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1 Introduction

The Department of Energy and Climate Change (2012a) states, in the UK's Climate Change Act 2008, that a decrease of 80% in Greenhouse Gas emissions by 2050 is required. *The Department of Energy and Climate Change (2012b)* has indicated in the Government's Renewable Energy Strategy that to facilitate this target "by 2020 30% or more of our electricity should come from renewable sources, compared to around 6.3% in 2011."

The Government has introduced Feed-In Tariff (FITs), as outlined by *The Carbon Trust (2012)*, to incentivise growth in renewable energy sources to help meet this target. The level of FITs/kWh for small wind installations is accelerating growth of generation which currently represents a small proportion (0.03%) of the total UK electricity generation. See *Figure* 1

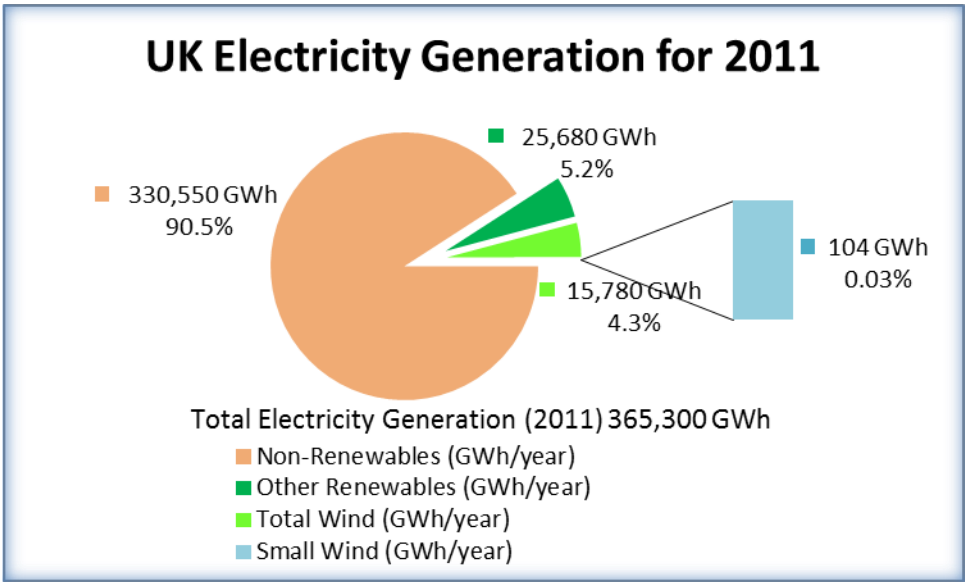


Figure 1. UK Electricity Generation –Appendix 6.1.

Small wind installations must maximise energy output to:

- Contribute effectively to emissions reduction.
- Maximise the return on investment of the turbine installation using the revenue derived from FITs

This report will document a small wind turbine in Cornwall. It will outline the turbine:

- Selection and financial case.
- Design and installation
- Monitoring and assessment.

2 Method

2.1 Purpose

Candor is the site where the conversion of three traditional cob barns will create a facility for a yoga and meditation retreat. A condition of the planning application involved a requirement to install a number of renewable technologies designed to ensure that the site was a net producer of renewable energy. The mainstay of the renewable strategy is the production of electricity via a wind turbine.

This report will detail the method and outcome of the project to evaluate, select, design, install, commission and monitor the on-going performance of the turbine.

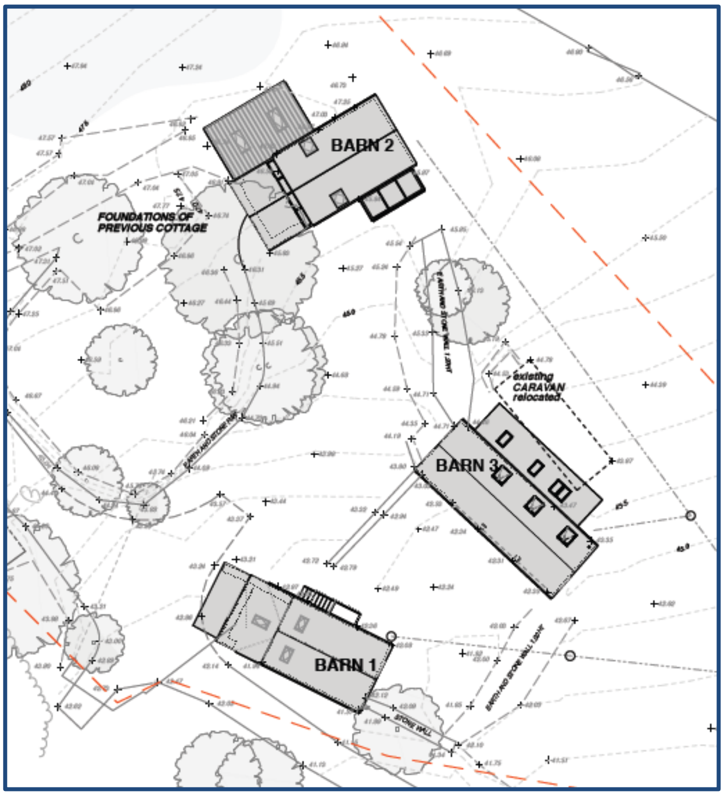


Figure 2. Three cob and stone barns.

2.2 Design

The report's analytical design involved assessing the site energy requirements and wind resource. From this information a turbine was selected using site specific data and financial analysis. Once installed, the performance of the turbine was monitored for a short period of time.

2.2.1 Site Evaluation

The site energy requirement was assessed using *SAP 2005 (BRE 2012a)*

The site wind resource was assessed using observation, the NOABL database (*DECC 2012*) and a local wind rose.

2.2.2 Turbine and Site Selection

An initial sizing for the turbine used the formula:

*Annual Turbine Output (MWh) = (Turbine capacity (kW) * hours/year * 25%)/1000*

RETScreen *(RETScreen 2012)* was then used to assess the generation potential of the selected turbines.

The selection of the turbine was based on MCS (Feed In Tariff) approved turbines, capital budget, payback time, NPV and net revenue generation.

Turbine siting was assessed using the following parameters:

- Available land
- Optimum position for wind
- Distance from mains electricity
- Planning considerations
- Environmental considerations

2.2.3 Monitoring

Turbine monitoring required the following data to be collated:

- Half hourly average power readings (kW) using Meter Online (Meter Online 2012)
- Daily total generation using Meter Online (Meter Online 2012)
- Wind speed vs. power (power curve). A total of 283 readings of wind speed and power from the Gaia display panel were taken 3 times per day for 15 days.

2.3 Potential design issues

The energy assessment for the site is an approximation for the build. The full performance of the barns will not be available until the build is complete.

A full wind site assessment was not undertaken using an anemometer/wind vane and data logger. A proxy assessment using the NOABL database is an approximation which is no substitute for an onsite assessment. The site, however, has obvious potential for good wind and only retrospective measurement will give the actual energy generation.

The monitoring equipment set up for the report is insufficient to give the best estimate of the power curve. The next steps section outlines improvements that are required for on-going monitoring.

3 Results and observations

3.1 Site assessment

3.1.1 Energy requirement

The energy requirement of the 3 barns and site ancillary equipment was estimated using the SAP 2005 method *(BRE 2012a)*. The results are outlined in *Table 1*

Building	**Space and Water Heating Requirement (MWh/year)**	**Electrical Requirements (MWh/year)**
Barn 1	3.5	1.5
Barn 2	6.0	2.5
Barn 3	3.5	1.5
Ancillary site equipment (water pumps, sewage treatment etc.)		1.2
Total	**13.0**	**6.7**

Table 1. Energy Requirements for site.

3.1.2 Wind resource

The site is on the lower section of a hillside orientated towards the southwest. It has significant wind shading from the hill to the west and surrounding trees. The neighbouring farmer agreed to site the turbine on a section of his land towards the top of the hill to the north east (altitude 65m and 40m above the site). It is free from hill and tree shading. See *Figure 3* and *Figure 4* for details of the location, topology and aspect.

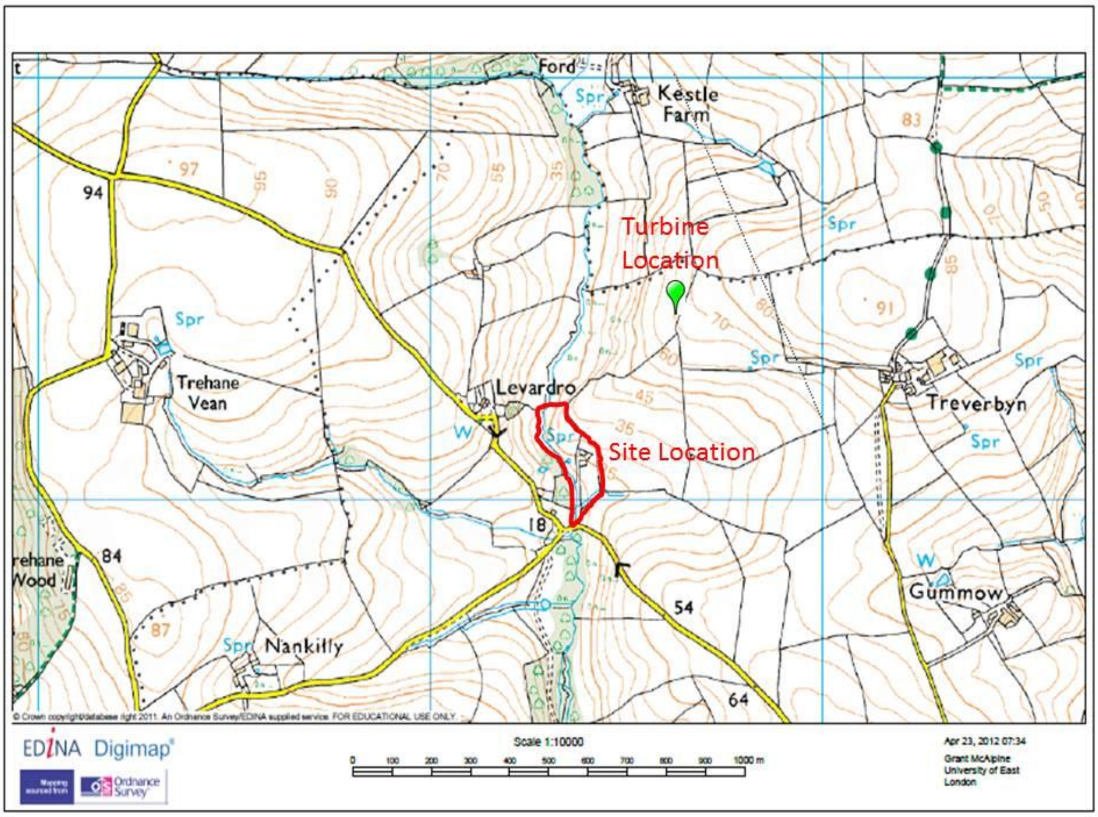


Figure 3. Site and Turbine location. Edina Digimap (2012a)

South West

West

North West

North East

South East

Figure 4. Site aspect

Empirical wind measurements were not undertaken. However, anecdotal observations of the site over the past 2 years indicate that it is not a marginal site, with steady prevailing winds of west/north west. Wind data from the NOABL database for the 1 km grid centred on the turbine site grid reference SW 87 49 (marked in green) and an indicative wind rose is outlined in *Table 2* and *Figure 5* respectively.

Wind speed at 45m above ground level (agl) (in m/s)		
6.8	6.6	6.7
6.9	6.6	6.5
6.8	6.4	6.3
Wind speed at 25m agl (in m/s)		
6.2	5.9	6.1
6.3	5.9	5.8
6.2	5.7	5.5
Wind speed at 10m agl (in m/s)		
5.5	5.3	5.5
5.7	5.2	5.1
5.5	4.9	4.7

Table 2. NOABL wind speeds estimate for grid reference SW 87 49.

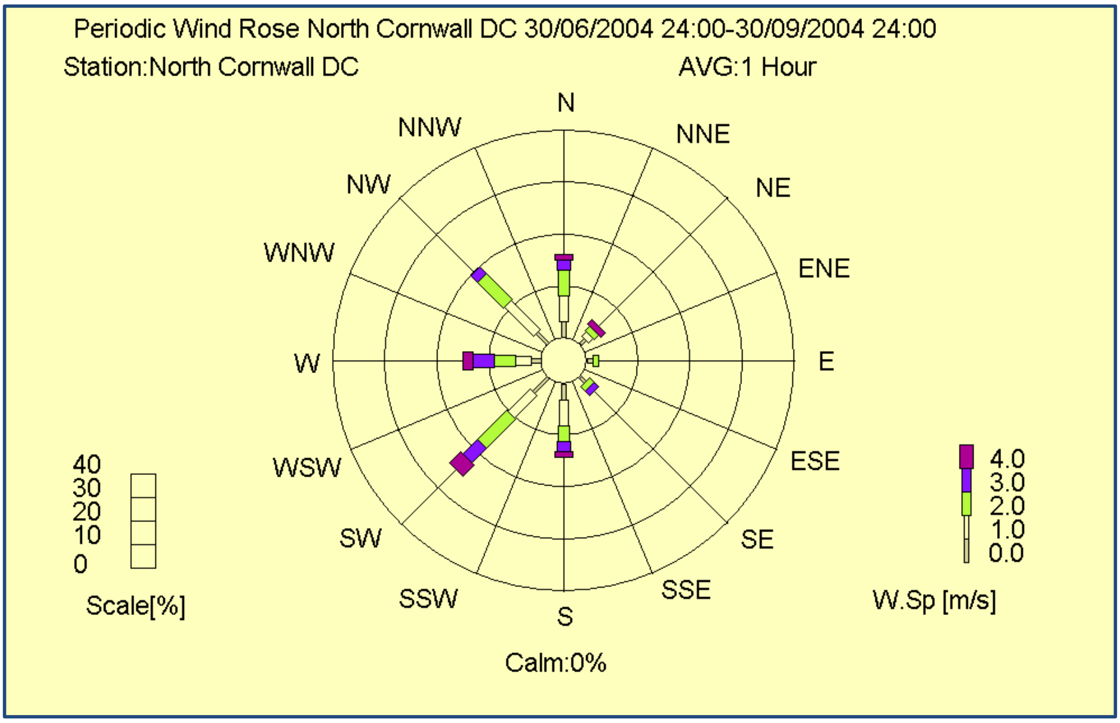


Figure 5. Wind rose from a location approx. 30 miles north east of the turbine site. (North Cornwall DC 2008). 90% of the wind blows from the north to south via west.

Due to the aspect of the site (i.e. altitude, no obstacles within 50m and north to south via west facing), there is good reason to assume that the NOABL data and wind rose are reasonably accurate and confirm the observations.

3.2 Evaluation and selection of a turbine

3.2.1 Sizing of wind turbine.

Section 3.1.1 outlined the energy requirements of the site. A ground source heat pump (GSHP) is an option for space and DHW heating given that the turbine will produce renewable electricity. Assuming a GSHP coefficient of performance (COP) of 3.0 the total site electricity requirement is calculated in *Table* 3

Requirement	Heat (MWh/year)	Electrical equivalent (MWh/year)
Space heating	13.0	4.4
Other electricity (building and ancillary)		6.7
Total	**13.0**	**11.1**

Table 3. Total electricity requirements. Space heating converted at a COP of 3.0.

Figure 6 shows turbine annual output vs. turbine capacity using the following "rule of thumb" formula:

*Annual Turbine Output (MWh) = (Turbine capacity (kW) * hours/year * 25%)/1000*

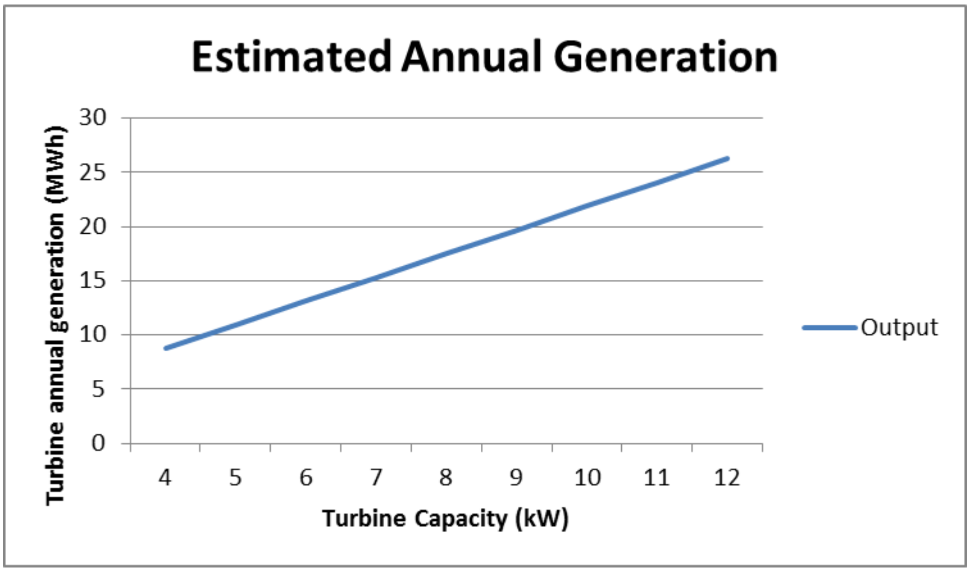


Figure 6. Estimated annual generation

The estimation shows that a turbine of more than 6kW capacity would potentially yield in excess of the required annual site requirement of 11.1MWh providing the generation was matched to load.

3.2.2 Turbine Selection – Short List.

Available MCS approved turbines (eligible for the feed in tariff - FITs) with rated capacity above 5 and less than 15kW are listed in *Table 4.*

Turbine	Rated Capacity (kW)
EVANCE R9000	5
XZERES 442SR	10
Aircon 10S	10
Bergey Excel 10	10
Eoltec Scirocco	6
C&F Green Energy	11
Gaia 133	11
Kingspan Wind (Proven)	6

Table 4. MCS Approved turbines. Capacity 5-15kW. Above 15kW would be too large and the FIT drops making the payback time less than a turbine just less than 15kW.

The installed cost of the above turbines is between £35,000 and £100,000 (excluding VAT).

The list was shortened to the Gaia 133 (11kW) and Aircon 10S (10kW) based on:

- Both turbines fell within the project budget of £50,000 – £100,000
- 10 - 11 kW will more likely match load with generation and ensure the site can use a higher proportion of renewable electricity at lower wind speeds. Hence reducing reliance on grid import.
- Larger turbines (up to 15kW) yield shorter paybacks on capital within the FIT 1.5 – 15kW band
- Both turbines are predominant in Cornwall and well supported.

3.2.3 Turbine Selection – Final

The final selection was based on site specific parameters for each turbine which assessed:

- Generation potential
- Financial criteria

1. <u>Generation Potential</u>

The power curves for each turbine are summarised in *Figure* 7 and *Figure 8.*

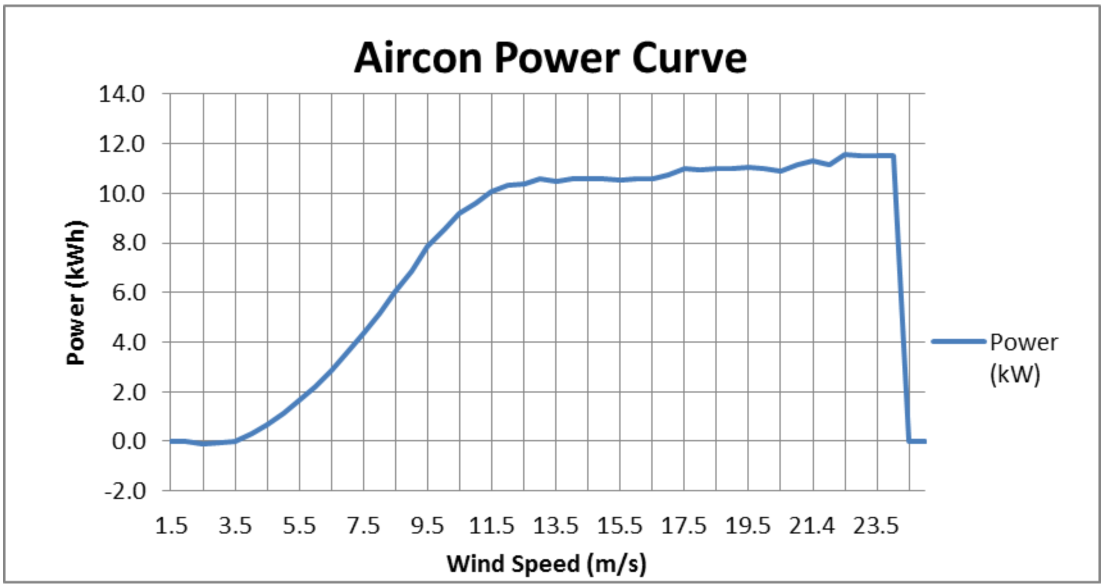


Figure 7. Aircon Power Curve – see appendix 6.2.1.

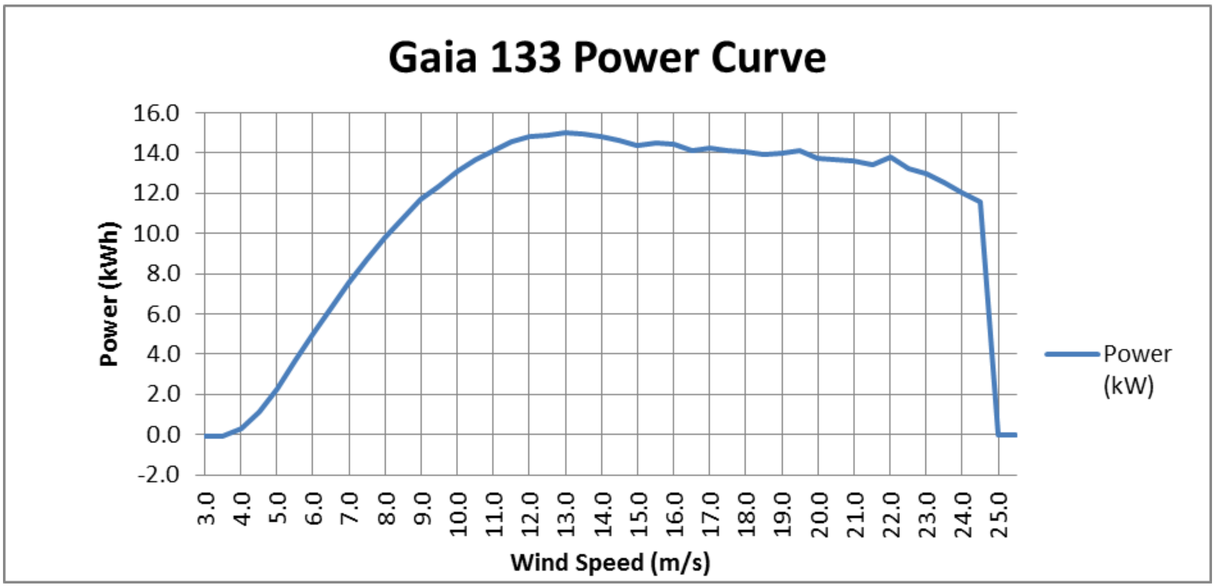


Figure 8. Gaia Power Curve - see appendix 6.2.2.

RETScreen *(RETScreen 2012)* was used to estimate the annual energy output for each turbine. The parameters used are outlined in *appendix 6.3.1 and 6.3.2* and summarised in *Table 5*.

Parameter	**Value/reference**
Power curve data	*See appendix 6.2.1 and 6.2.2*
Wind speed data: 5.2 m/s at 10m	*See Table 2*
Wind share exponent	0.14
Shape Factor	2.0
RETScreen method	Method 2

Parameter	Value/reference
Hub height	18m
Weather Data	Camborne station (from RETScreen database)
Aircon technical data	Aircon (2012).
Gaia technical data	NREL (2012)
Losses assumed to be 0	0%
Availability assumed	95%

Table 5. RETScreen Energy Generation Parameters

RETScreen uses the power curve and site wind data to calculate the annual energy. The RETScreen results are summarised in *Table 6*.

Parameter	Value	
	Aircon	Gaia
Wind speed at hub height (m/s)	5.6	5.6
Capacity Factor (%)	34.8	41.5
Specific yield (kWh/m^2)	690	301
Gross annual energy (MWh)	32	42
Annual electricity exported to grid (MWh) (allowing for an availability of 95%)	30	40
Annual carbon saving (metric tons) @ 0.524kg/kWh.	15.7	21.0

Table 6. RETScreen results

2. Financial Assessment

Both turbines were assessed for capital, revenue and expenditure. *See Appendix 6.4.1, 6.4.2 and 6.4.3.*

Using the capital costs and annual electricity generation (*see Table 6*), the estimated payback time and NPV for both turbines are presented in *Figure 9, Figure 10, Figure 11 and Figure 12.*

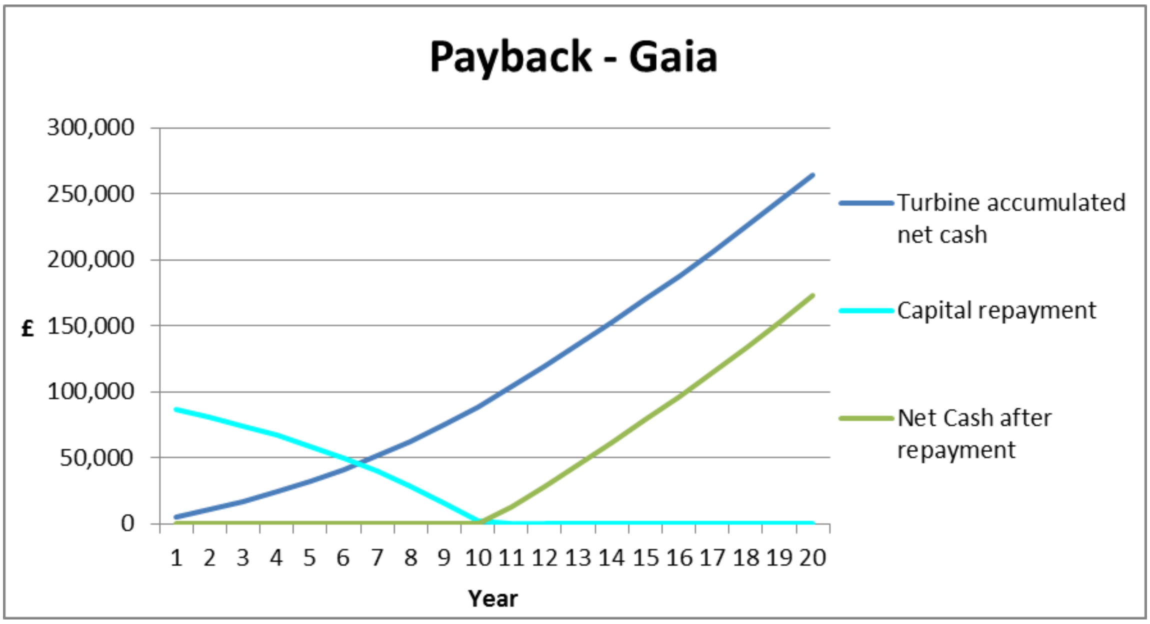


Figure 9. Gaia payback time.

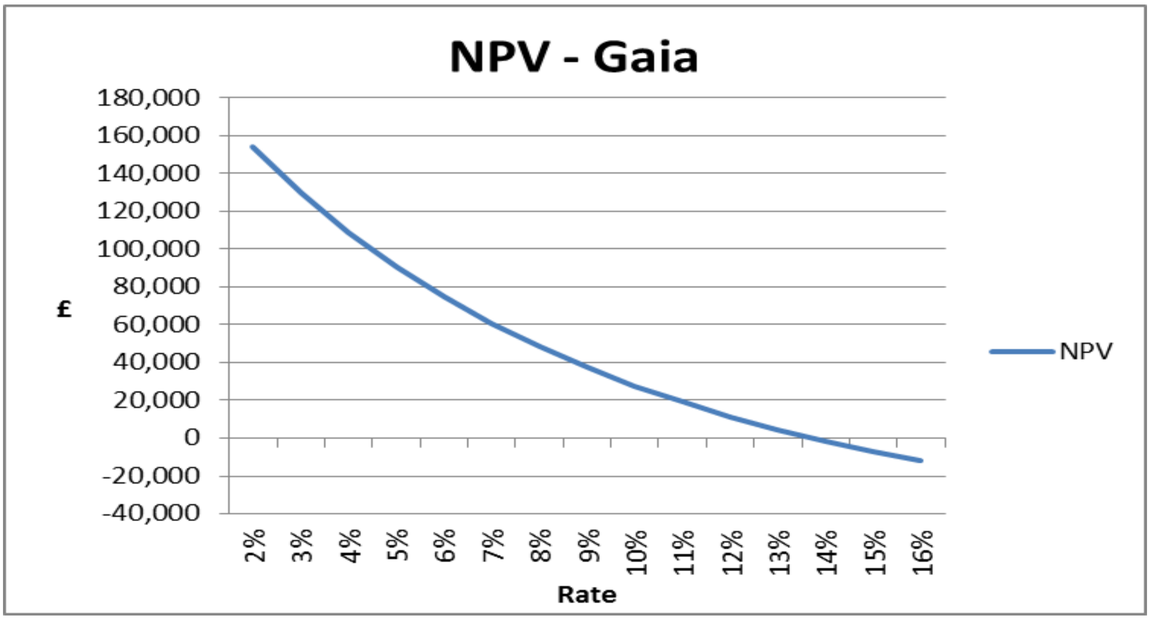


Figure 10, Gaia NPV

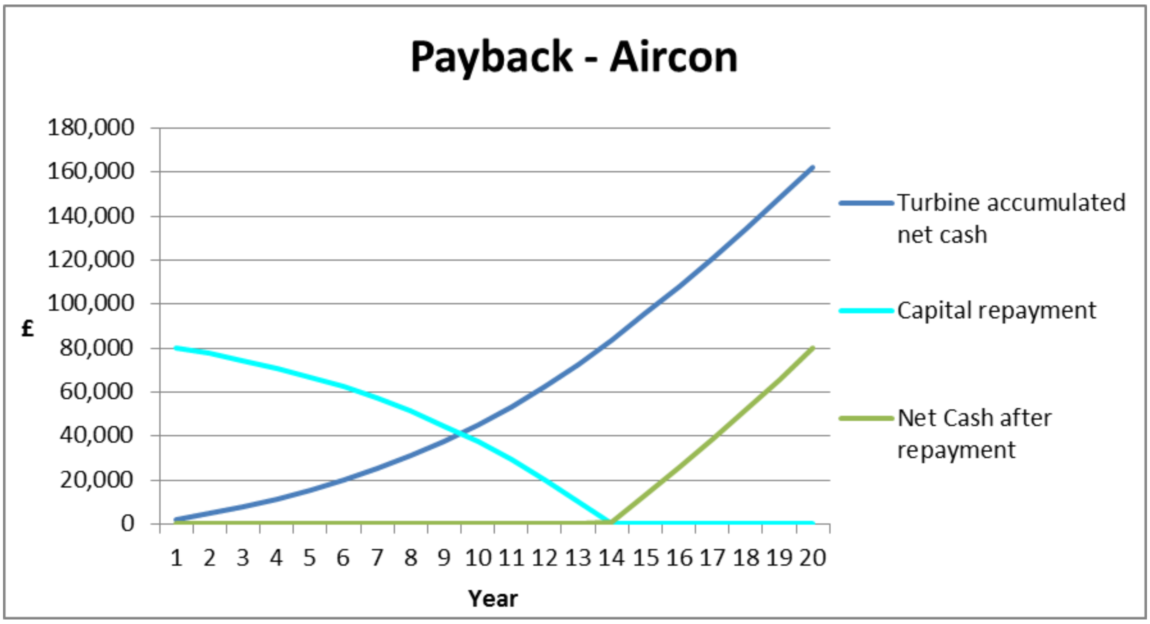


Figure 11. Aircon payback time

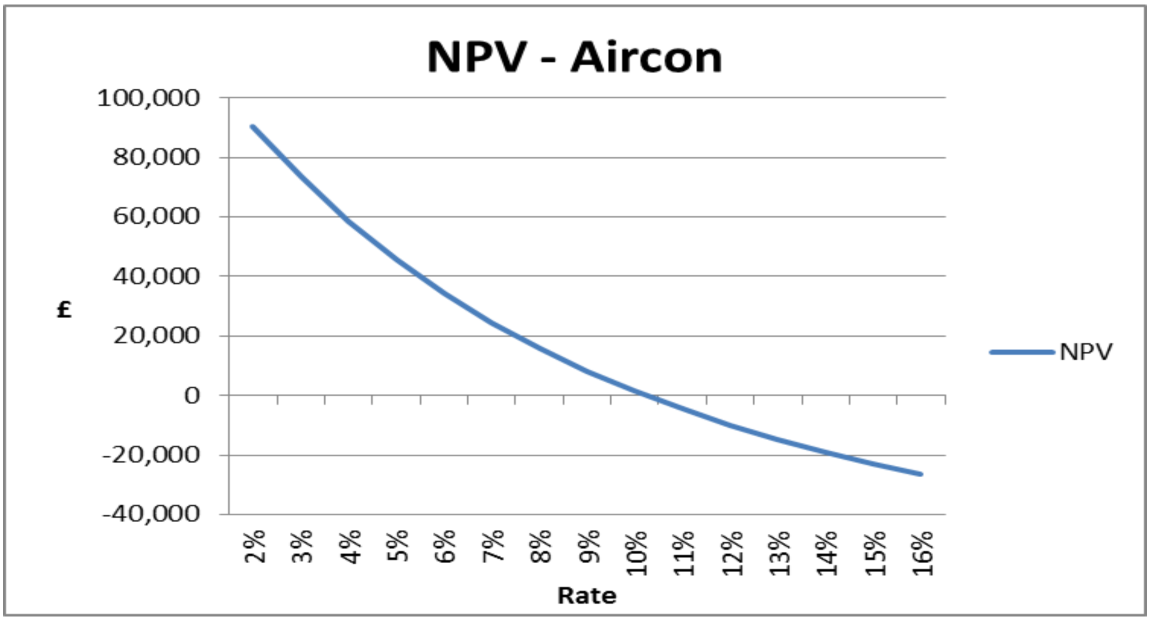


Figure 12. NPV Aircon

Table 7 summarises the financial assessment.

Parameter	Value	
	Aircon	Gaia
Capital cost (£)	82,351	91,577
Revenue after expenses and capital repayment (20 years life) (£)	79,777	173,134
Payback time. (Years)	14	11
NPV (%)	10.5	13.5

Table 7. Summary of financial assessment.

Although the capital cost of the Gaia is 12% more than the Aircon, the Gaia has the best net revenue, payback time and NPV due to its larger blade size and therefore larger energy output.

For the above reasons, the Gaia was chosen over the Aircon. (*And the turbine looks great! See* Figure 14*.)*

3.3 Design & Installation of the turbine

3.3.1 Siting considerations

1. <u>Access to grid and transformer upgrade.</u>

The site has single phase which could practically be upgraded to 3 phase. The transformer was upgraded from single phase 25kVA to 3 phase 50kVA.

The turbine required a cable run of 440m of 25mm 4 core SWA cable. (see *Appendix 6.5* for cable loss calculations). *Figure 13* shows the cable run to the 3 phase consumer board.

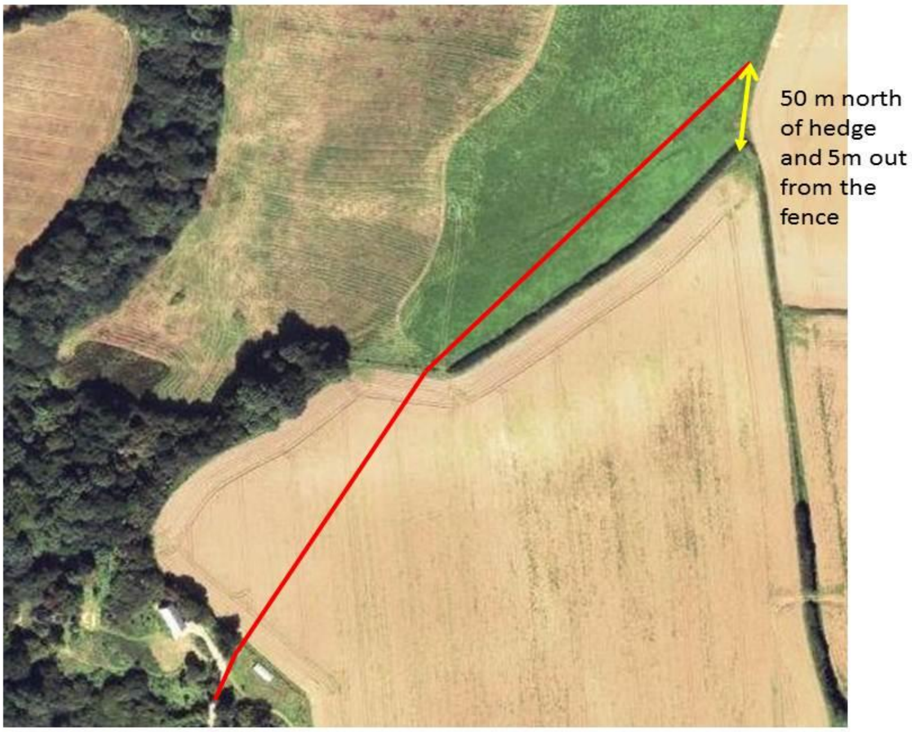


Figure 13. Cable run from turbine to 3 phase consumer board.

2. <u>Environment considerations.</u>

The turbine was sited over 500m from the nearest neighbour and 54m from the nearest habitable Cornish hedge.

The Local Authority Environment Health confirmed that the nearest neighbour would not be impacted by the turbine noise. A Local Authority EIA Scoping report confirmed that there was negligible environmental impact and a full EIA would not be required. Siting the turbine over 50m from the hedge negated the need for a Bat survey.

3. <u>Planning permission.</u>

There were no major planning considerations. There were no objections from formal consultees such as communications, heritage etc.

3.3.2 Installation

Access to the site for turbine delivery and installation equipment was from the east across the farmer’s field. Fortuitously, the dry March ensured the stubble fields remained hard packed thus negating the need for a hard road to be constructed.

Figure 14. Releasing the crane.

3.4 Monitoring

The turbine was monitored for a period of 15 days after installation. The following data was collated:

- Half hourly average power readings (kW)
- Daily total generation
- Wind speed vs. power (power curve)

3.4.1 Half hourly average power readings

Half hourly average power readings were uploaded from the turbine generation meter to the Meter Online website on a daily basis (*Meter Online 2012*). *Figure 15* shows the readings for each ½ hour averaged over 15 days. The green line represents the daily average required to reach the annual target generation of 40MWh. The red line is the current average.

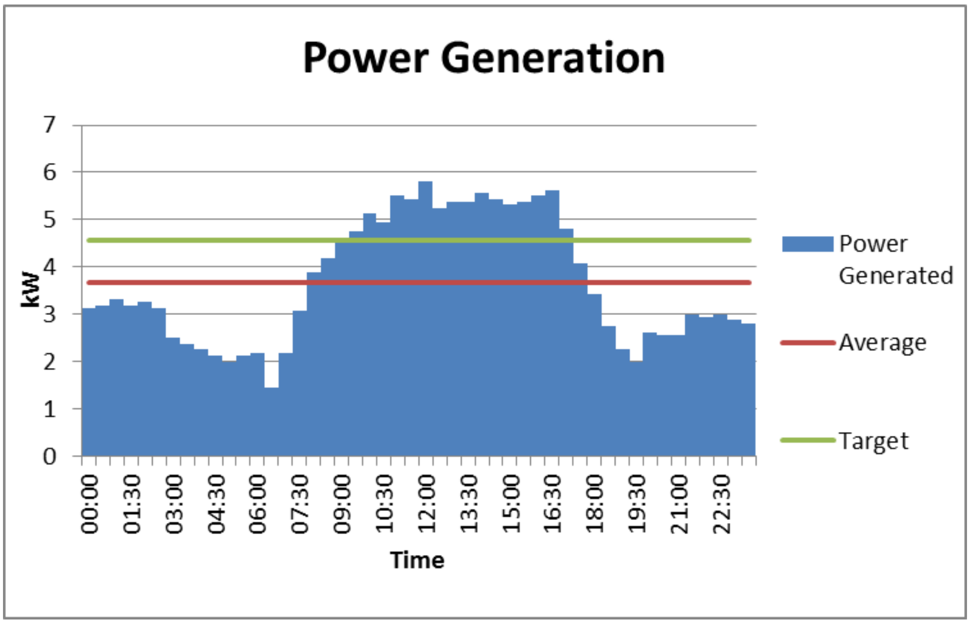


Figure 15. Measured ½ hourly average power generation

3.4.2 Energy Generation

Daily generation readings were uploaded from the turbine generation meter to the Meter Online website (*Meter Online 2012*). *Figure 16* shows the readings for each day. The green line represents the daily generation required to reach the 40MWh/year target. The red line is the current average daily generation.

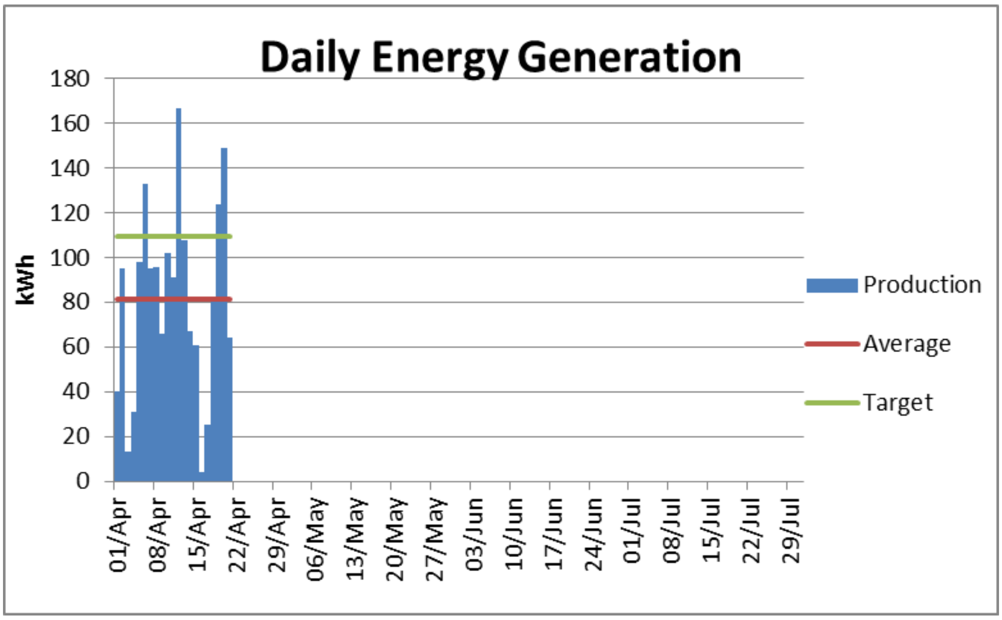


Figure 16. Daily total generation.

Figure 17 shows the actual cumulative generation as a percentage of the target.

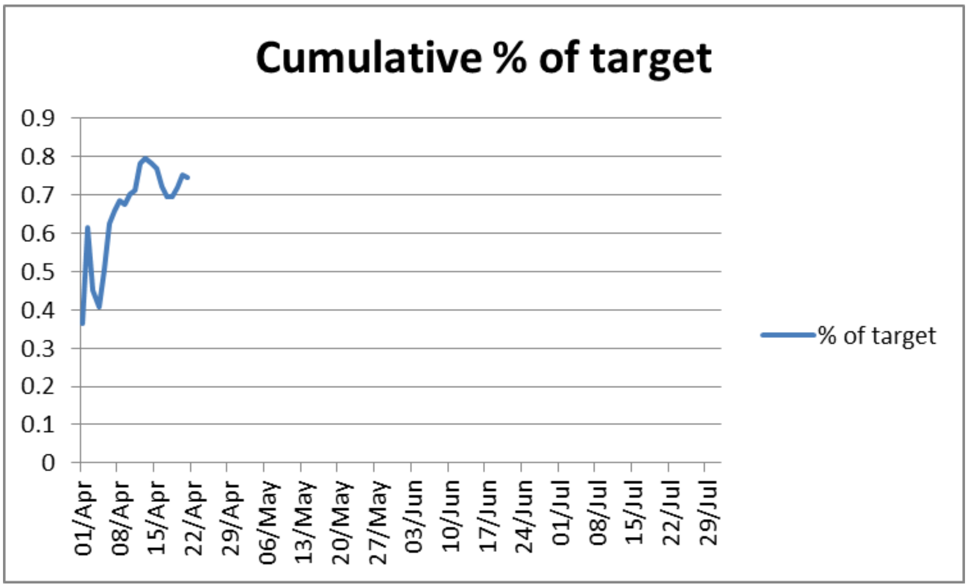


Figure 17. Cumulative generation as a % of target.

After15 days the turbine had produced 75% of the accumulated target.

3.4.3 Power curve

Over 15 days, a total of 283 wind speed versus power readings were taken from the turbine display panel. *Figure 18* compares the readings with the published power curve (*NREL 2012*).

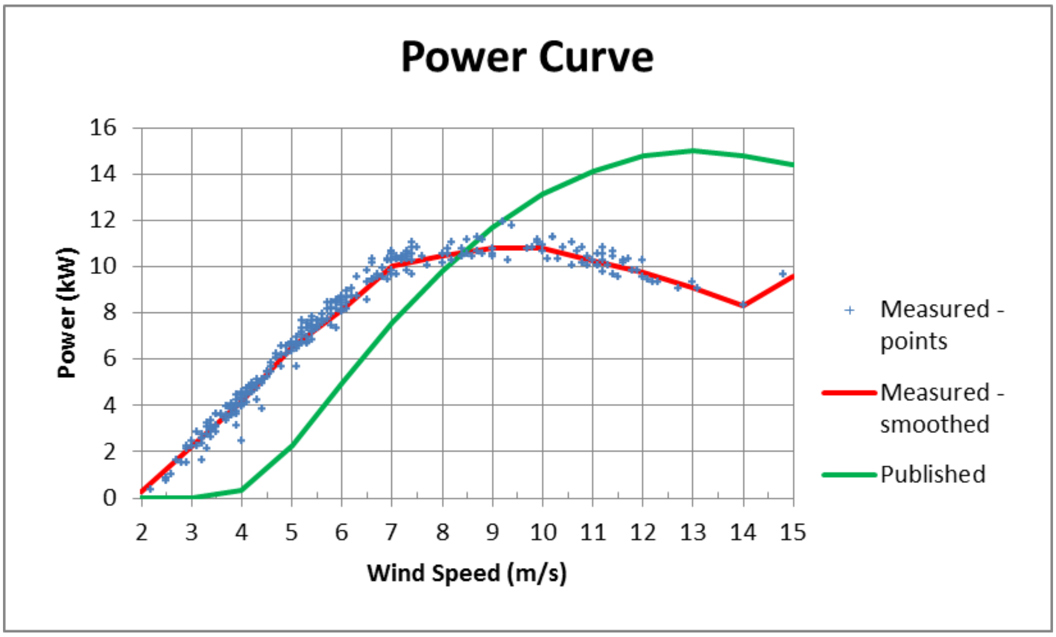


Figure 18. Measured compared with published power curve.

The measured curve was higher than the published curve at wind speeds less than 8 m/s.

Measurements were registered below the cut in speed of 3.5 m/s. Due to the large swept area, once the turbine has cut in, it is able to maintain momentum and provide useful energy at wind speeds as low as 2.5 m/s.

From the power curve, RETScreen is able to model the predicted annual energy and average annual power as a function of wind speed. *Figure 19* compares the results from the published and measured data for both annual average power and annual energy generation. It shows that at less than 8 m/s, the turbine is performing better than the published data.

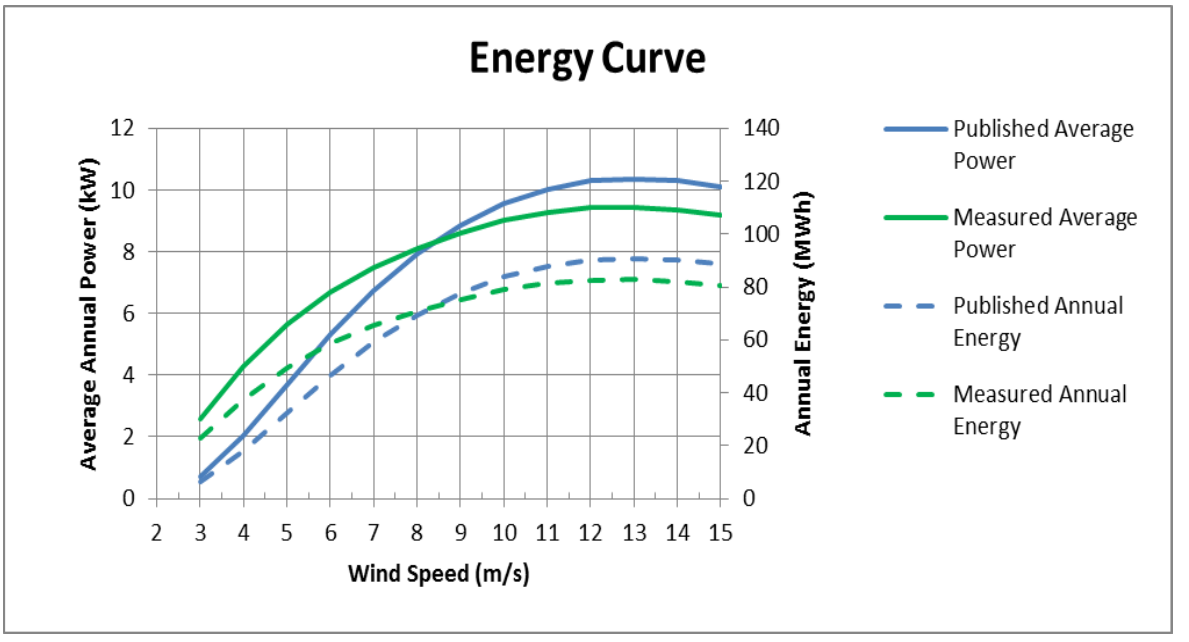


Figure 19. Energy Curve.

3.5 Revised financial benefits.

Figure 16 shows the average measured daily generation is 81 kWh, 75% of the target to meet financial expectations. The reduced annual generation of 10 MWh would change the financial model as outlined in *Table 8*.

Parameter	Initial model	Current prediction
Revenue after expenses and capital repayment (20 years life) (£)	173,134	53,517
Payback time. (Years)	11	16
NPV (%)	13.5	9

Table 8. Revised model

Figure 19 shows the measured and extrapolated annual generation (dashed green line). The current prediction of 30 MWh/year corresponds to an average wind speed of 3.6 m/s over the monitored period. The chart also shows that if the turbine performs to the measured power curve, the wind speed need only rise to 4.3 m/s to achieve the financial target of 40MWh/year. This is a significantly lower average wind speed than the 5.6 m/s used by the RETScreen (based on published power curve) to predict the same 40MWh/year.

4 Analysis and conclusions

On initial evaluation it appeared that the Aircon might be the best turbine to install due to the Gaia higher capital cost and requirement for 3 phase. However, on full assessment, the benefit of the Gaia was:

- Lower cable costs due to the generation load being spread over 3 phases
- Significant generation capacity due to a swept area 3 times that of the Aircon

- 3 phase to the site has other advantages e.g. a 3 phase GSHP compressor can spread the electrical load more evenly than a single phase compressor. The load from the 3 barns is best spread over 3 phases.

The installation of the turbine will remove 21T of carbon/year from the grid (420T over 20 years). The installation of a GSHP will make efficient use of the renewable electricity.

The site worked very well with no major grid access, planning or environmental problems. Easy access to the site was made possible due to the March dry conditions.

There is a slight concern over the generation monitored during the first 15 days. The average wind speed has been low and generation is 75% of target. However, it is early days yet. The use of NOABL should still be reasonably accurate due to site altitude, aspect and clear area surrounding the turbine.

The measured power curve was higher than the published curve at wind speeds less than 8 m/s. It is difficult to assess without more detailed monitoring (see next section) whether the readings are accurate. Reasons for the variation could be:

- The turbine anemometer is reading too low.
- The turbine power meter is reading too high
- The air density is much higher (colder air temp) than the reference published data.

If the readings are accurate then the upside is that the average wind speed need only be at least 4.3 m/s, rather than 5.6 m/s, to achieve the financial target of 40MWh/year.

The final commission cost came in on budget at £90,000.

5 Next Steps

1. Current monitoring is missing the accurate sampling of wind speed and power to provide the local power curve. Gaia is unable to provide this facility.

   Ideally a data logger should be fitted to monitor the following:

   - Wind speed sampled every second and averaged over a 10 minute period
   - Power averaged over a 10 minute period
   - Wind vane to measure the wind direction.

   The data should be uploaded remotely to a website to allow data retrieval and analysis.

2. The Gaia has a number of parameters that can be programmed to optimise performance. The information gathered in 1. above could be used to inform the optimisation process.

6 Appendices

6.1 Calculation of UK Wind Generation.

Department of Energy and Climate Change (2012c) published the total electricity production in the UK for 2011 as 365.3 TWh, down by 4.2% from 2010. The renewables component was 9.5% of total production in 2011, up from 6.7% in 2010. Wind generated electricity was up 54% on 2010 at 15.9 TWh.

A breakdown comparison is summarised in *Table 9 and Figure 20*

Electricity Source	TW/year	% Total Generation
Small Wind (defined as production from turbines with a capacity of up to 100kW). *BWEA (2012).*	0.1	0.03
Total Wind (on and off shore). *Department of Energy and Climate Change (2012c)*	15.9	4.4
Total Renewables (NB This does not include nuclear!). *Department of Energy and Climate Change (2012c)*	34.8	9.5
Total Electricity *Generation. Department of Energy and Climate Change (2012c)*	365.3	

Table 9. Electricity Generation by source.

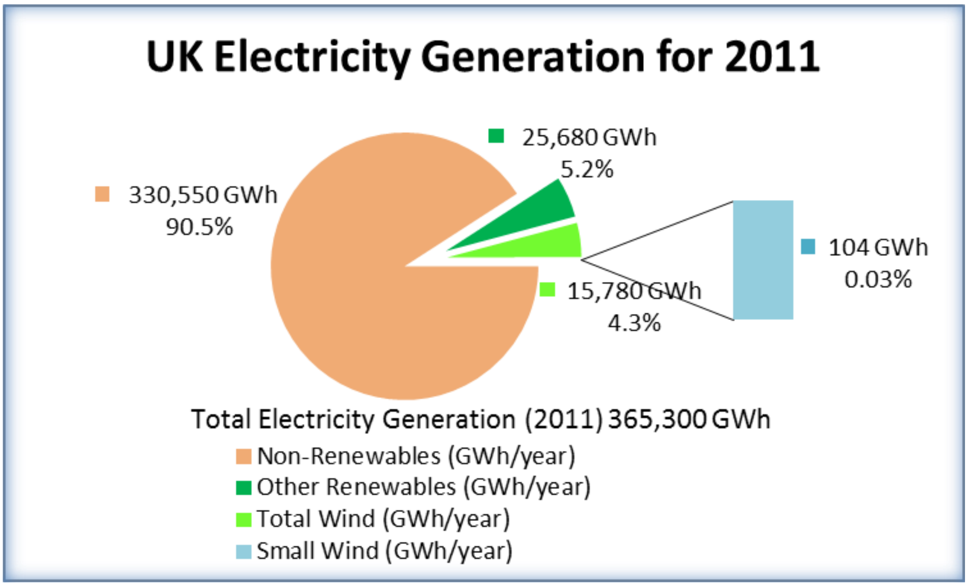


Figure 20. UK Energy generation by source.

6.2 Power Curves.

The following sections detail the power curves for the Aircon and Gaia 133. Note the negative power before cut in speed. This is due to the method of using the generator as a motor to "kick" the blade into motion.

6.2.1 Aircon

Table 10 summarises the power curve for the Aircon 10kW wind turbine.

Wind (m/s)	Power (kW)	Wind (m/s)	Power (kW)
1.50	0.000	13.52	10.480
2.00	0.000	14.02	10.600
2.60	-0.132	14.53	10.570
3.03	-0.079	14.98	10.600
3.54	0.009	15.52	10.560
4.02	0.312	15.98	10.600
4.57	0.680	16.47	10.600
5.00	1.120	17.00	10.740
5.52	1.650	17.53	10.990
6.00	2.203	17.98	10.940
6.49	2.855	18.50	10.980
6.99	3.600	18.97	10.990
7.48	4.344	19.48	11.050
7.99	5.159	19.99	10.990
8.48	6.022	20.51	10.920
9.01	6.892	20.95	11.160
9.50	7.826	21.41	11.310
10.00	8.500	21.99	11.160
10.51	9.186	22.66	11.560
10.99	9.608	23.00	11.500
11.46	10.080	23.50	11.500
11.99	10.310	24.00	11.500
12.47	10.400	24.50	0.000
12.98	10.570	25.00	0.000

Table 10. Aircon Power Curve. Aircon (2012).

6.2.2 Gaia 133

Table 11 summarises the power curve for the Gaia 133 11 kW turbine.

Wind (m/s)	Power (kW)	Wind (m/s)	Power (kW)
3.0	-0.10	14.5	14.60
3.5	-0.11	15.0	14.40
4.0	0.31	15.5	14.49
4.5	1.15	16.0	14.42
5.0	2.28	16.5	14.15
5.5	3.67	17.0	14.24
6.0	5.00	17.5	14.13
6.5	6.27	18.0	14.08
7.0	7.57	18.5	13.91
7.5	8.70	19.0	14.00
8.0	9.80	19.5	14.11
8.5	10.77	20.0	13.74
9.0	11.67	20.5	13.70
9.5	12.36	21.0	13.60
10.0	13.12	21.5	13.40
10.5	13.69	22.0	13.80
11.0	14.15	22.5	13.20
11.5	14.59	23.0	13.00
12.0	14.80	23.5	12.50
12.5	14.90	24.0	12.00
13.0	15.00	24.5	11.60
13.5	14.93	25.0	0.00
14.0	14.80	25.5	0.00

Table 11. Gaia 133 Power Curve. NREL (2012)

6.3 **RETScreen input and output data.**

The following sections summarise the input and output data for the RETScreen turbine energy generation calculations.

6.3.1 Aircon

Resource assessment

Resource method		Wind speed	☑ Show data	See maps
			Camborne	
Wind speed - annual	m/s	5.2	5.6	
Measured at	m	10.0	10.0	
Wind shear exponent		0.14		
Air temperature - annual	°C	10.8	10.8	
Atmospheric pressure - annual	kPa	101.3	101.3	
Wind turbine				
Power capacity per turbine	kW	10.0		See product database
Manufacturer		Aircon		
Model				
Number of turbines		1		
Power capacity	kW	10.0		
Hub height	m	18.0	5.6 m/s	
Rotor diameter per turbine	m	8		
Swept area per turbine	m²	44		
Energy curve data		Custom		
Shape factor		2.0		

☑ Show data

Show figure

Wind speed m/s	Power curve data kW	Energy curve data MWh
0	0.0	
1	0.0	
2	0.0	
3	0.3	7.0
4	1.1	15.4
5	2.2	25.3
6	3.6	35.1
7	5.2	43.9
8	6.9	51.4
9	8.5	57.5
10	9.6	62.2
11	10.3	65.5
12	10.6	67.5
13	10.6	68.3
14	10.6	68.1
15	10.6	67.2
16	10.7	
17	10.9	
18	10.9	
19	10.9	
20	11.1	
21	11.1	
22	11.5	
23	11.5	
24	11.5	
25 - 30		

Array losses	%	0.0%
Airfoil losses	%	0.0%
Miscellaneous losses	%	0.0%
Availability	%	95.0%
Summary		
Capacity factor	%	34.8%

☑ Show data

		Per turbine
Unadjusted energy production	MWh	32
Pressure coefficient		1.000
Temperature coefficient		1.015
Gross energy production	MWh	32
Losses coefficient		0.95
Specific yield	kWh/m²	690

6.3.2 Gaia

			Camborne
Wind speed - annual	m/s	5.2	5.6
Measured at	m	10.0	10.0
Wind shear exponent		0.14	
Air temperature - annual	°C	10.8	10.8
Atmospheric pressure - annual	kPa	101.3	101.3

Wind turbine

See product database

Power capacity per turbine	kW	11.0	
Manufacturer		Gaia	
Model		133	
Number of turbines		1	
Power capacity	kW	11.0	
Hub height	m	18.0	5.6 m/s
Rotor diameter per turbine	m	13	
Swept area per turbine	m²	133	
Energy curve data		Custom	
Shape factor		2.0	

☑ Show data

Show figure

Wind speed m/s	Power curve data kW	Energy curve data MWh
0	0.0	
1	0.0	
2	0.0	
3	0.0	6.3
4	0.3	18.0
5	2.3	32.3
6	5.0	46.4
7	7.6	59.0
8	9.8	69.4
9	11.7	77.7
10	13.1	83.8
11	14.2	87.9
12	14.8	90.1
13	15.0	90.8
14	14.8	90.1
15	14.4	88.5
16	14.4	
17	14.2	
18	14.1	
19	14.0	
20	13.6	
21	13.6	
22	13.8	
23	13.0	
24	12.0	
25 - 30	0.0	

Array losses	%	0.0%
Airfoil losses	%	0.0%
Miscellaneous losses	%	0.0%
Availability	%	95.0%

Summary

Capacity factor	%	41.5%

☑ Show data

		Per turbine
Unadjusted energy production	MWh	41
Pressure coefficient		1.000
Temperature coefficient		1.015
Gross energy production	MWh	42
Losses coefficient		0.95
Specific yield	kWh/m²	301

6.4 Financial Analysis

6.4.1 Capital Costs

Table 12 compares the capital costs for each turbine.

	10 kW Aircon single phase		11 kW Gaia 3 phase	
Item	**£**	**Notes**	**£**	**Notes**
Capital costs				
Turbine & tower	62,251	18m 10kw Aircon, with inverters Cable included. 420m 100mm 3 core cable approx. $13,000 Fully installed and commissioned	54,897	18m Gaia 11kw grid tie turbine (no inverters required) 420m 35mm 4 Core Cable approx. £4,872.00 Fully installed and commissioned
Foundation hardware	1,000			Included in quote
Concrete	1,280	16m3 @ 80/m3	1,360	17m3 @ 80/m3
WPD install	9,000	Upgrade transformer: 25kVA to 100kVA split.	20,000	Upgrade transformer: 25kVA to 3 phase 50kVA and 3 phase connection (1.2km cabling extension)
Other electrical install	500	Provision for rewiring main consumer unit	500	Provision for rewiring main consumer unit
Hire of digger	500		500	
Hire of skip loader	300		300	
Hire of tele handler	200		200	
Planning cost	320	Fee. Planning application undertaken by author.	320	Fee. Planning application undertaken by author.
Land lease setup cost	1,000		1,000	
Land access	3,000	Farmer way-leave costs to install new transformer	10,000	Farmer way-leave costs to install new transformer and 3 phase connection
Crop damage	500	Provision for transformer installation		Included in way-leave costs
Crop damage	500	Provision for trenching across field from turbine to consumer unit	500	Provision for trenching across field from turbine to consumer unit
Contingency	2,000		2,000	
Trenching, cable laying, ground works and foundation installation.	0	Self-build. Normally £8 - 13,000.	0	Self-build. Normally 8,000 - 13,000
Total capital costs	**82,351**		**91,577**	

Table 12. Capital Cost Comparison

6.4.2 Gaia Income, expenditure and payback

Table 13 details the predicted Income, expenditure and payback for the Gaia Turbine with the following assumptions.

Assumptions
- Turbine output 40MWh p.a. *See Table 6*
- FITS 28.1p/kWh (2011/12 year). 20 years. Increase by 3% p.a.
- FITs non taxable
- Land Lease increase 3% p.a.
- VAT recovery
- Site uses 11.1 MW p.a.
-2% increase in sales price electricity to grid p.a.
- Annual maintenance charge increase 3% p.a.
- 7% Interest on finance
- Assume there is no import to site

	Year																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Item	**12/13**	**13/14**	**14/15**	**15/16**	**16/17**	**17/19**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**	**23/24**	**24/25**	**25/26**	**26/27**	**27/28**	**28/29**	**29/30**	**30/31**	**31/32**	**Total £**
£																					
Annual (Cash)																					
Revenue																					
FITs	11,840	12,195	12,561	12,938	13,326	13,726	14,138	14,562	14,999	15,449	15,912	16,389	16,881	17,387	17,909	18,446	19,000	19,570	20,157	20,762	**318,145**
Sale to Grid	1,347	1,374	1,401	1,429	1,458	1,487	1,517	1,547	1,578	1,609	1,642	1,675	1,708	1,742	1,777	1,813	1,849	1,886	1,923	1,962	**32,722**
Total Revenue	**13,187**	**13,569**	**13,962**	**14,367**	**14,784**	**15,213**	**15,654**	**16,109**	**16,576**	**17,058**	**17,554**	**18,064**	**18,589**	**19,130**	**19,686**	**20,259**	**20,849**	**21,455**	**22,080**	**22,723**	**350,867**
Expenditure																					
Annual Maintenance	480	494	509	525	540	556	573	590	608	626	645	664	684	705	726	748	770	793	817	842	**12,898**
Interest on finance	6,410	6,061	5,662	5,211	4,703	4,134	3,497	2,788	2,001	1,129	166	0	0	0	0	0	0	0	0	0	**41,762**
Land lease	800	824	849	874	900	927	955	984	1,013	1,044	1,075	1,107	1,141	1,175	1,210	1,246	1,284	1,322	1,362	1,403	**21,496**
Repairs (provision)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	**10,000**
Total Exp	**8,190**	**7,879**	**7,520**	**7,110**	**6,644**	**6,118**	**5,525**	**4,862**	**4,122**	**3,299**	**2,386**	**2,272**	**2,325**	**2,380**	**2,436**	**2,494**	**2,554**	**2,616**	**2,679**	**2,744**	**86,156**
Net (Cash)	**4,996**	**5,690**	**6,442**	**7,257**	**8,140**	**9,095**	**10,129**	**11,246**	**12,454**	**13,759**	**15,168**	**15,792**	**16,264**	**16,750**	**17,250**	**17,765**	**18,294**	**18,840**	**19,401**	**19,979**	**264,711**
Net Cash for Capital repayment	4,996	5,690	6,442	7,257	8,140	9,095	10,129	11,246	12,454	13,759	15,168	15,792	16,264	16,750	17,250	17,765	18,294	18,840	19,401	19,979	**264,711**
Accum Cash for Capital repayment	4,996	10,686	17,128	24,385	32,525	41,620	51,749	62,995	75,449	89,208	104,376	120,168	136,432	153,182	170,432	188,197	206,491	225,331	244,732	264,711	
Accum Residual cash	0	0	0	0	0	0	0	0	0	0	12,799	28,591	44,855	61,605	78,855	96,620	114,914	133,754	153,155	173,134	
Loan on capital start year	91,577	86,581	80,891	74,449	67,192	59,052	49,957	39,828	28,582	16,128	2,369	0	0	0	0	0	0	0	0	0	
Loan on capital year end	86,581	80,891	74,449	67,192	59,052	49,957	39,828	28,582	16,128	2,369	0	0	0	0	0	0	0	0	0	0	
Grid sale price per £/kWh	0.0466	0.0475	0.0485	0.0495	0.0504	0.0515	0.0525	0.0535	0.0546	0.0557	0.0568	0.0579	0.0591	0.0603	0.0615	0.0627	0.0640	0.0653	0.0666	0.0679	
MWh produced p.a.	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	**800**
MWh Site Requirement p.a.	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	**222**
MWh feed to Grid p.a.	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	

Table 13. Gaia Income, Expenditure and payback.

6.4.3 Aircon Income, expenditure and payback

Table 14 details the predicted Income, expenditure and payback for the Aircon Turbine with the following assumptions.

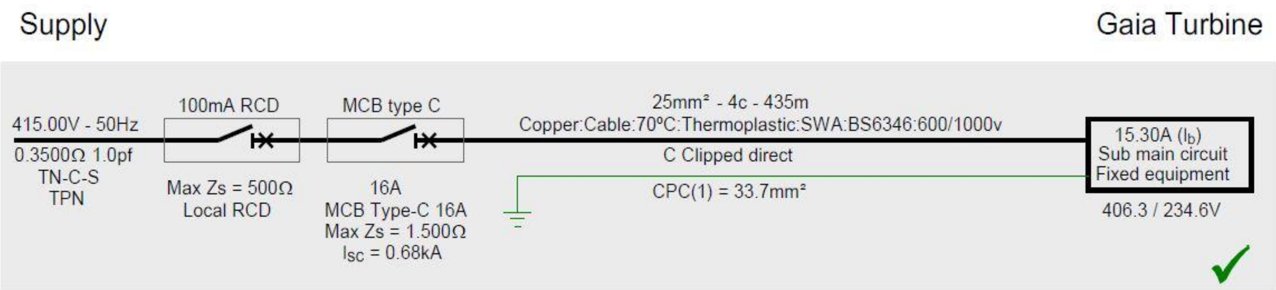
Assumptions
- Turbine output 30MWh p.a. *See Table 6*
- FITS 28.1p/kWh (2011/12 year). 20 years. Increase by 3% p.a.
- FITs non taxable
- Land Lease increase 3% p.a.
- VAT recovery
- Site uses 11.1 MW p.a.
-2% increase in sales price electricity to grid p.a.
- Annual maintenance charge increase 3% p.a.
- 7% Interest on finance
- Assume there is no import to site

	Year																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Item	**12/13**	**13/14**	**14/15**	**15/16**	**16/17**	**17/19**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**	**23/24**	**24/25**	**25/26**	**26/27**	**27/28**	**28/29**	**29/30**	**30/31**	**31/32**	**Total**
Annual (Cash)																					
Revenue																					
FITs	8,880	9,146	9,421	9,703	9,995	10,294	10,603	10,921	11,249	11,586	11,934	12,292	12,661	13,041	13,432	13,835	14,250	14,677	15,118	15,571	**238,609**
Sale to Grid	881	898	916	935	953	972	992	1,012	1,032	1,053	1,074	1,095	1,117	1,139	1,162	1,185	1,209	1,233	1,258	1,283	**21,400**
Total Revenue	**9,761**	**10,045**	**10,337**	**10,638**	**10,948**	**11,267**	**11,595**	**11,933**	**12,281**	**12,639**	**13,008**	**13,387**	**13,778**	**14,180**	**14,594**	**15,020**	**15,459**	**15,911**	**16,376**	**16,854**	**260,009**
Expenditure																					
Annual Maintenance	480	494	509	525	540	556	573	590	608	626	645	664	684	705	726	748	770	793	817	842	**12,898**
Interest on finance	5,765	5,609	5,426	5,213	4,966	4,683	4,361	3,996	3,586	3,126	2,612	2,040	1,404	701	0	0	0	0	0	0	**53,487**
Land lease	800	824	849	874	900	927	955	984	1,013	1,044	1,075	1,107	1,141	1,175	1,210	1,246	1,284	1,322	1,362	1,403	**21,496**
Repairs (provision)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	**10,000**
Total Exp	**7,545**	**7,428**	**7,284**	**7,111**	**6,906**	**6,667**	**6,389**	**6,071**	**5,707**	**5,296**	**4,832**	**4,311**	**3,729**	**3,081**	**2,436**	**2,494**	**2,554**	**2,616**	**2,679**	**2,744**	**97,881**
Net (Cash)	**2,216**	**2,617**	**3,053**	**3,527**	**4,042**	**4,600**	**5,206**	**5,862**	**6,573**	**7,343**	**8,176**	**9,076**	**10,049**	**11,099**	**12,158**	**12,526**	**12,905**	**13,295**	**13,696**	**14,110**	**162,128**
Net Cash for Capital repayment	2,216	2,617	3,053	3,527	4,042	4,600	5,206	5,862	6,573	7,343	8,176	9,076	10,049	11,099	12,158	12,526	12,905	13,295	13,696	14,110	**162,128**
Accum Cash for Capital repayment	2,216	4,833	7,886	11,413	15,454	20,054	25,260	31,123	37,696	45,039	53,215	62,290	72,339	83,438	95,596	108,122	121,027	134,322	148,018	162,128	
Accum Residual cash	0	0	0	0	0	0	0	0	0	0	0	0	0	1,087	13,245	25,771	38,676	51,971	65,667	79,777	
Loan on capital start year	82,351	80,135	77,518	74,465	70,938	66,897	62,297	57,091	51,228	44,655	37,312	29,136	20,061	10,012	0	0	0	0	0	0	
Loan on capital year end	80,135	77,518	74,465	70,938	66,897	62,297	57,091	51,228	44,655	37,312	29,136	20,061	10,012	0	0	0	0	0	0	0	
Grid sale price per £/kWh	0.0466	0.0475	0.0485	0.0495	0.0504	0.0515	0.0525	0.0535	0.0546	0.0557	0.0568	0.0579	0.0591	0.0603	0.0615	0.0627	0.0640	0.0653	0.0666	0.0679	
MWh produced p.a.	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	**600**
MWh Site Requirement p.a.	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	**222**
MWh feed to Grid p.a.	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	

Table 14. Aircon Income, expenditure and payback.

6.5 Cable loss calculations.

Figure 21 details the cable loss calculation for 435m of 25mm four core SWA cable. Initial costing allowed for 35mm but further analysis showed that 25mm cable passed the cable loss tests.



Cable Data				25mm² - 4c - 435m
Copper:Cable:70ºC:Thermoplastic:SWA:BS6346:600/1000v:Table 4D4				
Cable Rating I_t (tabulated)	Table 4D4A Col-3	102A		
Cable Rating I_Z (effective)		102A	$I_Z \geq I_b$	PASS
mV/A/mtr (tabulated)	Table 4D4B Col-4	1.5mV/A/m (r)	0.145 mV/A/m (x)	1.5 mV/A/m (z)
mV/A/mtr (temperature corrected)	operating 30.90ºC	1.313mV/A/m (r)	0.145 mV/A/m (x)	1.5 mV/A/m (z)
Voltage drop permitted (per phase)	3.00% (7.19V)			
Voltage drop Calculated (per phase)	2.11% (5.04V)	Circuit voltage drop = 5.04V		PASS

Figure 21. Cable loss calculations

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