardised method using publicly available information. It is given as guidance only and should* ***not*** *be considered to be guaranteed. The energy performance of wind turbine systems is impossible to predict with a high degree of certainty due to the variability in the wind from location to location and from year to year."*

*For a greater level of certainty, it is recommended that on-site wind speed monitoring is undertaken for at least a year. Note: it may be useful to monitor for shorter periods, especially if the acquired data is then correlated with other sources in order to estimate an annual mean wind speed".*

The details of the standardised and any additional estimates of the acoustic performance shall be recorded and retained in the project file.

### 7.3 Method

1. Establish a 10m altitude mean wind speed for the proposed location using the [Global Wind Atlas (GWA)] database (**$VN_{10}$**, at 10m height)

2 Assume a Rayleigh wind distribution[1] and calculate the 90% wind speed for 10m height as:

$$V_{90,10} = 1.71 \times VN_{10}$$

For a given mean wind speed and the assumed distribution, the wind speed will be less than this value for 90% of the time.

---

[1] In probability theory and statistics, the Rayleigh distribution is a continuous probability distribution for nonnegative-valued random variables. It is essentially a chi distribution with two degrees of freedom. A Rayleigh distribution is often observed when the overall magnitude of a vector is related to its directional components. One example where the Rayleigh distribution naturally arises is when wind velocity is analysed in two dimensions. Assuming that each component is uncorrelated, normally distributed with equal variance, and zero mean, then the overall wind speed (vector magnitude) will be characterised by a Rayleigh distribution.

The cumulative distribution is given by

$$F(b) = 1 - e^{-(b/c)^2}$$

Where F(b) is the cumulative density function [in the case above 0.9 (90%)].

c = 2 x **$VN_{10}$** / sqr.rt π

b = wind speed at 90% which is equal to Y x **$VN_{10}$**

Therefore, by substitution Y = 1.71

3. Apply a wind correction factor from 10m height using power law (in accordance with IEC 61400-2) to get an estimate of wind at the installed rotor centre, H, as:

$$V_{90,H} = V_{90,10} \times \left(\frac{H}{10}\right)^{0.143}$$

   In the above equation, the exponent is an empirically derived coefficient that varies dependent upon the stability of the atmosphere. For neutral stability conditions, the value is approximately 1/7, or 0.143. Note that in places where trees or structures impede the near-surface wind, the use of a constant 1/7 exponent may yield erroneous estimates.

4. Draw a horizontal line on the Emission Noise Map in the BWEA Noise Label (per BWEA Small Wind Turbine and Performance Standard) at the V90, H wind speed.
5. Read off the distance for the acoustic dB(A) values of interest.
6. Compare these distances with the slant distance from the turbine hub to the nearest noise sensitive locations(s) for the planned installation.

# APPENDIX A – LOOKUP DATA

| Category | Terrain type |
|---|---|
| 1 | Flat grassland, parkland, or bare soil, without hedges and only a few isolated obstructions. |
| 2 | Gently undulating countryside, fields with crops, fences or low boundary hedges and few trees. |
| 3 | Farmland with high boundary hedges, occasional small farm structures, houses, and trees. |
| 4 | Woodland or low-rise urban/suburban areas (e.g. domestic housing) with a plan area density of up to about 20%. |
| 5 | Dense urban areas and city centres (e.g. buildings of four storeys or higher) with a plan area density of greater than about 20%. |

*Table 1: Categories of Terrain*

| Column 1 $h_c$ | Terrain categories | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | 0.74 | 0.60 | 0.43 | 0.24 | 0.05 |
| 1.5 | 0.80 | 0.67 | 0.51 | 0.33 | 0.14 |
| 2 | 0.85 | 0.72 | 0.56 | 0.39 | 0.20 |
| 2.5 | 0.89 | 0.76 | 0.60 | 0.43 | 0.25 |
| 3 | 0.92 | 0.79 | 0.64 | 0.47 | 0.29 |
| 3.5 | 0.94 | 0.82 | 0.67 | 0.50 | 0.33 |
| 4 | 0.96 | 0.84 | 0.69 | 0.53 | 0.35 |
| 4.5 | 0.98 | 0.86 | 0.71 | 0.55 | 0.38 |
| 5 | 1.00 | 0.88 | 0.73 | 0.57 | 0.40 |
| 6 | 1.03 | 0.91 | 0.77 | 0.61 | 0.44 |
| 7 | 1.05 | 0.94 | 0.80 | 0.64 | 0.48 |
| 8 | 1.08 | 0.96 | 0.82 | 0.67 | 0.51 |
| 9 | 1.09 | 0.99 | 0.84 | 0.69 | 0.53 |
| 10 | 1.11 | 1.00 | 0.86 | 0.71 | 0.56 |
| 11 | 1.13 | 1.02 | 0.88 | 0.73 | 0.58 |
| 12 | 1.14 | 1.04 | 0.90 | 0.75 | 0.60 |
| 13 | 1.16 | 1.05 | 0.92 | 0.77 | 0.62 |
| 14 | 1.17 | 1.06 | 0.93 | 0.78 | 0.63 |
| 15 | 1.18 | 1.08 | 0.94 | 0.80 | 0.65 |
| 16 | 1.19 | 1.09 | 0.96 | 0.81 | 0.66 |
| 17 | 1.20 | 1.10 | 0.97 | 0.83 | 0.68 |
| 18 | 1.21 | 1.11 | 0.98 | 0.84 | 0.69 |
| 19 | 1.22 | 1.12 | 0.99 | 0.85 | 0.70 |
| 20 | 1.23 | 1.13 | 1.00 | 0.86 | 0.71 |
| 25 | 1.24 | 1.14 | 1.01 | 0.87 | 0.72 |
| 30 | 1.24 | 1.14 | 1.02 | 0.88 | 0.74 |
| 35 | 1.25 | 1.15 | 1.03 | 0.89 | 0.75 |
| 40 | 1.26 | 1.16 | 1.03 | 0.90 | 0.76 |
| 45 | 1.26 | 1.17 | 1.04 | 0.91 | 0.76 |
| 50 | 1.27 | 1.17 | 1.04 | 0.91 | 0.76 |
| 60 | 1.28 | 1.18 | 1.06 | 0.92 | 0.78 |
| 70 | 1.28 | 1.19 | 1.06 | 0.93 | 0.79 |
| 80 | 1.29 | 1.19 | 1.07 | 0.94 | 0.80 |
| 90 | 1.30 | 1.20 | 1.08 | 0.95 | 0.81 |
| 100 | 1.32 | 1.23 | 1.11 | 0.98 | 0.84 |

*Table 2: Mean windspeed correction factors*

| Landscape type | Friction coefficient (α) |
|---|---|
| Lakes, ocean and smooth hard ground | 0.10 |
| Grasslands (ground level) | 0.15 |
| Tall crops, hedges and shrubs | 0.20 |
| Heavily forested land | 0.25 |
| Small town with trees and shrubs | 0.30 |
| City areas with high buildings | 0.40 |

*Table 3: Friction coefficient*

# APPENDIX B – WORKED EXAMPLES

<u>Example based on mean wind speed</u>

*A horizontal wind turbine is proposed for a site located in Argyll.*

*The calculation would be as follows:*

(a) *The hub height = 15m*

(b) *The turbine Annual Energy Performance curve is as below in Table 4*

| Mean wind speed (m/s) | Annual energy performance (kWh) |
|---|---|
| 2 | 375 |
| 3 | 1,250 |
| 4 | 2,700 |
| 5 | 4,450 |
| 6 | 6,300 |
| 7 | 8,160 |
| 8 | 9,800 |
| 9 | 11,100 |
| 10 | 12,100 |

*Table 4: Annual Energy Performance of proposed turbine*

(c) *Local terrain category = 3 (farmland with high boundary hedges and small farm structures)*

(d) *Obstructions = small tree 6m high 20m upwind of the proposed turbine. Therefore, the upwind and downwind zones are 60m and 12m respectively.*

(e) *Height of the highest obstruction in the zone ($h_o$) = 6m*

(f) *Corrected hub height $H_c$ =*

$$h_t - (0.8 \times ho)$$

$$8 - (0.8 \times 6)$$

$$3.2m$$

(g) *Mean wind speed ($V_{10}$) at 10m surface height (see Figure 4) = 7.17m/s*

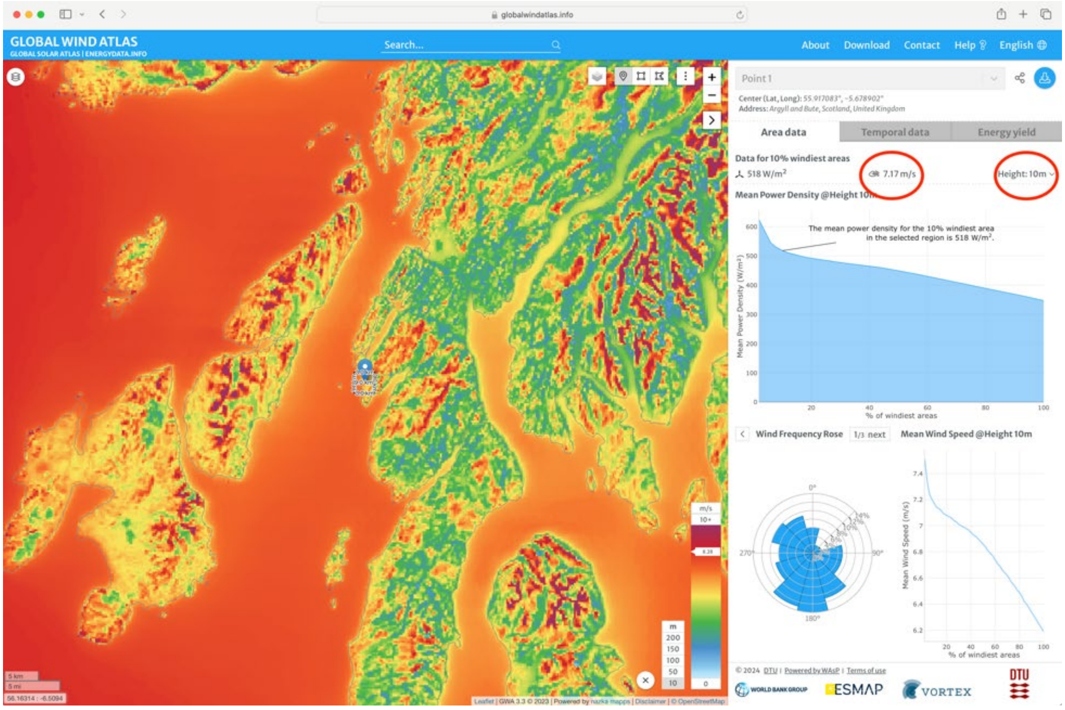


*Figure 3: Global wind atlas result for example location*

(h) *Using terrain category 3 and $H_c$ of 3.2m the correction factor = 0.64*

(i) *Adjusted mean wind speed ($V_c$) =*

$$V_{10} \times C_f$$

$$7.17 \times 0.64$$

$$4.57 \text{ m/s}$$

(j) *Proposed turbine Annual Energy Performance using $V_c$ rounded to one decimal place of 4.6m/s =*

*3,750 kWh*

Example based on site monitoring

*Another horizontal access wind turbine with a hub height of 24m located in open grassland.*

(a) *Turbine swept area = 78.5m²*

(b) *The turbine Power curve is as below in Figure 5*

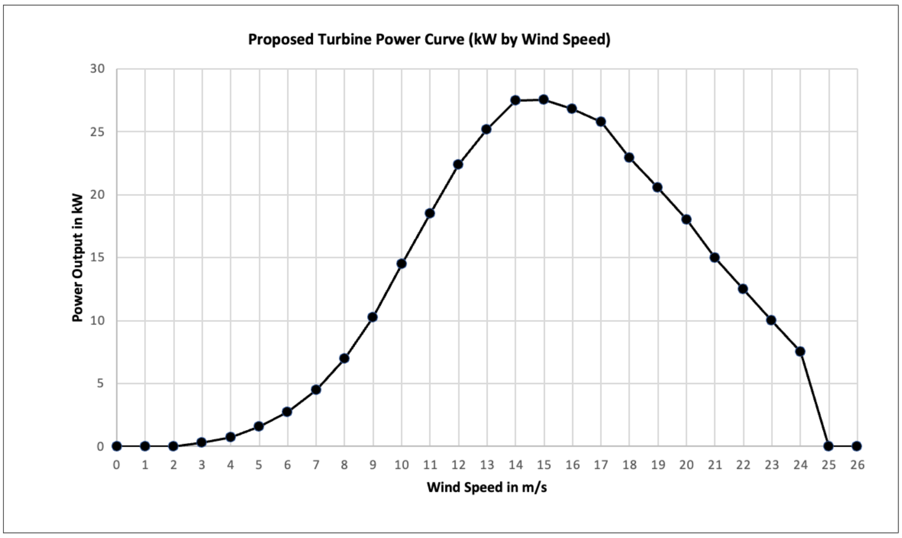


*Figure 4: Proposed turbine power curve*

(c) *Number of measurements taken of wind speed, temperature and air pressure at 10-minute intervals = 34,465*

(d) *Measurement height (H1) 20m whereas proposed hub height (H2) is 24m so wind speed measurements scaled using a friction coefficient from Table 3 of 0.15 by =*

$$V2 = V1 \times \left(\frac{H2}{H1}\right)^{\alpha}$$

$$V2 = V1 \times (24/20)^{0.15}$$

$$V2 = V1 \times 1.027$$

(e) The percentage of datapoints in each wind speed band, are calculated and represented in Figure 6 below.

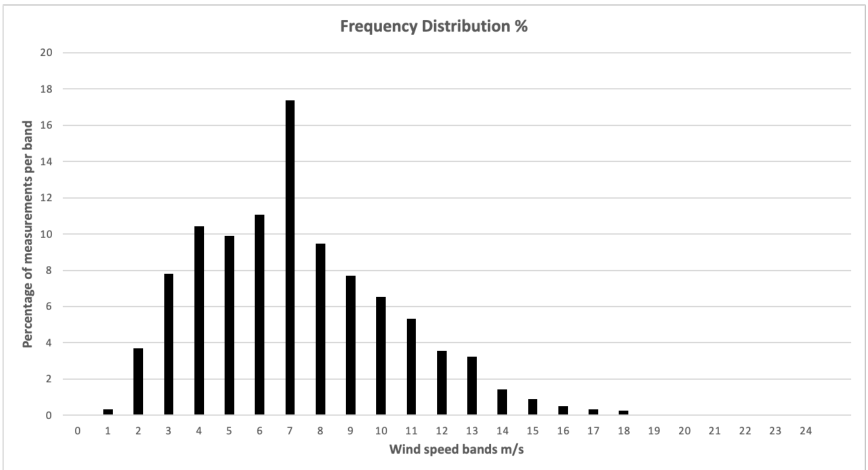


*Figure 5: Frequency distribution (percentage) of wind speed measurements*

(f) The percentages above are converted to hours per year by multiplying by 8760.

(g) As a simple calculation, the energy for each wind speed band is calculated for each wind speed band by multiplying the hours by the power output from the power curve as in Table 5

| Wind speed band (m/s) | Hours per year | Power Curve (kW) | Energy delivered (kWh) |
|---|---|---|---|
| 0 | 30 | 0.0 | 0 |
| 1 | 324 | 0.0 | 0 |
| 2 | 684 | 0.0 | 0 |
| 3 | 913 | 0.3 | 274 |
| 4 | 868 | 0.7 | 608 |
| 5 | 969 | 1.6 | 1550 |
| 6 | 1520 | 2.8 | 4256 |
| 7 | 830 | 4.5 | 3735 |
| 8 | 673 | 7.0 | 4711 |
| 9 | 572 | 10.3 | 5892 |
| 10 | 466 | 14.5 | 6757 |
| 11 | 311 | 18.5 | 7918 |
| 12 | 283 | 22.4 | 3718 |
| 13 | 124 | 25.2 | 3125 |
| 14 | 80 | 27.5 | 2200 |
| 15 | 43 | 27.5 | 1183 |
| 16 | 28 | 26.8 | 750 |
| 17 | 22 | 25.8 | 568 |
| 18 | 5 | 23.0 | 115 |
| 19 | 4 | 20.6 | 82 |
| 20 | 5 | 18.0 | 90 |
| 21 | 3 | 15.0 | 45 |
| 22 | 1 | 12.5 | 13 |
| 23 | 0 | 10.0 | 0 |
| 24 | | 7.5 | 0 |
| Total | 8760 | | 47590 |

*Table 5: Measured data calculation*

(h) The estimate of the annual generation ($E_{total}$)is the sum of the values in the last column of Table 5 =

$$\sum (E_1, E_2, E_3...)$$

*47,590kWh*