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MCS Summary Report for the CF11 (Phase A) Small Wind Turbine

Report No. :	101510200LHD-001a
Date Issued :	31 January 2014
Date Revised :	*None*

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1 Summary

1.1 Objectives

The purpose of this report is to provide a summary of the following in accordance with the requirements for Certification against the MCS006 and BWEA standards. In particular, the following requirements are addressed:

Table 1: Objectives

Report Section	Topic	Reference[1]
6	Power Performance Test Summary	6.1.2
7	Acoustic Test Results including noise label	6.1.3
8	BWEA Reference Annual Energy	6.1.4
9	BWEA Reference 60m Sound Level, Lp,60m	6.1.5
10	BWEA Reference Power, at 11.0 m/s (24.6 mph)	6.1.6
11	Wind Turbine Strength and Safety Report	6.1.7
12	Top tower design loads	6.1.7.1
13	Duration Test Summary	6.1.8

Note 1: Reference - *BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008*

This investigation was authorized by purchase order no. 34194, dated 17th January 2014.

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the signatories on this report.

Please note, this report on its own does not represent authorization for the use of any Intertek certification marks.

1.2 Changes to the Certified Product

The C& F Green Energy CF11 is a modification of CF12 turbine which is currently the Subject of MCS Certification (Intertek Certificate no. INT WT22134/1). The modification is to the programming of the inverter which has been changed to cap the maximum output power at 11 kW. This report has been issued to detail changes to the Certified Product and has been prepared in accordance with the requirements of the BWEA Small Wind Turbine Performance and Safety Standard (2008), Section 8 as detailed below:

8.1.1 A study of the Power performance has been undertaken and is detailed in Section 5.0 of this report.

8.1.2 The modification is not considered to have an adverse effect on the Acoustics performance previously evaluated and summarised in Section 4.0 of this report.

8.1.3 The modification is not considered to have an adverse effect on the Strength and Safety Test previously evaluated and summarised in Section 8.0 of this report.

8.1.4 The modification is not considered to have an adverse effect on the Duration test previously evaluated and summarised in Section 10.0 of this report.

2 Revision History

Table 1: Revision History		
Date	**Revised By**	**Description of Changes**
31 Jan 2014	-	*None – First Issue*

3 References

British Wind Energy Association (BWEA) Small Wind Turbine Performance and Safety Standard, 29 Feb 2008.

BSEN 61400-2:2006. Wind turbines – Part 2: Design requirements for small wind turbines (identical to IEC 61400-2:2006, Edition 2).

BSEN 61400-11:2003 +Amd1:2006. Wind turbine generator systems – Part 11: Acoustic noise measurement techniques (Identical to IEC 61400-11:2006, Edition 2.1)

BSEN 61400-12-1: 2006. Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines (identical to IEC 61400-12-1:2005, Edition 1).

Microgeneration Certification Scheme: MCS006. Product Certification Scheme Requirements: Micro and Small Wind Turbines, Issue 1.5, 10 Jul 2009.

4 Master Reports

The CF12 was installed at the manufacturers testing location at Ballyspellan, Republic of Ireland.

Full details of testing and evaluation performed are covered by the Master Reports detailed in the table below.

Table 2: Master Reports		
Report	**Report Title**	**Date**
101129165LHD-006c	Wind Turbine Generator System Duration Test Report for the C&F Green Energy CF12	16 December 2013
101129165LHD-008c	Wind Turbine Generator System Strength and Safety Test Report for the C&F Green Energy CF12	19 December 2013
101129165MKS-007c	Wind Turbine Generator System Acoustics Test Report for the C&F Green Energy CF12	18 December 2013
101129165LHD-005c	Wind Turbine Generator System Power Performance Test Report for the C&F Green Energy CF12	16 September 2013 (Revised 22 January 2014)

5 Description of the wind turbine

The CF12 is designed for grid-connected power delivery, with a manufacturer's declared rated power output of 12 kW. The CF12 is a horizontal axis machine with a 3-blade upwind rotor with active speed and power control through active blade pitch actuation and turbine yaw control. The CF12 has a three-phase permanent magnet variable-speed generator directly coupled to the rotor, the output of which is fully converted in the inverter. The inverter output is configured for connection to a three-phase, 50 Hz, 230V electrical network. Normal electrical network operating voltage and frequency ranges are 207 – 253 V and 49.8 to 50.2 Hz, respectively. The CF11 is identical in all respects except for the programming of the inverter which has been changed to cap the maximum power at 11 kW.

Figure 1: CF12 (Phase A) Wind Turbine

A summary of the test turbine configuration and manufacturer's declared ratings can be found in Table 4 below.

Table 1: Turbine Characteristics	
Manufacturer :	C&F Green Energy
Model No.	CF12 (Phase A)
Date of Manufacture :	2013, 1st quarter
Description:	Horizontal axis wind turbine with active blade pitch and active yaw
Rotor Diameter :	11.15 m (verified by measurement)
Rotor Swept Area :	97.6 m^3
Number of Blades :	3
Hub Height :	15.65 m
Tower :	Tubular steel monopole (not guyed)
Rated Power :	12 kW (nominal)
Rated Wind Speed :	9 m/s
Wind Class :	III (V_{ave} = 7.5 m/s)
Survival Wind Speed :	70 m/s
Cut-in Wind Speed :	2.2 m/s
Cut-out Wind Speed :	25 m/s
Rotor Speed Range :	0 - 75 rpm (normal operating range), maximum 110 rpm
Low Speed Shaft Speed :	N/A (generator runs at Rotor speed)
Speed Reduction Method :	N/A
Yaw Control :	Active
Blade Pitch Control :	Active
Blades specification :	Closed mould infusion of glass-filled vinylester resin over a polyurethane foam core with double spar, 7° twist from root to tip, airfoil geometry based on NACA 5415
Blade Identification :	Blade set no. CFGE-BS-5-0170, individual blade serial nos. 4712306, 4712310 & 4712312
Generator Type :	Permanent magnet, asynchronous, ac 3-phase, radial flux
Generator Identification :	CFGE1302E01 3PH 11KW
Power Conversion :	Solid-state inverter
Inverter Type :	ABB-ACS-800-11-40, 3-phase output
Inverter Software :	11kw_parameter.txt
Grid Protection Method :	Separate G59/2 relay
Grid Protection Type :	ComAp Mainspro
Turbine Controller :	Phoenix Contact PLC-ILC-150-GSM
Turbine Controller Software :	ABB_PLC_V6_Kilkenny.zwt

6 Power Performance Test Summary

Details of Power Performance testing can be found in Intertek Report no. 101129165LHD-005c.

Table 5 below shows the normalized and averaged results of the power performance test for the CF12 turbine, modified to show the effect of the inverter power capping for the CF11. This data is based on the analysis of 19,674 1-minute data sets (total 328 hours) collected between 01-May2013 00:00 and 31-May-2013 23:59.

Table 5: Performance at sea-level air density; 1.225 kg/m^3

Presentation of data in the measured power curve (database A)							
Reference air density: 1.225 kg/m^3							
Bin (m/s)	**Bin Average Wind Speed** (m/s)	**Power output** (W)	**Cp**	**Number of 1-Minute Data Sets**	**Category A Standard Uncertainty** (W)	**Category B Standard Uncertainty** (W)	**Combined Standard Uncertainty** (W)
3	1.50	-41	-0.20	95	0	6	6
4	2.03	-41	-0.08	116	0	6	6
5	2.54	-41	-0.04	233	0	6	6
6	2.99	-20	-0.01	288	3	8	9
7	3.50	145	0.06	281	9	41	42
8	4.02	558	0.14	429	11	104	105
9	4.51	1048	0.19	682	10	137	138
10	5.01	1637	0.22	876	10	167	168
11	5.50	2312	0.23	828	14	203	203
12	6.00	3146	0.24	850	15	255	255
13	6.50	4042	0.25	890	17	288	288
14	7.01	5096	0.25	988	17	346	346
15	7.50	6230	0.25	970	19	397	397
16	7.99	7505	0.25	865	26	467	468
17	8.50	9100	0.25	969	28	579	579
18	9.00	10616	0.24	1059	26	594	594
19	9.49	11000	0.22	*1029*	*21*	*225*	*226*
20	9.99	11000	0.18	*874*	*14*	*168*	*168*
21	10.50	11000	0.16	*803*	*7*	*168*	*168*
22	11.00	11000	0.14	*698*	*6*	*168*	*168*
23	11.49	11000	0.12	*710*	*4*	*168*	*168*
24	12.00	11000	0.11	*670*	*2*	*168*	*168*
25	12.50	11000	0.09	*693*	*15*	*168*	*168*
26	12.99	11000	0.08	*634*	*3*	*168*	*168*
27	13.51	11000	0.07	*602*	*4*	*168*	*168*
28	13.99	11000	0.07	*567*	*17*	*168*	*168*
29	14.49	11000	0.06	*440*	*3*	*168*	*168*
30	15.00	11000	0.05	*403*	*19*	*168*	*168*
31	15.48	11000	0.05	*314*	*4*	*168*	*168*
32	15.98	11000	0.05	*276*	*4*	*168*	*168*
33	16.49	11000	0.04	*219*	*4*	*168*	*168*
34	17.00	11000	0.04	*196*	*4*	*168*	*168*

Figure 2 below shows the graphical results of the power performance test for the CF12 modified to show the power capped by the inverter.

Figure 2: Power curve corrected to sea-level air density; 1.225 kg/m^3 (database A)

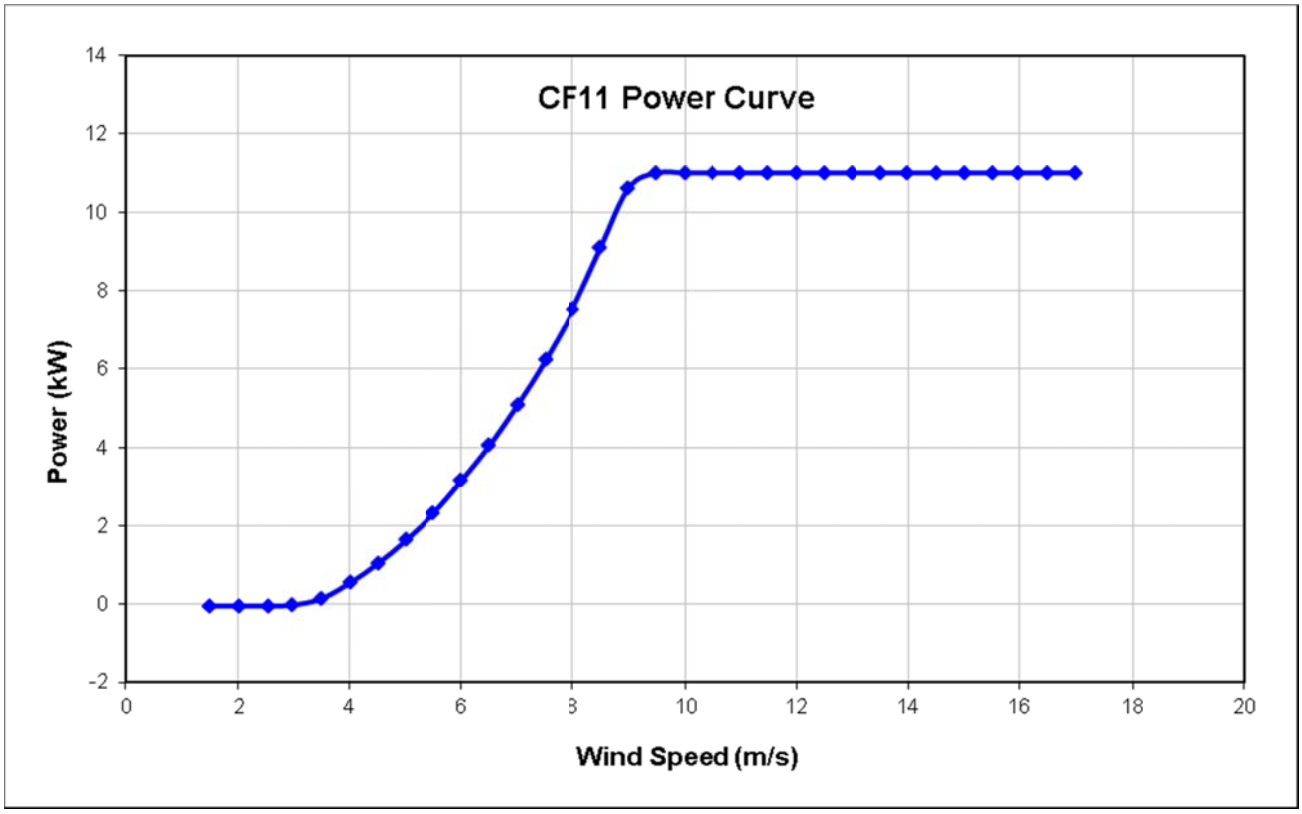
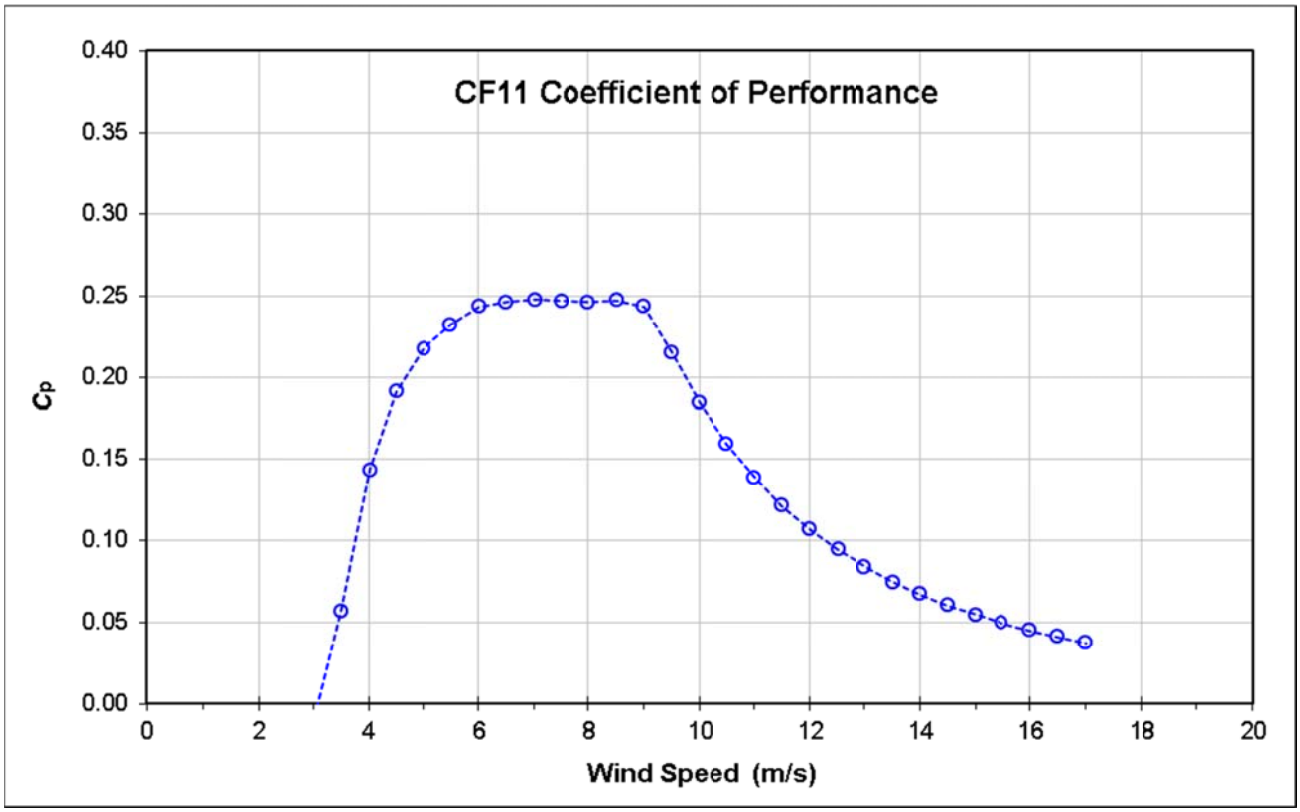


Figure 3 below shows the coefficient of performance at sea-level air density for the CF11.

Figure 3: Coefficient of performance at sea-level air density of 1.225 kg/m^3



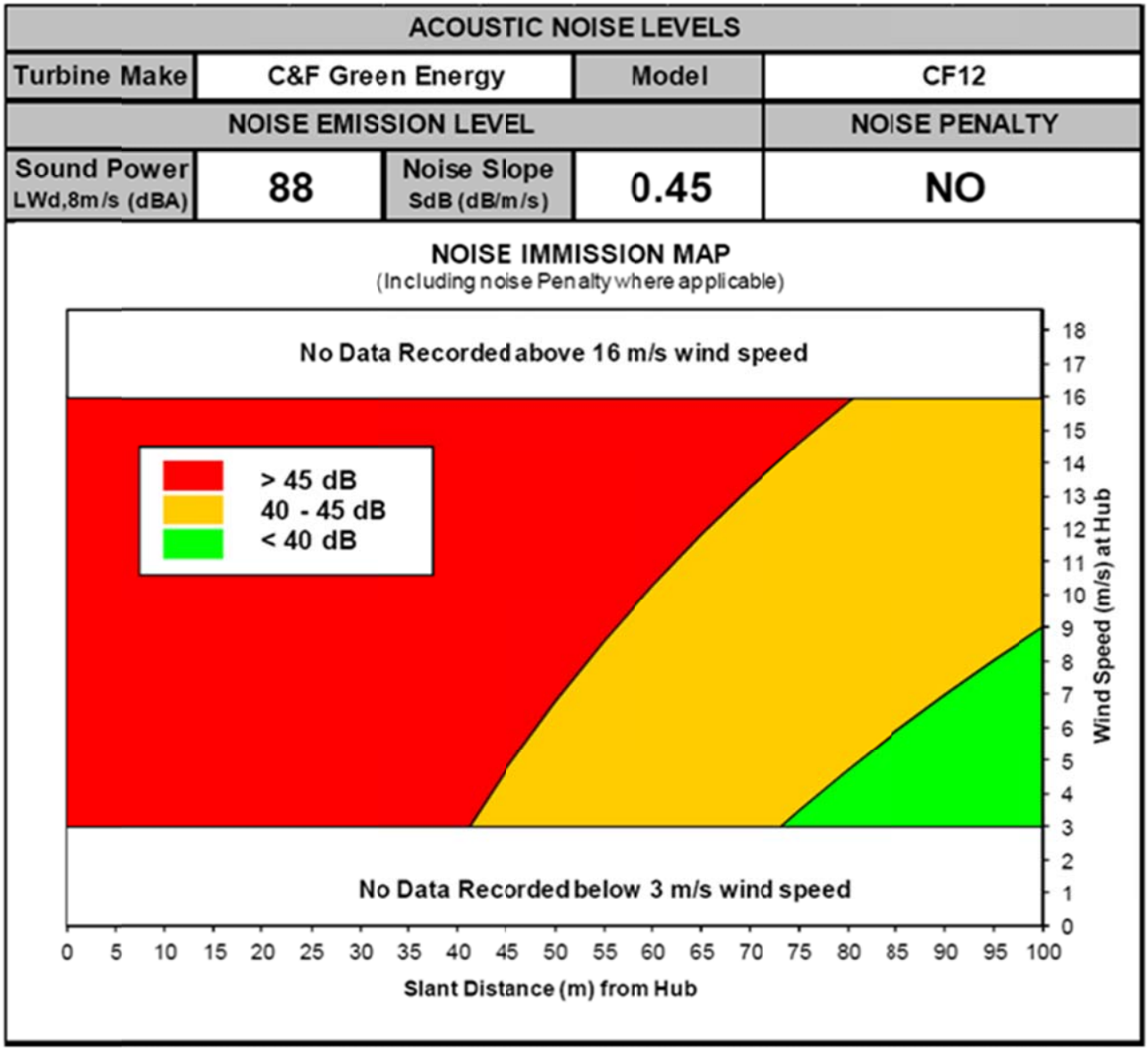
7 Acoustic Test Results including Noise label

This is a summary of the evaluation of the wind turbine noise over a range of wind speeds and directions for the CF12 which is not considered to be representative of the CF11. Characterizations of the turbines apparent sound power level, 1/3 octave bands, and tonality are made.

The resulting acoustic performance for normal operation in accordance with the BWEA standard is as follows:

Wind speed dependence	**0.45 dB/m/s**
Immission Sound Pressure Level at 60m $L_{p,60m}$	**44.04 dBA**
Immission Sound Pressure Level at 25m $L_{p,25m}$	**51.54 dBA**

Figure 4: Noise Immission Map



8 BWEA Reference Annual Energy

Table 6 below summarises the estimation of expected annual energy production (AEP) at sea-level air density for the CF11.

Table 6: Estimated annual energy production of the CF11 at sea-level air density

Estimated annual energy production
(database A)
Reference air density: 1.225 kg/m³
Cut-out wind speed: 25 m/s
(extrapolation by constant power from last bin)

Hub height annual average wind speed (Rayleigh)	*AEP*-measured (measured power curve) [note 1]	Standard uncertainty in *AEP* $ [note 4]	Standard uncertainty in *AEP* $ [note 4]	*AEP*-extrapolated (extrapolated power curve) [note 2]	Complete if *AEP*-measured is at least 95% of *AEP*-extrapolated [note 3]
m/s	kWh	kWh	%	kWh	
4	13299	1045	8	13299	Complete
5	**24417**	1487	6	24428	Complete
6	35416	1755	5	35592	Complete
7	44520	1876	4	45452	Complete
8	50903	1896	4	53633	Incomplete
9	54524	1851	3	60141	Incomplete
10	55819	1769	3	65059	Incomplete
11	55386	1666	3	68477	Incomplete

Note 1: AEP-measured assumes zero power below cut-in (2.5 m/s) and zero power above the range of the database (17.0 m/s).

Note 2: AEP-extrapolated assumes zero power below cut-in (2.5 m/s) and constant (maximum) power up to cut-out (25 m/s).

Note 3: "Incomplete" means that AEP-measured is not within 95% of AEP-extrapolated. This does not imply that the database is incomplete.

Note 4: The uncertainty figures in the above table are based on a coverage factor of 1.

BWEA Reference Annual Energy: 24417 kWh @ 5m/s

9 BWEA Reference 60m Sound Level, $L_{p,60m}$

From the summary presented in section 7 of this report:

BWEA Reference 60m Sound Level, $L_{p,60m}$: 44.04 dBA

10 BWEA Reference Power at 11.0m/s (24.6mph)

From the data summarised in the table in Section 8 of this report:

BWEA reference output power (11.0m/s) is 11.0 kW

The power curve and power coefficient plots are included in Section 6 of this report

11 Strength and Safety Test Results

11.1 Mechanical Safety

The mechanical safety of the turbine system was assessed according to the requirements in section 4 of the BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008. This standard further references IEC 61400-2 Wind turbines – Part 2: Design requirements for small wind turbines – Clause 7.4, 7.8 and 7.9 (Mechanical Safety).

The load cases defined in the standards were evaluated according to the simplified load model defined in the standards listed from Design Calculations submitted by C&F Green Energy.

The design file details analysis of the simplified load model including ultimate and fatigue loading analysis, as well as final material and load factors of safety. The design file was found to be in compliance with all requirements of the Standards regarding structural integrity. All supporting documentation is maintained within the project file.

11.2 Visual inspection

The machine was inspected both before and after testing and the condition documented. No significant damage or wear was noted. Photographs of the condition after testing of the principal components are included in 101192165LHD-006c

No adverse faults, deterioration or malfunction due to wind turbine performance were recorded during the test period.

11.3 Safety and Function

A Safety and Function test in accordance with IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines – Clause 9.6 was completed. The results of this test are reported in the Intertek Strength and Safety Test Report 101192165LHD-008c

No adverse faults, control problems or safety issues were raised during the observation period.

12 Tower Top Loads

Table 7 below summarizes the top tower topple moment and tower data. This data has been supplied by C&F Green Energy

Table 7: Tower Data	
Turbine Class	III
Average Wind Speed, V_{ave}	7.5 m/s
Reference Wind Speed, V_{ref} (m/s)	37.5 m/s
50 year extreme Wind Speed, V_{e50}	52.5 m/s
Total Topple Moment	516.6 kNm
Wind force on nacelle	1720 N
Wind force on blades	24210 N
Wind force on mast	21040 N
Mass of nacelle	2100 kg
Mass of blades	285 kg
Mass of tower	3200 kg
Height of Tower	15 m
Tower Base Diameter	877 mm
Tower Top Diameter	490 mm
Sheet Steel Thickness	6 mm to 8 mm

13 Duration Test Summary

Intertek report 101129165LHD-006c provides full details of this analysis.

13.1 Hours of Power Production

Table 8 below indicates the number of power production hours that were observed during the 6 month test duration.

Table 8: Hours of Power Production			
IEC SWT Class III – V_{ave} = 7.5 m/s			
Wind Speed	**Measured**	**Required**	**Pass/Fail**
> 0 m/s	2059.8	2500	N/A
> 1.2 V_{ave}	405.7	250	Pass
> 1.8 V_{ave}	84.2	25	Pass
> 15 m/s	36.2	25	Pass

Note that even with the reduced overall test period, the required hours of operation at wind speeds above Vave exceeded the requirements for the 6-month test period specified by BSEN 61400-2:2006.

13.2 Operational Time Fraction

The operational time fraction is defined by the following equation:

$$O = \frac{T_T - T_N - T_U - T_E}{T_T - T_U - T_E} \times 100\ \%$$

where:

T_T is the total time period under consideration,
T_N is the time during which the turbine is known to be non-operational,
T_U is the time during which the turbine status is unknown, and
T_E is the time which is excluded in the analysis.

The **overall operational time fraction** of the combined wind turbine system in the total test period was **99.9%**. The pass criteria for this parameter is 90% (*IEC 61400-2 Wind turbines – Part 2: Design requirements for small wind turbines, Clause 9.4.2.1)* so the wind turbine is deemed to **PASS**

13.3 Environmental Conditions

In order to understand environmental conditions over the testing period, several wind speed statistics were required by the Standard. These values are summarized in Table 9 below.

Table 9: Environmental Conditions During Test Period	
Description	**Value**
Highest instantaneous wind speed	24.9 m/s
Average turbulence intensity at 15 m/s	7.9 %

13.4 Power Degradation

No significant power degradation over the test period at comparable wind speeds was recorded.

13.5 Dynamic Behaviour

During the test period the turbine and tower were observed for any potentially harmful turbine or tower dynamics. The turbine was observed over a wide range of wind speeds. During these observations there was no presence of any observable problems.

13.6 Post-Test Inspection

The machine was inspected both before and after testing and the condition documented. No significant damage or wear was noted. Photographs of the condition after testing of the principal components are included in Intertek Report no. 101192165LHD-006c.