EXECUTIVE SUMMARY

This report summarises the full findings from the Encraft Warwick Wind Trials Project covering 168950 hours of operation of 26 building mounted wind turbines from five manufacturers across the UK during 2007-2008. These turbines were mounted on sites ranging from theoretically poor (single storey urban buildings) through to theoretically excellent (45m tall exposed flats in isolated settings on hilltops).

The objectives in setting up the trial were to see how grid connected microwind turbines perform on a variety of building types and to see if any patterns emerged that could provide a helpful guide to potential purchasers and also help manufacturers and installers direct their sales and marketing efforts appropriately.

Important caveat

Non-technical readers should be aware that the findings of this report apply only to currently available models of building-mounted wind turbines, designed for connection to the national grid. As anyone who knows anything about wind power will attest, urban environments and building mounting is probably the most challenging context in which to try to make wind power work, and the findings of this study cannot be generalised to larger-scale wind, nor to freestanding wind of any size mounted on poles or masts well away from obstructions. All the evidence (and theory) is that wind power is an excellent and highly effective choice for such conditions, which exist widely across the UK away from buildings and towns.

Trial results

The average energy generated per turbine per day across the sample set has been 214 Wh (including times when turbines were switched off for maintenance or due to failures). This is equivalent to an average of 78 kWh of energy produced per site per year and an average capacity factor of 0.85%. (This compares to typical capacity factors of between 10% and 30% for larger turbines on free standing sites in good areas).

If the results are adjusted to exclude data from periods when turbines were switched off or broken the average energy generated per turbine per day rises to 628 Wh (230kWh per year equivalent) and an average capacity factor of 4.15%.

Of particular note is that turbines on our high rise sites, Eden, Ashton and Southorn Court were able generate as much energy in one month as other turbines in the trial did in one year. It is unfortunate that these high performing turbines had to remain switched off for the majority of the trial following complaints about noise from the building residents.

The best performing turbine in the trial generated an average of 2.382 kWh per day when in operation, equivalent to 869 kWh in a full year. The poorest site generated an average of 41Wh per day when in operation or 15 kWh per year, which is less than the energy it consumed to run the turbine’s electronics.

Energy consumption averages 80Wh per day per turbine (29kWh per year) which is significant on some sites.

Wind speed and power curve data available to predict performance is not very accurate and requires significant adjustment to generate predictions that fall within error ranges of +/-25%. Using unmodified wind speed data by postcode from the national NOABL model and manufacturer power curves for turbines can lead to overestimating likely energy output by factors of between 15 and 17. Buyers should beware.

Overall the trial has painted a picture of an industry and technology that is still at development stage and is likely to make a tangible contribution to energy and carbon saving only on the most exposed sites and tallest buildings. The combination of this reality, aggressive and over-optimistic marketing by some suppliers, and the enthusiasm and credulity of the market (and regulators) has potentially led to an unfortunate outcome where the wind industry as a whole is in danger of suffering from a setback in credibility.

The evidence form this trial is that such potential setbacks can be avoided in future by greater openness by the industry as a whole, and more effort to educate the market and opinion formers about the fundamental science and challenges of new technologies earlier. Micro-technologies need not fear customer resistance, because there are plenty of early adopters out there willing to give things a go. Sustainable technologies and a sustainable future require customers who are properly informed and able to take individual decisions that are both economically optimal and environmentally sustainable. Without open data this is impossible.

Acknowledgements

This project would not have been possible without the support of the individual customers who volunteered their turbines for the trial, and we are very grateful to all of them.

Particular thanks to Pilkington Energy Efficiency Trust and BRE Trust who have provided funding to enable the trials to maintain their independence, and to Warwick District Council, in whose planning area eleven of the turbines are located.

BWEA, the Micropower Council and DTI all offered support in kind initially which helped the trials get off the ground, and the Energy Saving Trust has more recently provided financial support to the Warwick Wind Trial to fund the inclusion of additional sites and extend the period of data collection.

Contents

1. INTRODUCTION

This document is the final report from the Warwick Wind Trials Project. The purpose of this report is to present a complete picture of the trial, from first beginnings to final analysis and conclusions. We have collected a total of 168,950 hours of data from 26 sites across the UK during the year from October 2007 to October 2008.

We start with a brief history of the trial followed by a summary of turbine sites, including information on equipment and instrumentation installed. We describe our data collection methods and the challenges encountered during data collection, both with the instrumentation and with the turbines.

We then present findings and data analysis, firstly looking at measured wind speeds in comparison to industry recognised methods for predicting wind speeds, including the NOABL wind speed database and the Weibull probability distribution function. We explore the idea of using scaling factors for NOABL as presented in the Microgeneration Certification Scheme industry standard (MIS 3003) and suggest improvements for these together with proposed scaling factors for the Weibull shape factor.

We analyse energy data by comparing measured generation with predictions for output based on manufacturer supplied power curves. The two major factors affecting accuracy of energy output predictions are highlighted as the accuracy of wind speed predictions and the accuracy of manufacturer supplied power curves. Manufacturer supplied power curves are further analysed as we construct power curves using our own data. Finally in this section we present two different ways of calculating capacity factors where the “perfect in use” capacity factor ignores times when turbines are switched off and ignores imported energy, while the “actual in use” capacity factor takes both of these issues into account.

Conclusive findings and recommendations from the trial are outlined in the final section of this report. This is followed by a series of appendices including individual site summary sheets outlining the headline figures for each site.

2. TRIAL OVERVIEW

This report summarises the findings from the performance study of building mounted wind turbines carried out as part of the Warwick Wind Trials Project. The other aspect of the Warwick Wind Trials (a study of community reactions to wind turbines is covered by a separate report not funded by BRE). The objectives in setting up the trial were to see how microwind turbines perform on a variety of building types and to see if any patterns emerged that could provide a helpful guide to potential purchasers and also help manufacturers and installers direct their sales and marketing efforts appropriately.

The initial concern was to identify a good mix of sites, and to instrument them with straightforward monitoring and logging equipment to monitor energy flows and average wind speeds. We did not set out to monitor wind direction, turbulence, noise or structural impacts. The benefit of this approach was that it enabled us to cover a larger number of sites for the same budget, and to identify major issues and questions that could then be addressed in more detail by manufacturers or in more focused follow up research if appropriate.

All the turbines in the trial are grid connected and owned by individuals and organisations who have bought them commercially from one of five UK suppliers of building-mounted wind systems. This ensures the trial results reflect market realities as far as possible.

2.1. Summary of sites

The following pages present information about each turbine site including

- NOABL wind speed estimate
- Number of hours of data collected
- Mounting type
- Turbine type
- Instrumentation type

Information on the data that has been collected from each site can be found in Appendix A.

1. Lillington Road

Lillington Road is a semi detached Victorian property. It is highly insulated with a low annual electricity demand and now has both solar thermal and solar PV panels installed.

NOABL wind speed estimate:	5ms^{-1} at 10m agl
Hours of data collected:	8275
Mounting type:	Pole mounted to gable end
Turbine:	Ampair 600 230
Inverter:	Sunny Boy SB700
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

2. Hill Close Gardens

Hill Close Gardens is a single storey building heated by a ground source heat pump. The turbine on a 4m tilting mast mounted next to the building and linked to the building foundations.

NOABL wind speed estimate:	4.5ms^{-1} at 10m
Hours of data collected:	8612
Mounting type:	Pole at edge of flat roof
Turbine:	Ampair 600 230
Inverter:	Sunny Boy SB700
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

3. Princes Drive

Princes Drive is Leamington Spa's waste management facility. The installation is an example of mounting wind turbines on small industrial units.

NOABL wind speed estimate:	4.9ms^{-1} at 10m
Hours of data collected:	5489
Mounting type:	Pole at edge of pitched roof
Turbine:	Ampair 600 230
Inverter:	Sunny Boy SB700
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

4. Birds Hill

This turbine is installed on a modern detached house and is mounted on the gable end. There is a large open field to the south west of the property. To the north of the house is an urban area.

NOABL wind speed estimate:	5.1ms^{-1} at 10m
Hours of data collected:	9995
Mounting type:	Pole at gable end
Turbine:	Eclectic StealthGen 400
Inverter:	Mastervolt Soladin 600
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

5. **Eden Court 1**	Eden Court is a fourteen story block of flats in Leamington Spa. The turbine is mounted on a non penetrating flat roof mount that is held onto the roof by ballast.
	NOABL wind speed estimate: $6.4ms^{-1}$ at 45m Hours of data collected: 6844 Mounting type: Non-penetrating pole on flat roof Turbine: Ampair 600 230 Inverter: Sunny Boy SB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

6. **Leicester**	This turbine is at a residential urban site in Leicestershire. The turbine is mounted on a free standing pole that is positioned close to the house as seen in the photo.
	NOABL wind speed estimate: $4.7ms^{-1}$ at 10m Hours of data collected: 8405 Mounting type: Pole at gable end Turbine: Zephyr Air Dolphin Inverter: Windy Boy LG1100 Anemometer: Schiltknecht Meteo, Type: f.555.1.18 Data logger: Novus LogBox DA Wattmeter: Iskraemeco ME162

7. **Southorn Court 1** 	Southorn Court is a seven storey block of flats. Like on Eden Court the turbine is mounted on top of a 5 meter pole held down by ballasting the base of the mount.
	NOABL wind speed estimate: 5.8ms-1 at 25m Hours of data collected: 8390 Mounting type: Non-penetrating pole on flat roof Turbine: Ampair 600 230 Inverter: Sunny Boy SB700 Anemometer: Schiltknecht Meteo, Type: f.555.1.18 Data logger: Novus LogBox DA Wattmeter: Iskraemeco ME162

8. **Ashton Court 1** 	Ashton Court is the same design as Southorn Court and sits 200meters west of Southorn court. The height of the building is about 30meters above ground level.
	NOABL wind speed estimate: 5.8ms-1 at 25m Hours of data collected: 6817 Mounting type: Non-penetrating pole on flat roof Turbine: Ampair 600 230 Inverter: Sunny Boy SB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

9. Napier

This turbine is being monitored by Napier University. The hub height is approximately 2m above a flat roof. The building is around 25m tall but it is surrounded by other tall buildings.

NOABL wind speed estimate:	5.6ms^{-1} at 10m
Hours of data collected:	7434
Mounting type:	Pole at edge of flat roof
Turbine:	Ampair 600 230
Inverter:	Sunny Boy SB700
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

10. Daventry Town Hall

The Civic Centre is in the centre of Daventry. The wind turbine is installed on the civic centre building at about 15 meters above ground level and 2 meters above the roof line of the building.

NOABL wind speed estimate:	5.4ms^{-1} at 10m
Hours of data collected:	7557
Mounting type:	Pole at gable end
Turbine:	Windsave WS100
Inverter:	Windsave plug and save
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

11. Ashton Court 2	This is the second turbine mounted on Ashton Court.	
	NOABL wind speed estimate:	$5.8ms^{-1}$ at 25m
	Hours of data collected:	6719
	Mounting type:	Non-penetrating pole on flat roof
	Turbine:	Ampair 600 230
	Inverter:	Sunny Boy SB700
	Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
	Data logger:	Novus LogBox DA
	Wattmeter:	Iskraemeco ME162

12. Southorn Court 2	This is the second turbine mounted on Southorn Court	
	NOABL wind speed estimate:	5.8ms-1 at 25m
	Hours of data collected:	7705
	Mounting type:	Non-penetrating pole on flat roof
	Turbine:	Ampair 600 230
	Inverter:	Sunny Boy SB700
	Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
	Data logger:	Novus LogBox DA
	Wattmeter:	Iskraemeco ME162

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13. Daventry Country Park

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The country park installation has been installed as an educational demonstration project for visitors to the park and for school children.

NOABL wind speed estimate:	4.8ms^{-1} at 10m
Hours of data collected:	6720
Mounting type:	Pole at gable end
Turbine:	Windsave WS1000
Inverter:	Windsave plug and save
Anemometer:	NRG #40 calibrated
Data logger:	Pace Scientific XR5
Wattmeter:	Iskraemeco ME162

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14. Fountain Farm

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Fountain Farm was one of the first installations of the Ampair 600 230. The turbine is installed on a pole that is about 12meters above ground level and about 5 meters above the roof line.

NOABL wind speed estimate:	5.3ms^{-1} at 10m
Hours of data collected:	7726
Mounting type:	Pole at edge of flat roof
Turbine:	Ampair 600 230
Inverter:	Sunny Boy SB700
Anemometer:	NRG #40 calibrated
Data logger:	Pace Scientific XR5
Wattmeter:	Iskraemeco ME162

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15. Misty Farm	Misty Farm is our test reference site for the urban wind trial. This site has been selected for its good rural location, close to the sea on top of a hill with very little obstructions to air flow.
	NOABL wind speed estimate: $6.3ms^{-1}$ at 10m Hours of data collected: 7623 Mounting type: Freestanding pole – reference site Turbine: Ampair 600 230 Inverter: Windy Boy WB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

16. Eden Court 2	This is the second turbine mounted on Eden Court
	NOABL wind speed estimate: $6.4ms^{-1}$ at 45m Hours of data collected: 6865 Mounting type: Non-penetrating pole on flat roof Turbine: Ampair 600 230 Inverter: Windy Boy WB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

17. Tannery Court	Tannery Court is a retirement home in the West Midlands. The turbine is mounted off the fourth floor and is 3 meters above the roof line. In total the turbine is 18 meters above ground level.
	NOABL wind speed estimate: 4.8ms^{-1} at 10m Hours of data collected: 5241 Mounting type: Pole at edge of flat roof Turbine: Ampair 600 230 Inverter: Windy Boy WB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

18. Nottingham	This turbine is being monitored by Nottingham University. It is mounted on their purpose built turbine monitoring platform.
	NOABL wind speed estimate: 4.7ms-1 at 10m Hours of data collected: 9552 Mounting type: Pole at edge of flat roof Turbine: Zephyr Air Dolphin Inverter: SMA Windy Boy 1100LV Anemometer: RM Young Wind Monitor (05103) Data logger: SMA Sunny WebBox Wattmeter:

19. Antrobus Road

This turbine is mounted at the rear of a terrace property in Birmingham.

NOABL wind speed estimate:	5.0ms^{-1} at 10m
Hours of data collected:	3566
Mounting type:	Pole at edge of pitched roof
Turbine:	Windsave WS1000
Inverter:	Windsave plug and save
Anemometer:	NRG #40 calibrated
Data logger:	Pace Scientific XR5
Wattmeter:	Iskraemeco ME162

20. Summerfield Crescent

This turbine is mounted on a terraced property in Birmingham.

NOABL wind speed estimate:	5.3ms-1 at 10m
Hours of data collected:	7654
Mounting type:	Pole at edge of pitched roof
Turbine:	Windsave WS1000
Inverter:	Windsave plug and save
Anemometer:	NRG #40 calibrated
Data logger:	Pace Scientific XR5
Wattmeter:	Iskraemeco ME162

21. Park Farm	Park Farm is in Bracknell. There are two wind turbines in the picture. The trial is monitoring the turbine towards the back amounted on the telegraph pole which is tied to the building.
	NOABL wind speed estimate: 4.7ms^{-1} at 10m Hours of data collected: 7726 Mounting type: Pole at edge of pitched roof Turbine: Ampair 600 230 Inverter: Windy Boy WB700 Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

22. Northamptonshire	This turbine is mounted on a Local Authority building in Northamptonshire.
	NOABL wind speed estimate: 4.6ms^{-1} at 10m Hours of data collected: 7703 Mounting type: Pole at edge of pitched roof Turbine: Windsave WS1000 Inverter: Windsave plug and save Anemometer: NRG #40 calibrated Data logger: Pace Scientific XR5 Wattmeter: Iskraemeco ME162

23. Delta Court

Delta Court is a four story block of flats in Nottingham. The building is on top of a hill and the turbine is mounted 3 meters above the roof line.

NOABL wind speed estimate:	$4.8ms^{-1}$ at 10m
Hours of data collected:	5439
Mounting type:	Pole at gable end
Turbine:	StealthGen D400
Inverter:	Soladin 600
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

24. West Staddon

West Staddon Farm is a farm house located in north Devon close to the coast. This is the latest Windsave mounting system with a mass damper attached to the pole to reduce vibrations.

NOABL wind speed estimate:	$6.3ms^{-1}$ at 10m
Hours of data collected:	4348
Mounting type:	Pole at gable end
Turbine:	Windsave WS1200
Inverter:	Windsave plug and save
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

25. Huddersfield

This turbine is mounted on top of a three storey building at Huddersfield University. The hub height is approximately 25m above ground level.

NOABL wind speed estimate:	$4.6ms^{-1}$ at 25m
Hours of data collected:	1392
Mounting type:	Pole at edge of flat roof
Turbine:	StealthGen D400
Inverter:	Soladin 600
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

26. Thatcham

There are eight wind turbines installed here at the Thatcham Motor Insurance Research Centre. The turbines are mounted on free standing poles 15 meters above ground level.

NOABL wind speed estimate:	$4.5ms^{-1}$ at 10m
Hours of data collected:	2829
Mounting type:	Pole at edge of flat roof
Turbine:	Zephyr Air Dolphin
Inverter:	Windy Boy LG1100
Anemometer:	Schiltknecht Meteo, Type: f.555.1.18
Data logger:	Novus LogBox DA
Wattmeter:	Iskraemeco ME162

2.2. Data collection

Information was recorded every ten minutes by the data loggers; this included an average wind speed for the ten minute period and the amount of energy generated during that period. At the sites with Pace Scientific data loggers installed we were also able to record the amount of energy consumed during each ten minute period.

Due to the nature of the trial and initial budget constraints, the instrumentation we installed only allowed for manual collection of data. This was done by visiting sites individually once per month and downloading data from the data loggers via a cable to a laptop computer. We also took readings direct from the watt meter LCD displays. Manual collection of data had limitations; if technical issues arose they could only be rectified on the next site visit, thereby losing one month's data. GPRS data loggers were not used due to constraints on the initial budget but if multiple sites are being monitored, GPRS data loggers can highlight issues earlier, allowing them to be rectified sooner. However, there are advantages to manual collection of data; visiting sites once per month allowed us to document useful feedback from turbine owners.

2.3. Turbine reliability

The wind trials project has highlighted a number of technical reliability issues with the wind turbines. We experienced reliability problems with inverters and control boxes that caused capacitor failures in early models. There have been moisture ingress issues through slip rings in the wind turbines themselves. Blade failures on two of the manufacturer's wind turbines have been the most serious reliability issue to date due to public safety. We also experienced one tail failure. Many of these failures occurred due to a lack of adequate durability testing and the UK micro wind turbine industry still being in its infancy when the project started. The response from the manufacturers to the reliability issues has been good throughout the wind trials.

The responsibility for turbine reliability involves not just the manufacturers but also the installers. One example of this was demonstrated during the trial when there was a structural failure of a gable end wall. Part of the installation procedure is to do a pull test on the fixings to 5kN. Although this procedure ensures that the bolt is bonded sufficiently into the wall and that the brick is securely cemented to the other bricks it does not test the structural strength of the wall itself.

Noise levels have been an unexpected issue at three of our trial sites. All of the sites where noise has been an issue have involved multiple occupancy buildings. Generally it was not the turbine owners that complained about noise but the residents. Two of these wind turbines are now permanently turned off due to a local environmental health officer stating that the turbines are a statutory noise nuisance.

The BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008 (BWEA 2008) has now set the standard for manufacturers and installers to adhere to. This standard was not in place when the turbines in this trial were installed and suggests that the industry is responding well to issues raised in the field. This standard covers performance testing, acoustic noise testing, durability and safety testing.

3. FINDINGS

3.1. Overview

In this section we compare measured wind speeds to those predicted by the NOABL wind speed database. We also explore the potential value of using scaling factors for NOABL. Further analysis of the spread in wind speeds throughout the year enable comparison with the Weibull function and allow site specific values for the Weibull shape factor, “k”, to be determined. This analysis allows us to suggest scaling factors for k.

We use the energy data to compare measured energy generation with predictions for output obtained by applying manufacturer supplied power curves to measured wind speeds. We also report on figures for the average energy exported and imported per day for each site. And we use energy data, correlated to wind speeds to produce our own power curves for a number of sites to enable further comparison with manufacturer data. Finally we calculate capacity factors for each turbine.

3.2. Average wind speed

The measured average wind speed at all sites is lower than the NOABL prediction. Wind speeds at 16 sites are more than 40% lower than NOABL. The sites where wind speed is in closest agreement with NOABL (within 10%) are Misty Farm (the reference site) and Eden Court 1 and 2.

Using scaling factors for NOABL may help to improve predictions for wind speed in urban areas. The Microgeneration Certification Scheme installer standard (MIS 3003) suggests potential scaling factors and we have suggested our own, based on the data we have collected. The methodology behind our own scaling factors is presented in Appendix B.

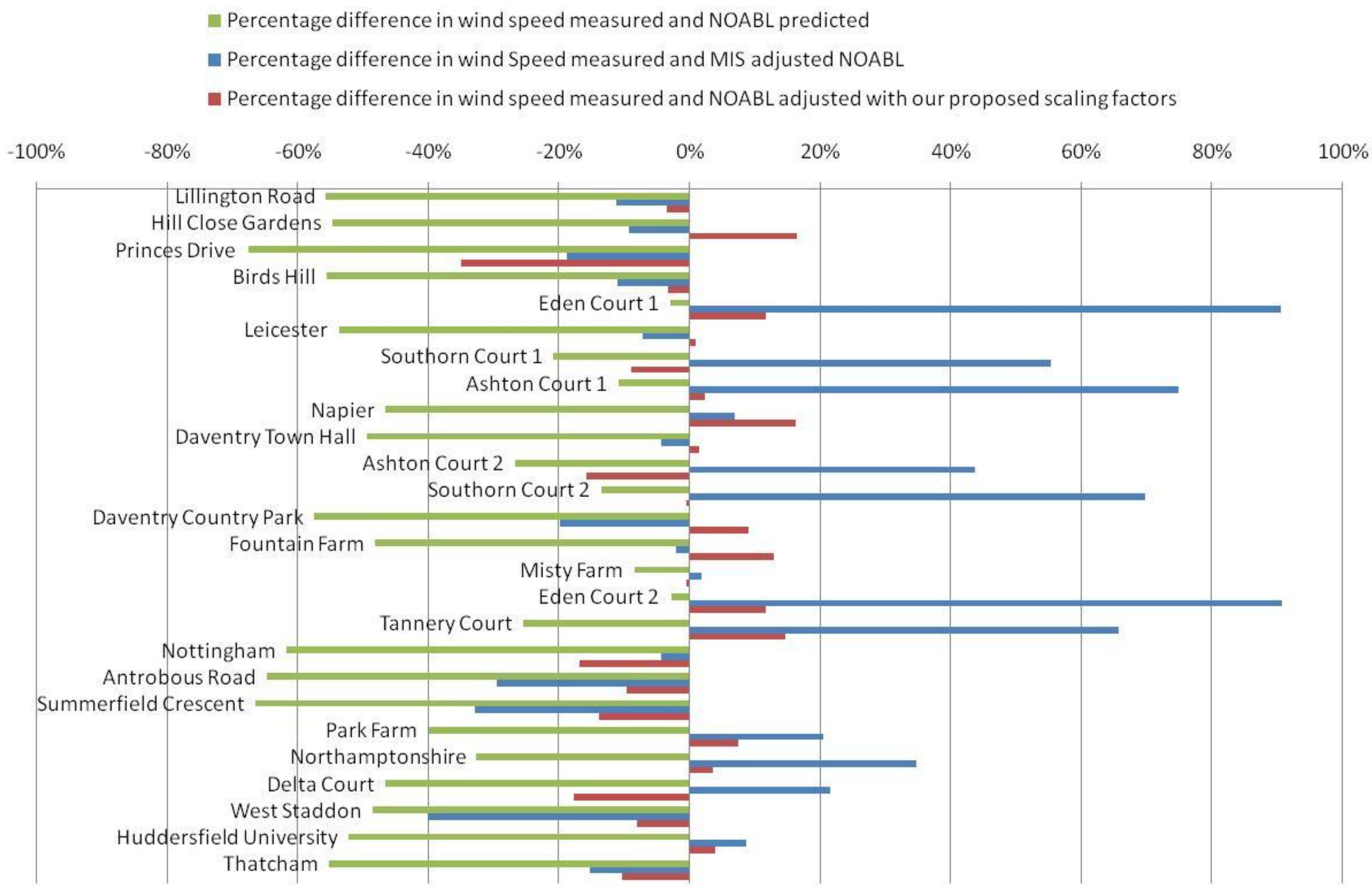
MIS 3003 scaling factors do not account for the special case of installations on high rise buildings or at sites which are significantly higher than the height assumed by the chosen NOABL prediction. Therefore there is a risk of over-scaling at these sites. However predictions are improved over all, with 19 sites agreeing with MIS adjusted NOABL to within 40% and 7 of these agreeing within 10%.

Our suggested scaling factors (presented in Appendix B) are an attempt to improve on the MIS scaling factors. Predictions are improved over all, with all 25 sites now agreeing with adjusted NOABL to within 20% and 15 of these agreeing to within 10%.

Figure 1 shows how well scaled NOABL agrees with measured wind speeds and compares MIS scaling factors with our own.

The trend in monthly average wind speed measured for each site is presented graphically in Appendix A. 23 sites exhibit peaks in average wind speed measured during January and March 2008.

Figure 1



Percentage difference in wind speed measured and NOABL predicted
Percentage difference in wind Speed measured and MIS adjusted NOABL
Percentage difference in wind speed measured and NOABL adjusted with our proposed scaling factors
-100%
-80%
-60%
-40%
-20%
0%
20%
40%
60%
80%
100%
Lillington Road
Hill Close Gardens
Princes Drive
Birds Hill
Eden Court 1
Leicester
Southorn Court 1
Ashton Court 1
Napier
Daventry Town Hall
Ashton Court 2
Southorn Court 2
Daventry Country Park
Fountain Farm
Misty Farm
Eden Court 2
Tannery Court
Nottingham
Antrobous Road
Summerfield Crescent
Park Farm
Northamptonshire
Delta Court
West Staddon
Huddersfield University
Thatcham

3.3. Wind speed distributions

The spread in measured wind speeds over the past year is presented in the form of probability distribution graphs for each site and these can be found in the site summary sheets in Appendix A. Patterns have emerged between different site types where the spread in wind speeds exhibits a different shape at urban sites when compared to good rural and high rises sites as classified in Appendix B.

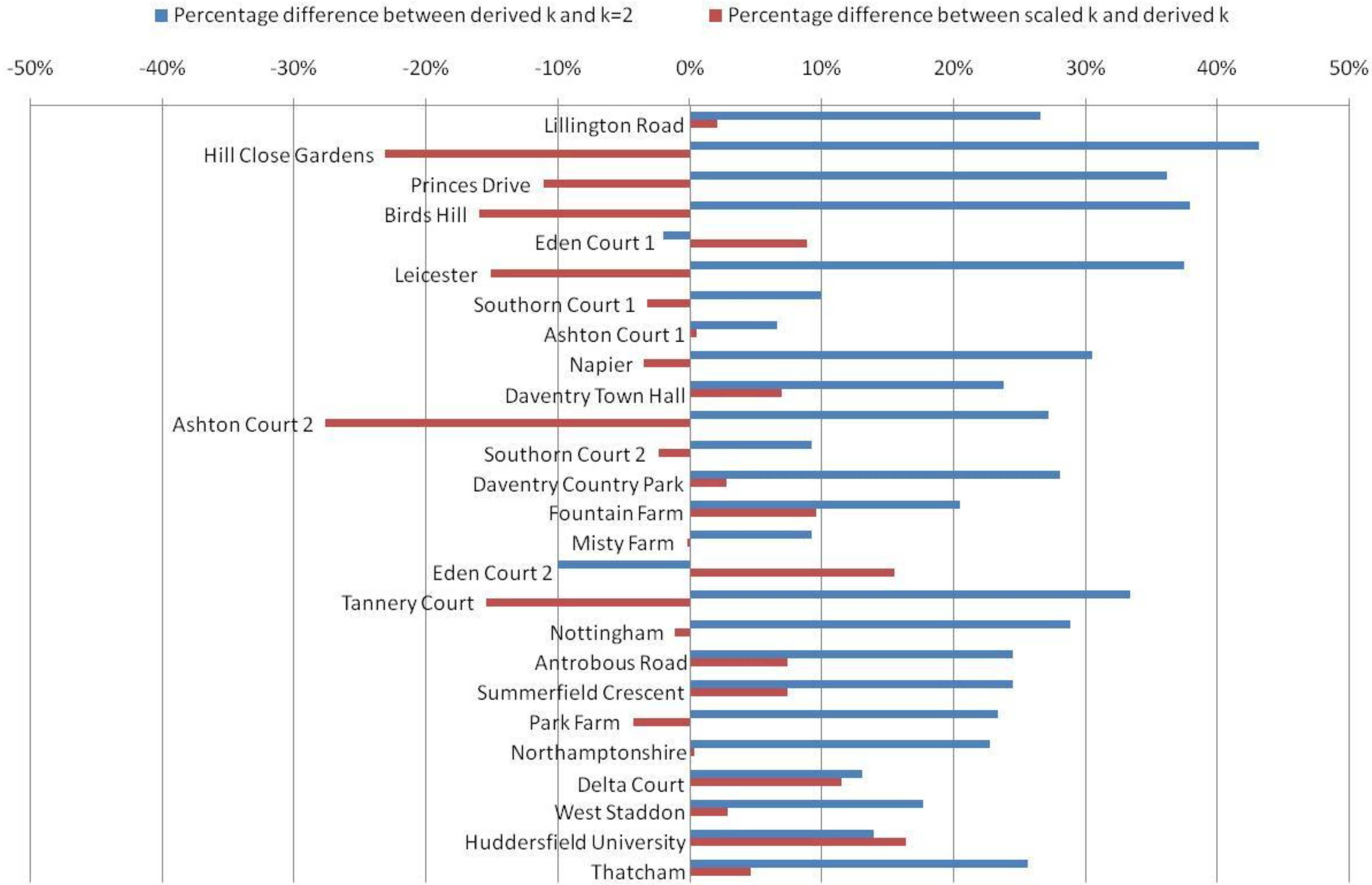
We have compared the measured wind speed distributions at each site to the Weibull function and initially assumed that the Weibull shape factor “k” would be 2 (a normal assumption for a north European site). However we noticed early on in the trial that this value of k was not a good match for the majority of our sites.

It is possible to derive site specific parameters for the Weibull function using data that has been collected and we have done this for all our sites. An explanation of how these parameters are derived was given in a previous interim report for the trial, published in January 2008, and will not be reproduced here. The derived k values are presented in the site summary sheets in Appendix A.

Shape factors derived for our sites tend to be less than 2. Derived values for k at 18 sites are less than 1.6 and the overall average across all sites is 1.56. However, the shape factor at the reference and high rise sites tends to be closer to 2.

Scaling factors for k are suggested and presented in Appendix B. Figure 2 shows how well the scaled values of k agree with derived values compared to the standard assumption that k=2. The use of scaling factors shows a general improvement for assumed values of k with 16 sites in agreement to within 10% of the derived value of k. However there are 4 sites where the scaled k is more different from the derived k than it is from k=2, suggesting more work could be done to improve accuracy in this area. Improving accuracy would require further measurements to be taken at a greater number of sites.

Figure 2



Percentage difference between derived k and k=2
Percentage difference between scaled k and derived k
-50%
-40%
-30%
-20%
-10%
0%
10%
20%
30%
40%
50%
Lillington Road
Hill Close Gardens
Princes Drive
Birds Hill
Eden Court 1
Leicester
Southorn Court 1
Ashton Court 1
Napier
Daventry Town Hall
Ashton Court 2
Southorn Court 2
Daventry Country Park
Fountain Farm
Misty Farm
Eden Court 2
Tannery Court
Nottingham
Antrobous Road
Summerfield Crescent
Park Farm
Northamptonshire
Delta Court
West Staddon
Huddersfield University
Thatcham

3.4. Energy

We compare measured energy generation with that predicted by applying manufacturer supplied power curves to measured wind speeds. Predictions for energy generation can also be based on predicted wind speeds for each site. The two major factors affecting accuracy of energy output predictions are the accuracy of wind speed predictions and the accuracy of manufacturer supplied power curves.

Of the two factors it is the accuracy of wind speed predictions that has the greatest effect. Table 1 illustrates this for four example sites. Each of these sites has a different make of turbine installed. To gauge the effect of each factor we apply manufacturer's power curves first to a Weibull distribution about the NOABL predicted wind speed (without scaling), second to a Weibull about NOABL with scaling and third to the measured wind speeds. Only the times when turbines have been switched on have been included in this analysis. To scale NOABL we have used our own scaling factors, both for NOABL and for k.

Table 1

Site	Predicted energy output using manufacturer supplied power curves			Measured energy output (kWh)
	Using NOABL wind speeds (kWh)	Using scaled NOABL wind speed (kWh)	Using measured wind speeds (kWh)	
Lillington Road	819	127	88	52
Birds Hill	574	114	135	48
Leicester	1101	157	217	64
Daventry Town Hall	650	129	166	69

For the sites listed in the table above, predictions based on:

1. NOABL without scaling; consistently overestimate by a factor between 15.8 and 17.2
2. NOABL with scaling; will overestimate by a factor between 1.8 and 2.4
3. Measured wind speeds; have a tendency to overestimate by a factor between 1.7 and 3.4

Points 1 and 2 reflect the accuracy of wind speed predictions while point 3 reflects the accuracy of different power curves.

Figures 3 to 6 provide a graphical illustration of measured output compared to the measured wind speed applied to the power curve. They show energy output for each of the sites in listed Table 1. Only the times when turbines have been switched on have been included in this analysis. The difference between the two sets of bars can be explained by a number of factors including the accuracy of manufacturer supplied power curves; the accuracy of the measured wind speed; and the response time of the instrumentation and turbines.

Figure 3 – Ampair 600 – Lillington Road

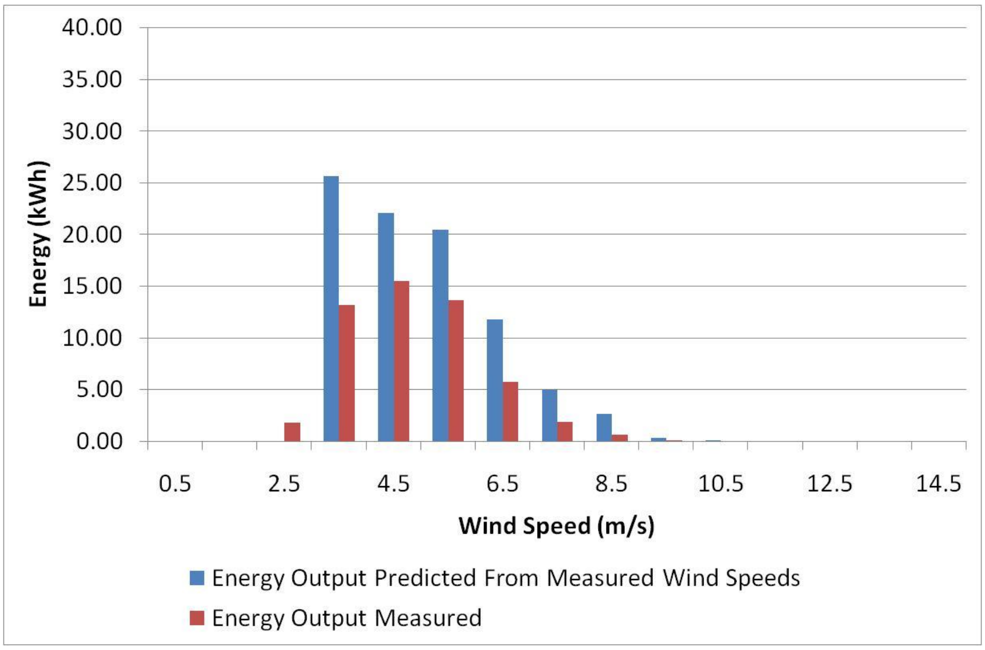


Figure 4 – Eclectic StealthGen D400 – Birds Hill

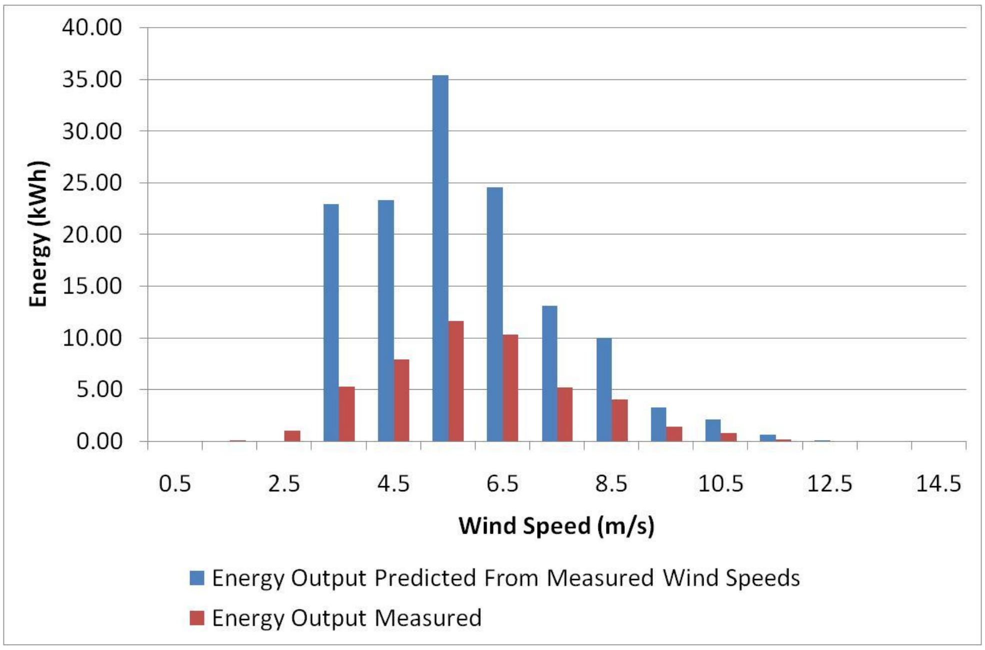


Figure 5 – Zephyr Air Dolphin Z1000 – Leicester

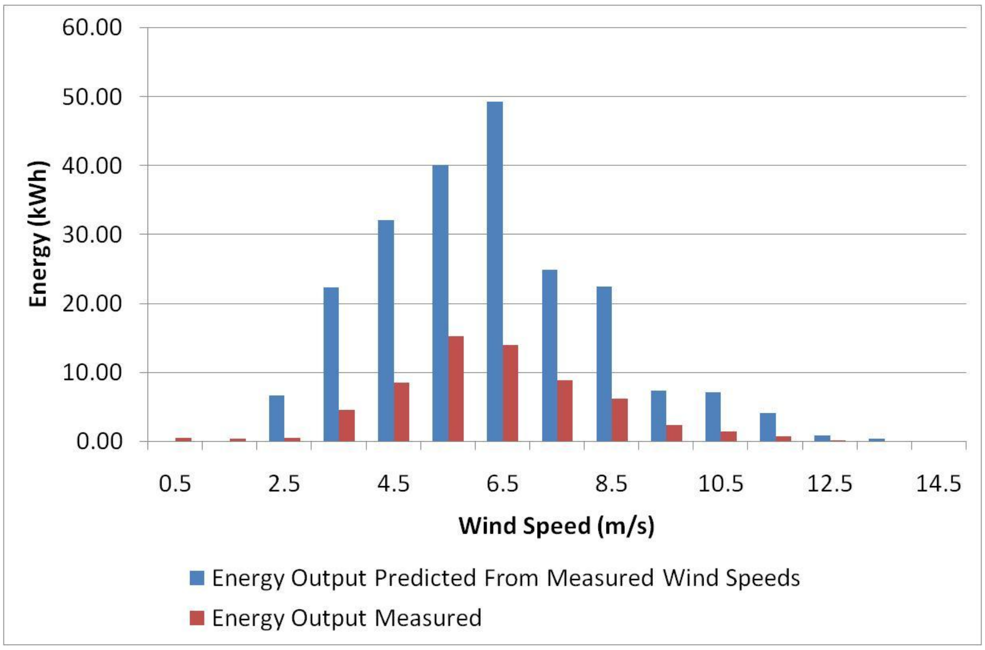
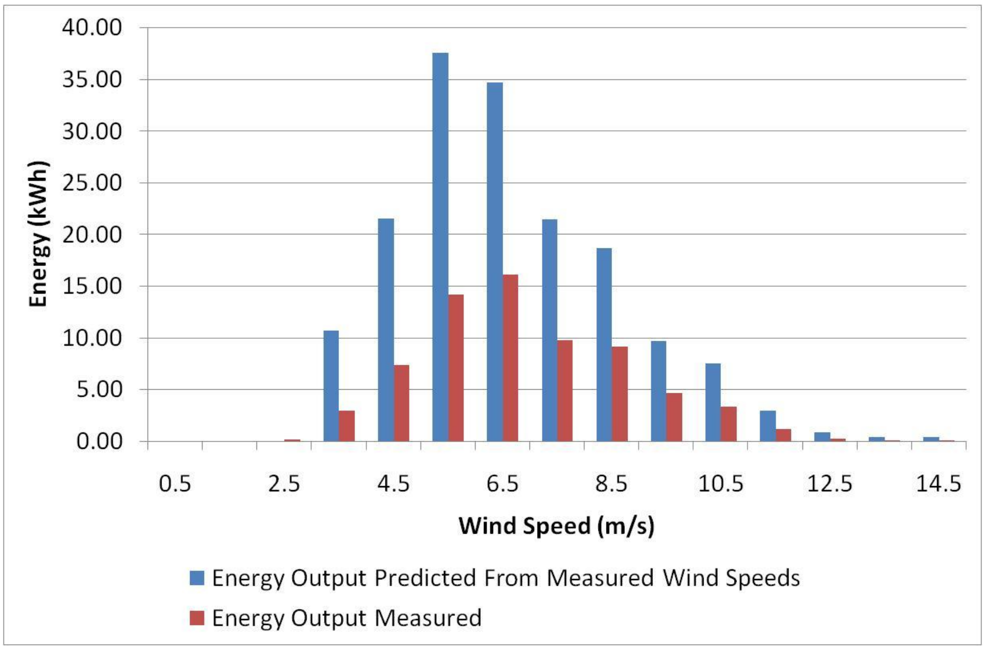


Figure 6 – Windsave WS1000 – Daventry Town Hall



3.5. Average energy imported and exported per day

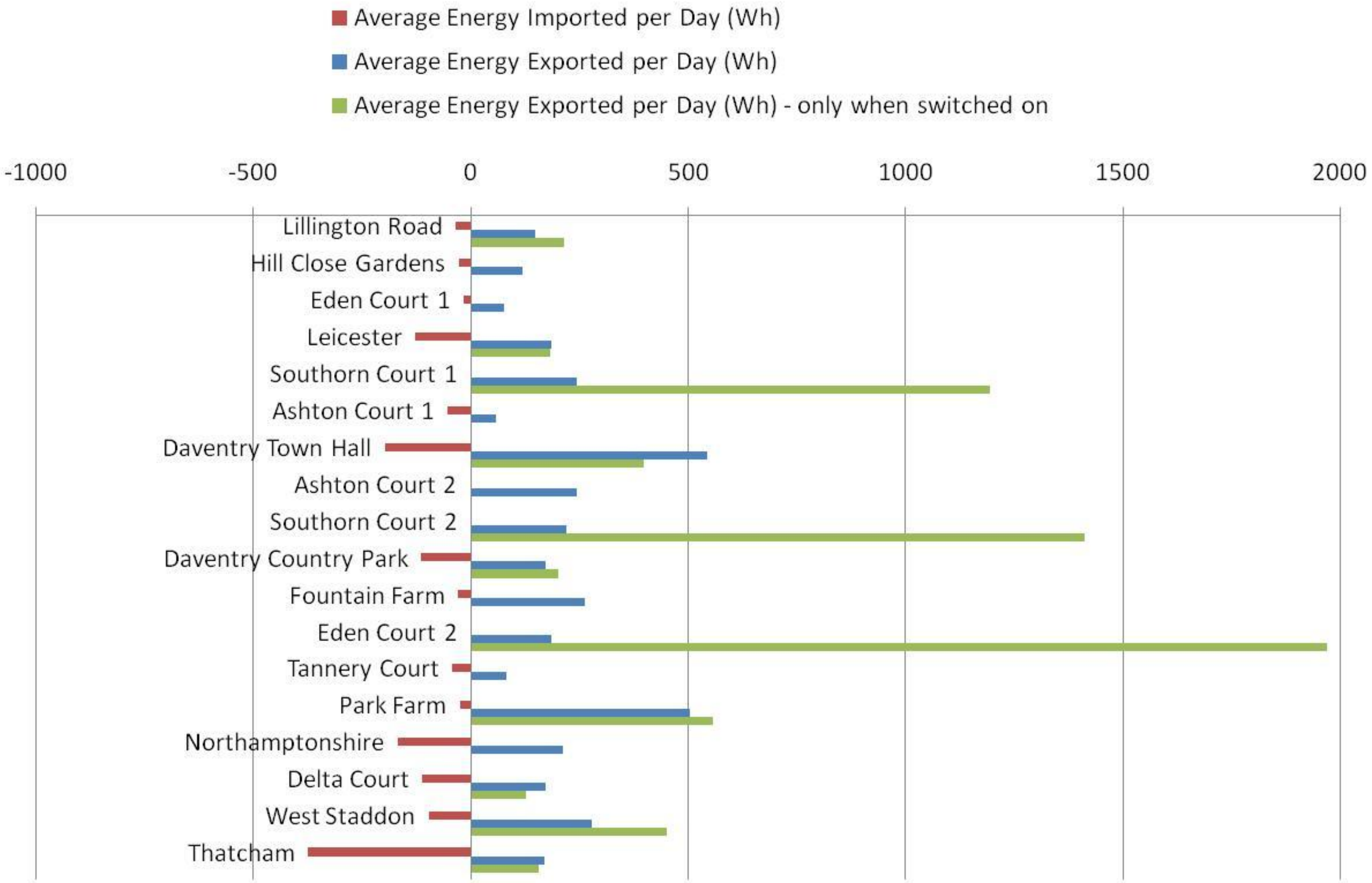
The average energy imported and exported per day by each turbine is in a constant state of flux as turbines are switched on and off for varying periods of time and for various reasons. Figure 7 shows the latest figures for averaged energy at most sites. As in previous reports we have collected data by taking readings direct from the watt meter and these figures are represented by the blue bars in Figure 7.

For comparison, the green bars in Figure 7 show averaged energy for only those days when turbines were known to be switched on. The data for the green bars was taken from the data loggers and is not available for all sites in this graph.

Overall average generation per day is 628Wh if only counting times when turbines are switched on, or just 258Wh if the reference and high rise sites are omitted. The range is from 41Wh to 2382Wh per day. If times when turbines are switched off are included then the overall average generation per day is 214Wh.

The red bars in Figure 7 represent imported energy, averaged over all the days (including when turbines were switched off). Imported energy continues to be an important factor where the average is 80Wh per day and the range across all sites is from 3Wh to 375Wh per day.

Figure 7



Average Energy Imported per Day (Wh)
Average Energy Exported per Day (Wh)
Average Energy Exported per Day (Wh) - only when switched on
-1000
-500
0
500
1000
1500
2000
Lillington Road
Hill Close Gardens
Eden Court 1
Leicester
Southorn Court 1
Ashton Court 1
Daventry Town Hall
Ashton Court 2
Southorn Court 2
Daventry Country Park
Fountain Farm
Eden Court 2
Tannery Court
Park Farm
Northamptonshire
Delta Court
West Staddon
Thatcham

3.6. Power curves

We can construct our own power curves for the turbines on the trial because we have energy data that is correlated to wind speed. That is for every 10minute period we have an average wind speed and figure for the amount of energy generated during that period. If we multiply this energy by 6 we get a value for the average power produced during that period and plotting this against the corresponding wind speed gives us a power curve.

Figures 8 to 12 show the power curves produced from measured data at 5 different sites with 4 different makes of turbine. The red line on each graph is the manufacturer supplied power curve, while the blue data points are our measured data. The graphs show that power curves agree more closely with manufacturer supplied data at low wind speeds. There seems to be a tailing off trend in power production at high wind speeds. This is even true for two turbines of the same make installed at two different sites as shown by comparison of Figures 9 and 10. More work is required in this area to determine the source of the discrepancy found at high wind speeds.

Figure 8 – Zephyr Air Dolphin Z1000 - Leicester

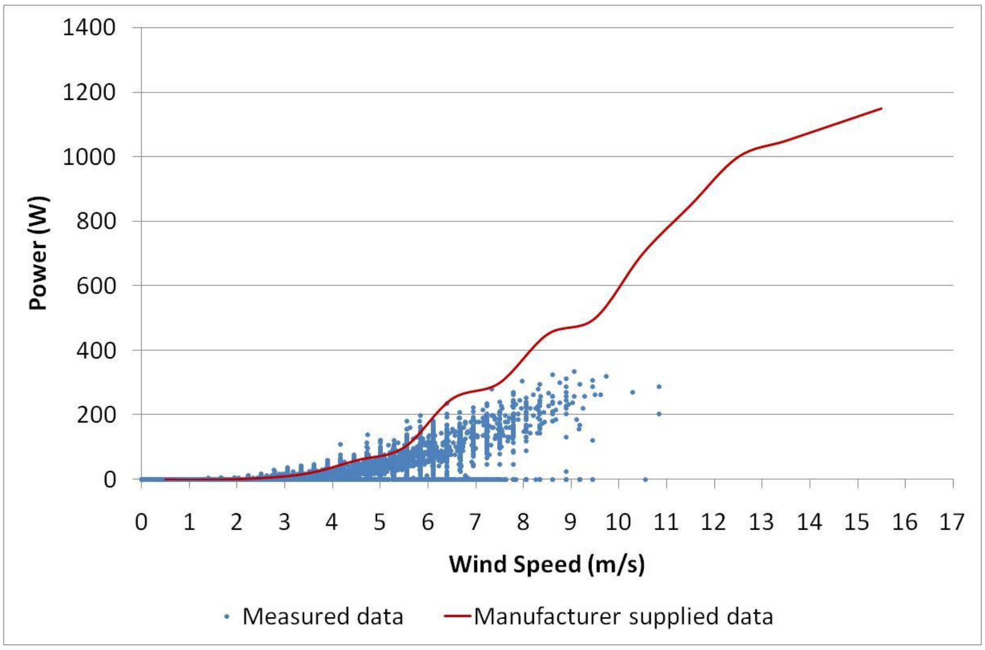


Figure 9 – Ampair 600 – Misty Farm

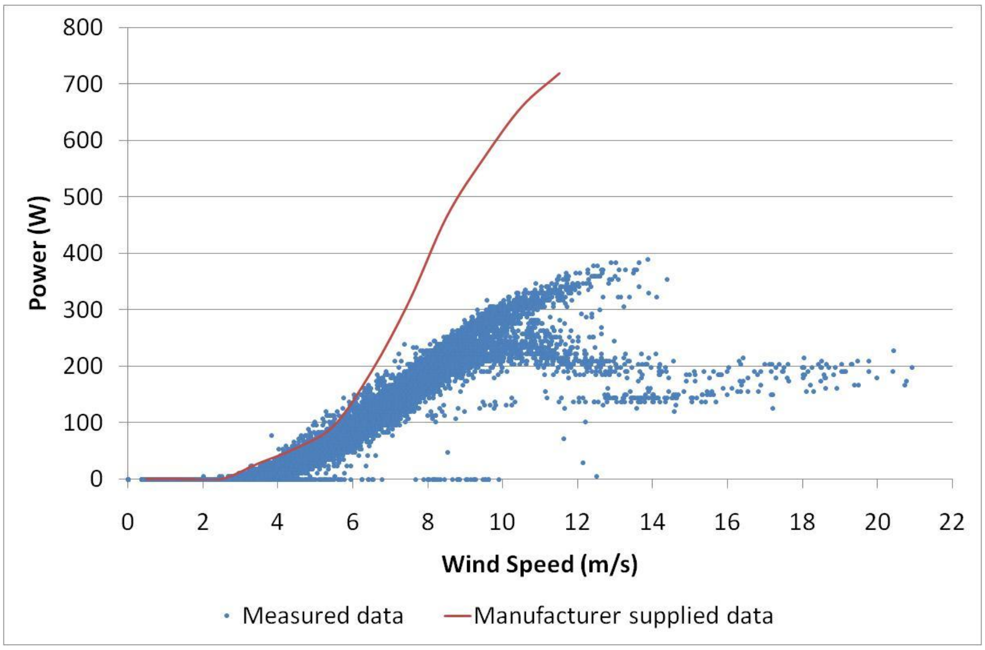


Figure 10 – Ampair 600 – Eden Court 2

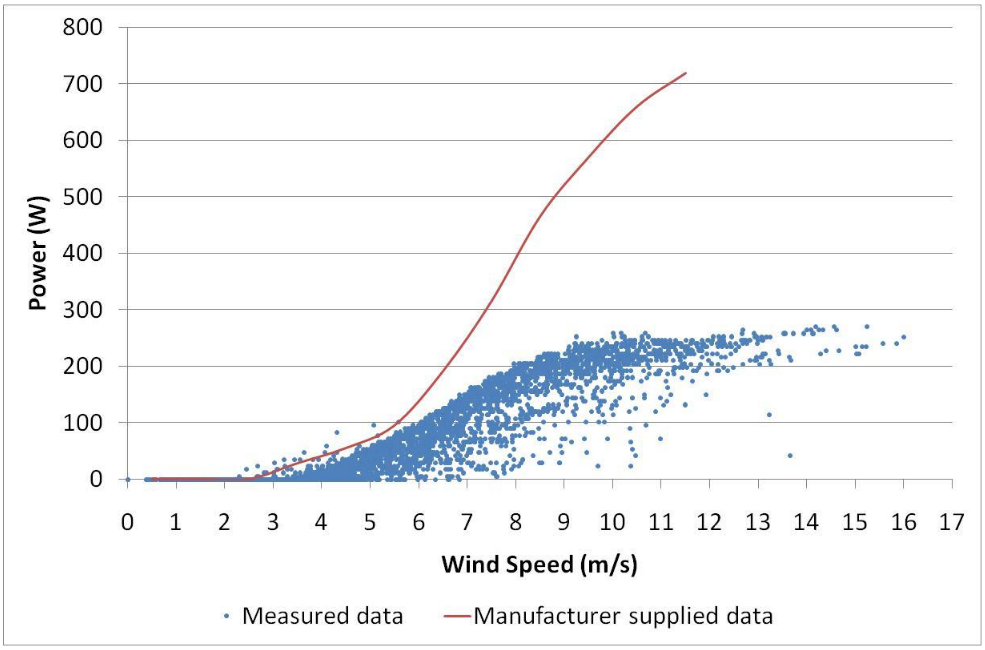


Figure 11 – Eclectic StealthGen D400 – Delta Court

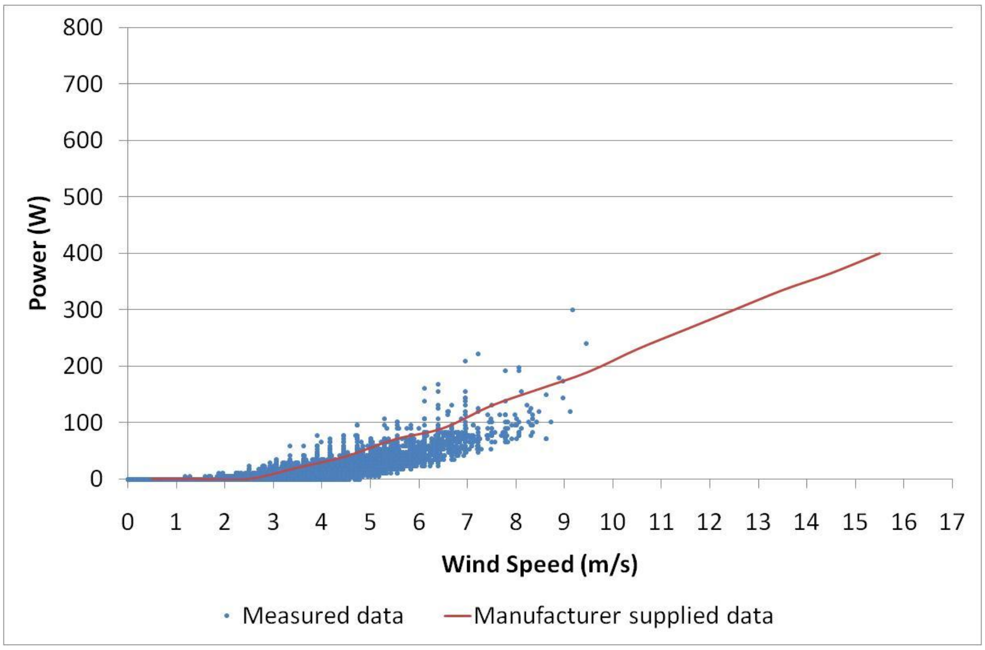
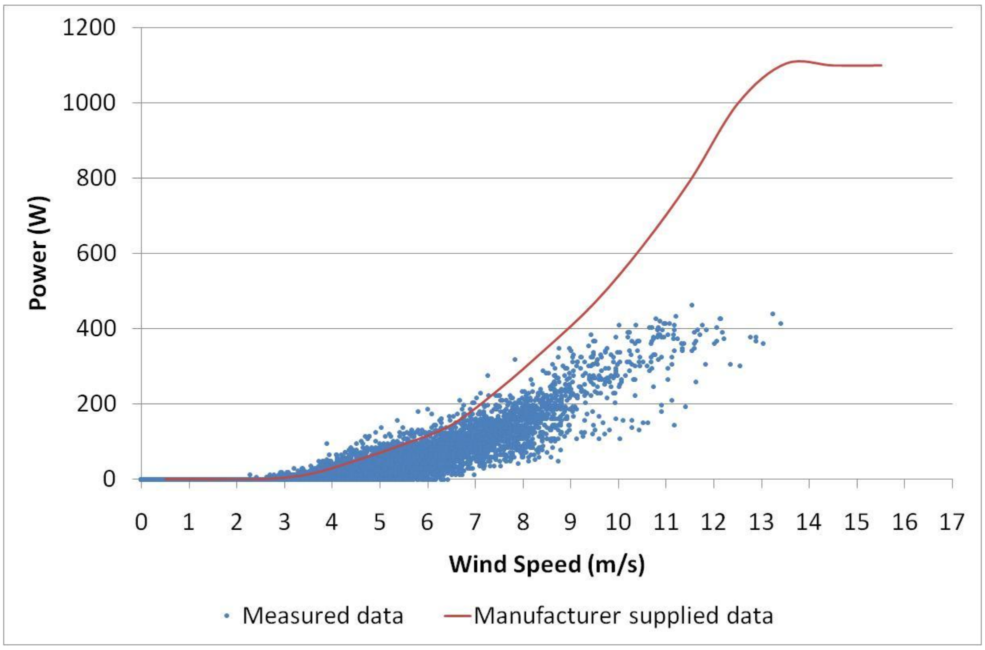


Figure 12 – Windsave WS1200 – West Staddon



Our method of producing the power curves in Figures 8 to 12 is not dissimilar to that recommended by the British Standard BS EN 61400-12-1:2006. However the planning stage of the trials project predates this standard and not all methodologies from the standard were employed to the exact detail.

3.7. Capacity factors

The capacity factor for wind turbines is expressed as a percentage and is obtained by dividing the theoretical maximum energy output by the measured energy generated within a given time period (usually one year). The theoretical maximum energy output is calculated by multiplying the rated output of the turbine by the number of hours within the given time period.

Where data is available we have used readings from the data loggers and direct readings from the watt meters to calculate two different types of capacity factor for each site defined as follows:

- Perfect in use capacity factor - The given time period only includes those times when we know turbines were switch on. Imported energy is ignored.
- Actual in use capacity factor - The given time period includes times when turbines were switched off and imported energy is subtracted from the generation total.

Both types of capacity factor are listed for each site (where possible) in Appendix A.

If only counting the times when turbines are switched on perfect in use capacity factors range from 0.29% to 16.54% and the overall average is 4.15%. The overall average drops to 1.51% if the reference and high rise sites are omitted.

The overall average for actual in use capacity factors is 0.85%.

This latter figure, while low, is probably the most realistic for planning projects, as the turbines on the trial were not turned off unless this became unavoidable. Downtime reflects real in use problems, and appears to be inherent in the technology at this stage of development.

4. Conclusion and Recommendations

It should be noted that these are the facts relating to building-mounted, grid connected microwind systems less than 2kW only and the findings cannot and should not be generalised to larger scale or freestanding wind.

Our findings from the trial are as follows:

- Average wind speeds measured at all sites are lower than the NOABL prediction. Wind speeds at 16 out of 26 sites are over 40% lower than NOABL.
- Our suggested scaling factors for NOABL help to improve wind speed predictions but more work is required to progress accuracy in this area.
- Observed wind speed distributions at most sites fit best to a Weibull distribution with a shape factor (k) that is less than 2. Derived values for k at 18 sites are less than 1.6
- Our suggested scaling factors for k help to improve wind speed predictions but more work is required to progress accuracy in this area.
- Energy generated at times when turbines are switched on is lower than that predicted by applying manufacturers supplied power curves to measured wind speeds.
- Some power curves appear more accurate than others but the major factor affecting accuracy of energy output predictions is the accuracy of wind speed prediction.
- If only counting times when turbines were switched on, the average energy generated per day is 628Wh (or just 258Wh if the reference and high rise sites are excluded). If times when turbines were switched off are included then the overall average drops to 214Wh per day.
- Energy consumption averages 80Wh per day and is therefore a significant factor at some sites.
- If only counting the times when turbines are switched on and ignoring imported energy; perfect in use capacity factors range from 0.29% to 16.54% and the overall average is 4.15%.
- Actual in use capacity factors average 0.85%.

Our recommendations from the trial are as follows:

- Great care should be taken in selecting suitable sites for building-mounted turbines.
- More work is required to create a robust method for predicting average wind speed in urban locations.
- More research could be done on the appropriate choice of shape factor in the Weibull function when predicting wind speed in urban locations.
- The use of scaling factors for NOABL and the Weibull shape factor has potential to improve wind speed predictions although more work is required in this area.
- Our data shows the (now recognised) need for an industry standard that normalises the way in which manufacturers' power curves are produced and this data should be published.

Appendix A – Site Summary Sheets

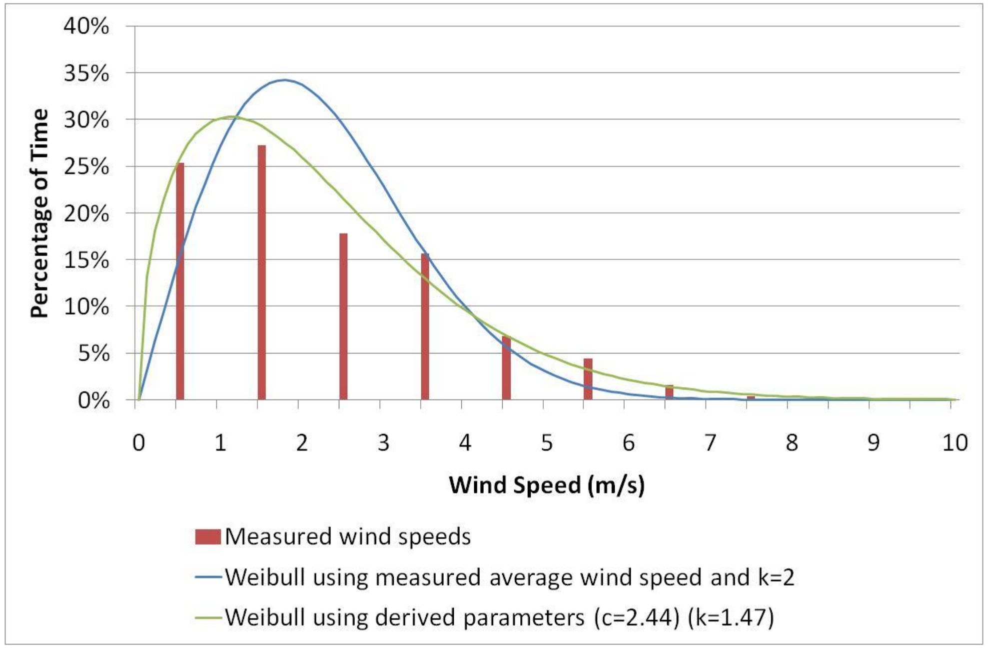
1. Lillington Road

Data collection period	29/10/07 – 08/10/08
Average wind speed	2.22 ms^{-1}
Derived Weibull shape factor	1.47
Total energy output	53.67kWh
Predicted energy output	154.81kWh
Perfect in use capacity factor	1.48%
Actual in use capacity factor	0.78%

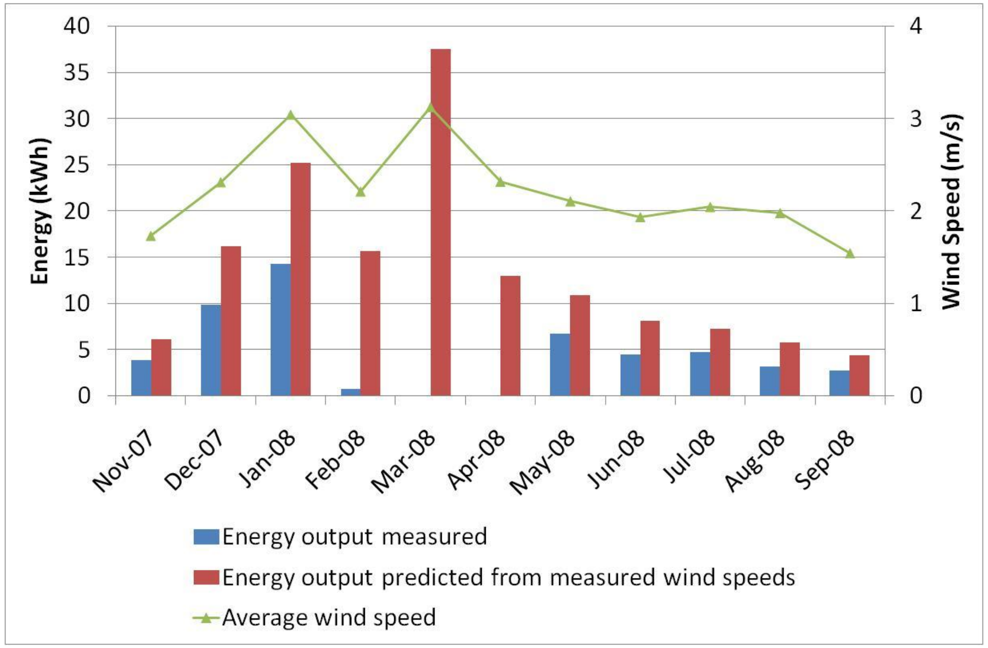
Notes

The turbine was switched off from 3rd February to 9th May 2008 due to a mechanical noise. A new nose cone, blades and interconnect box with speed control were all fitted on 9th May 2008.

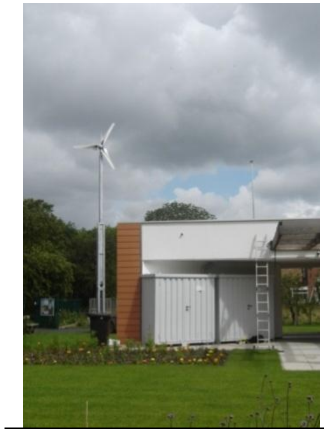
Wind speed distribution



Trend in monthly average wind speed and energy output per month



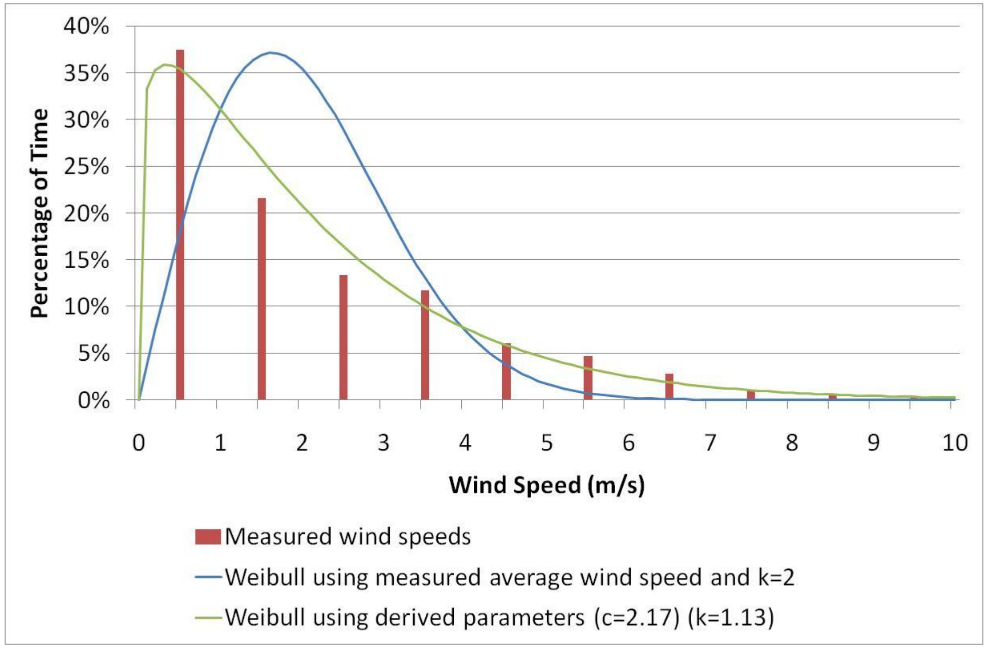
2. Hill Close Gardens



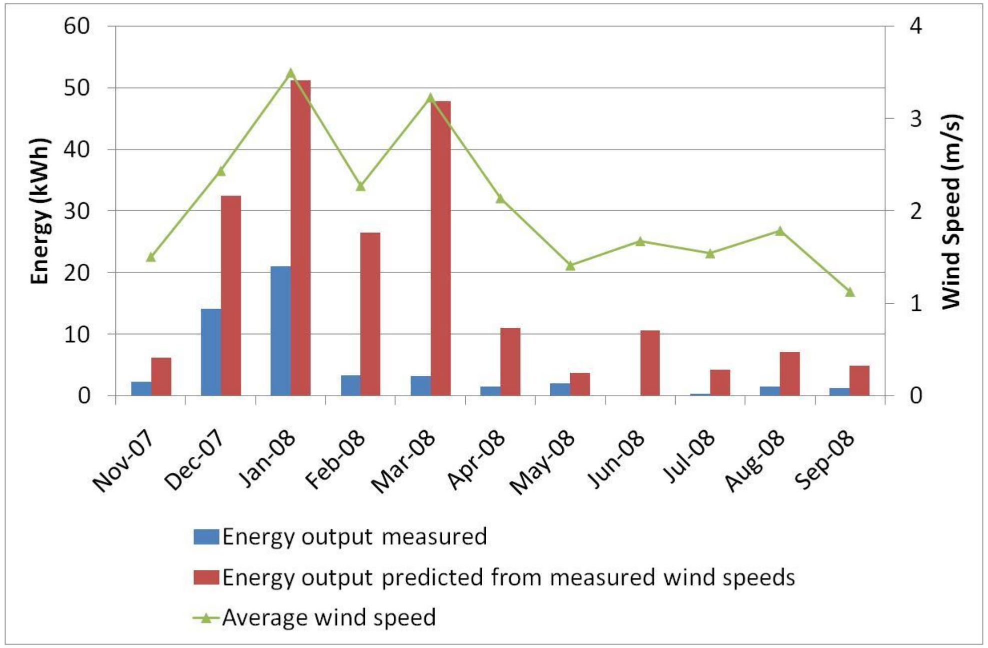
Data collection period	30/10/07 – 23/10/08
Average wind speed	2.04 ms^{-1}
Derived Weibull shape factor	1.13
Total energy output	54.88kWh
Predicted energy output	216.45kWh
Perfect in use capacity factor	
Actual in use capacity factor	0.62%

Notes
This turbine has been switched off intermittently due to concerns about noise levels.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



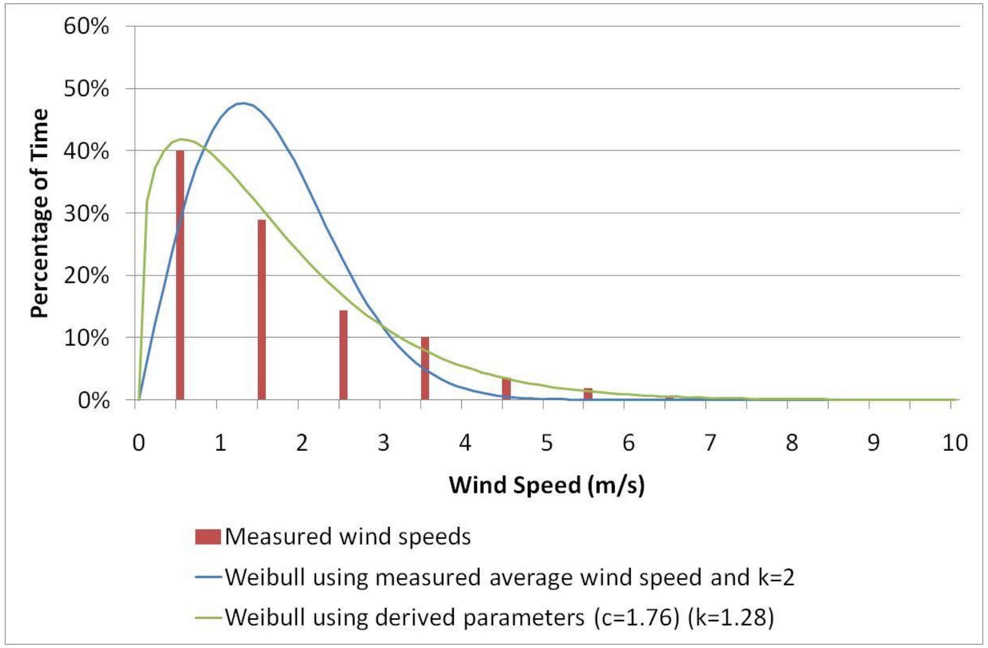
3. Princes Drive

Data collection period	30/10/07 – 01/07/08
Average wind speed	1.72ms^{-1}
Derived Weibull shape factor	1.28
Total energy output	9.45kWh
Predicted energy output	45.93kWh
Perfect in use capacity factor	0.29%
Actual in use capacity factor	

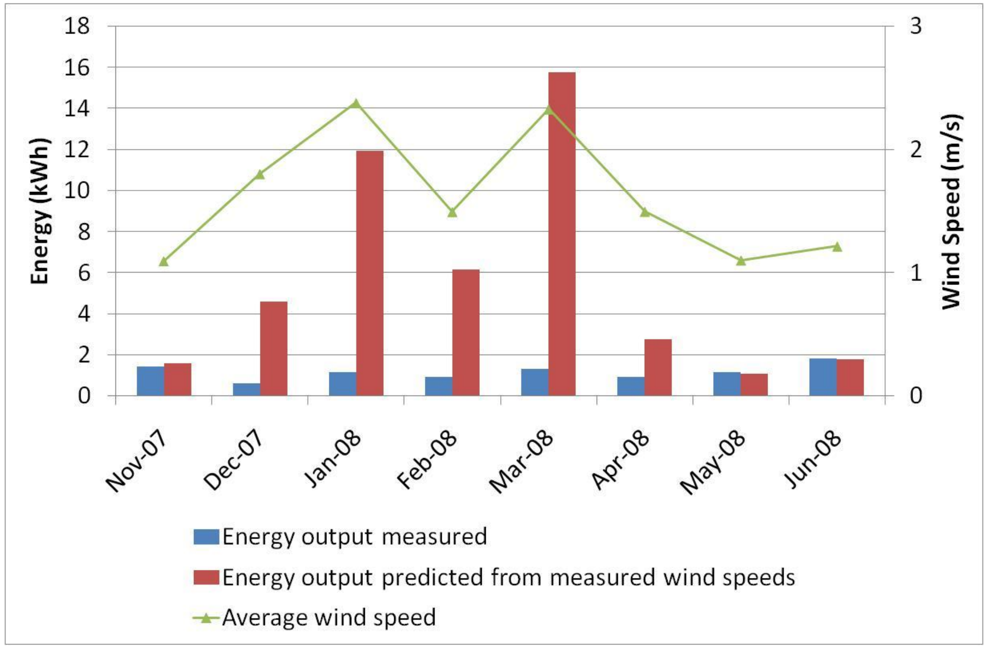
Notes

Due to a battery failure in the data logger data was lost between 18th December 2007 and 4th January 2008. New nose cone and blades were fitted on 9th May 2008. The turbine was switched off and inverter removed from site on 1st July 2008 for safety reasons while modifications to the building structure made. Note that the building structure modifications are not related to the turbine in any way.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



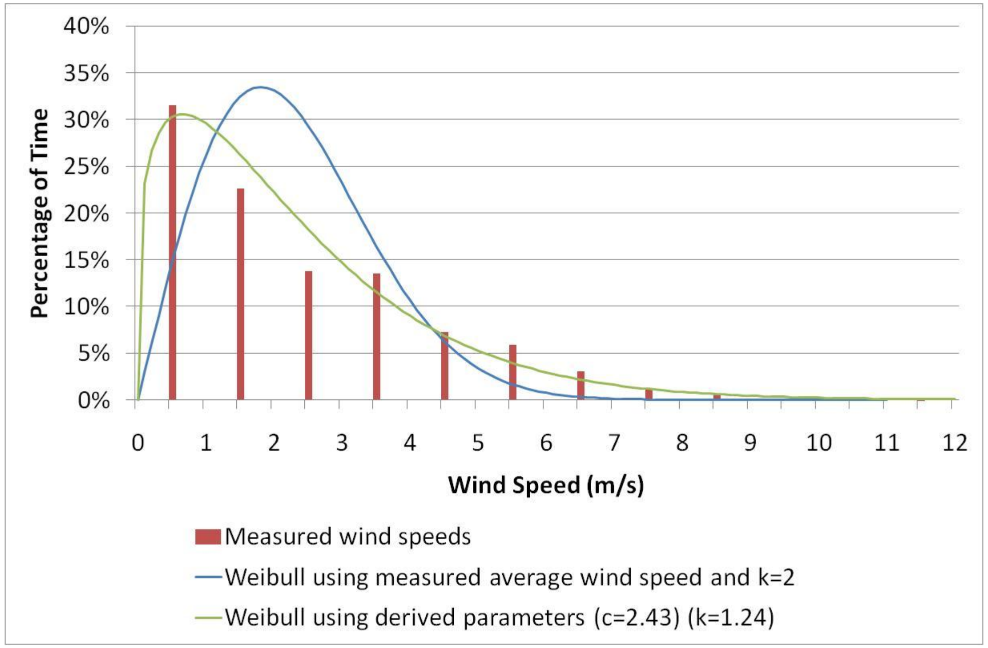
4. Birds Hill

Data collection period	26/07/07 – 14/10/08
Average wind speed	2.27ms^{-1}
Derived Weibull shape factor	1.24
Total energy output	47.85kWh
Predicted energy output	156.83kWh
Perfect in use capacity factor	1.41%
Actual in use capacity factor	

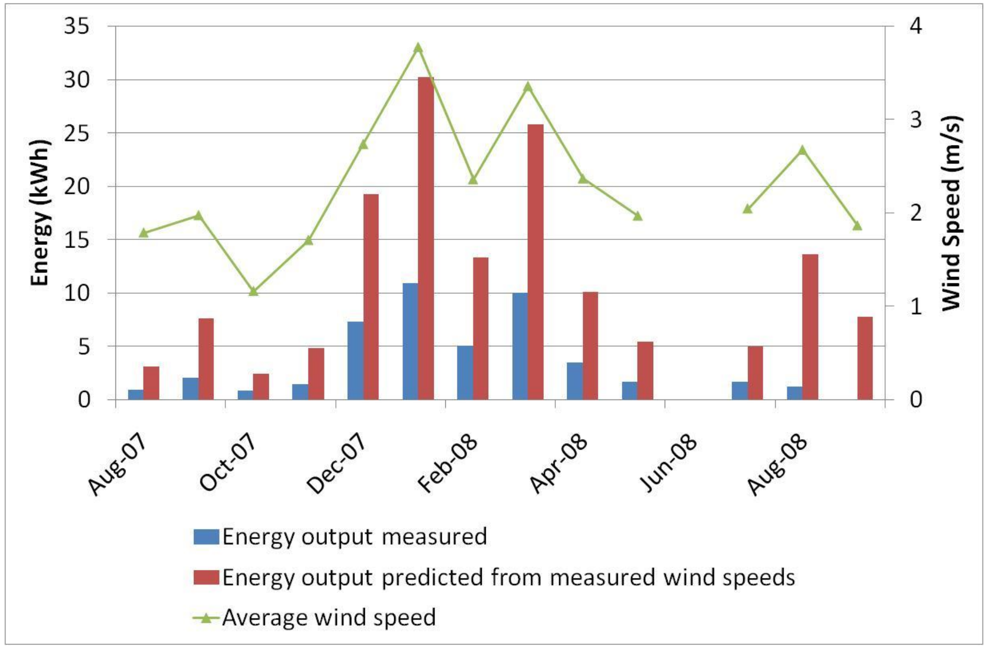
Notes

Data is missing from 11th June to 9th July 2008 (figures for July are based on data collected from this date onwards). Energy data is also missing from 10th August 2008 onwards.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



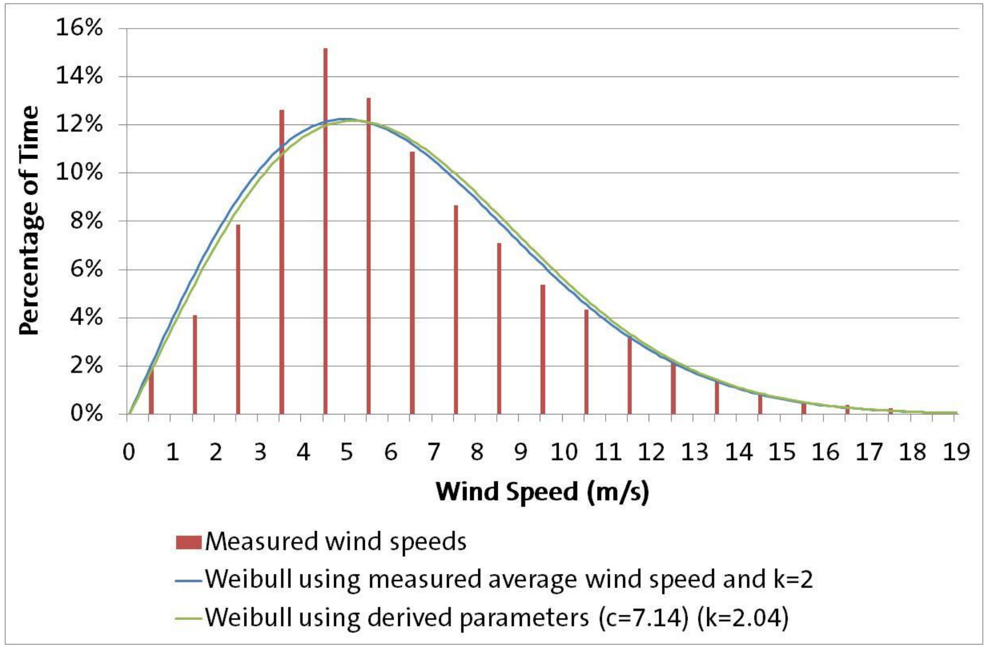
5. Eden Court 1

Data collection period	28/11/07 – 13/10/08
Average wind speed	6.22ms^{-1}
Derived Weibull shape factor	2.04
Total energy output	
Predicted energy output	1283kWh
Perfect in use capacity factor	
Actual in use capacity factor	

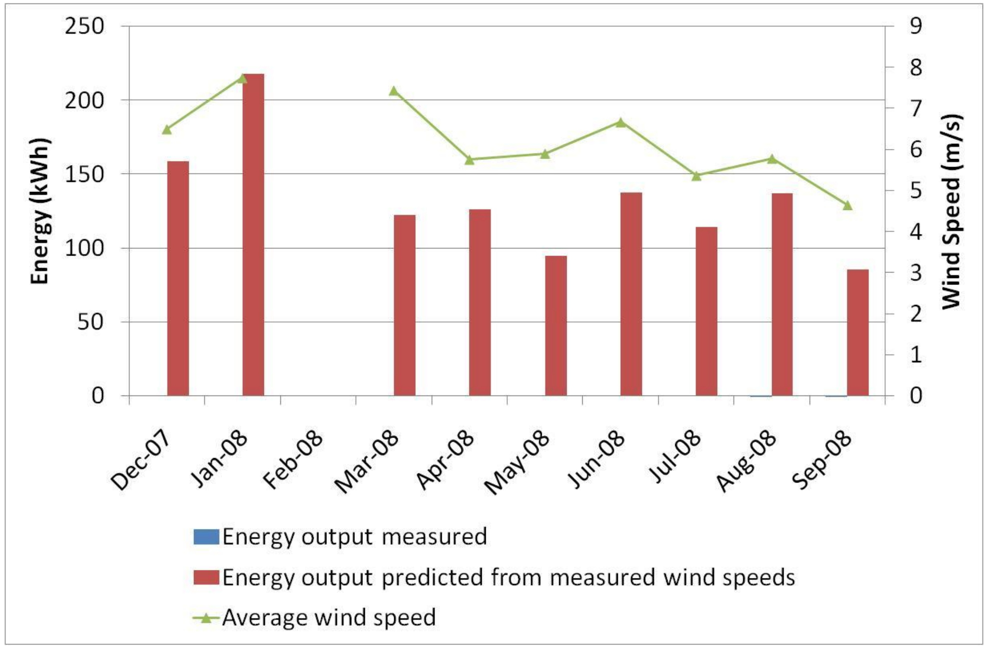
Notes

This turbine is switched off due to concerns about the level of noise produced in high winds. Data is missing from 1st February to 7th March 2008 due to a data logger failure.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



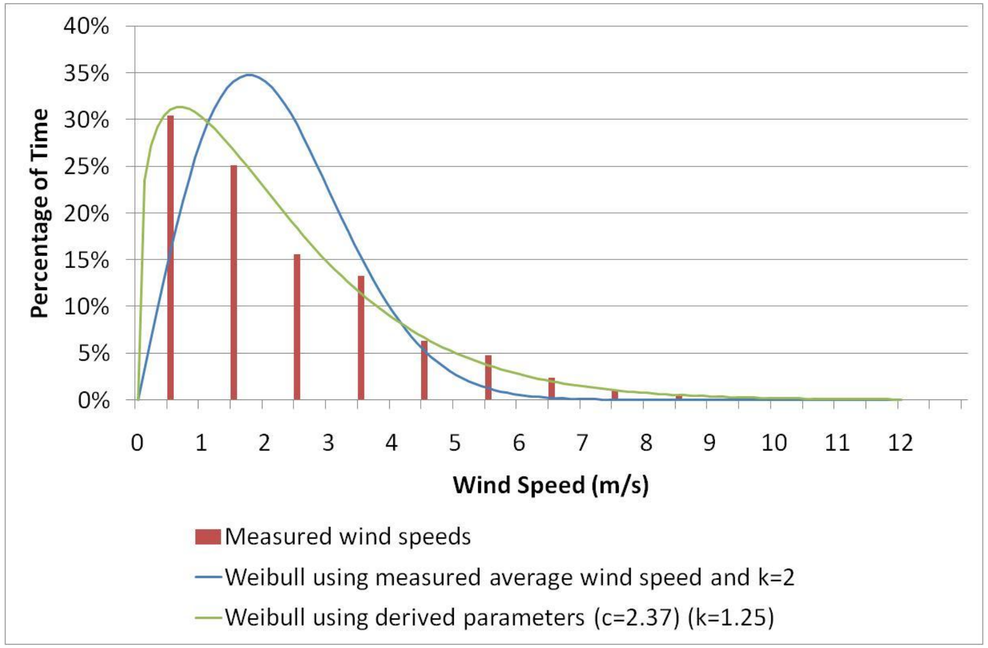
6. Leicester

Data collection period	01/11/07 – 16/10/08
Average wind speed	2.18ms^{-1}
Derived Weibull shape factor	1.25
Total energy output	63.75kWh
Predicted energy output	217.43kWh
Perfect in use capacity factor	0.76%
Actual in use capacity factor	0.23%

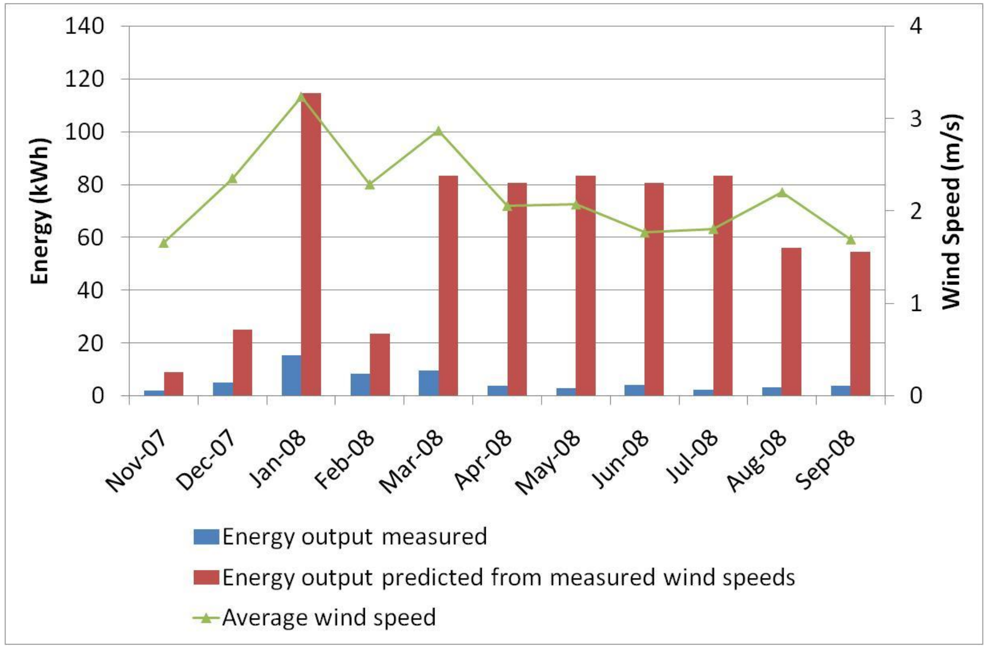
Notes

This turbine has been switched on for the entire time we have been collecting data.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



7. Southorn Court 1

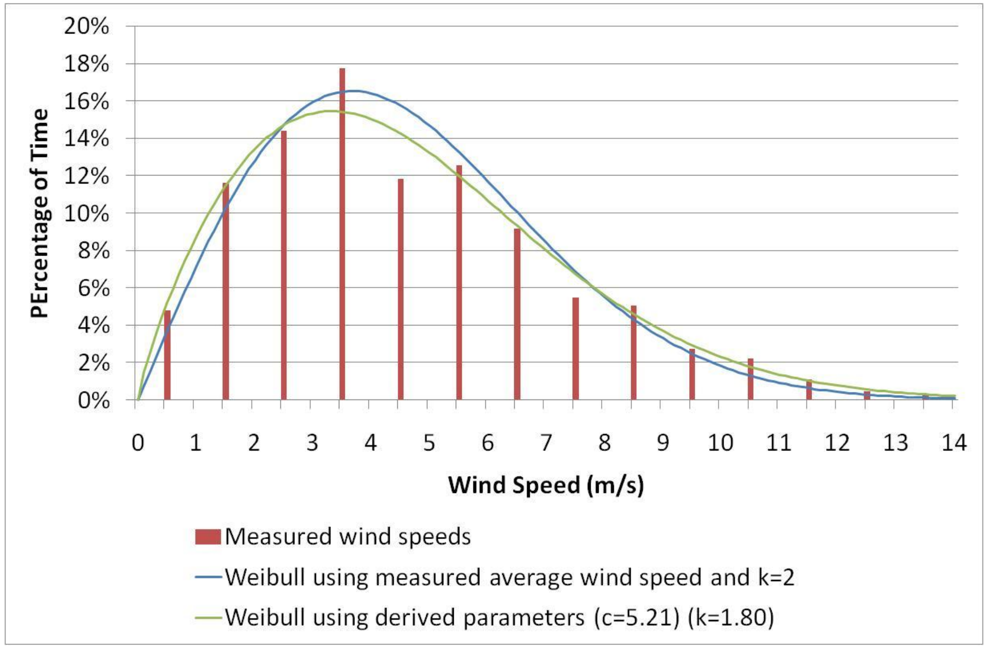
Data collection period	30/10/07 – 13/10/08
Average wind speed	4.59ms^{-1}
Derived Weibull shape factor	1.80
Total energy output	74.63kWh
Predicted energy output	1012.26kWh
Perfect in use capacity factor	8.28%
Actual in use capacity factor	1.66%

Notes

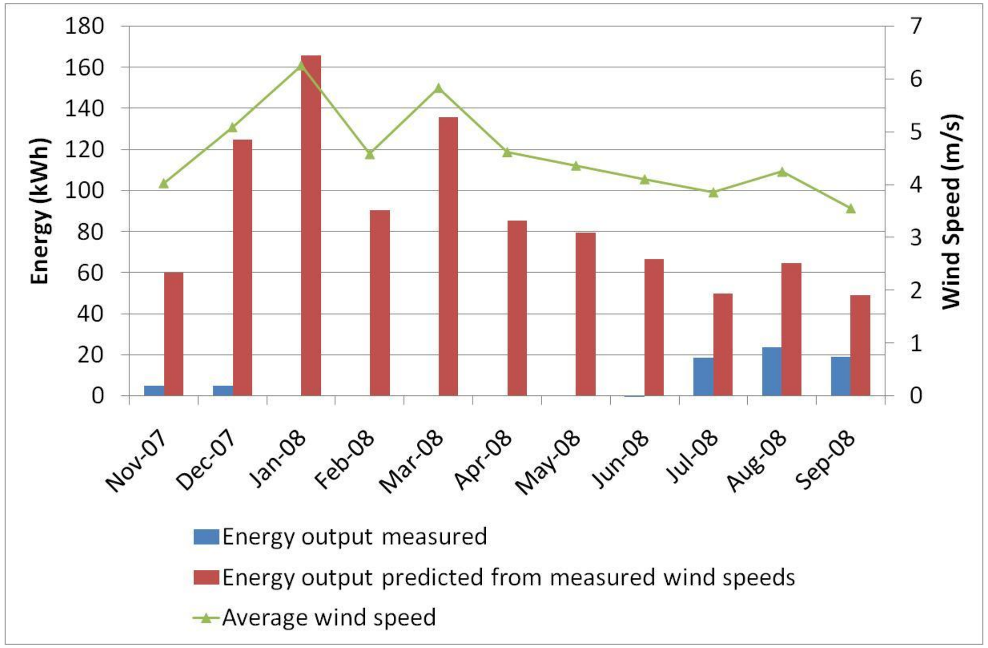
This turbine was switched off from December 2007 to 2nd July 2008 due to concerns about noise levels in high winds. The turbine was switched on occasionally during November and December 2007 but only on days of predicted low wind speed.

A new nose cone, blades and interconnect box were fitted on 2nd July 2008. On this date the turbine was also switched on – but only during the daytime (it was routinely switched off at night by an automatic timer switch).The turbine was switched off permanently on 1st October 2008 due to a noise complaint.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



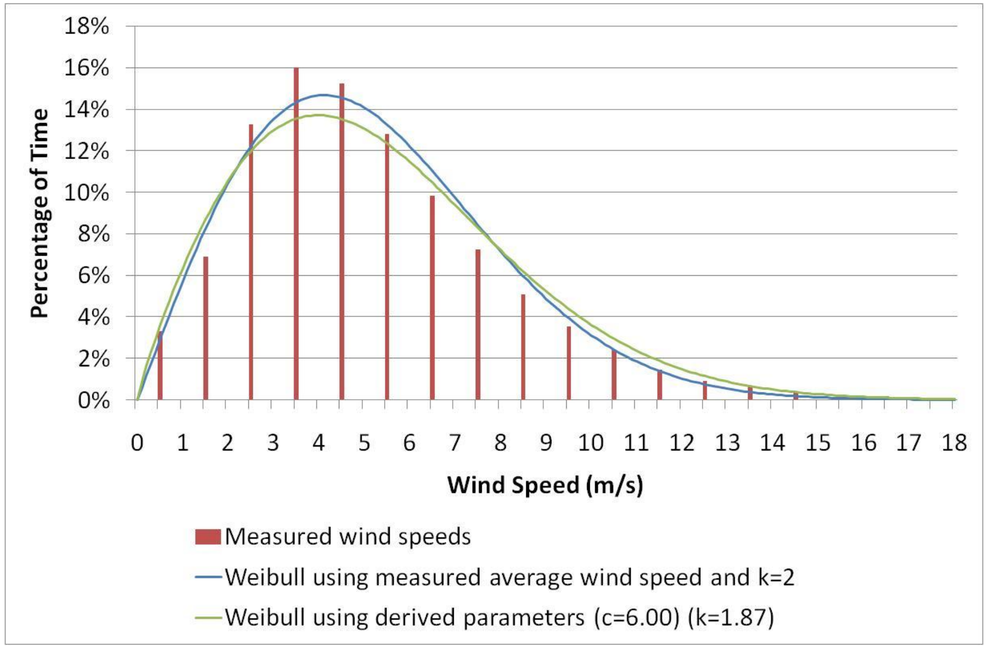
8. Ashton Court 1

Data collection period	03/01/08 – 13/10/08
Average wind speed	5.17ms^{-1}
Derived Weibull shape factor	1.87
Total energy output	
Predicted energy output	935.89kWh
Perfect in use capacity factor	
Actual in use capacity factor	

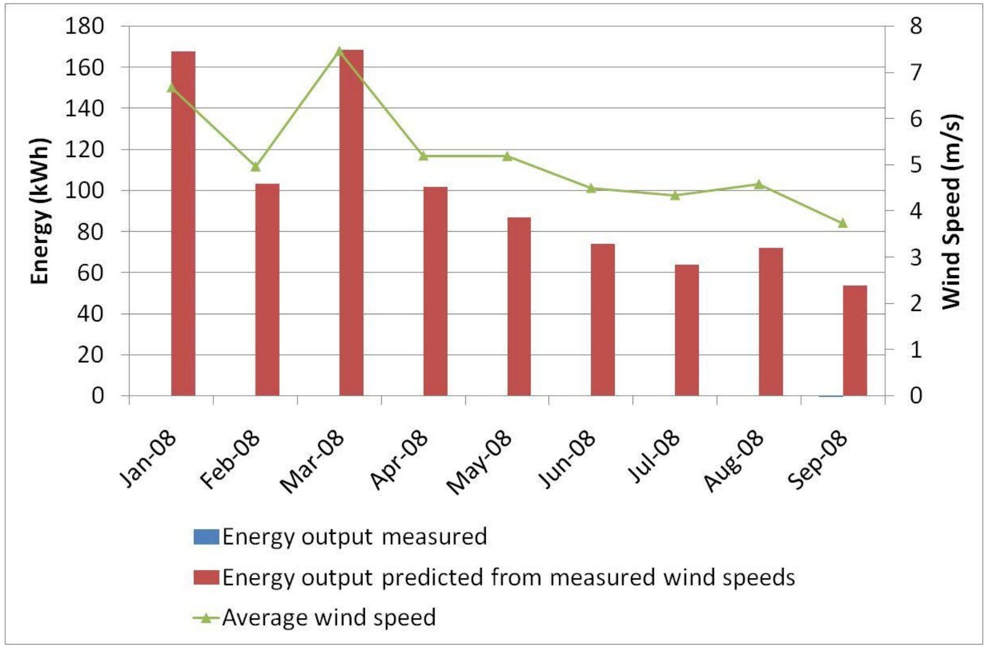
Notes

This turbine has been switched off throughout the period of time we have been collecting data for. A loose connection on the anemometer delayed the start of data collection until 3rd January 2008.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



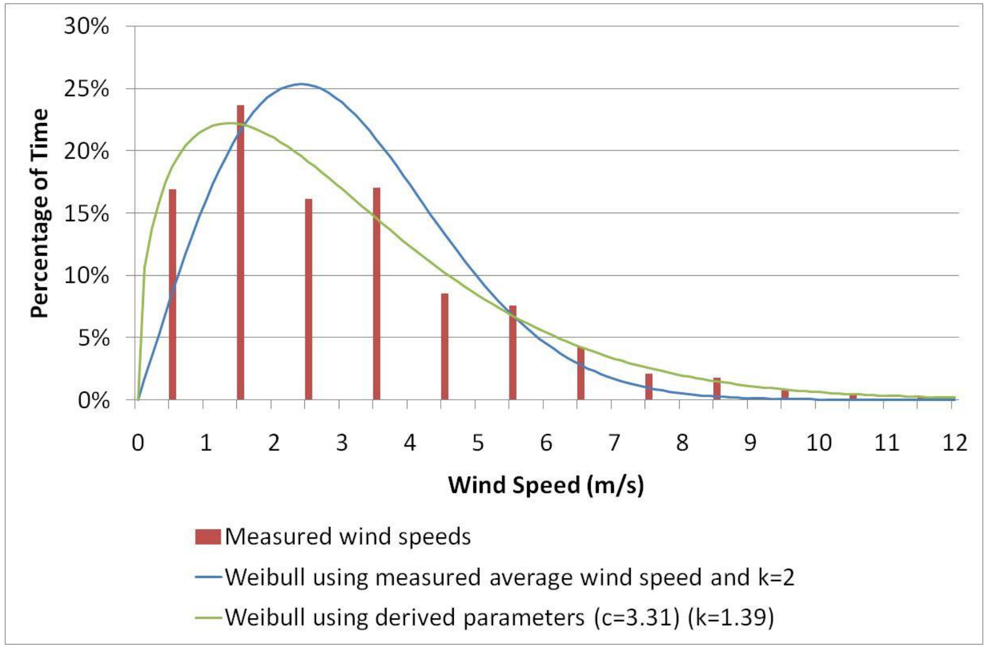
9. Napier

Data collection period	20/11/07 – 10/10/08
Average wind speed	$2.99ms^{-1}$
Derived Weibull shape factor	1.39
Total energy output	91.84kWh
Predicted energy output	371.91kWh
Perfect in use capacity factor	2.90%
Actual in use capacity factor	

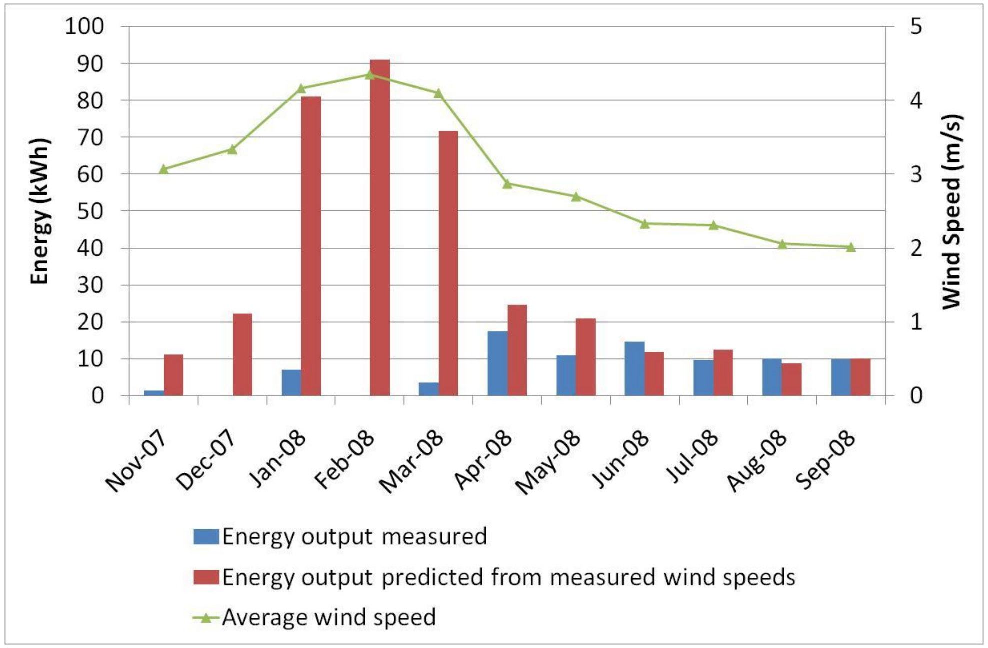
Notes

Data is missing from 4th to 20th December 2007. The turbine was also switched off intermittently from 24th December 2007 to 26th March 2008 but is currently switched on.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



10. Daventry Town Hall

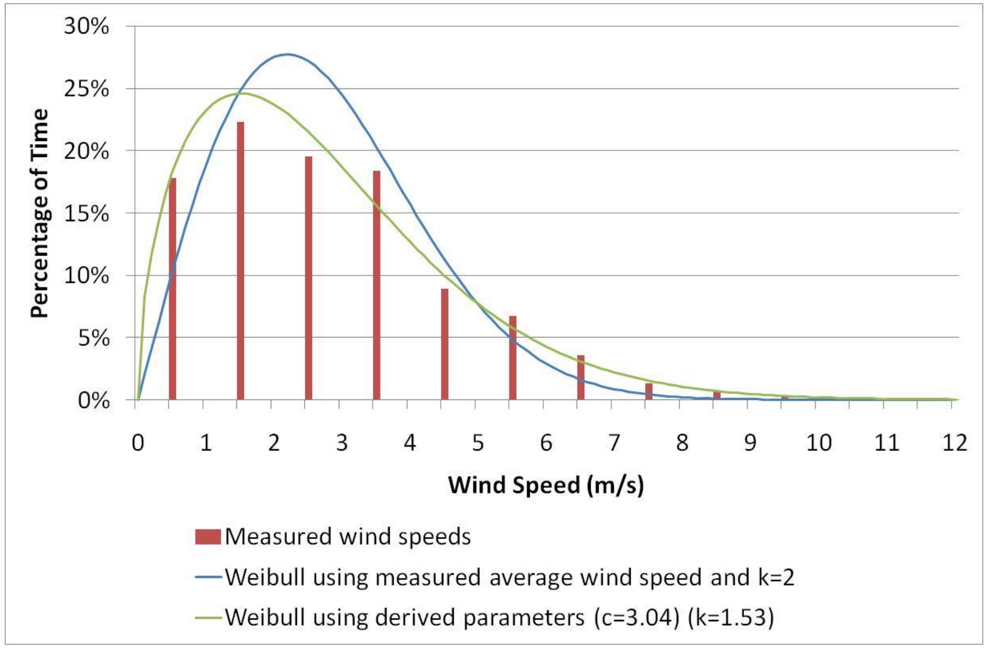
Data collection period	04/12/07 – 14/10/08
Average wind speed	2.74ms^{-1}
Derived Weibull shape factor	1.53
Total energy output	109.13kWh
Predicted energy output	204.82kWh
Perfect in use capacity factor	1.50%
Actual in use capacity factor	1.31%

Notes

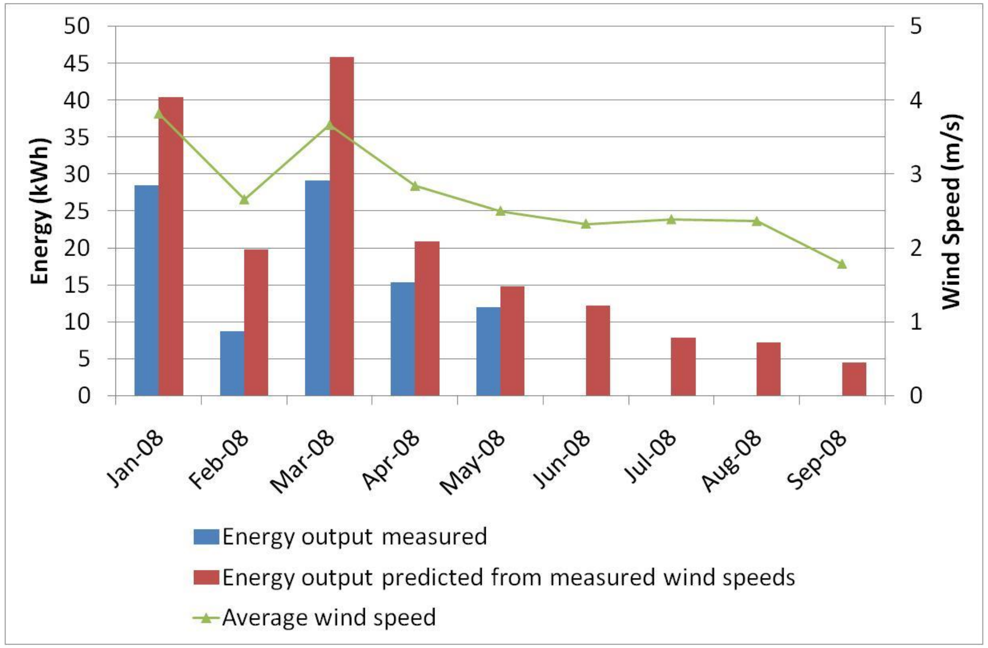
Structural damage to the gable end of this building is suspected to have been caused by the wind turbine and it was removed on 27th May 2008. Wind speed data is still being collected from this site.

This turbine averaged 627Wh per day during the 174 days that the turbine was installed and working with energy output monitored.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



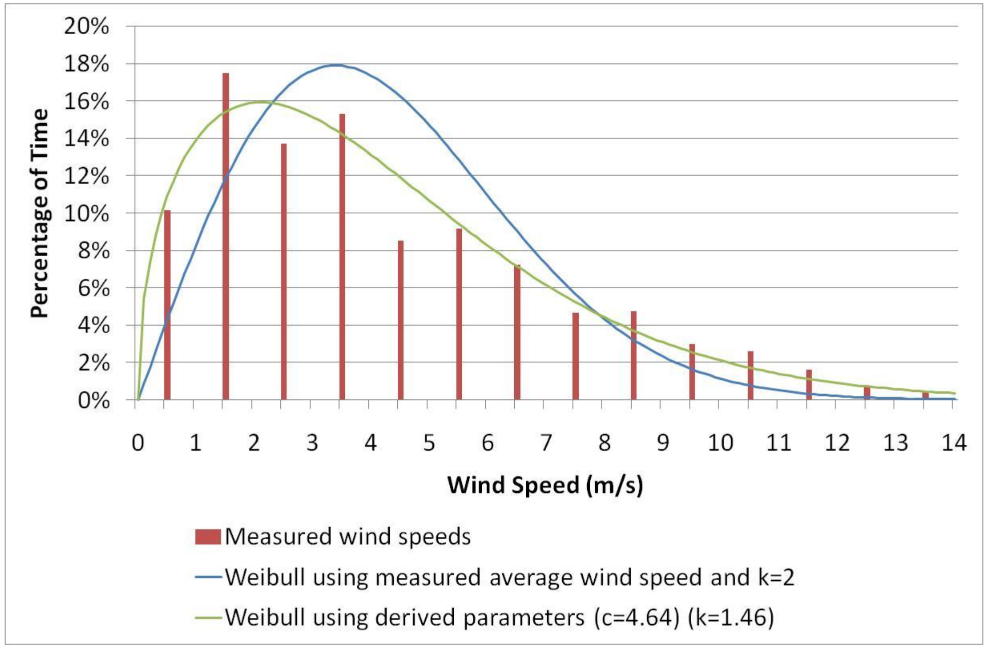
11. Ashton Court 2

Data collection period	01/10/07 – 04/08/08
Average wind speed	$4.25ms^{-1}$
Derived Weibull shape factor	1.46
Total energy output	34.75kWh
Predicted energy output	770.80kWh
Perfect in use capacity factor	
Actual in use capacity factor	1.66%

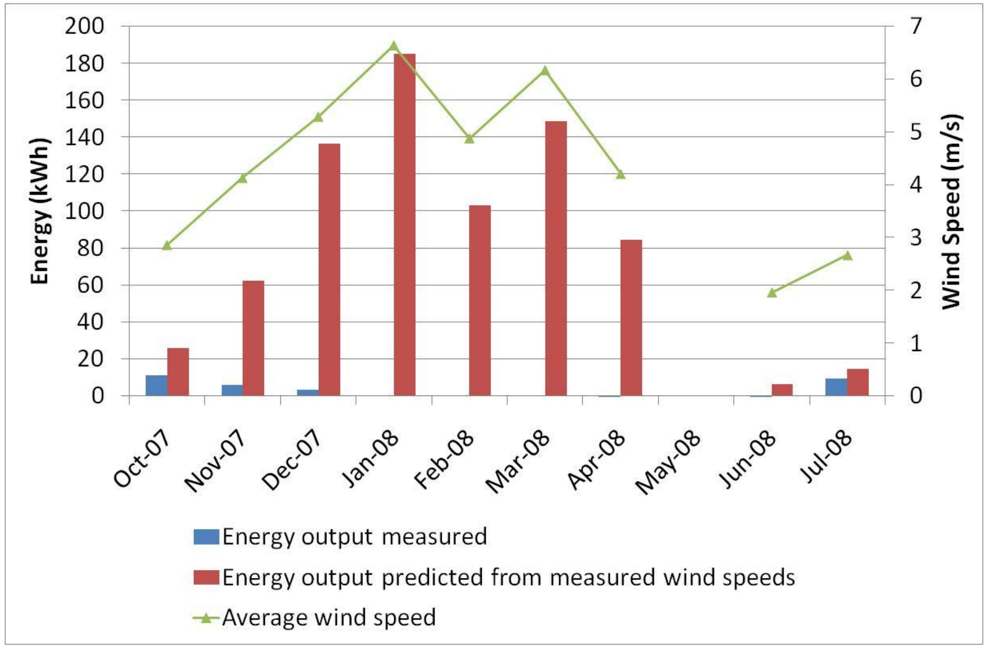
Notes

This turbine has been switched off the majority of time due to concerns over noise. Data is missing from 12th May to 9th June 2008 due to a battery failure on the data logger. A new nose cone, blades and interconnect box were fitted on 18th July 2008. On this date the turbine was also switched on – but only during the daytime (it was routinely switched off at night by an automatic timer switch).The turbine was switched off permanently on 1st October 2008 due to a noise complaint.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



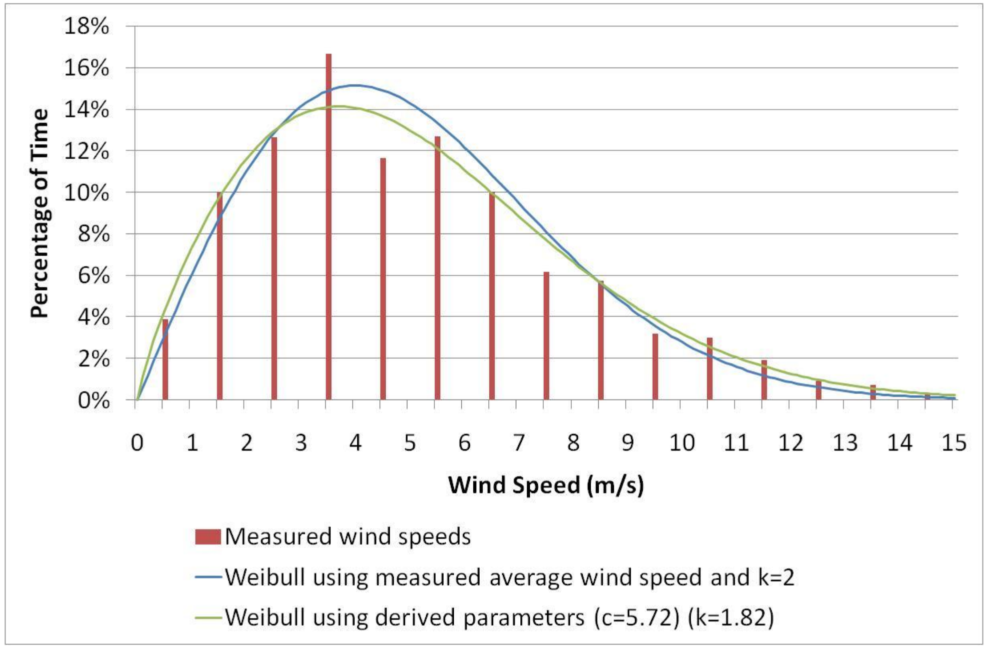
12. Southorn Court 2

Data collection period	30/10/07 – 13/10/08
Average wind speed	$5.02ms^{-1}$
Derived Weibull shape factor	1.82
Total energy output	50.27kWh
Predicted energy output	1084.48kWh
Perfect in use capacity factor	9.79%
Actual in use capacity factor	1.49%

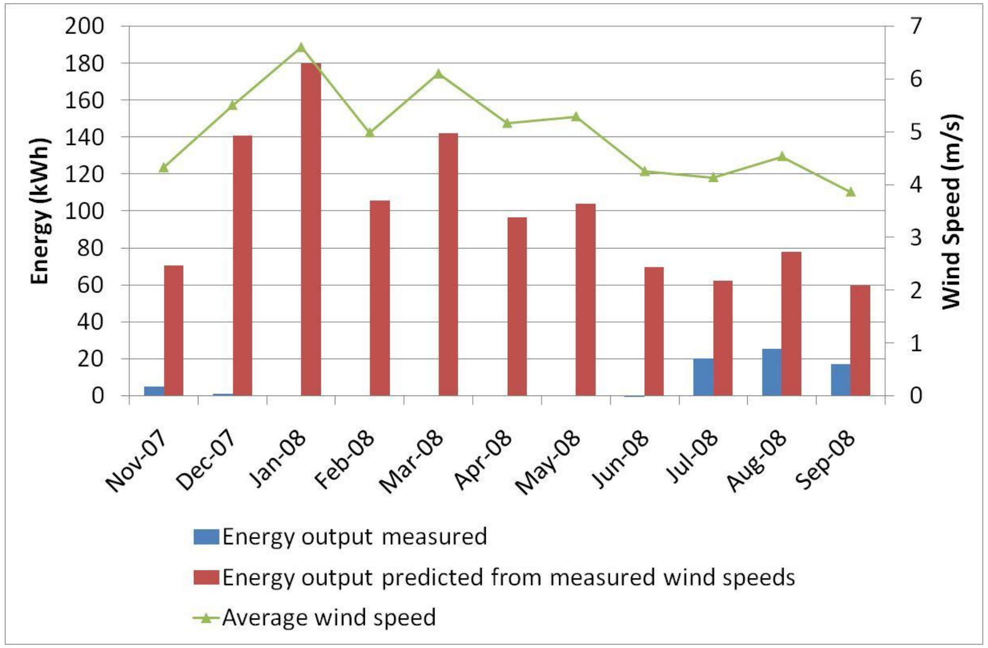
Notes

This turbine has been switched off the majority of time due to concerns over noise. A new nose cone, blades and interconnect box were fitted on 2nd July 2008. On this date the turbine was also switched on – but only during the daytime (it was routinely switched off at night by an automatic timer switch).The turbine was switched off permanently on 1st October 2008 due to a noise complaint.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



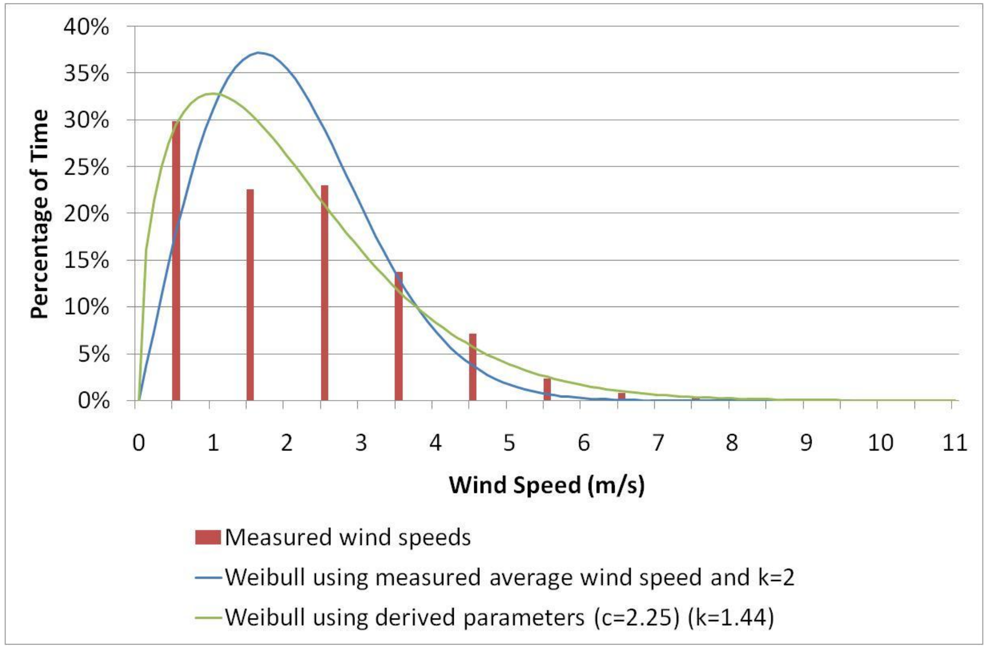
13. Daventry Country Park

Data collection period	28/11/07 – 23/09/08
Average wind speed	2.04ms^{-1}
Derived Weibull shape factor	1.44
Total energy output	55.79kWh
Predicted energy output	68.78kWh
Perfect in use capacity factor	0.75%
Actual in use capacity factor	0.21%

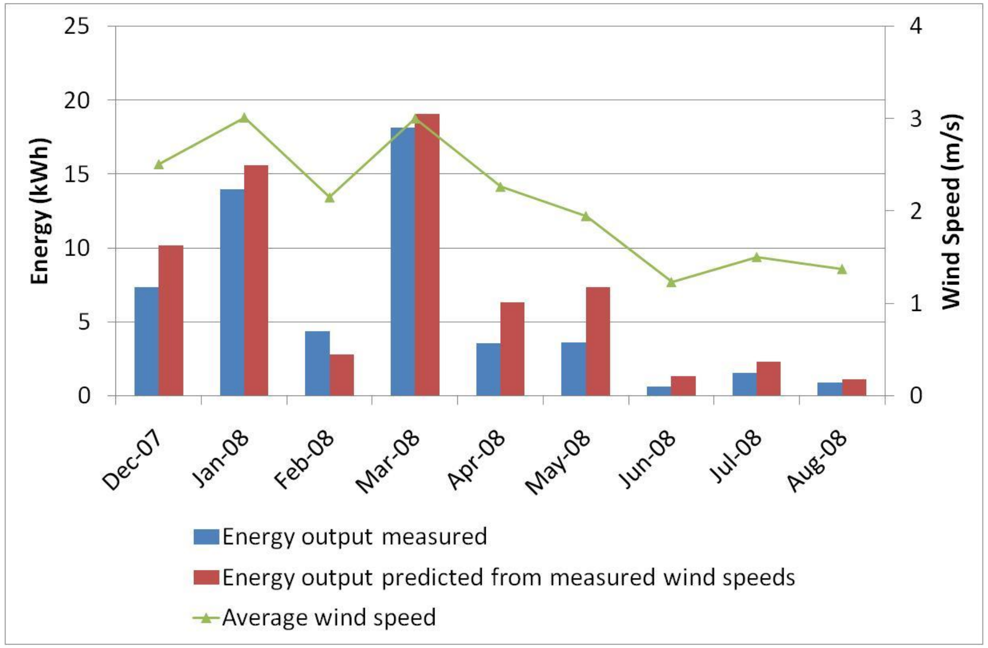
Notes

Data is missing from 12th February to 3rd March 2008 due to a data logger failure but the turbine has been switched on the entire time.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



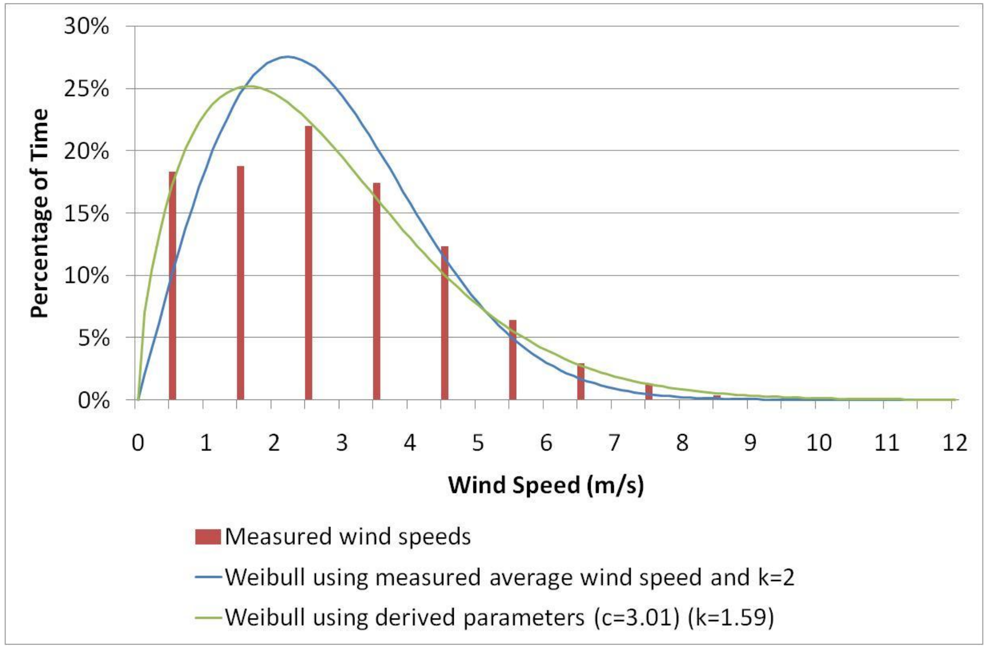
14. Fountain Farm

Data collection period	17/09/07 – 16/10/08
Average wind speed	2.75ms^{-1}
Derived Weibull shape factor	1.59
Total energy output	86kWh
Predicted energy output	234.06kWh
Perfect in use capacity factor	
Actual in use capacity factor	1.61%

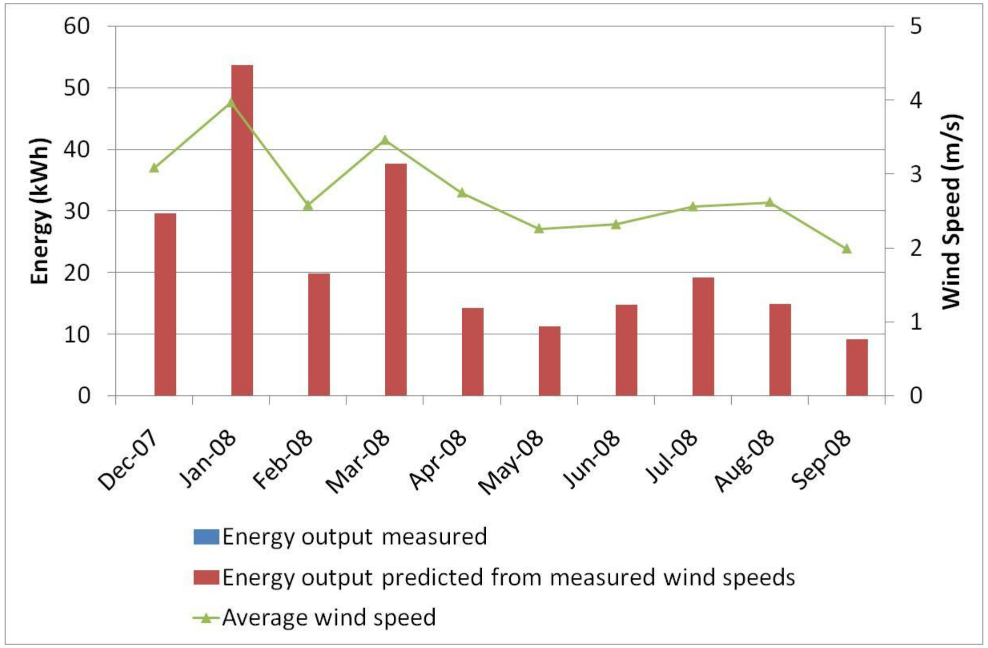
Notes

This turbine has been switched on for the entire time we have been collecting data. However the energy data has not been recorded by the data logger. The only energy data we have are manual readings taken directly from the watt meter.

Wind speed distribution



Trend in monthly average wind speed and energy output per month

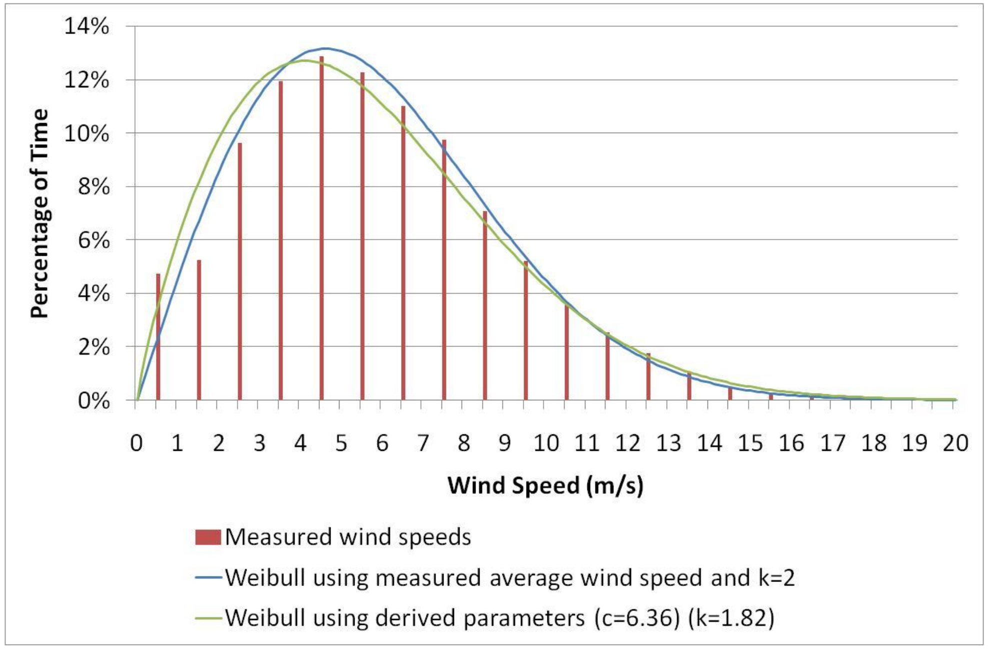


15. Misty View Farm

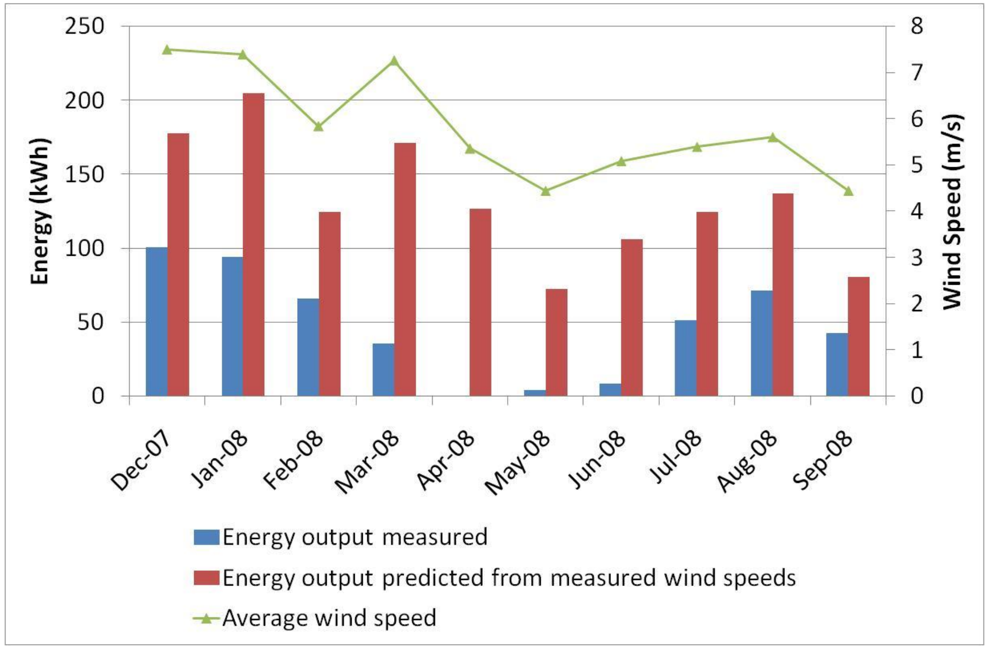
Data collection period	17/11/07 – 16/10/08
Average wind speed	5.77ms^{-1}
Derived Weibull shape factor	1.82
Total energy output	439.09kWh
Predicted energy output	1361.57kWh
Perfect in use capacity factor	16.54%
Actual in use capacity factor	

Notes
This turbine was switched off intermittently from 11th March until 6th July 2008.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



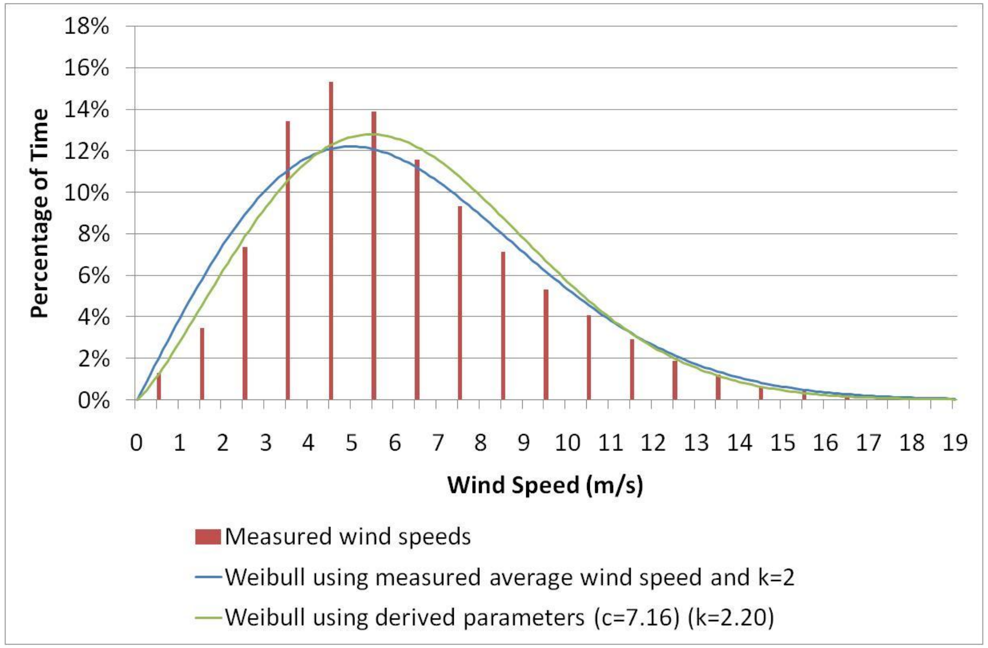
16. Eden Court 2

Data collection period	28/11/07 – 13/10/08
Average wind speed	6.22ms^{-1}
Derived Weibull shape factor	2.20
Total energy output	51.64kWh
Predicted energy output	1295.44kWh
Perfect in use capacity factor	13.67%
Actual in use capacity factor	1.26%

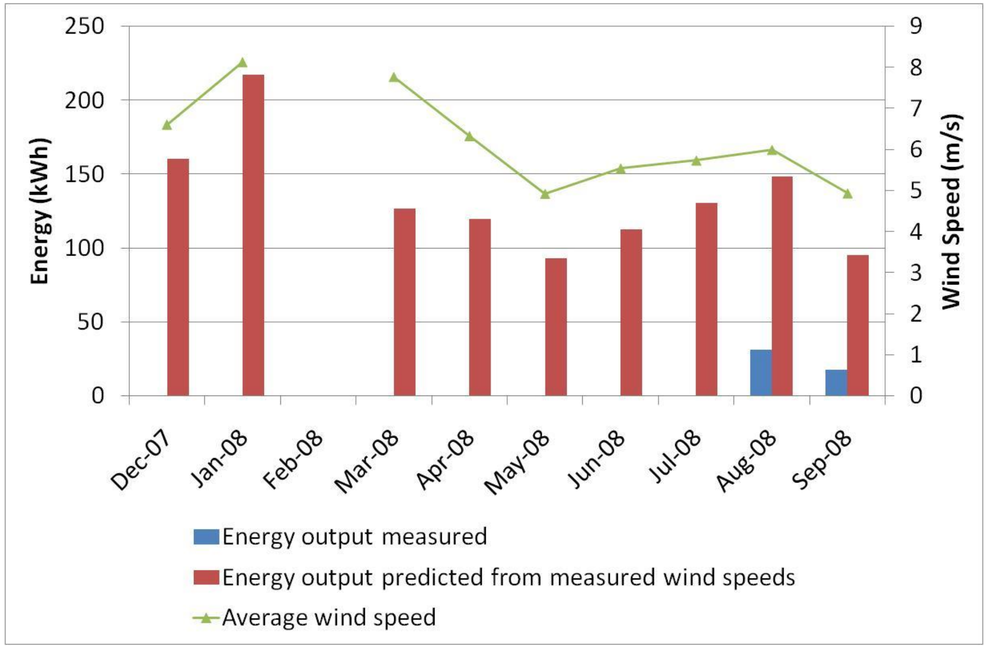
Notes

This turbine has been switched off the majority of time due to concerns over noise. A new nose cone, blades and interconnect box were fitted on 6th August 2008. On this date the turbine was also switched on – but only during the daytime (it was routinely switched off at night by an automatic timer switch).The turbine was switched off permanently on 1st October 2008 due to a noise complaint. Data is missing from 1st February to 7th March 2008.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



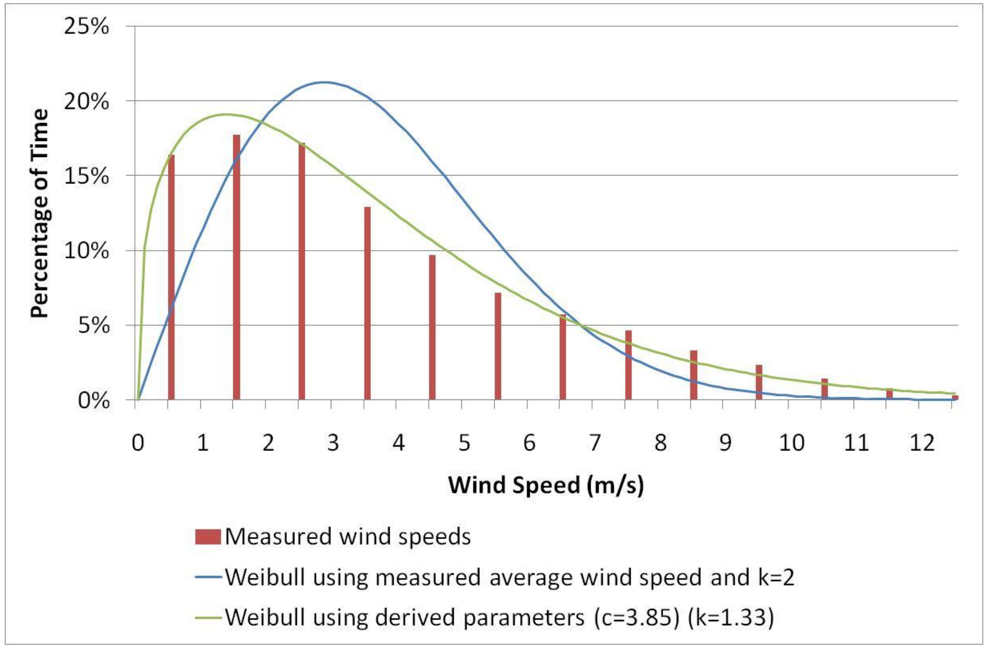
17. Tannery Court

Data collection period	19/02/08 – 20/10/08
Average wind speed	$3.58ms^{-1}$
Derived Weibull shape factor	1.33
Total energy output	26kWh
Predicted energy output	450.31kWh
Perfect in use capacity factor	1.52%
Actual in use capacity factor	0.25%

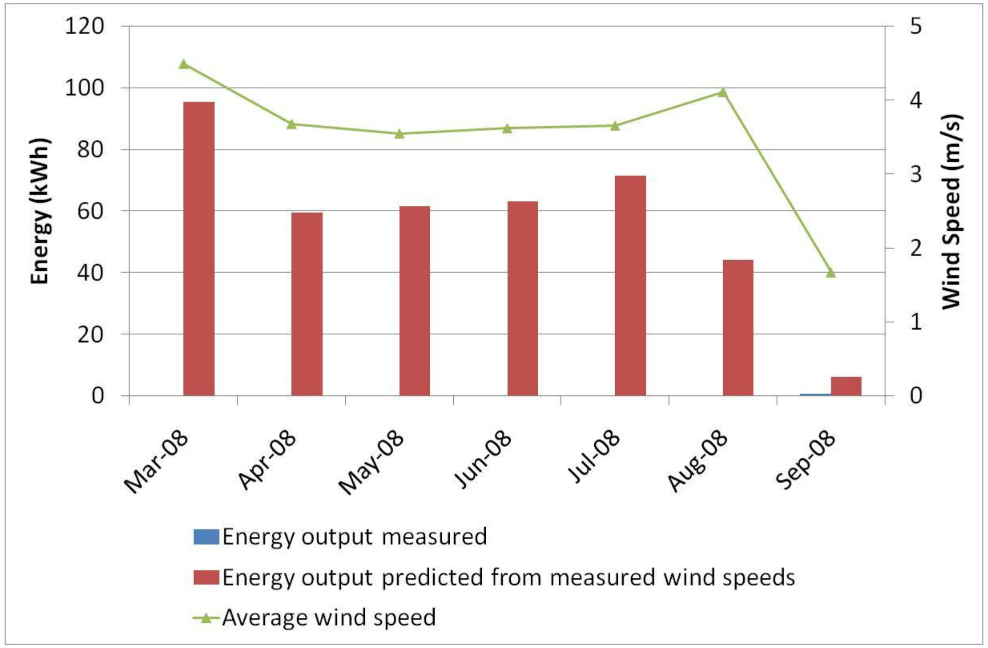
Notes

Problems with the wind speed monitoring kit delayed data collection until 19th February 2008. Continued problems with energy data collection delayed logging of energy by the data logger until 11th September 2008. The figure for total energy output is based on manual watt meter readings. Data is also missing from 16th August until 11th September due to a data logger failure.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



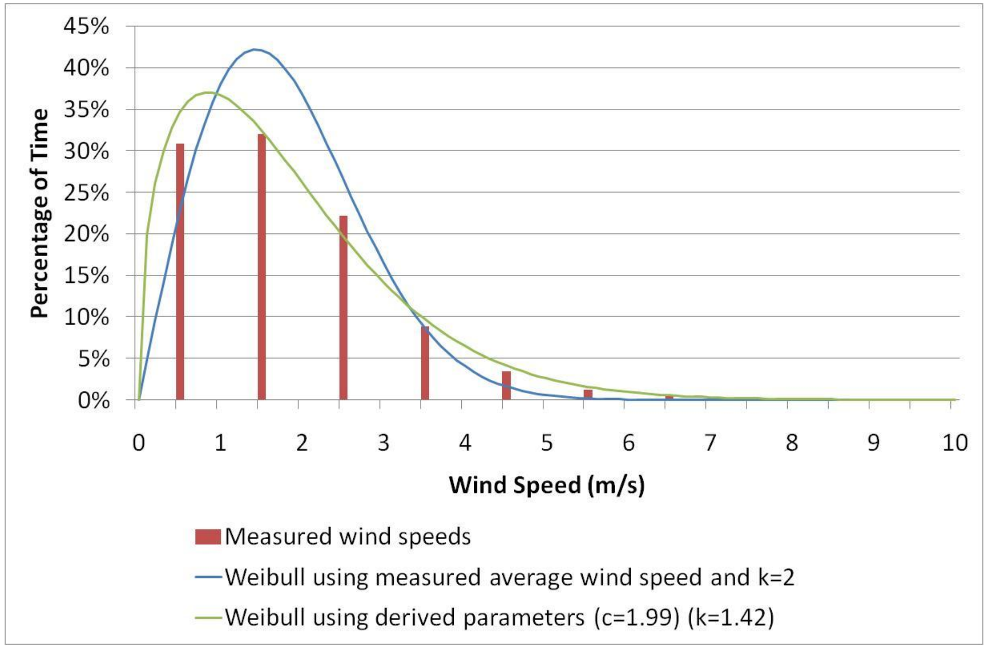
18. Nottingham

Data collection period	30/10/07 – 31/08/08
Average wind speed	1.80ms^{-1}
Derived Weibull shape factor	1.42
Total energy output	
Predicted energy output	90.36kWh
Perfect in use capacity factor	
Actual in use capacity factor	

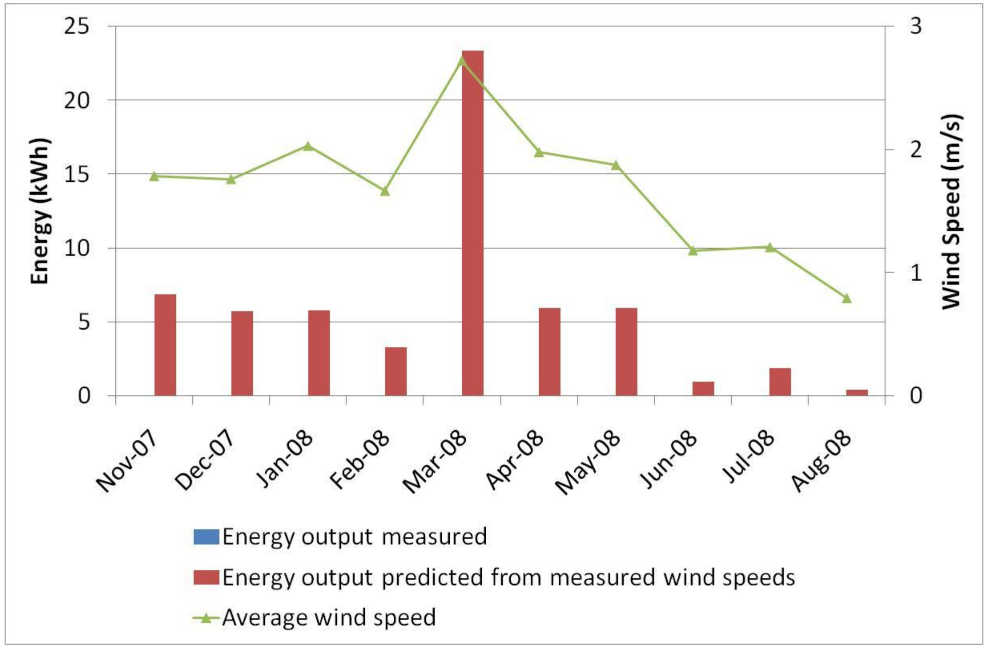
Notes

This turbine has a slightly different installation arrangement and different data logging equipment to all other turbines on the trial and so energy data is not directly comparable. Therefore only wind speed data has been published.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



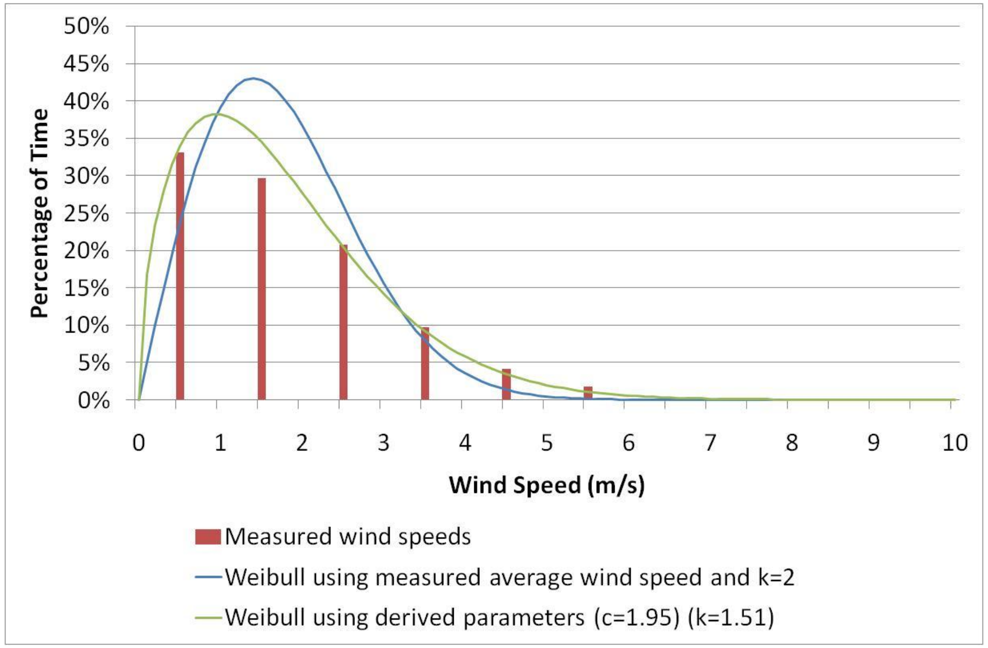
19. Antrobus Road

Data collection period	30/11/07 – 23/05/08
Average wind speed	1.76ms^{-1}
Derived Weibull shape factor	1.51
Total energy output	
Predicted energy output	20.67kWh
Perfect in use capacity factor	
Actual in use capacity factor	

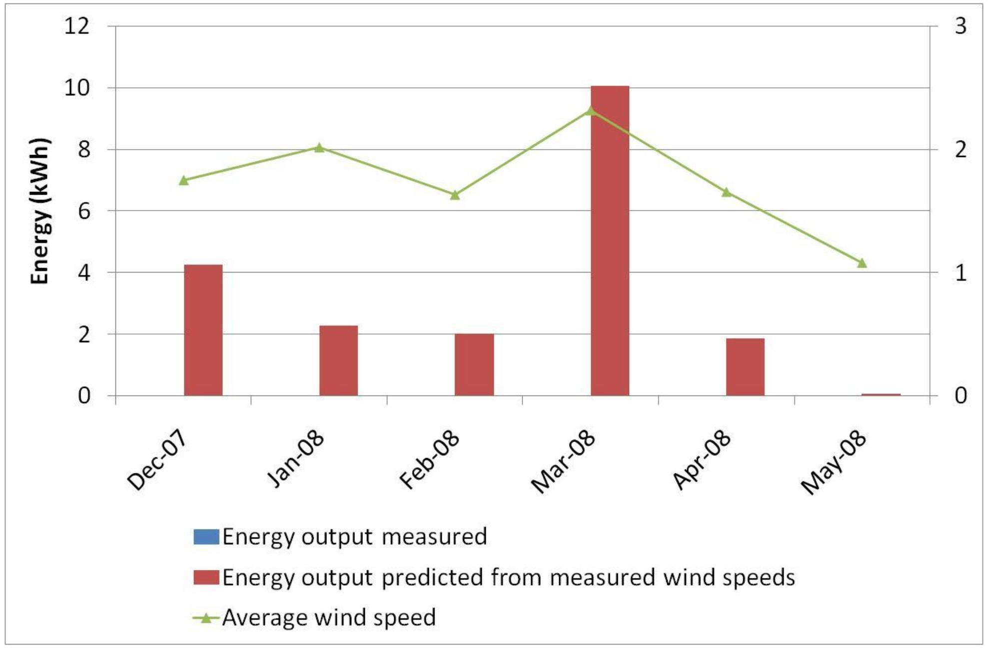
Notes

The turbine has been switched off for the entire time we have been collecting data. Wind speed data is missing from 18th January to 14th February 2008 due to a loose battery wire on the data logger. We have been unable to gain access to the property for collecting data since May 2008.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



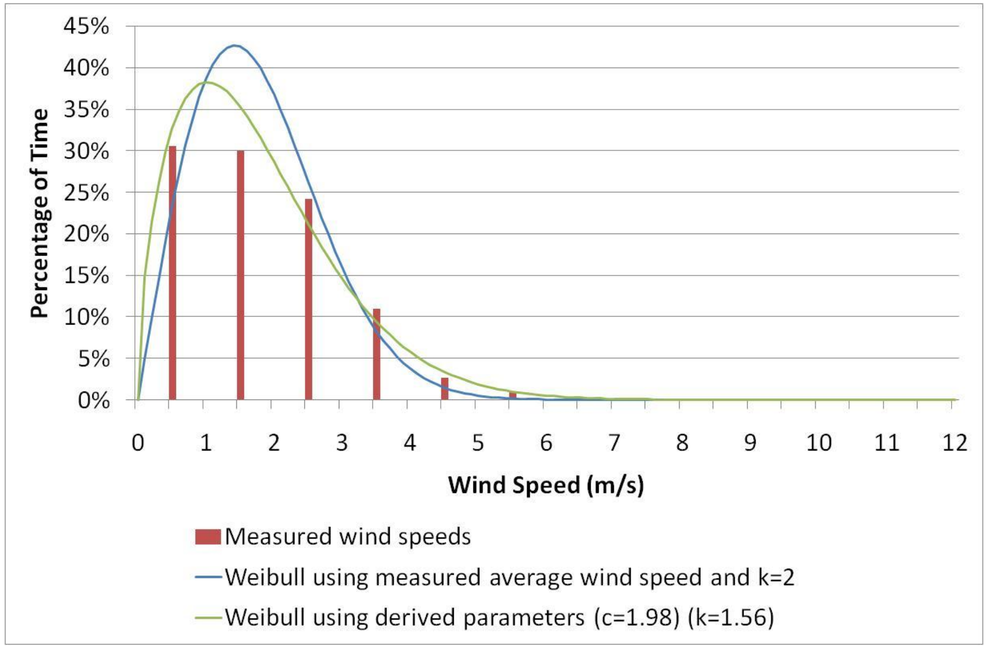
20. Summerfield Crescent

Data collection period	30/11/08 – 18/09/08
Average wind speed	1.78ms^{-1}
Derived Weibull shape factor	1.54
Total energy output	1.01kWh
Predicted energy output	33.41kWh
Perfect in use capacity factor	
Actual in use capacity factor	

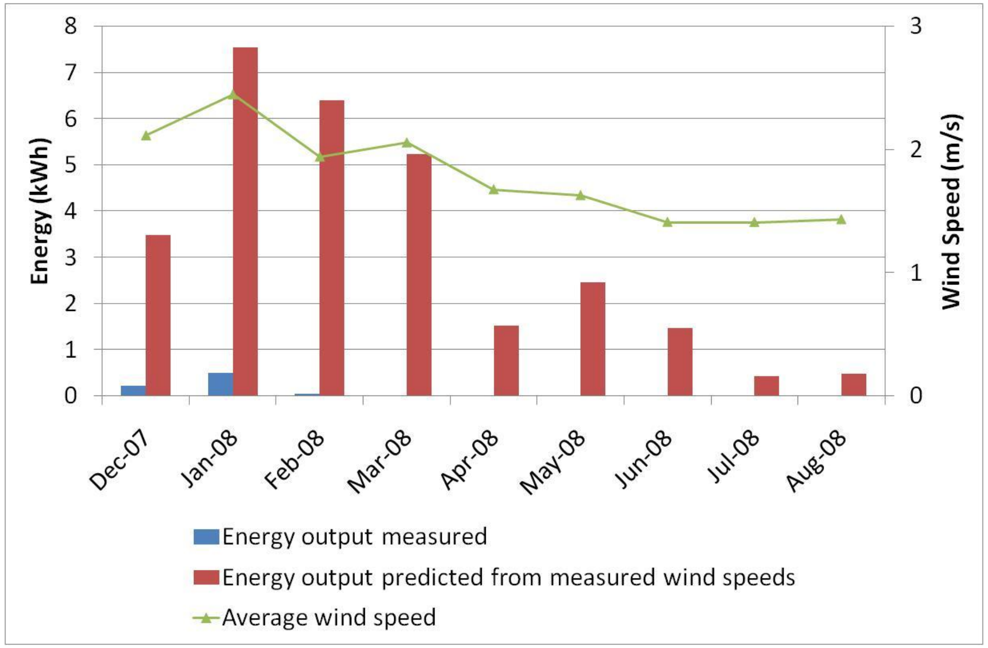
Notes

The turbine has been switched off for the majority time we have been collecting data.

Wind speed distribution



Trend in monthly average wind speed and energy output per month

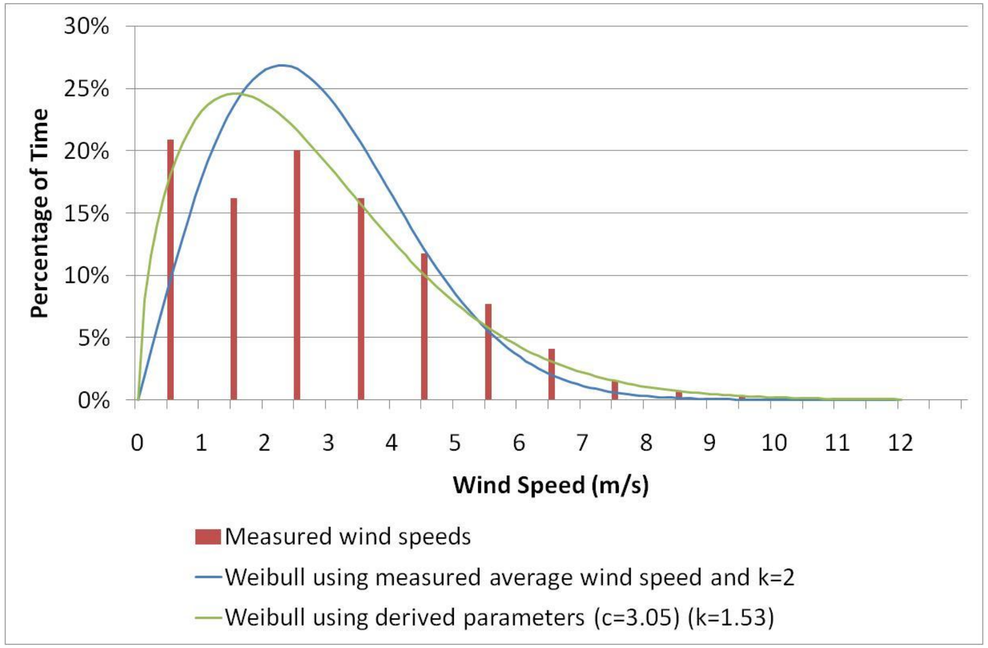


21. Park Farm

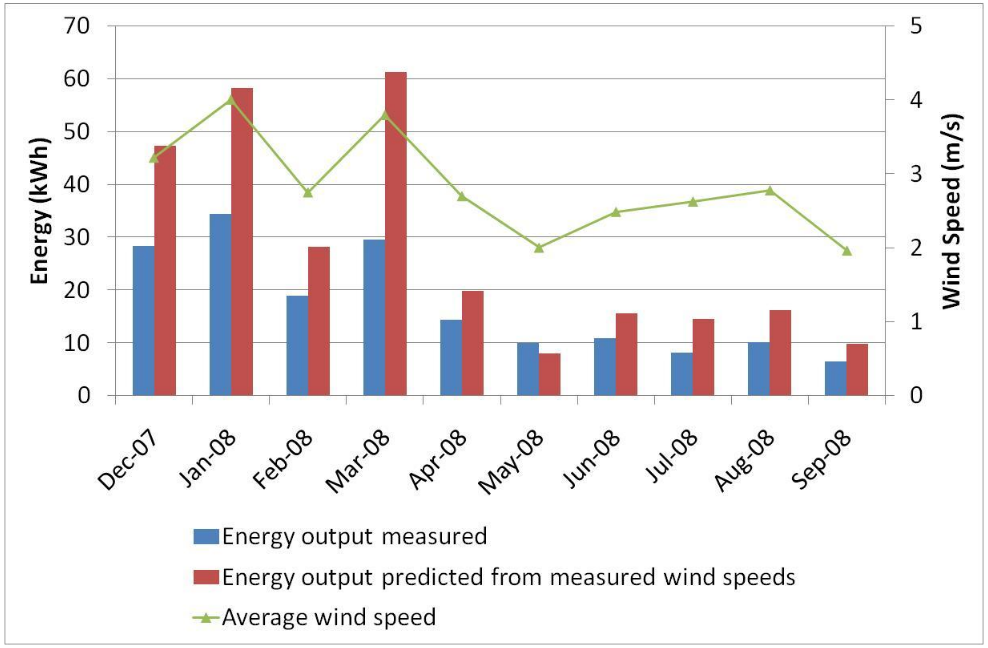
Data collection period	29/11/07 – 16/10/08
Average wind speed	2.83ms^{-1}
Derived Weibull shape factor	1.53
Total energy output	178.62kWh
Predicted energy output	290.87kWh
Perfect in use capacity factor	3.85%
Actual in use capacity factor	3.32%

Notes
This turbine has been switched on the entire time we have been collecting data for.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



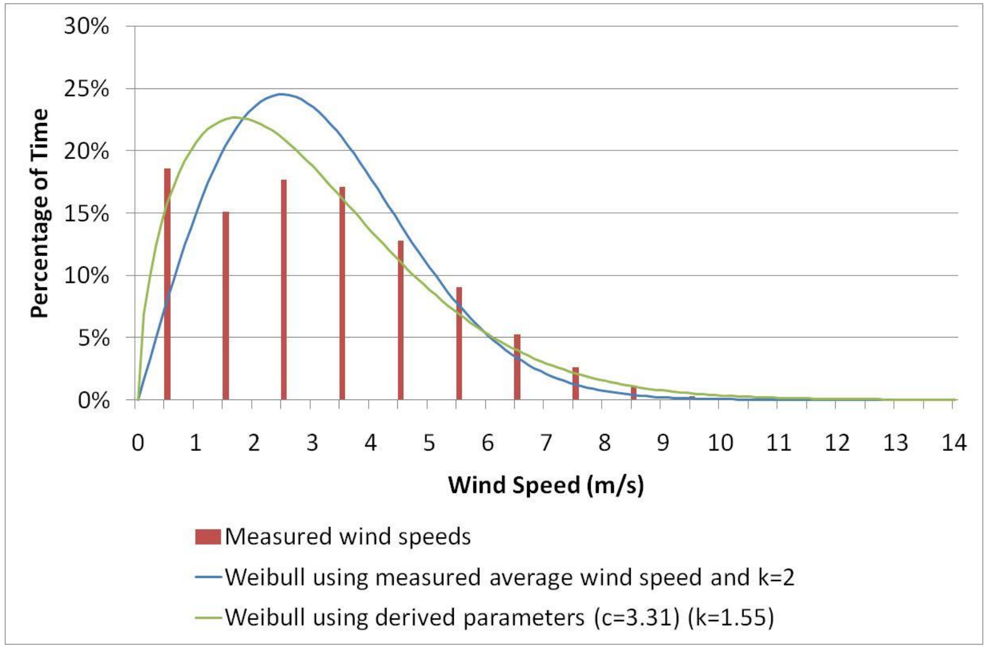
22. Northamptonshire

Data collection period	28/11/07 – 14/10/08
Average wind speed	3.10ms^{-1}
Derived Weibull shape factor	1.55
Total energy output	69kWh
Predicted energy output	293.41kWh
Perfect in use capacity factor	
Actual in use capacity factor	0.16%

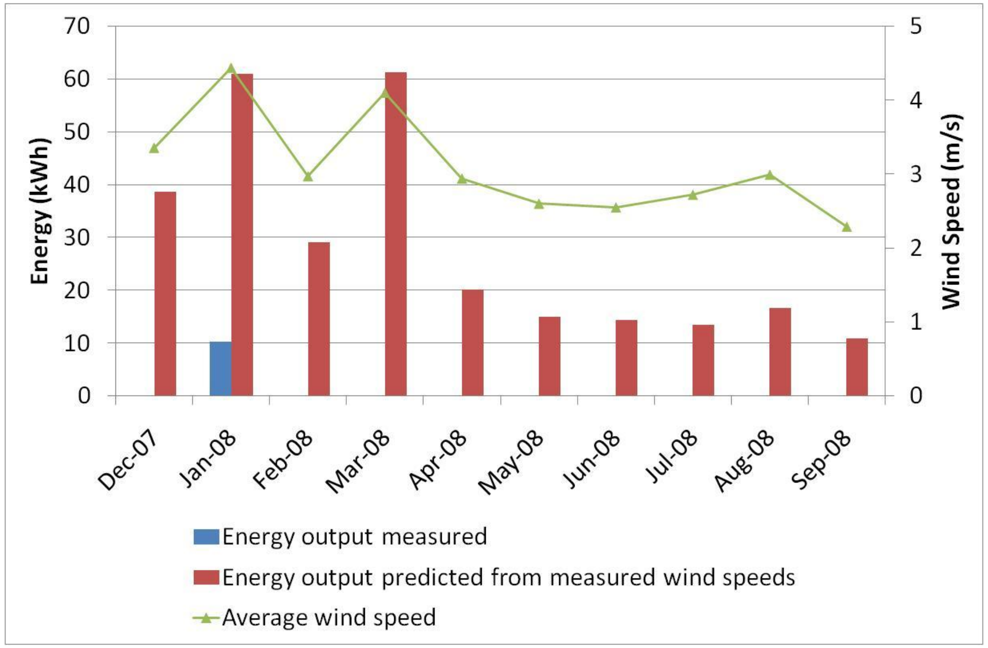
Notes

This turbine was switched off intermittently during December 2007 and January 2008. Since then energy data has not been collected by the data logger due to a problem with the wattmeter. Manual readings have been taken from the watt meter. The turbine is currently switched on.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



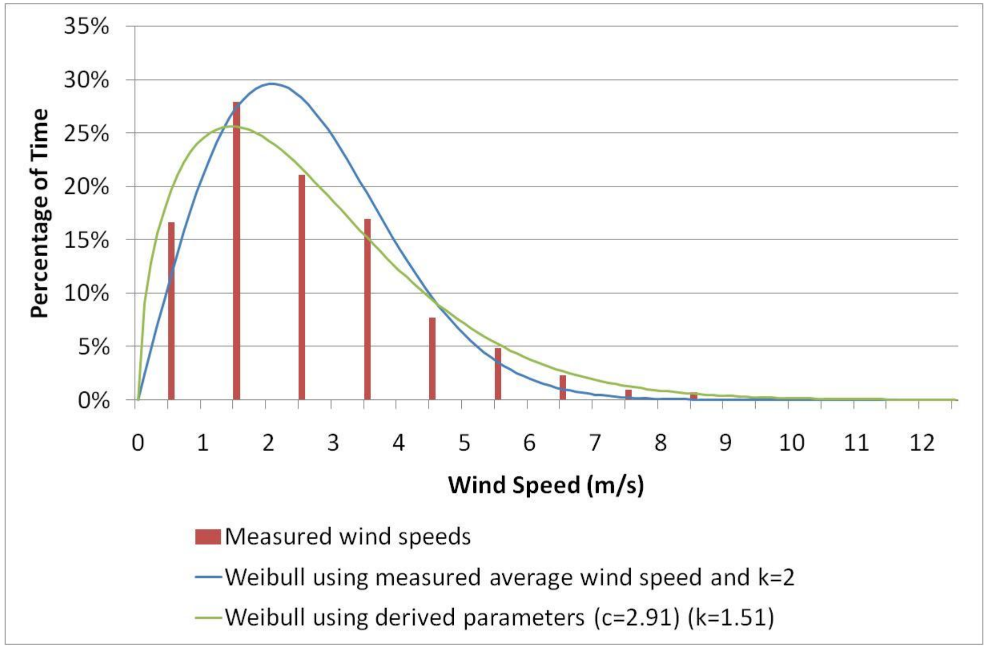
23. Delta Court

Data collection period	20/02/08 – 27/10/08
Average wind speed	2.57ms^{-1}
Derived Weibull shape factor	1.51
Total energy output	19.44kWh
Predicted energy output	85.03kWh
Perfect in use capacity factor	1.31%
Actual in use capacity factor	0.61%

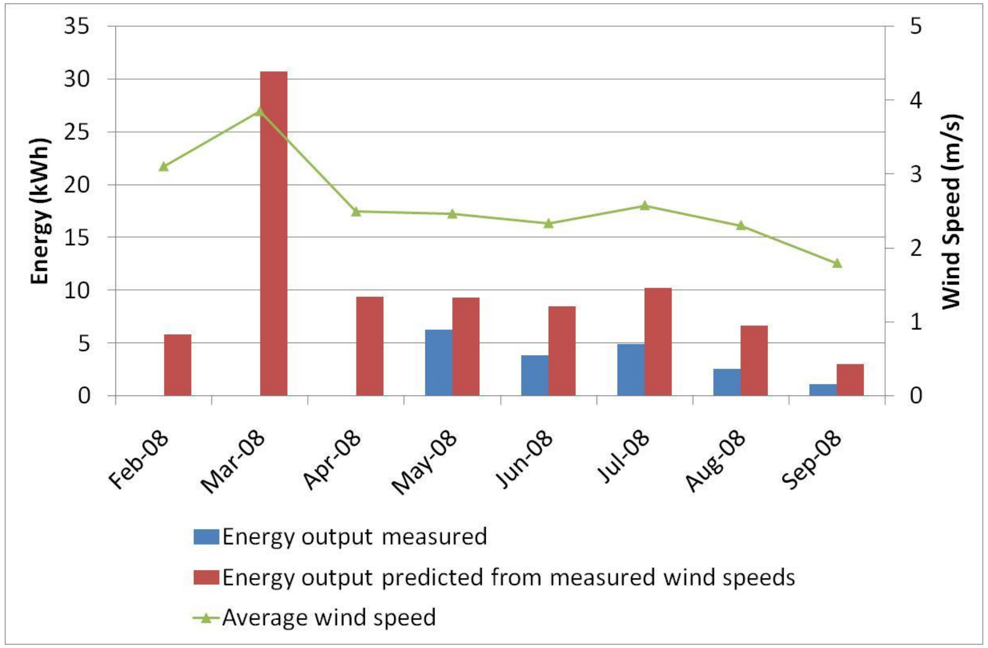
Notes

Energy data has been collected since 22nd April 2008 when the turbine was commissioned. Wind speed data collection started before this on the 20th February.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



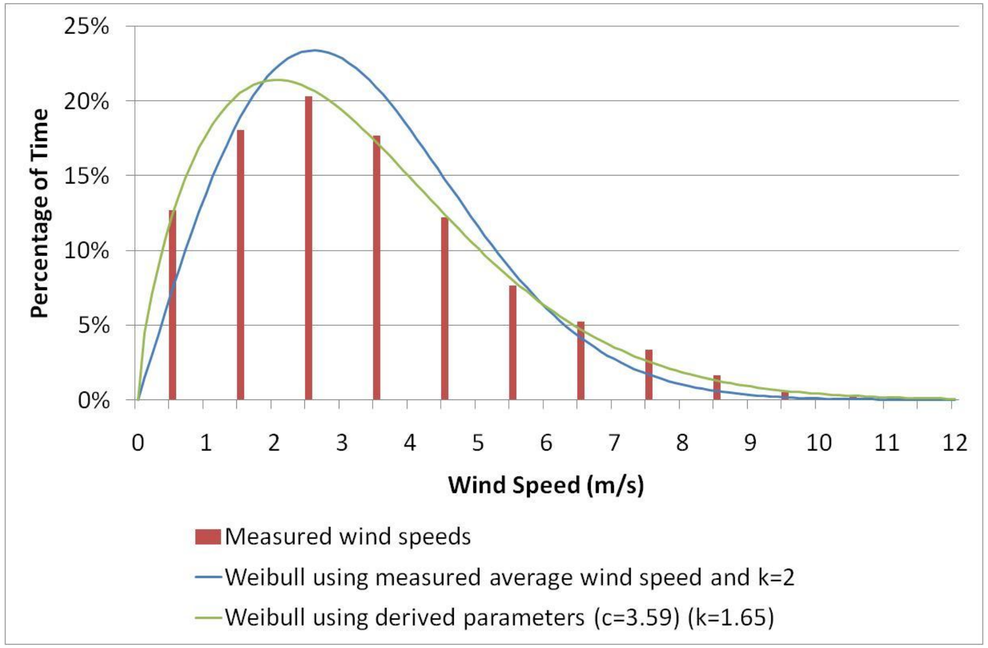
24. West Staddon

Data collection period	16/04/08 – 16/10/08
Average wind speed	3.25ms^{-1}
Derived Weibull shape factor	1.65
Total energy output	68.41kWh
Predicted energy output	185.64kWh
Perfect in use capacity factor	1.70%
Actual in use capacity factor	0.68%

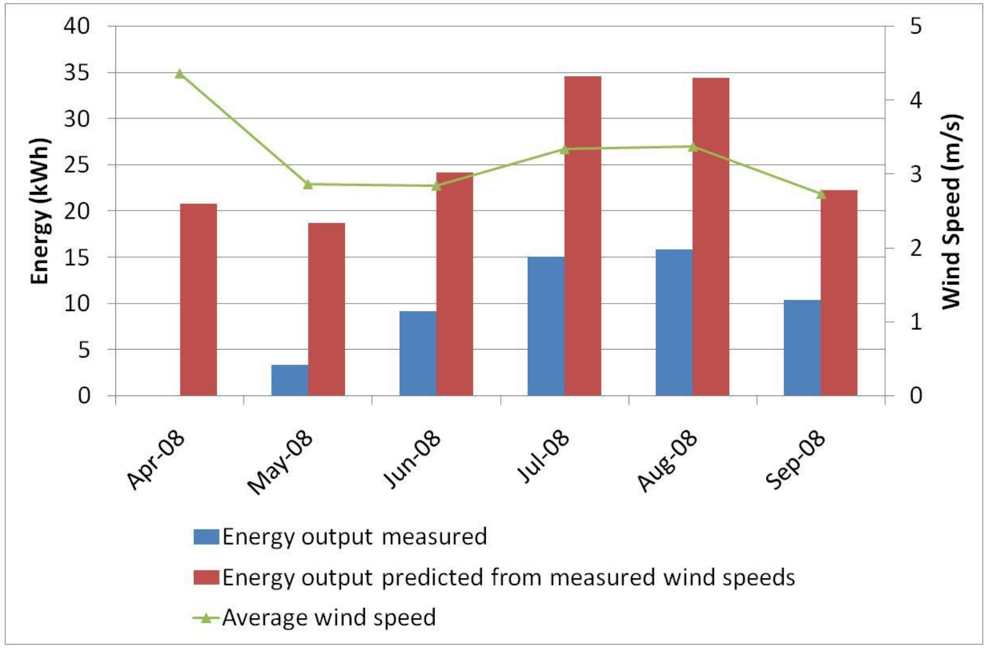
Notes

This turbine was switched off until 17th May 2008.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



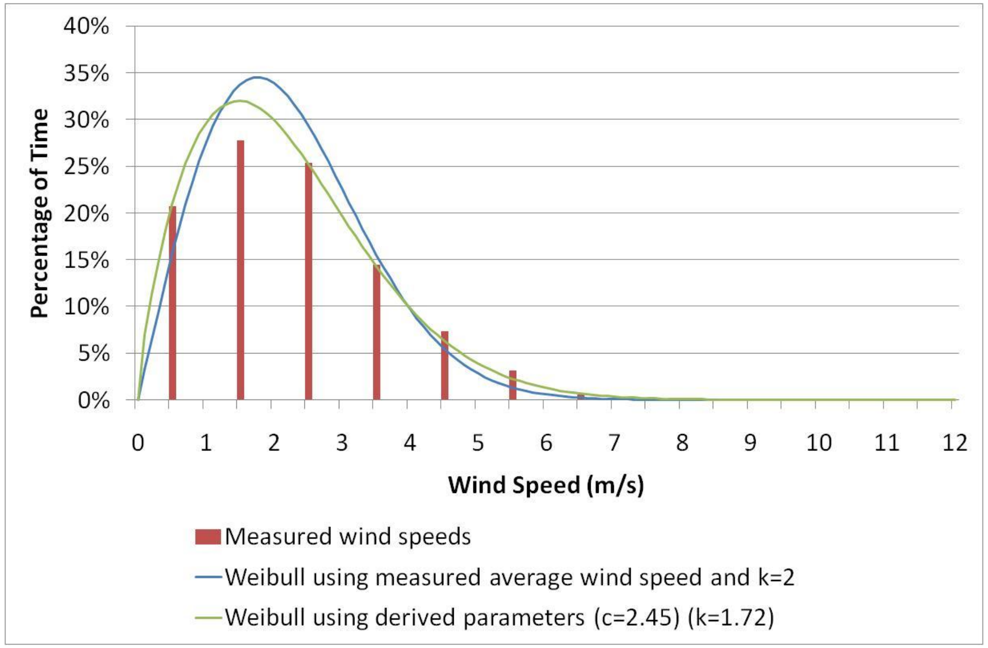
25. Huddersfield

Data collection period	01/07/08 – 07/09/08
Average wind speed	2.20ms^{-1}
Derived Weibull shape factor	1.72
Total energy output	
Predicted energy output	12.44kWh
Perfect in use capacity factor	
Actual in use capacity factor	

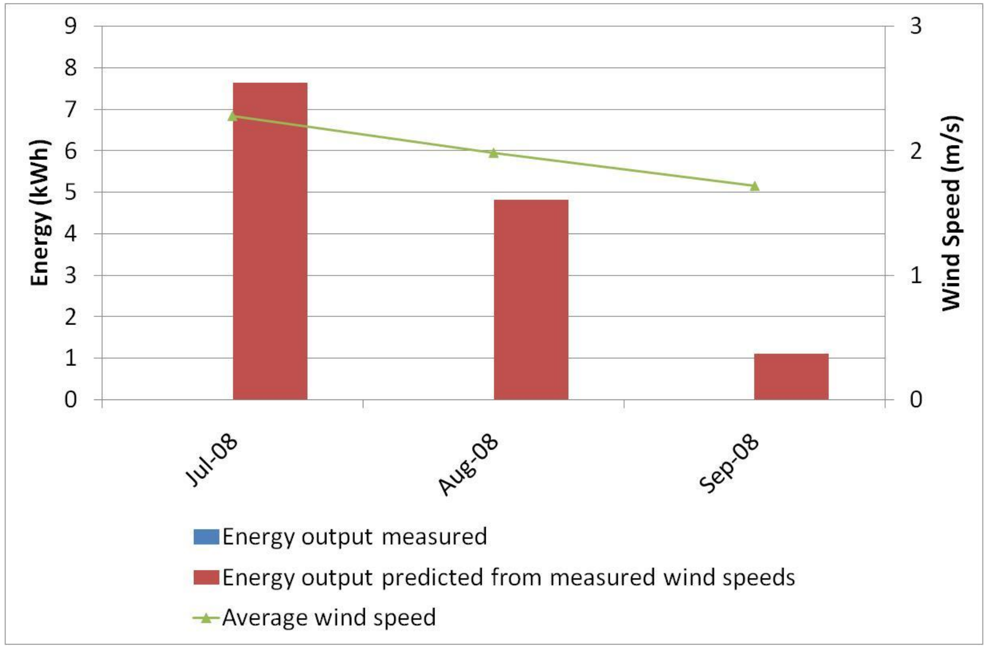
Notes

Only just over 2 months of data has been collected from this site and the turbine has been switched off for this period of time.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



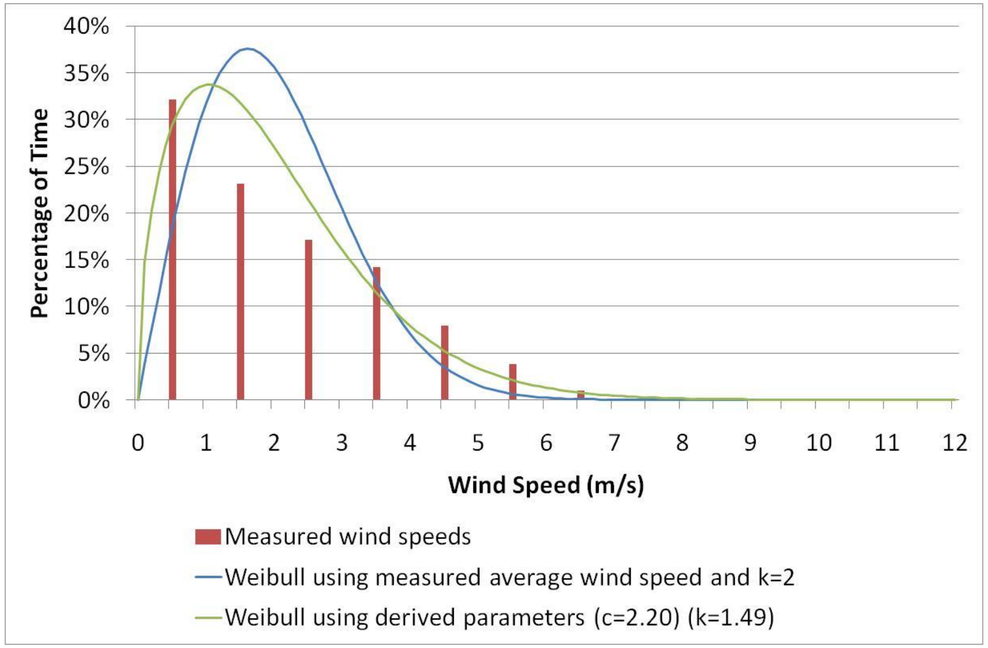
26. Thatcham

Data collection period	15/04/08 – 16/10/08
Average wind speed	2.02ms^{-1}
Derived Weibull shape factor	1.49
Total energy output	14.20
Predicted energy output	32.35kWh
Perfect in use capacity factor	0.65%
Actual in use capacity factor	-0.86%

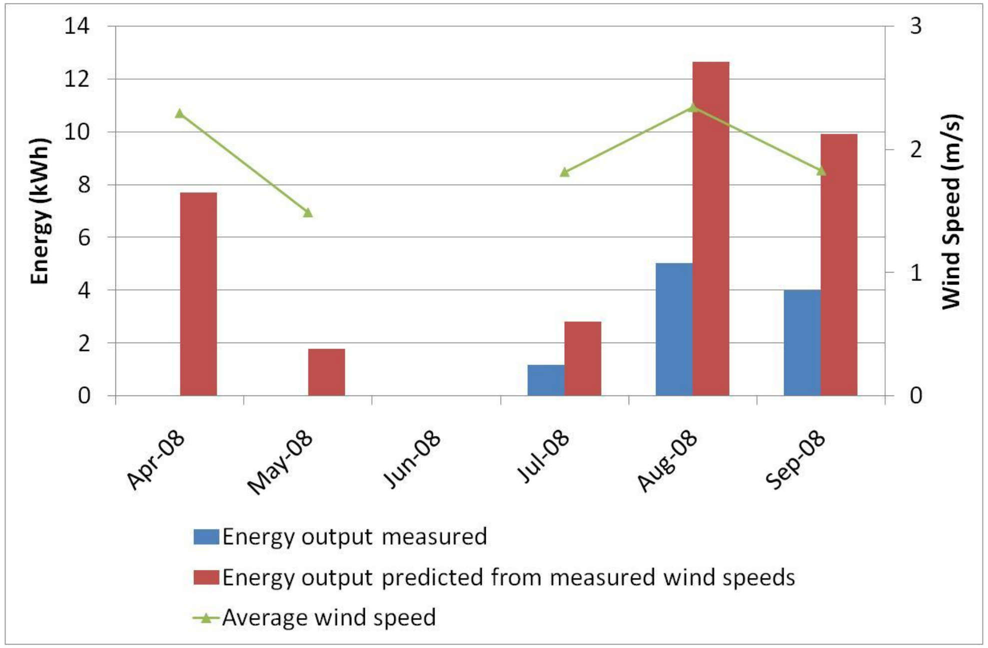
Notes

Only wind speed data is available from 15th April to 12th May 2008. After this no data was collected until 17th July 2008, from this date both energy and wind speed data is available.

Wind speed distribution



Trend in monthly average wind speed and energy output per month



Appendix B – Scaling factors for NOABL and Weibull shape factor

One way of improving the accuracy of wind speed predictions, particularly urban environments, is to use scaling factors for NOABL. This idea is presented in the Microgeneration Certification Scheme installer standard (MIS 3003). We have found that the MIS 3003 scaling factors do improve predictions but not in all cases and for this reason we have begun the process of devising a new scheme. This was introduced in previous interim reports but has since been refined to give more plausible site classifications.

We first classified sites according to their height relative to the closest NOABL height. Sites where turbines are mounted at a height well below or above the closest NOABL height are expected to show a marked difference in measured wind speed compared to NOABL. Further classification of sites was dependent on the presence of obstructions in the vicinity of the turbine. This stage of classification was based loosely on MIS 3003 where obstructions are defined as anything (building or tree etc.) that is higher than the turbine hub height. These obstructions have greatest effect when they are located within a radius of the turbine that is less than ten times the hub height of the turbine away.

Each classification of site is described in the tables below, alongside example sites from our trial. Figures for the NOABL and k scaling factors were calculated by taking an average of the actual scaling factors for each site. These actual scaling factors were calculated by, for example, dividing the measured average wind speed by the NOABL wind speed for each site.

The only exceptions to the rules are Ashton and Southorn Court which are classed as having no obstructions in the vicinity but in reality they both have Eden Court nearby. However Eden Court is the only obstruction of significant height, within a radius that stretches to the horizon and so the exception may be justified. The situation would be very different for Ashton and Southorn Court if they had been completely surrounded by taller buildings.

Of course there are limitations to the current values calculated for scaling factors. We are primarily limited by the number of sites being small and not all site types have an example site from our trial. Future trials or research could help to fill in the blanks. In particular, if more example sites could be found in future it would be important to analyse the standard deviation of actual scaling factors compared to the average for each site type to ensure that site classifications are meaningful.

We have separated out building mounted turbines from those mounted on freestanding poles for which we only have one example site (that is the reference site, Misty Farm).

Building mounted turbine where the hub height is more than 2m higher than the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example site**
1a	0.87	0.93	None	Eden Court, Ashton Court, Southorn Court
1b	0.65	0.77	Some obstructions but all are more than 10x hub height away	Northamptonshire, Tannery Court. Delta Court
1c	0.50	0.71	Some obstructions and some are less than 10x hub height away	Thatcham, Daventry Town Hall, Princes Drive

Building mounted turbine where the hub height is within 2m of the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example**
2a			None	
2b	0.56	0.80	Some obstructions but all are more than 10x hub height away	Park Farm, West Staddon
2c	0.46	0.72	Some obstructions and some are less than 10x hub height away	Lillington Road, Birds Hill, Leicester, Napier, Fountain Farm, Nottingham, Huddersfield

Building mounted turbine where the hub height is more than 2m lower than the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example**
3a			None	
3b			Some obstructions but all are more than 10x hub height away	
3c	0.39	0.70	Some obstructions and some are less than 10x hub height away	Daventry Country Park, Hill Close Gardens, Summerfield Crescent, Antrobus Road

Freestanding turbine where the hub height is more than 2m higher than the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example site**
4a			None	
4b			Some obstructions but all are more than 10x hub height away	
4c			Some obstructions and some are less than 10x hub height away	

Freestanding turbine where the hub height is within 2m of the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example**
5a			None	
5b			Some obstructions but all are more than 10x hub height away	
5c			Some obstructions and some are less than 10x hub height away	

Freestanding turbine where the hub height is more than 2m lower than the chosen NOABL height				
Ref	**NOABL scaling**	**K scaling**	**Obstructions higher than turbine hub height**	**Example**
6a			None	
6b	0.92	0.91	Some obstructions but all are more than 10x hub height away	Misty Farm
6c			Some obstructions and some are less than 10x hub height away	

Appendix C – Turbine specifications

The table below provides the specification of turbines used in the trial

Turbine	Full model name	Specification
Ampair	Ampair 600 230	600 W
Air Dolphin	Zephyr AirDolphin Z1000	1 kW
StealthGen	Eclectic StealthGen D400	400W
Windsave	Windsave WS1000 and WS1200	1 kW and 1.25kW Windsave modified their WS1000 machines during summer 2007. These are being replaced in 2008 by the WS1200.

Initially there was also a Swift 1.5kW turbine on the trial. There were unresolved problems with the instrumentation at this site and therefore no data was collected. The site was eventually removed from the trial in order to enable instrumentation of a replacement site in July 2008.

