Stewart Island Wind Investigation

Completed by
Roaring40s Wind Power

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CONTENTS

1 EXECUTIVE SUMMARY

Stewart Island is seeking alternative means of electricity generation for the island that reduces and stabilises the cost of electricity to the Islanders, offsetting or eliminating the current dependency on diesel. While the latter is important from a sustainability and CO_2 emission reduction viewpoint (with the Island being 98% National Park), it is clear that cost reduction will be a major driver in the decision to change from the existing generation system. The current cost of electricity on the Island is 62 c/kWh, about 2.5 times mainland costs.

This report has been prepared for Ministry of Business, Innovation and Employment (MBIE). The report provides an updated assessment of wind energy electricity generation on Stewart Island previously reported in the McCutcheon report in 2016.

This report has:

- updated and added to wind measurement records
- completed a wind flow analysis of the study area
- assessed potential wind turbine sites in proximity to Oban, and recommended a preferred site
- assessed wind turbines suitable for the preferred site
- assessed supply and construction practicalities
- provided initial information on consenting
- provided cost estimates for and the levelised cost of energy (LCOE) from wind generation

Seven sites within close proximity to Oban were assessed and the recommended preferred site is at the Airport, located to the south of the airstrip. Landownership is a mix of private and DOC land. [redacted] Further discussions with Stewart Island Flights and CAA will also need to be had to ensure turbines could be sited here.

Wind modelling has shown that the wind resource is significantly more favourable at the preferred site adjacent to the Airport. Using a range of turbine configurations, and the corresponding balance of plant costs, the LCOE of the best turbine option is 31 to 41 c/kWh.

Roaring40s Wind Power recommends that in the first instance, all activities be completed to gain a resource consent, including land access agreements. Without land access and resource consents there is no wind project.

2 BACKGROUND

Stewart Island lies approximately 30km south of the South Island of New Zealand. The island has approximately 456 electricity consumers (at the end of 2017) which are provided electricity generated by a central diesel power station. The power station currently has 5 diesel gensets. The cost of electricity on Stewart Island is higher than that of “grid connected” electricity provided to customers in the North and South Islands. Stewart Islanders pay 62 c/kWh for electricity. The cost of the “diesel only” portion of the electricity cost is 23 c/kWh (2016) however there have been recent increases in diesel fuel prices (refer Section 3).

There have been a significant number of reports, studies and investigations completed on possible alternative energy generation options on the island however none have yet resulted in an economic and practical solution. The most recent report is one prepared by Power Business Limited in September 2016 and is sometimes referred to as the McCutcheon[1] report. Two of the possible options, that appear to attract the most discussion are an undersea cable back to Bluff and a hydro generation option in Maori Creek. More recently wind and solar have been considered.

Local residents believe that reducing the consumption of diesel and having a renewable source of electricity generation is one of the islands highest priorities. Roaring40s Wind Power has been engaged by Ministry of Business, Innovation and Employment (MBIE) to undertake a review of the wind opportunities on Stewart and provide an updated assessment of any practical wind solution and the cost of energy from such a development. This report is a summary of that work.

Roaring40s Wind Power acknowledges the input from those persons and parties listed in Appendix C.

[1] Stewart Island Future Supply – John McCutcheon, Power Business Limited, Sep 2016

3 THE ELECTRICITY SYSTEM

The Stewart Island Electrical Supply Authority (SIESA) undertakes the generation, distribution and supply of electricity on Stewart Island. SIESA is owned by Southland District Council. Relevant key statistics of the system owned by SIESA are listed in Table 1[2].

Item	Detail	Comment
Generation units	Gen#1. 320 kW CAT3406 Gen#2. 208 kW CAT3408 Gen#3. 360 kW Detroit Series60/14L Gen#4. Scania DC13 Series Gen#5. Scania DC13 Series (self-contained)	Installed Dec 2005. 17,658 hrs Installed 1987. 45,567 hrs Installed Nov 2006. 20,339 hrs Installed 2014. 89 hrs Installed 2016. 6225 hrs
Generator control	Interlinked Woodward EGCP-2 digital control units	Installed 2006-07. Unit #4 new in 2014.
Overhead lines	18 km High Tension 14km low voltage 1.9 km streetlighting cable	
Underground	1.9 km high tension (ug?) 12 km of low voltage cable in 4.1km trench 1 km of streetlighting cable	
Transformers	43 distribution transformers 3 terminal step up transformers 3 earth protection transformers 6 airbreak switches (1used as tie switch between feeders)	
ICP's	467 (456 connected)	
Diesel consumption	4.28 kWh/litre diesel[1]	
Distribution line losses	7.8%	
Electricity sold	FY08/09 FY09/10 FY10/11 FY11/12 FY12/13 FY13/14 FY14/15 FY15/16 FY16/17	1.450 GWh 1.357 GWh 1.384 GWh 1.453 GWh 1.415 GWh 1.408 GWh 1.426 GWh 1.468 GWh 1.508 GWh

Note: 1. 12 month average for 2017

Table 3.1. Summary of the SIESA electrical system

Generation data was available for the period 1 July 2015 to 30 June 2016 which has been used to calculate the average monthly and hourly generation during the year. Those results are shown in Figures 3.1 and 3.2. Monthly average generation varied between 162 kW in August and 209 kW in January. Average hourly generation varied between 121 kW (3-4am) and 239 kW (6pm). It is believed that some of the "minimum" outliers are due to data monitoring issues.

[2] Stewart Island Electricity Supply (SIESA) Activity Management Plan (Part B – Asset-based) 2018 – 2028, June 2018

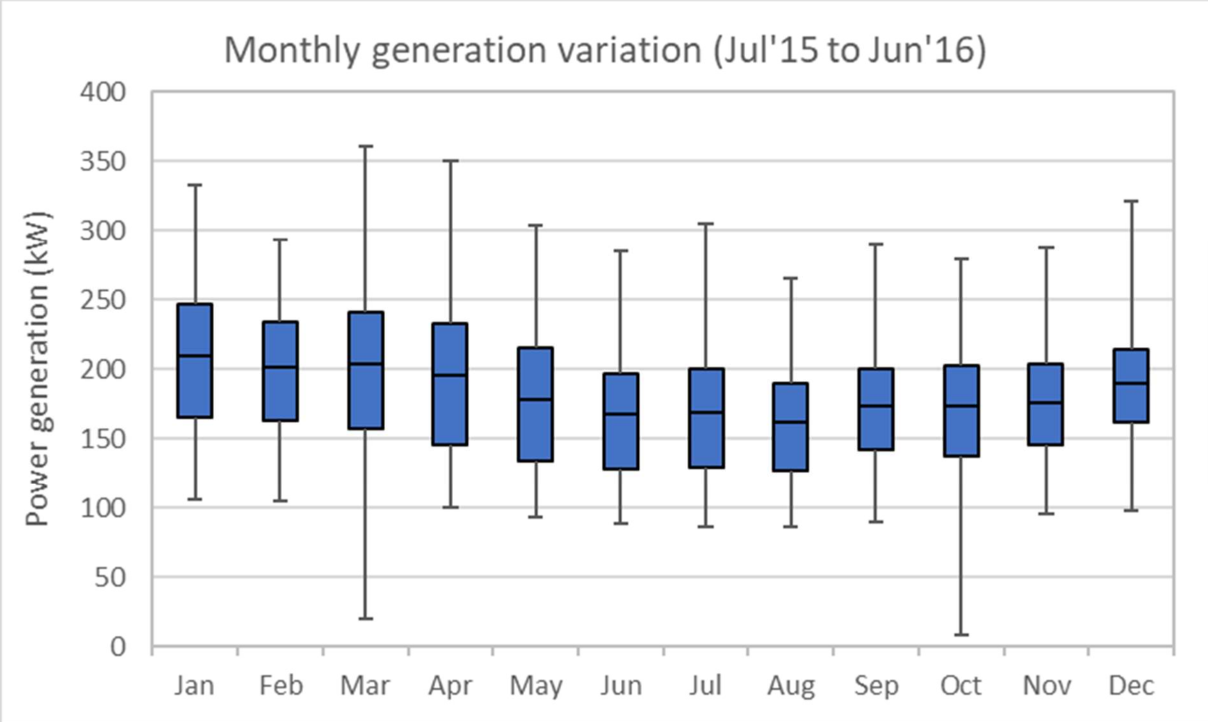


Figure 3.1. Summary of the average monthly generation on Stewart Island

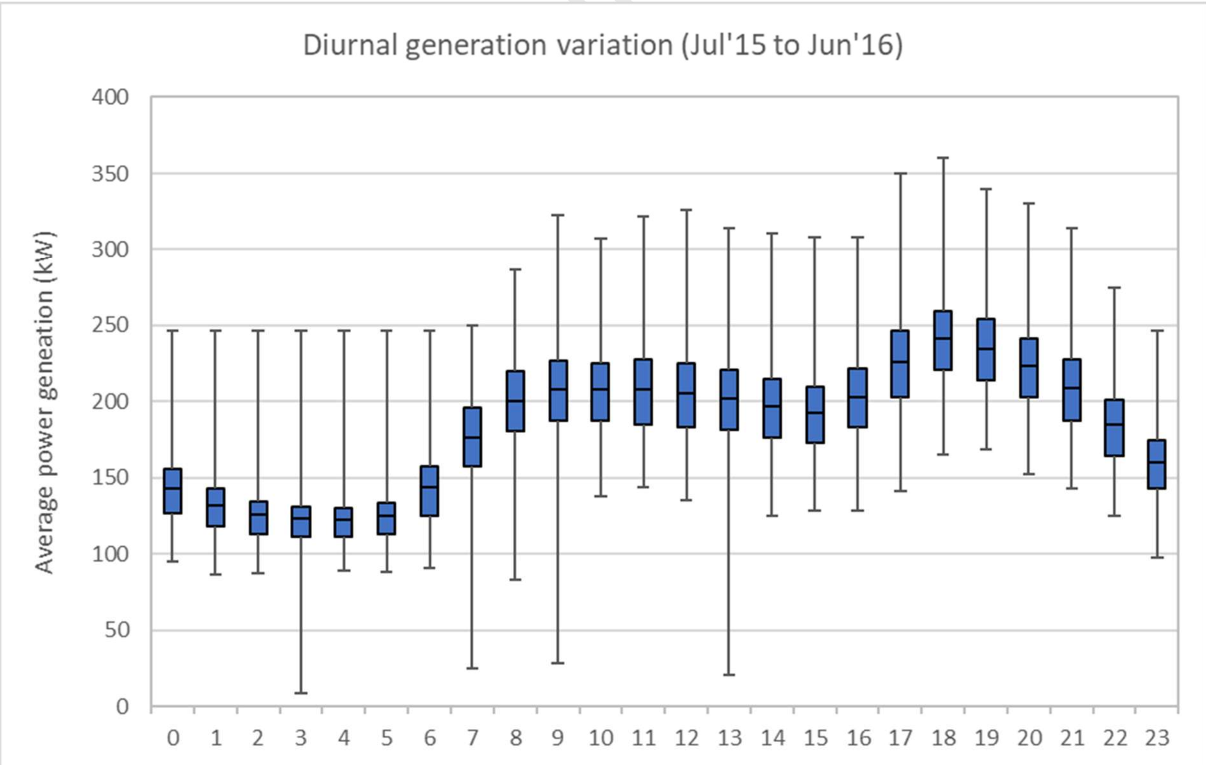


Figure 3.2. Summary of the average hourly generation on Stewart Island

In 2016, the McCutcheon report, calculated the marginal cost of electricity generation as 23 c/kWh and was essentially the cost of the diesel fuel. The current gensets operate at a production efficiency of 4.28 kWh/litre of diesel fuel. Assuming this same efficiency back in 2016, the diesel price would have been in the order of $0.98 / litre.

Southland District Council provided Stewart Island diesel prices, which included a fuel price and a handling charge. Those prices were available between January 2018 and May 2018. The total cost per litre is shown in Figure 3.3. Also shown in the figure is the New Zealand National diesel price, published by the Automobile Association (AA) for the period December 2017 to September 2018.

There is a similar trend in the two prices, the SIESA diesel price increasing by 14.1% between mid-March 2018 and late May 2018. During this same period the NZ National diesel price increased by 14.6%. Between mid-March and late August, the NZ National diesel price increased by 19.5%. Assuming this same increase in the SIESA prices, over a similar period, the cost of diesel is likely to be in the order of $1.22 / litre. At the generation efficiency stated above, the diesel cost per kWh of generation is now likely to be in the order of 28 c/kWh.

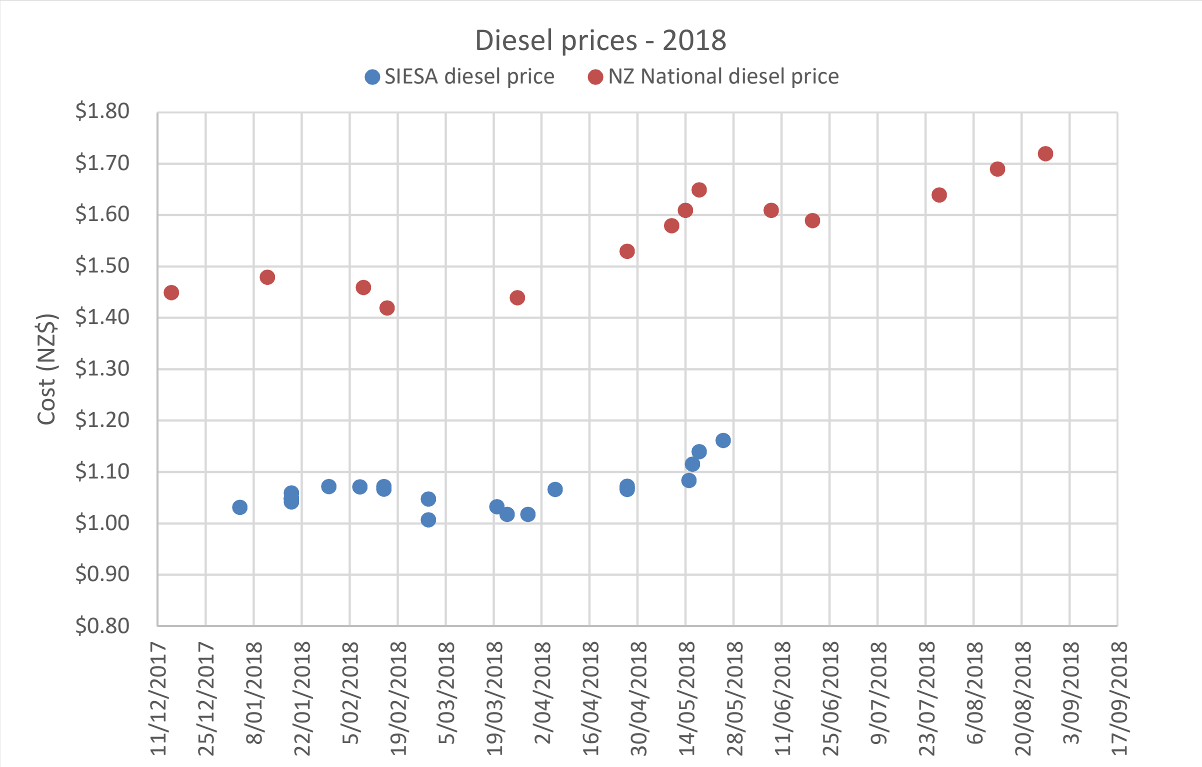


Figure 3.3. Diesel price variation over time

Reducing diesel consumption on Stewart Island will not only reduce the diesel fuel bill but will reduce operations and maintenance costs and increase the lifespan of the diesel gensets.

4 WIND MEASUREMENTS

Sources of good wind records on Stewart Island are limited, especially where such measurements are being used to determine the energy output from a wind turbine with a hub height of 30 m or more. The relatively dense vegetation on the island has an impact on measurements to at least the height of the trees and above. The most representative wind measurements are those undertaken by Energy3 at the quarry site for the three years between September 2014 and September 2017. These measurements were taken in a reasonable clearing and were taken at 30 m above ground level. Other measurements obtained and analysed were from a Fire and Emergency mast near the sewage ponds. That data was provided by Fire and Emergency through their service provider NIWA. Those measurements were however only recorded at 6 m above ground level and are significantly impacted by the surrounding vegetation. Wind data was also provided by Pioneer Generation from a 50 m met mast on their Flat Hill wind farm site near bluff. The Flat Hill site is very well exposed to the prevailing south-westerly wind and has about 30 km of open sea between it and Stewart Island. Any impact that Stewart Island itself has on the prevailing wind speed will have fully recovered over this distance.

4.1 QUARRY SITE MEASUREMENTS

Wind speed measurements were taken on a 30 m meteorological tower over 36 months between 28/08/2014 and 21/08/2017. The average measured mean of monthly wind speeds at 30 m was calculated as 5.48 m/s and at 29m was 5.25 m/s. The monthly variation in the wind speeds are shown in Figure 4.1 for the three different measurement heights.

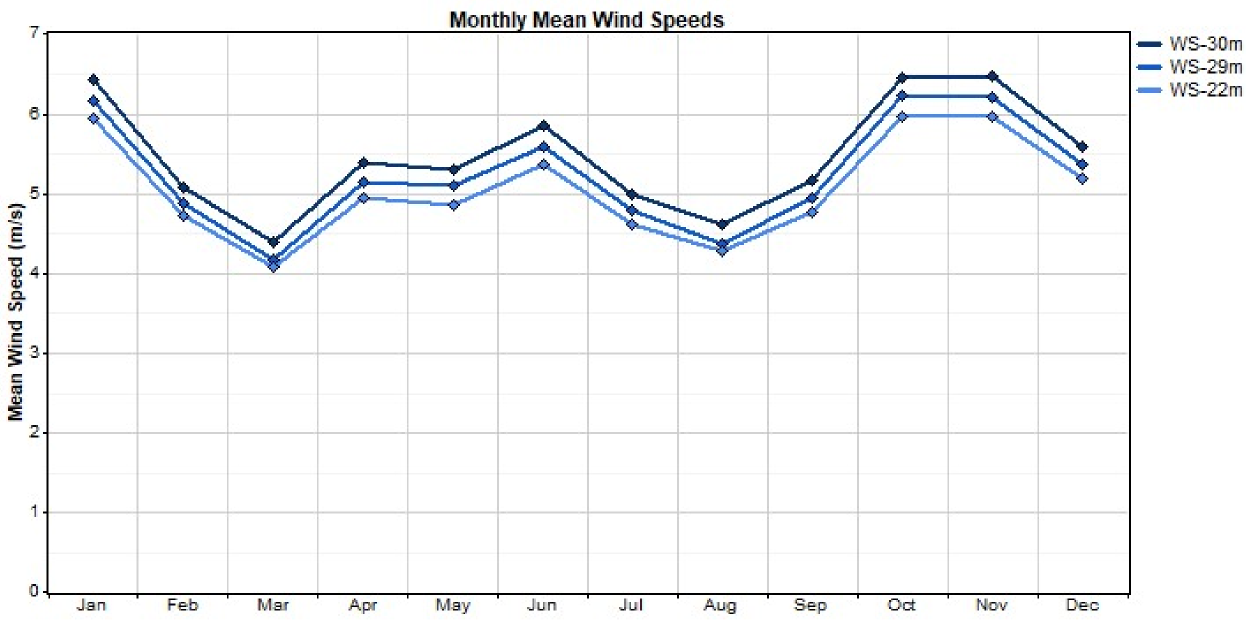


Figure 4.1. Monthly mean wind speeds at the Quarry site Stewart Island.

The diurnal wind speed profile is shown in Figure 4.2 for the three different measurement heights, together with the hourly temperature variation measured at the mast location. There is a strong relationship between the air temperature and the diurnal wind speed pattern which both peak at around 2pm. Various wind direction frequency distribution roses and combined wind speed and direction roses are shown in Figure 4.3.

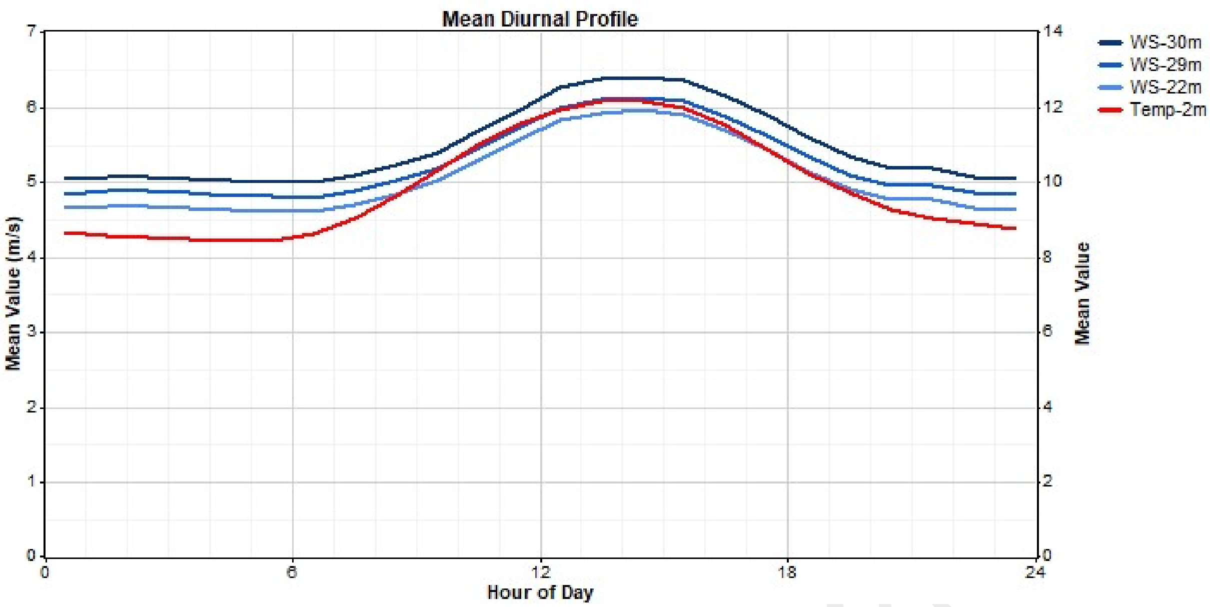
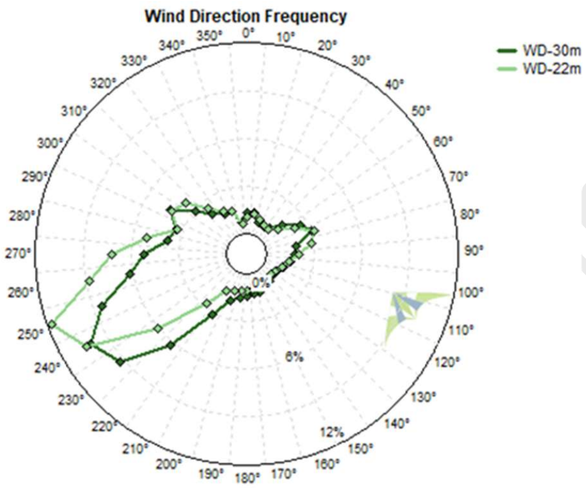
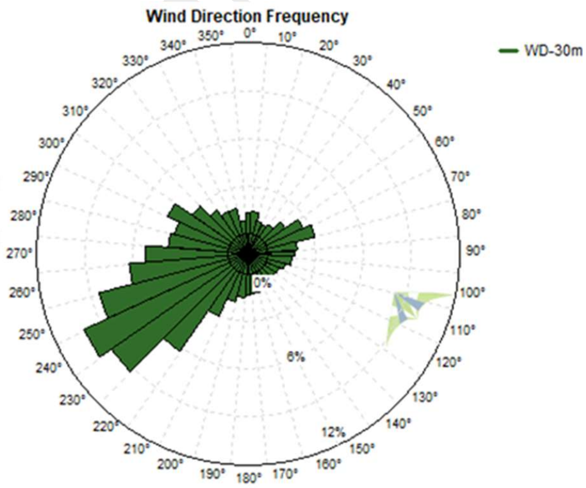


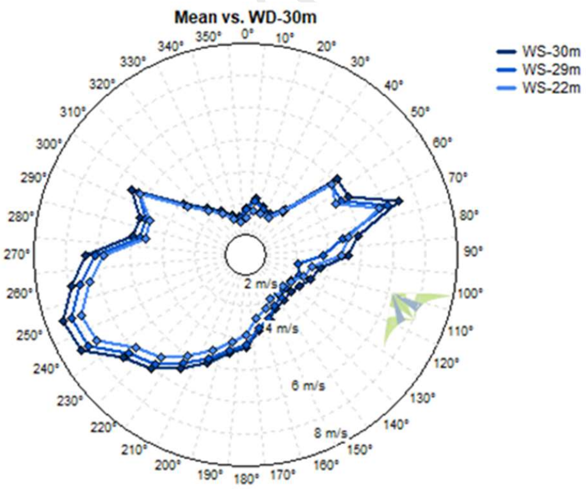
Figure 4.2. Diurnal wind speed distribution including temperature variation.



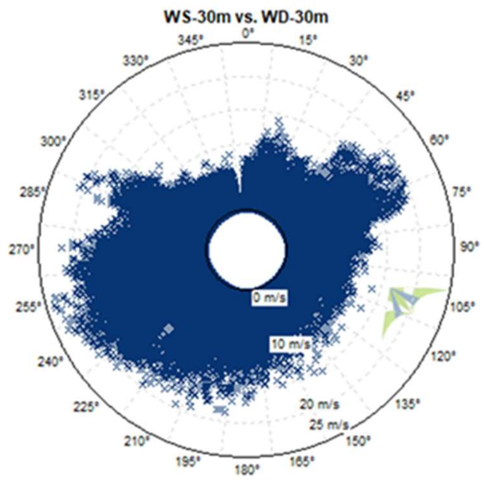
30m and 22m direction distribution (%)



30m wind direction distribution (%)



Wind speed (3 heights) & direction distribution



Scatter plot of wind speed & direction at 30m

Figure 4.3. Various wind speed and direction distributions.

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4.2 Sewage Ponds Measurements

Wind speed and direction data was provided by Fire and Emergency, through their agent NIWA, for a 6 m mast located at the sewage ponds site, west of Oban. As stated, the mast is only 6 m high and the vegetation in the surrounding area is of greater height that the mast itself. While the data is not of any real value from a wind turbine siting perspective, a few plots have been produced from that data.

Wind speed records were analysed for the period 1 July 2015 to 7 September 2018. The date covers a period of just over 3 years and the mean of the monthly mean wind speeds was calculated as 2.1m/s at 6m above ground level. The seasonal and diurnal wind speeds shown in the Figures 4.4 and 4.5 show similar trends to those measured at the Quarry site.

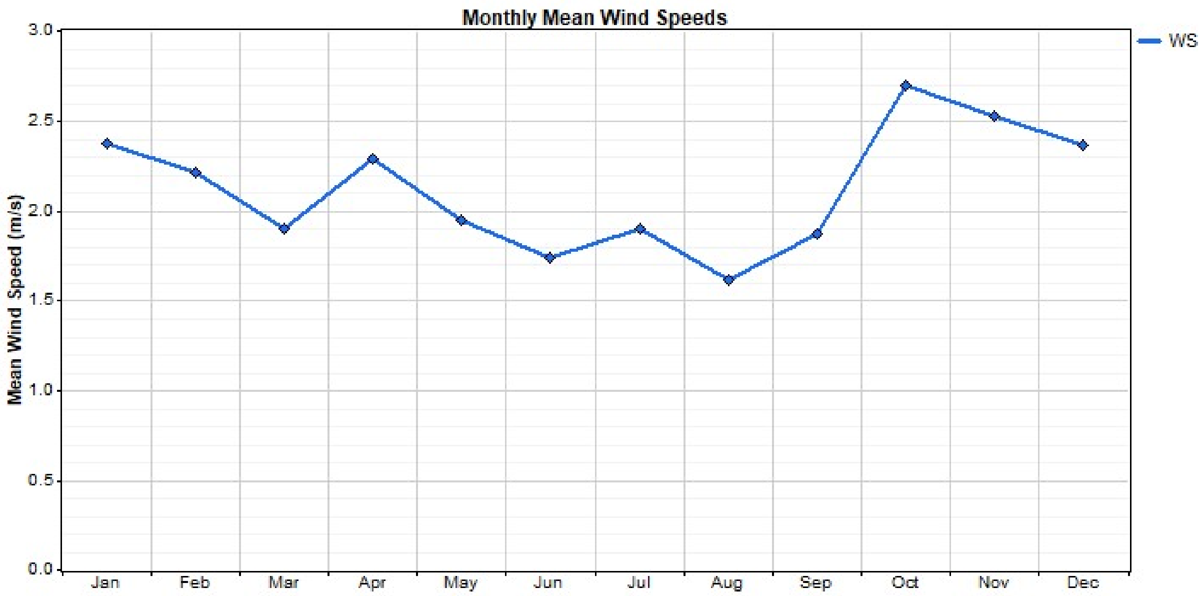


Figure 4.4. Monthly mean wind speeds at the sewage pond site Stewart Island.

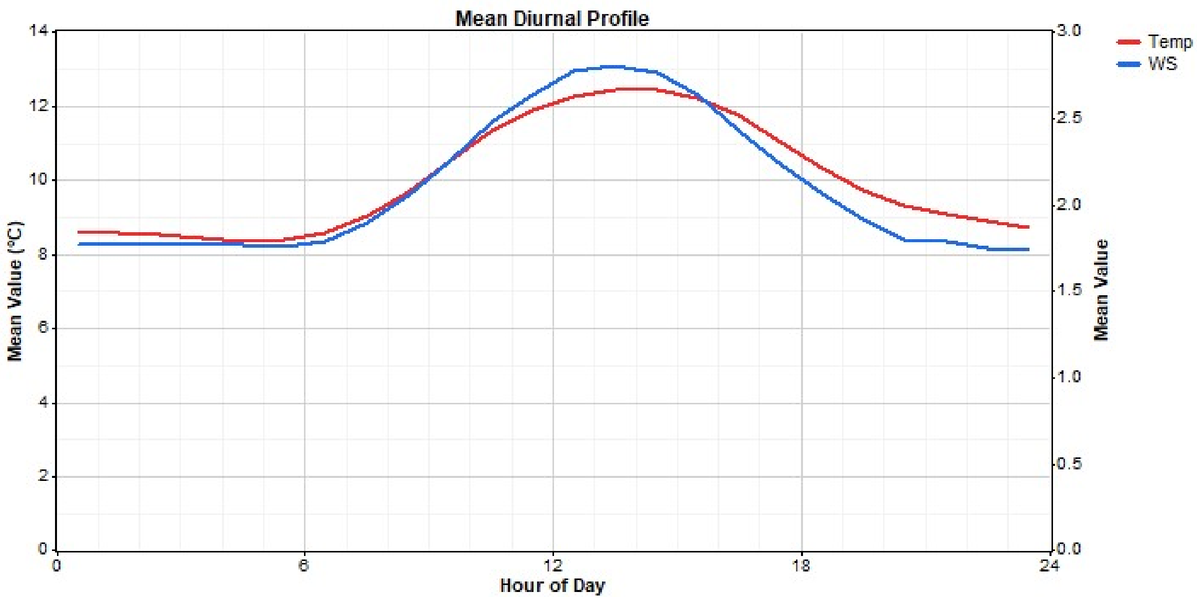


Figure 4.5. Diurnal wind speed distribution including temperature variation.

The most useful aspect of the data from the sewage ponds was to undertake a correlation check against that data from the Quarry site to confirm that there were no obvious changes in the data set. The overall correlation between the two sites had a R^2 of 0.71 using 112,507 co-incident data points. This is a relatively good correlation given the low measurement height of the sewage pond wind measurements. When correlating on a 12 direction basis, the three sectors making up more than 50% of the data had R^2 values of 0.77, 0.82 and 0.82.

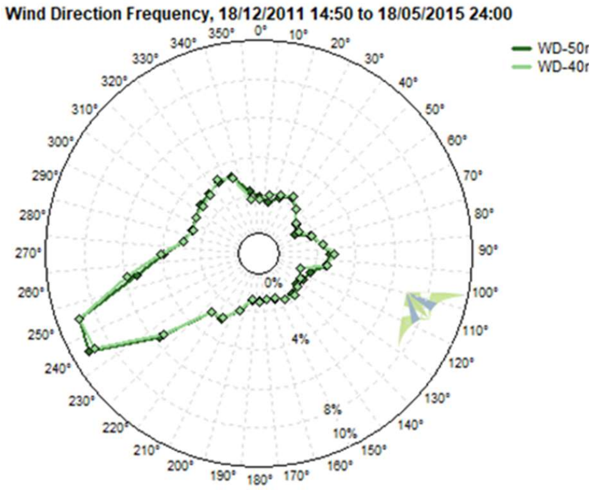
4.3 Flat Hill Wind Farm Measurements

Flat Hill wind farm data has kindly been provided by Pioneer Generation. Data was provided for the period 18 December 2011 to 2 October 2016. The data provided was from a 50 m guyed mast that continues to monitor wind data once the wind farm became operational. The wind records are impacted by the wake of the turbines in certain directions and for this reason we chose to analyse data for the period prior to the wind farm being commissioned. [redacted]

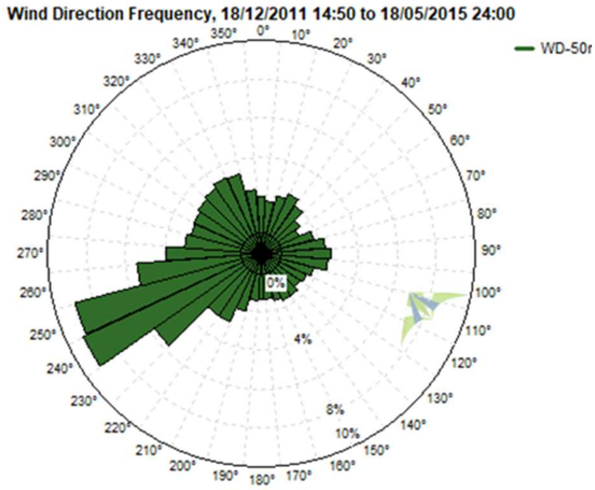
[redacted]

[redacted]

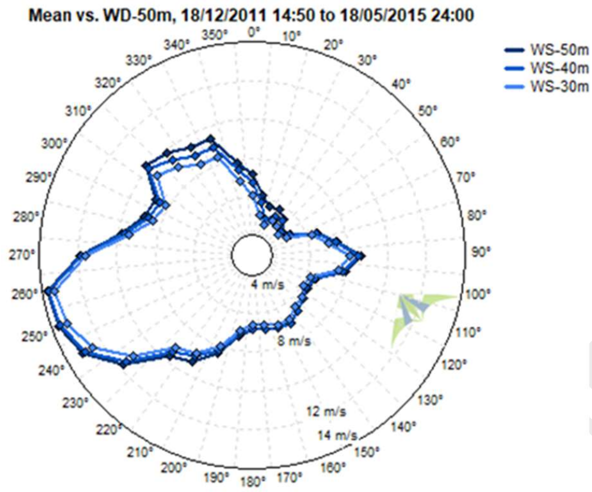
Figure 4.6. Diurnal wind speed distribution including temperature variation – Flat Hill.



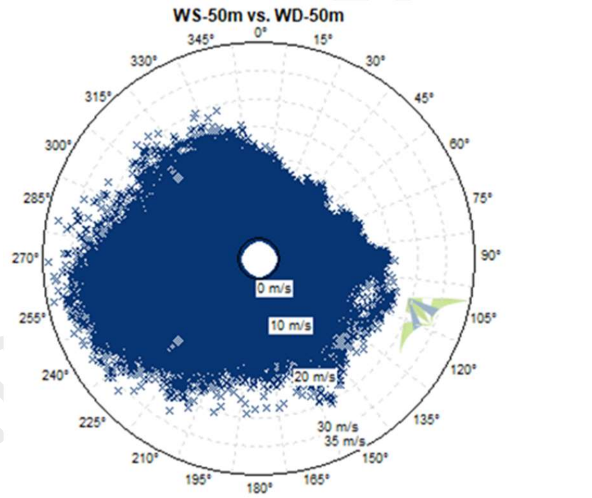
30m and 22m direction distribution (%)



30m wind direction distribution (%)



Wind speed (3 heights) & direction distribution



Scatter plot of wind speed & direction at 30m

Figure 4.3. Various wind speed and direction distributions – Flat Hill.

5 SITE VISIT

Consideration of possible wind turbine sites was given prior to the visit, by reviewing the previous reports and scanning topographical maps, aerial photos and the previously completed wind map. Given the high cost of construction of building new infrastructure (roads and power lines) on the island, the scope of realistic wind turbine sites was limited to within a few kilometres of Oban.

A number of possible sites were identified in advance, and some others were added to the list on seeing the terrain during the visit. The sites identified are shown in Figure 5.1 and the sections below summarise each of those sites. Some site photos are included in Appendix B.

Figure 5.1. Location of the sites identified.

In addition to visiting the sites identified, a few meetings were held as follows:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

5.1 MAMAKU POINT HEADLAND

A headland between Horseshoe Bay and Lee Bay, about 3 km north of Oban. With elevation reaching 120 m.a.s.l, the land appeared to have been cleared at some stage and still had some grassy areas. The highest part, however, has regenerating bush.

Installation of wind turbines at this site would require about 1.5 km of track. Connection to the network would require about the same distance of cable to the beginning of Lee Bay Rd. While these would probably have the same route (Cable buried in track), it would require clearance of trees. The site would also require tree clearance for optimum operation of wind turbines. Depending on the number of turbines and corresponding output capacity, it is likely the 11 kV transmission line back to the Hicks Road power station will need to be upgraded as this northern feeder is currently designed for a very low load.

There are a few houses at the southern end of the headland – about 800 to 850 m from the closest wind turbine location.

A feature of this site was the predator proof fence that had been erected by the previous owners to isolate the headlands and create a private ecological reserve. The current landowners [redacted] are continuing to develop the ecological reserve with the view of running an education centre.

[redacted]

5.2 Horseshoe Point

A headland between Halfmoon Bay and Horseshoe Bay, about 2 km northeast of Oban. At just under 100 m.a.s.l the area is covered in regenerating native bush with some patches of exotics. While it didn't appear to have any reserve status, it has a popular walkway around it. The land appears to be privately owned – multiple titles, and there are numerous houses adjacent to Horseshoe Bay Rd, with the closest house being approximately 600 m from a possible turbine location.

There is a flattish area on top, which is covered in regenerating bush. Contours appear favourable for access, less than 1 km, off Horseshoe bay Rd, but this has not been walked. The access would need to cross several properties as it is understood that the paper road in the area has unsuitable terrain.

5.3 Ackers Point

The headland at the southern end of Halfmoon Bay, is 68 m.a.s.l in elevation at its highest point, and relatively small in flattish area. The land, while privately owned, is a Scenic Reserve, and is primarily covered in regenerated native bush.

There are numerous houses nearby, the closest being about 450 m from a possible wind turbine location, and access would be quite difficult and likely to be very disruptive to the DOC walkway.

5.4 The Golf Course

The Golf Course at Wohlers Monument is only about 40 m.a.s.l but is well exposed to the prevailing winds. There is some adjacent private land that could site turbines, but there are a number of houses in close proximity, the closest at approximately 100 to 150 m from a potential turbine location.

This site is not to be considered any further due to the proximity of nearby houses.

5.5 The Airport, south of airstrip

The Airport is located on a relatively large flattish area at a general elevation of 80 m.a.s.l, about 1.5 km west of Oban. Access by road is good and connection to the line network is possible about 1 km away depending on the exact location of any turbines. It is well exposed to the prevailing winds and trees for the most part are regenerating Manuka.

The land is a mix of privately owned titles and DOC (Paterson Scenic Reserve), and the access along the airport runway.

It should be possible to place turbines in proximity of the runway and there are many examples of structures worldwide of relatively high structures (including wind turbines) near airport runways. Determining a suitable offset would involve consultation with the Civil Aviation Authority and Stewart Island Air. [redacted]. They also pointed out the restricted height zones around the airstrip which are included in the District Plan.

5.6 Sewage Ponds

The area around the sewage pons was observed from the air on the way in. The terrain around the sewage ponds appeared reasonably flat and exposed. A turbine site would need to be northwest of the sewage ponds to gain more elevation and exposure but would therefore require an access track through the bush. There is a Rural Fire Service weather station mast located adjacent to the sewage ponds, although it is only on a 6 m mast and surrounded by relatively high bush. The elevation of the sewage ponds is about 54 m.a.s.l. At about 1.2 km northwest, the terrain reaches elevations of between 100 and 120 m.a.s.l.

5.7 Quarry at Horseshoe Bay

This is the site of the wind monitoring completed by Energy3, commencing on 28 August 2014. The site has good access although up a relatively steep hill and has a reasonable clearing. The site has an elevation of 92 m.a.s.l and is reasonably exposed in the prevailing south west wind direction. There are houses within 300 m of the mast site, some of which may be screened from a turbine due to the topography in the area.

It was noted that E3's record resulted in a relatively low wind speed at 5.6 m/s.

5.8 Ridge above Hydro Site

This site was not visited due to lack of time. The site is however a significant distance from Oban. Using information in the previous study of renewable options (John McCutcheon Sep 2016), the hydro power station required a 9.5 km track to be built and was costed at $1.6m and would also require a similar length underground electrical cable at a cost of $1.5m. Any wind installation at this site would be disadvantaged to the order of $3.0m unless the intent was to complete it as part of a wind-hydro scheme.

6 WIND FLOW MODELLING

The output from any wind turbines sited on Stewart Island is extremely dependent on the annual mean wind speed at the turbine locations. Figure 6.1 shows the energy output from three possible wind turbine models (two different manufacturers) in a range of different wind speed conditions. Two of the turbines are rated as Class III and are only suitable up to annual mean wind speeds of 7.5 m/s without specific load analysis. The third turbine, which has a smaller rotor (21m) is a Class I turbine and can be sited in wind speeds up to 10 m/s.

In order assess the possible production from a wind turbine at the two most suitable sites identified, wind flow modelling has been completed by Vortex of Spain. They have a wealth of experience in undertaking wind modelling and mapping world-wide. Vortex have completed analysis on Stewart Island based on their "Farm" product and have calculated wind speeds (mean, extreme and turbulence) at a number of different heights. The results of that analysis are shown in Figures 6.2 to 6.4. In addition to the mean wind speeds, the extreme wind speeds and turbulence intensity levels have been calculated. Examples have been included in Appendix A for Mamaku Headland, identified as Point 1 and the Airport Site, identified as Point 4.

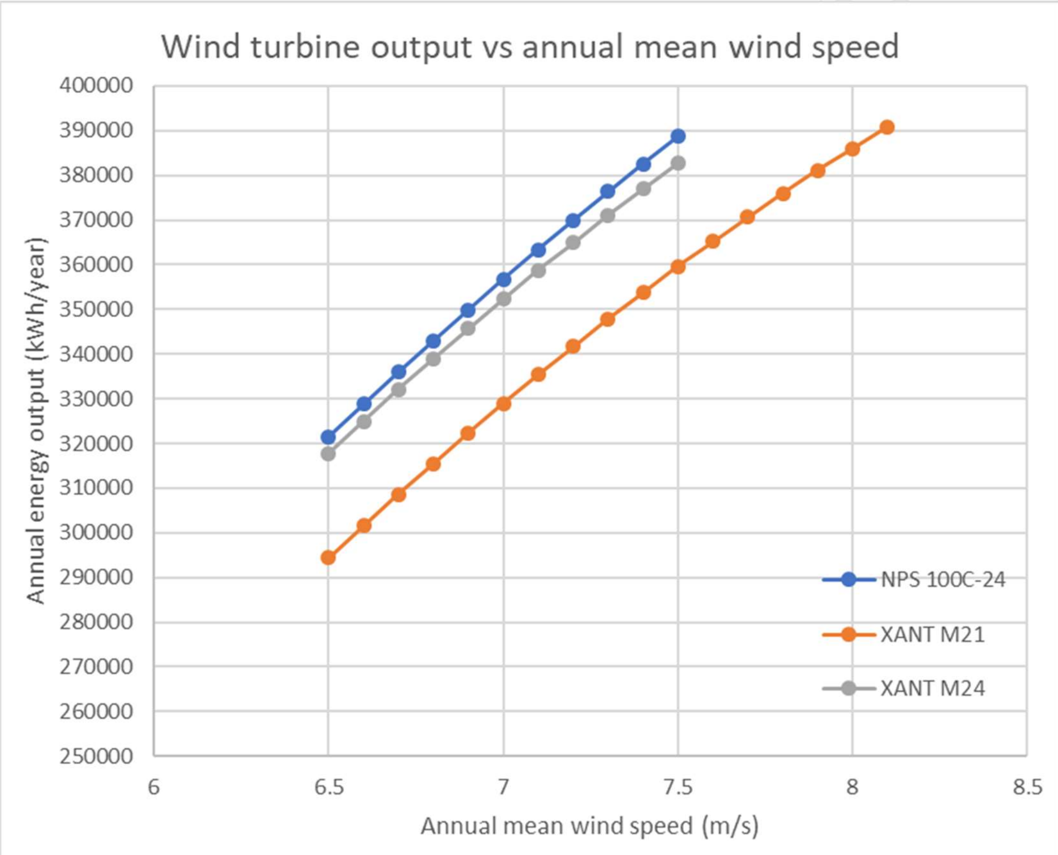


Figure 6.1. Wind turbine output versus annual mean wind speed.

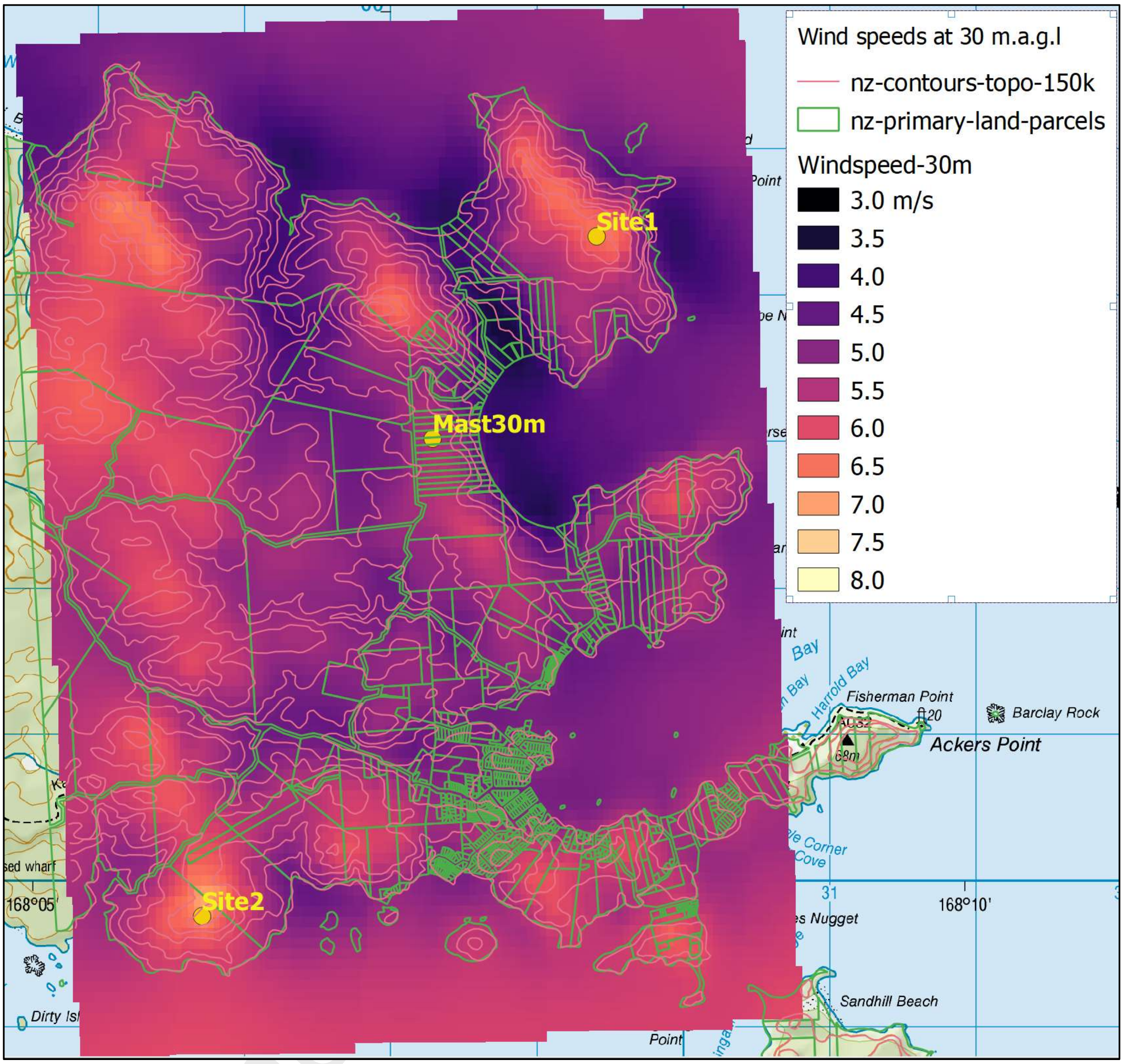


Figure 6.2. Modelled wind speeds at 30 m above ground level. (Mamaku = Site 1, Airport = Site 2)

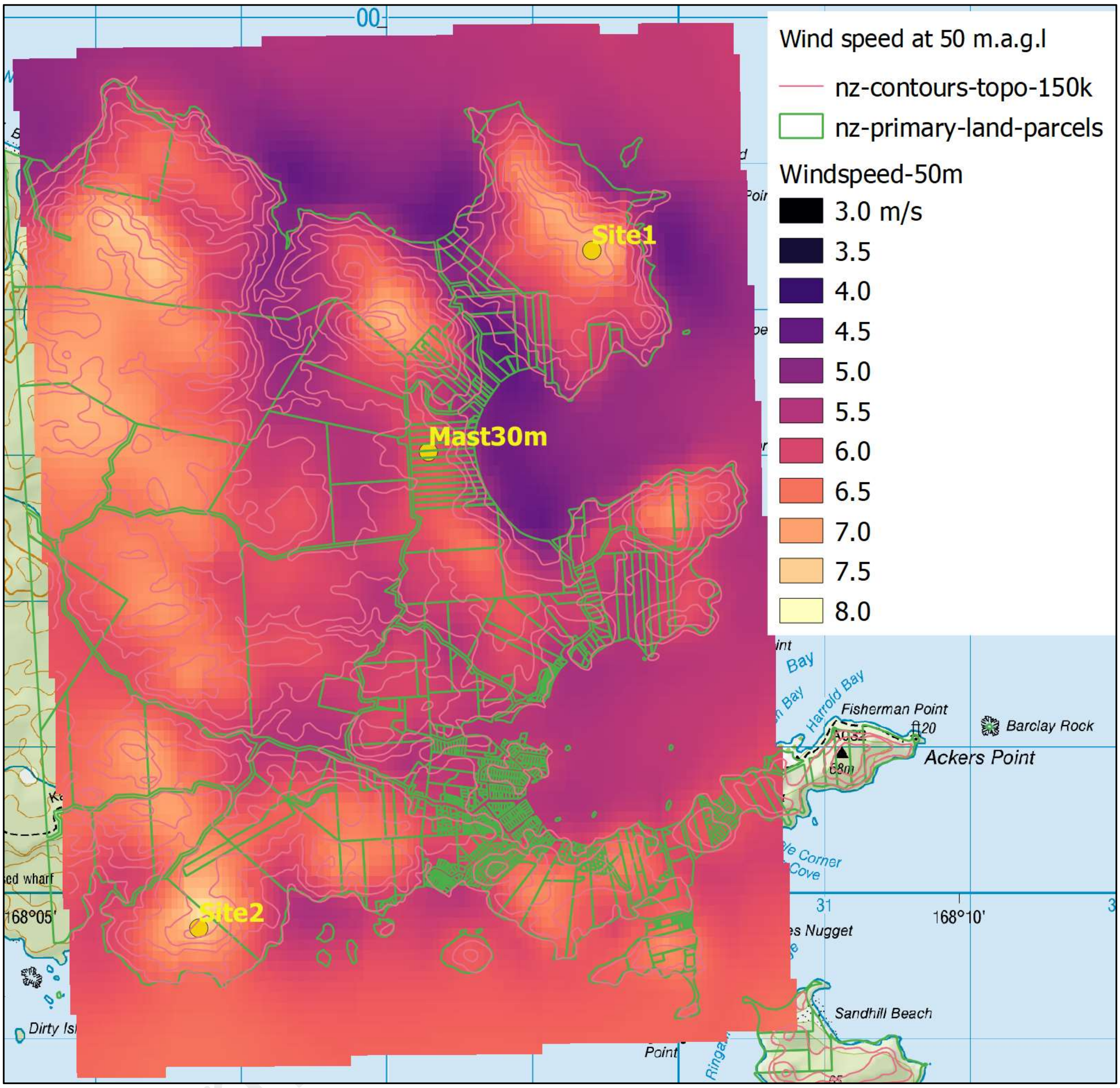


Figure 6.3. Modelled wind speeds at 50m above ground level. (Mamaku = Site 1, Airport = Site 2)

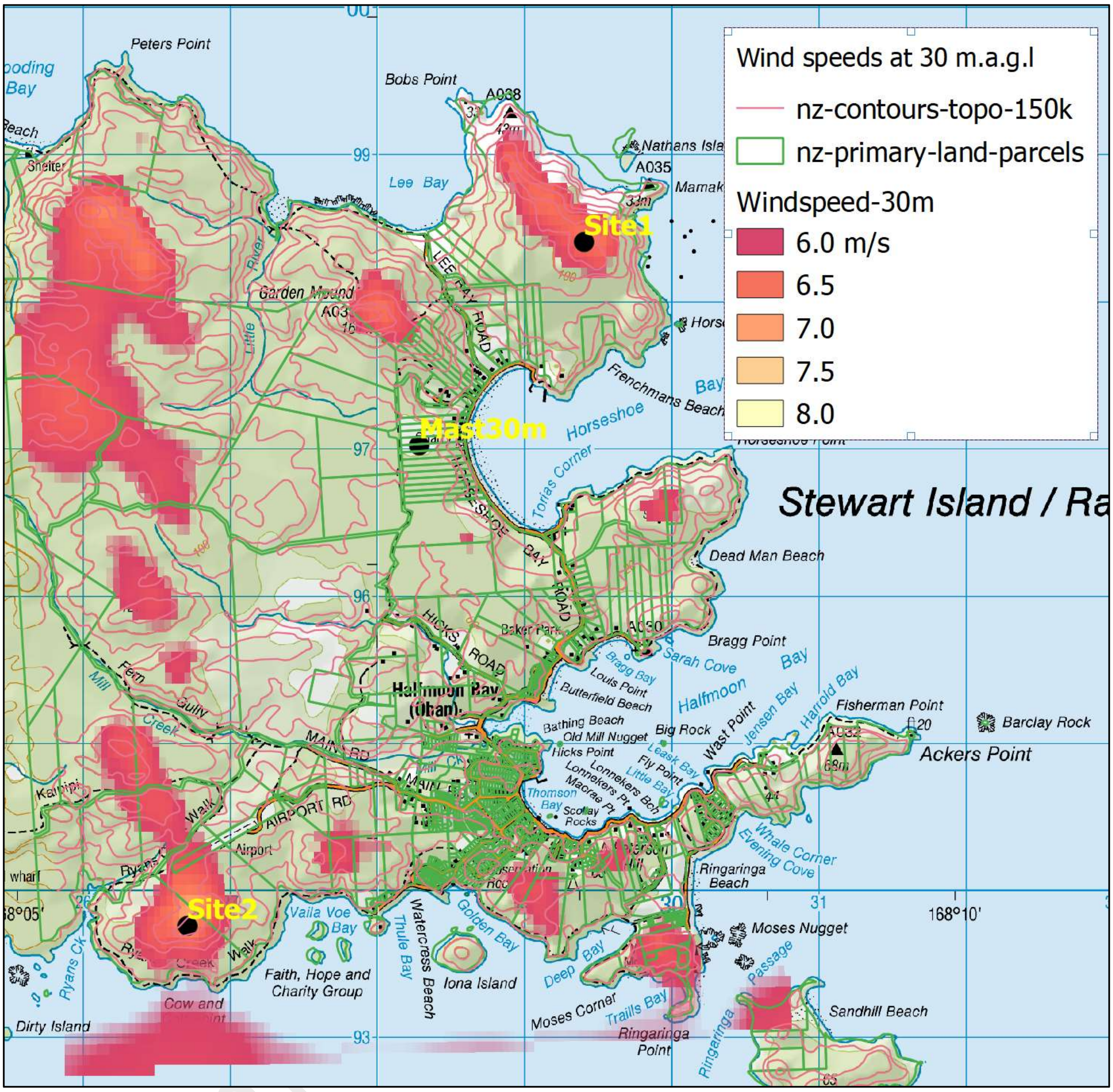


Figure 6.4. Modelled wind speeds at 30 m above ground level showing $V_{mean} \geq 6.0$ m/s.

(Mamaku = Site 1, Airport = Site 2)

Details of the Vortex predictions for the Mamaku Headland site and the Airstrip site are included in Appendix A and are referred to as Points 1 and 4 respectively there.

The Vortex modelling has a resolution of 100 m grid spacing. In order to establish an average "wind farm" wind speed, three adjacent modelled wind speeds were used to represent three separate wind turbine locations. Those results are listed in Table 6.1.

Vortex	Site	Vel_30m	Vel_50m	α	Vel_38m	Vel_55m
ID		30	50	Shear exp	38	55
(Appendix A)		(m/s)	(m/s)		(m/s)	(m/s)
Point 1	Mamaku	6.5	7.2	0.200	6.8	7.3
Point 2	Mamaku	6.4	7.1	0.203	6.7	7.2
Point 3	Mamaku	6.5	7.1	0.173	6.8	7.2
Average	**Mamaku**	**6.5**	**7.1**		**6.8**	**7.3**
Point 4	Airstrip	7.1	7.7	0.159	7.4	7.8
Point 5	Airstrip	7.0	7.6	0.161	7.3	7.7
Point 6	Airstrip	6.4	7.1	0.203	6.7	7.2
Average	**Airstrip**	**6.8**	**7.5**		**7.1**	**7.6**

Table 6.1. Modelled wind speeds at Mamaku Headland and the Airport.

From the wind speed modelling it is clear that both the Mamaku Headland site and the Airport site have far greater wind speeds than many of the other locations around Oban. Of those two sites, the Vortex wind modelling shows the Airport site to have 4% to 5% greater wind speeds than the Mamaku site.

The Vortex modelled wind speeds at 30 m.a.g.l are 19% to 24% greater than the wind speeds measured at the Quarry site at 30 m.a.g.l. Given the significant increase in wind speeds and the impact that this has on the economics of the project, it is recommended that some further validation of these modelled results should be completed prior to completing a final economic assessment but could be done at the same time as any consent work. Wind monitoring would require the clearing of some vegetation in order to install a monitoring mast.

Details on the wind analysis completed by Vortex are shown in Figures 6.5 to 6.7. Vortex runs Weather Research & Forecasting Model (WRF) to a resolution of 100 m. WRF is a next generation mesoscale numerical prediction system designed to serve both operational forecasting and atmospheric research needs. The meteorological input into the WRF model comes from three sources; NCEP (National Centres for Environmental Prediction), NASA (National Aeronautics and Space Administration) and ECMWF (European Centre for Medium Range Weather Forecasts). Data for two of the sets goes back to 1979 while the third set commences in 1980. It is noted that the data shown in Figure 6.5 is shown in UTC (Coordinated Universal Time) also known as GMT (Greenwich Mean Time).

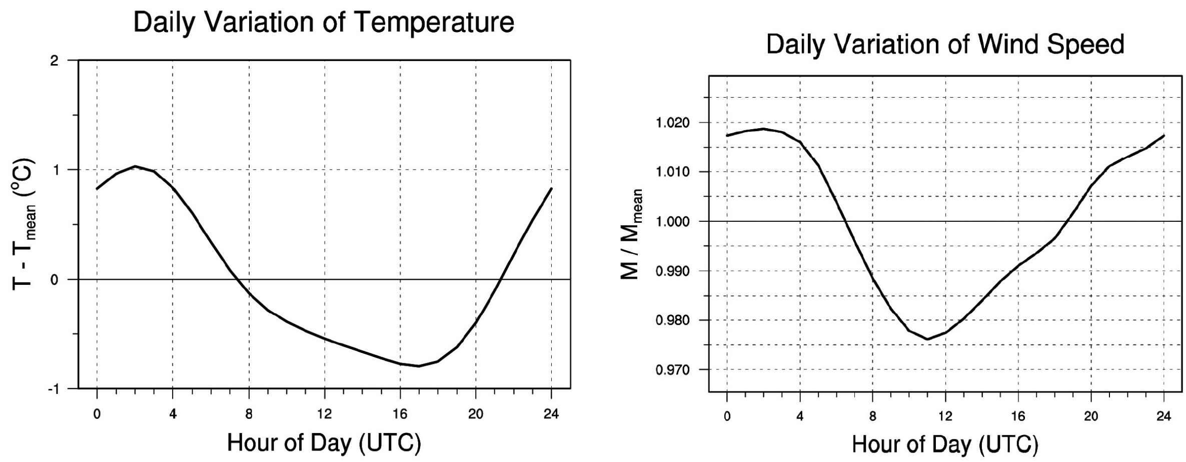


Figure 6.5. Wind analysis by Vortex. (Note 12 hour time difference).

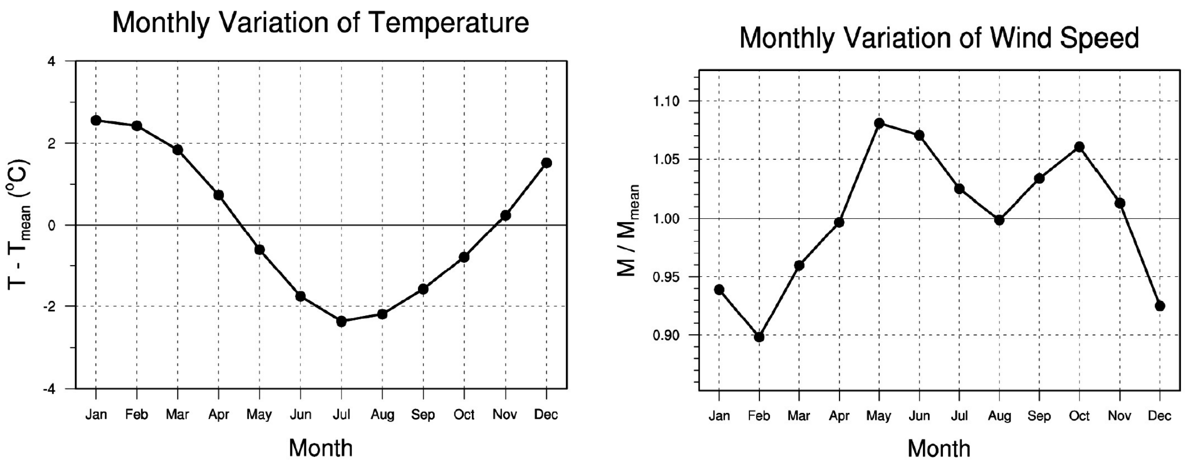


Figure 6.6. Wind analysis by Vortex. Monthly temperature and wind speed variation.

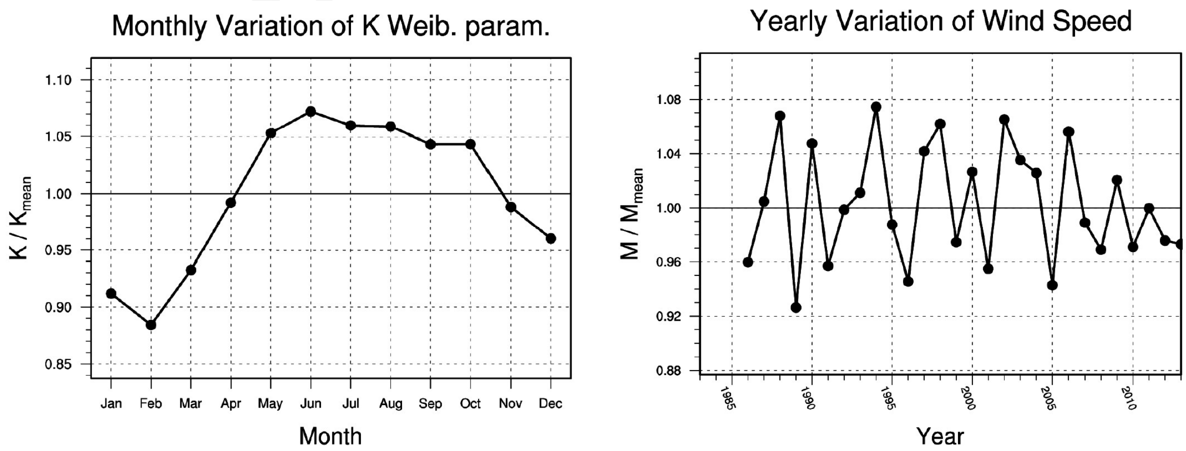


Figure 6.7. Wind analysis by Vortex. Monthly shape factor and annual wind speed variation.

7 WIND TURBINE OPTIONS

Given the infrastructure on Stewart Island, it is considered that smaller scale wind turbines would be more suitable for installation on the island. Two turbines which have been assessed as suitable options are the Northern Power Systems NPS100-24 (95 kW) turbine and the XANT M24 (95kW) turbine. The details of those two turbines are listed in Table 7.1. The XANT turbine is available in two different rotor diameters and free standing and guyed tower options. Various options for this turbine have been considered.

Manufacturer	**Northern Power Systems (NPS)**	**XANT**
Model	NPS100-24	XANT M-24 / XANT M-21
IEC Class[1]	IEC WTGS IIIA	IEC III / IEC IA
Design life	20 years	20 years
Rated power (kW)	95 kW	100 kW
Rotor diameter	24.4 m	24 m / 21 m
Hub heights	22m / 29.3 m / 36.6 m	31.5 m / 55 m (tilt) 38m free standing
Power control	Stall regulated	Stall regulated including aero-elastic swept planform blades
Number of blades	3	3
Rotor orientation	Upwind	Downwind
Yaw control	Active yaw	Semi auto yaw (with yaw damping)
Rotor speed	Variable (max 49.7 rpm)	Variable
Drive	Direct drive	Direct drive
Generator	Permanent Magnet	Permanent Magnet
Cut-in wind speed	3.0 m/s	3.0 m/s
Rated wind speed	12.0 m/s	11.0 m/s
Cut-out wind speed	25.0 m/s	20.0 m/s
Sound power level	103 dBA at V_{rated}	98.1 dBA V_{rated}
Weights & Dimensions	36.6 m hub height	31.6 m guyed tower
Upper tower section	12t	2.9 t (L = 10m D = 1.058m)
Mid tower section	Incl	2.3 t (L = 10m D = 0.905m)
Lower tower section	Incl	1.9 t (L = 10m D = 0.905m)
Gin pole	N/A	1.5 t (L = 9m D = 0.580m) 2 off
Blade		0.285t (L = 10m) 3 off
Hub	incl	0.49t (L = 1.25m)
Nacelle	6.9t	5.2t (L = 1.47m W =1.53m H = 1.58m)

Note 1:
Class III, V_{avg} = 7.5 m/s, V_{ref} = 37.5 m/s, V_{e50} = 52.5 m/s
Class 1, V_{avg} = 10.0 m/s, V_{ref} = 50.0 m/s, V_{e50} = 70.0 m/s

Table 7.1. Wind turbine characteristics

Northern Power Systems (NPS) are headquartered in Vermont USA. NPS manufacture a 60 kW and a 100 kW wind turbine which have similar configurations using a direct drive generator. Since these products were introduced in 2009, the company has produced over 400 units and also produces a load control and battery storage system for wind diesel integration. While their turbines are based on a tubular free-standing tower, they are considering the introduction of a hinged tower option, however at this point in time, assembly of that turbine still requires significant crane input.

XANT are a newer manufacturer of small wind turbines. They are based in Brussels, Belguim and commenced operations in 2011. As at August 2018, they had installed 10 turbines, including two turbines in Scotland and two in Alaska. Other units are installed in Singapore and Vanuatu. One of the possible benefits of the XANT turbine is that it is available in a tilt-up tower option (either 32 m or 55 m hub height) which is supported by guy wires. This reduces the crane requirement. Installation of the 95 / 100kW turbine can be achieved with access to a machine having a 5t lifting capacity to 2 m above ground level. The 32 m tilt-up tower option turbine is shipped in a single container while the tubular steel tower or the 55 m tilt-up tower require two containers to ship a single turbine. The 55 m tower also allows the turbines to harness greater wind speeds.

The two turbines have reasonably similar specifications however the biggest difference is that the XANT turbines are downwind machines and don't have an active yaw drive, but instead rely on the wind to orientate the nacelle in the correct orientation. The other big difference is that the XANT turbine is designed to Class I wind conditions (using a 21 m rotor) and can therefore be sited in locations with wind speeds of up to 10 m/s. The 24 m rotor XANT option and the NPS turbines are both only suited for wind conditions up to 7.5 m/s and both rated at 95 kW. This is another reason to confirm the site wind conditions.

Roaring40s Wind Power believes that the tilt-up XANT turbine could be transported to Stewart Island using the available freight ferry and installed using earth moving equipment already based on the island.

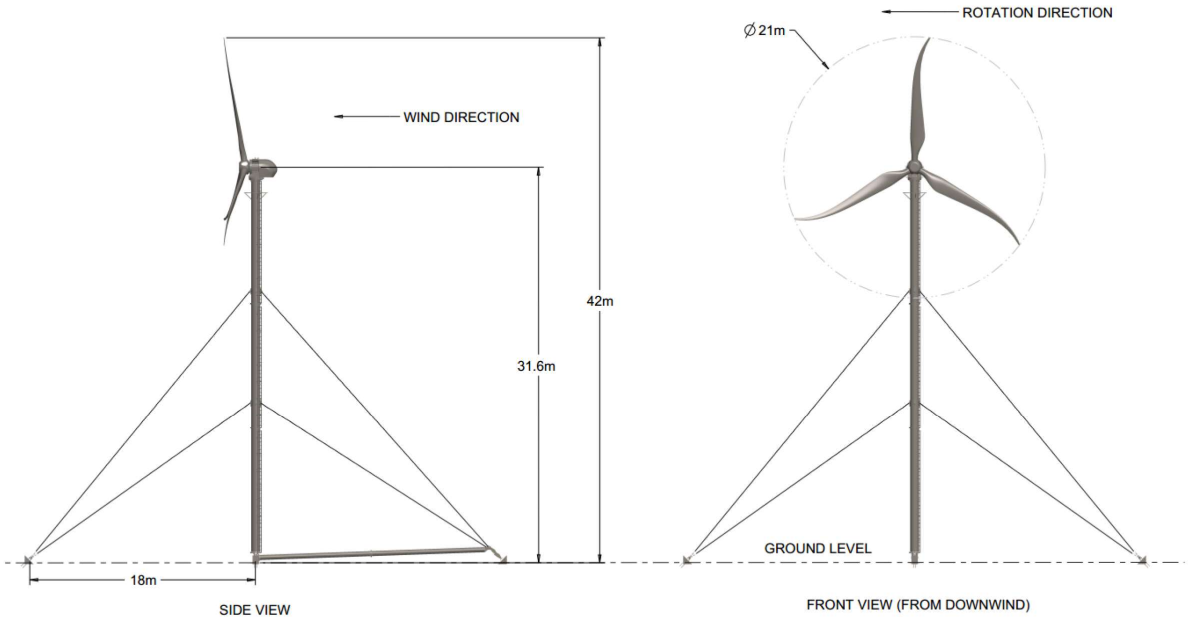


Figure 7.1. Diagram of the XANT M-21 with hub height of 31.6 m.

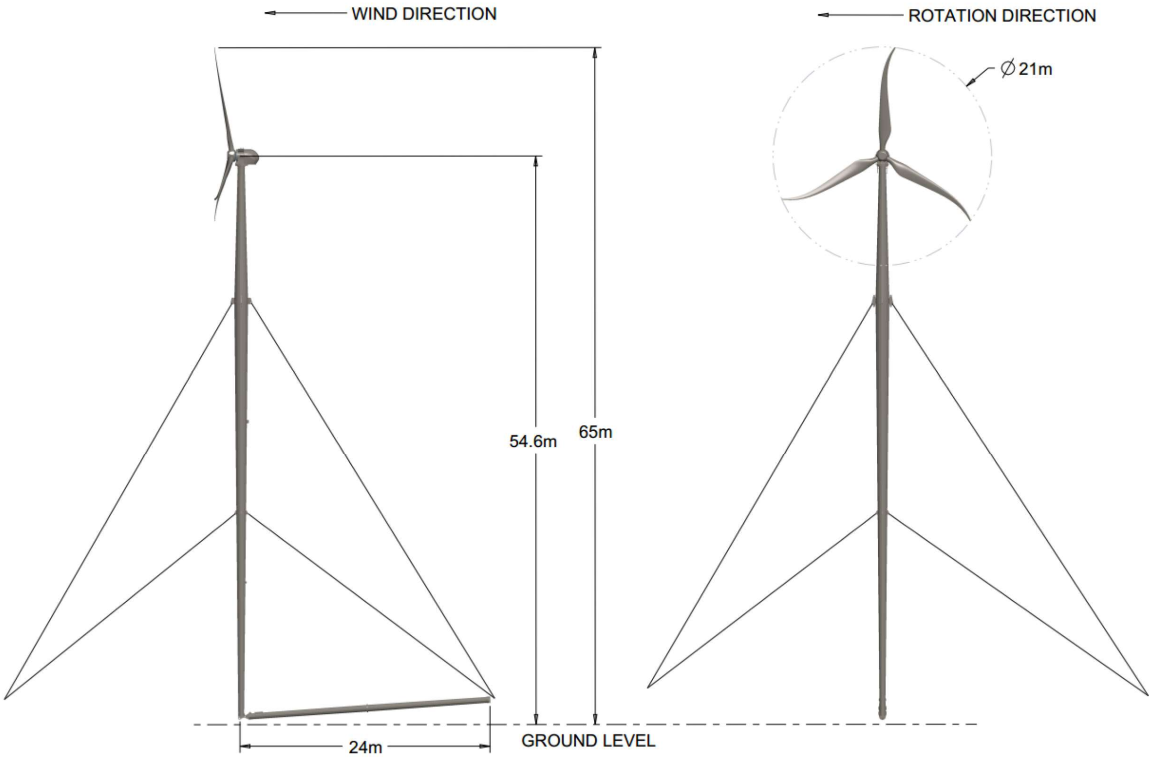


Figure 7.2. Diagram of the XANT M-21 with hub height of 55 m.

Figure 7.3. Photo of the tilt-up XANT turbine.

8 WIND TURBINE CONSTRUCTION

Construction will be dependent on the choice of turbine as discussed earlier. The tilt up option doesn't require the barging of a crane to Stewart Island, has a smaller concrete requirement and ships in a single 40 foot shipping container. It does however have a slightly higher capital cost and has a lower hub height at 32 m and hence lower wind speeds. For the purposes of this assessment Roaring40s has considered a range of scenario to represent the various options using the two turbines identified. That range is considered representative of the likely cost of wind generated electricity on Stewart Island.

8.1 TRANSPORT TO NZ

Transport of items such as the turbines and their related components is relatively straight forward and they are shipped in standard shipping containers. The number of containers depends on the turbine model and tower height. South Port in Bluff has container handling facilities. Mediterranean Shipping Company (MSC) call in at Bluff weekly. They are the second largest container liner in the world behind Maersk and have been calling in at Bluff for just over 10 years. Shipping turbine components direct to Bluff will save on local New Zealand transport and double handling. The deep water port at Bluff can be used as the staging point to barge equipment over to Stewart Island and turbine components can be stored temporarily at Bluff prior to shipping to Stewart Island, and broken down into smaller loads if necessary.

8.2 TRANSPORT TO STEWART ISLAND

Transport of items to Stewart Island using 'traditional' means is limited to loads of about 5 tonnes, and there are some concerns about the structural integrity of the wharf at present however this is likely to be resolved by the time a project occurs, if that outcome is reached. In recent times a self-contained Scania genset unit was shipped to the Oban wharf and off-loaded there. It had a weight of about 5 tonnes and was shipped on the local freight ferry owned and operated by Rakiura Shipping.

It appears at this stage that the charter of a ramped barge for transporting all the project loads to Stewart Island is the most practical option, especially where an 80t to 100t crane is required to install a wind turbine. This is a relatively infrequent occurrence for work on Stewart Island but was used for the transport of the recent gas drilling exploration rig at Horseshoe Bay. The company that shipped some of the heavy equipment over for that work was Nautilus Pacific.

The barge would operate out of Bluff Harbour, however there are no facilities to drive load onto the barge. The 90t crane barged over for the drilling project was indeed lifted onto the barge using the South Port harbour cranes. A special jetty / causeway was constructed of rockfill in Horseshoe Bay for off-loading the drilling rig parts, which remains there today. Subject to some minor upgrade, it should be suitable for use for off-loading the project equipment and materials.

8.3 TRANSPORT ON STEWART ISLAND

If a large crane needs to be barged to the island, equipment will be landed at the rockfill jetty in Horseshoe Bay. The preferred wind farm site is approximately 5 km from this location. The roads on Stewart Island are in good condition and there does not appear to be any vertical and horizontal alignment constraints for turbines of the size envisaged for this Project.

There are, however, two bridges along the route that may require some temporary strengthening to accommodate the heavier loads. These two bridges are located immediately north of Oban and are two river crossings. They are relatively short in length.

Equipment that is barged over would likely be loaded on to a trailer or a truck, on the barge, such that it can be driven off and transported directly to the site.

If the tilt-up turbine option was selected, it could be landed at the Oban wharf and no bridge strengthening would be required if the components were to be installed at the airport site.

8.4 Construction Materials

Most construction materials will need to be transported to Stewart Island. While it may be possible to source local rock for road and turbine platform and track construction, concrete aggregate will have to be sourced and transported from Bluff.

This applies to other general construction materials such as reinforcing steel, timber, ducting etc, and specialised materials such as electrical and communications cable.

8.5 Site Roading and Turbine Platforms

The preferred site will require about 350 m of purpose built track and would need to be approximately 3.5 m wide for truck / crane access. The access track would start on the south eastern end of the airstrip.

Vegetation would need to be cleared around the location of the turbine. If the guyed turbine option was to be installed, clearance would need to be about 40 m by 60 m for the 32 m tower while for the 55 m tower it would need to be approximately 50 m by 90 m. It is considered that the road could form part of this clearance. For the free standing tower options, a clearance of about 30 m by 30 m would be required as shown in Figure 8.1. The area below the crane would need to be of sufficient load bearing capacity for the lifting operations and the use of steel plate to distribute the load may be cost effective solution.

Geotechnical investigations would need to be completed prior to confirming a foundation design. It is considered that due to the size of the turbines, geotechnical investigation would need to be undertaken to a depth of about 10 m. In order to achieve this, a Cone Penetrating Test (CPT) rig will be required. There are smaller suitable rigs that could easily be transported over on the usual ferry, to enable such testing to be completed.

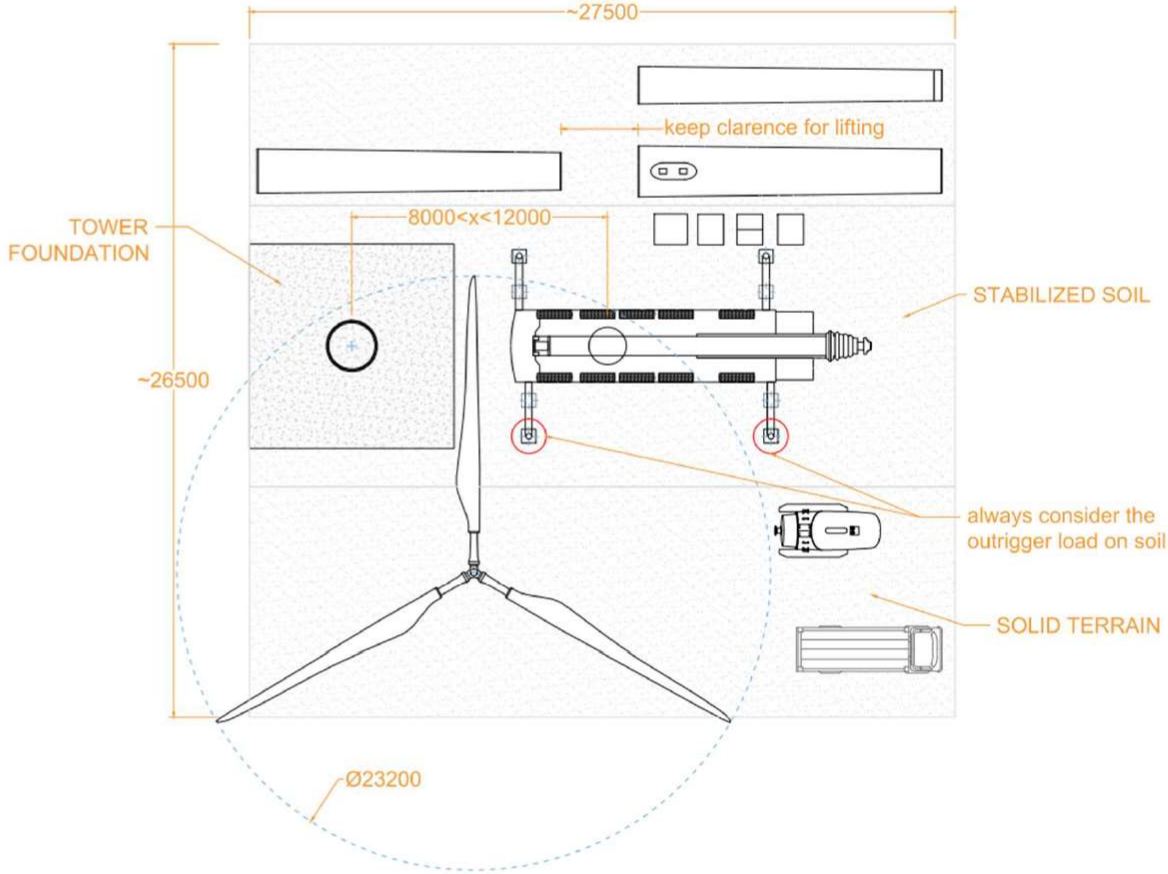


Figure 8.1. Indicative site layout – Northern Power Systems 95 kW turbine.

8.6 ELECTRICAL CABLING AND NETWORK UPGRADE

The turbines generate at 400V and would require a 400V / 11 kV transformer. For the NPS free-standing tower option it is possible to locate the transformer in the base of the tower. The tilt-up tower would require a transformer enclosure and the shipping containers have nee used for that purpose. It is recommended that the electrical connection between the turbines be underground but the connection back to the local network could be overhead. At the airport site, if overhead line is to be used, it will need to be setback the appropriate distance from the airstrip itself.

For the Airport site, the connection to the network would likely be at the intersection of Main Road and Back Road or the intersection of Main Road and Airport Road. It is understood that if the connection were at Back Road, approximately 90 m of existing network line may need to be upgraded from 25mm^2 conductor to 50 mm^2 conductor depending on the number of turbines installed. A new connection line of 1,500 m to 1,800 m would be required.

For the Mamaku Headland site, it is likely that the majority, of line from the end of Horseshoe Bay Road, back to within 670m of the Hicks Road power station would need to be upgraded from 25mm^2 conductor to 50 mm^2 conductor, again depending on the number of turbines installed. This is a length of about 2,500 m. In addition the Mamaku Headland site would require about 1,000 m of new connection line.

In addition to the electrical connection, communications would need to be provided between the wind turbines and the tower station.

8.7 Turbine Erection

The free standing turbine options require a crane of capacity of approximately 80t to 100t. The crane is require to lift 7t to about 40 m.

For the XANT tilt-up tower options, the turbine is assembled on the ground and then winched into place, a single winch being able to be used on multiple wind turbines. The XANT turbine can be assembled on the ground using a machine capable of lifting 5 t to 2 m height. This options significantly reduces the size of the equipment required to be barged over to Stewart Island.

Figure 8.2. Foundation example for free-standing Northern Power Systems 95 kW turbine.

9 RESOURCE CONSENTS

There are two elements for the consenting process for a wind generation proposal on Stewart Island:

- The Resource Consents to construct and operate and wind farm.
- The need for a Concession from DOC for any aspect of the project that may impinge on DOC estate.

The preferred site at the airfield will involve access over, and at least one turbine sited on DOC owned land as well as privately owned land. Any turbine(s) on the DOC land and the access track will require a Concession from DOC. While significant further discussion is required with DOC on this issue, it is expected that the DOC Concession and the Resource Consent process can be run in parallel.

While applying for Resource Consents without having the Concession in place has an element of risk, it is considered low risk on the assumption that prior to lodging there will be a high level of agreement between the wind farm project and DOC on avoiding, remedying or mitigating any issues they may raise.

Advice from Southland District Council on resource consent matters were that both the Mamaku Headland site and the Airport site would have the same activity status and rules from a planning perspective.

The two sites are in the Fiordland Rakiura Zone and are subject to the Coastal Environment Overlay and Outstanding Natural Feature/Landscape Overlay this does not change if there were turbines to be located on the conservation estate land or private land. The following sections of the District Plan will apply to turbines in these locations:

- Tangata Whenua
- Biodiversity
- Natural Features and Landscapes
- Coastal Environment
- Energy Minerals and Infrastructure
- Noise
- Fiordland Rakiura Zone which includes the approach vectors for the airport (Schedule 5.3).

Key matters are:

- Vegetation clearance – Discretionary Activity (Biodiversity Section - note an "avoid" policy (BIO.1) with respect to significant indigenous vegetation)
- The turbines – Discretionary Activity (Infrastructure Section)
- Earthworks – Discretionary Activity (Fiordland Rakiura Zone)
- Noise – this is covered in two locations (Fiordland Rakiura Zone and Noise section). The noise section refers to the NZ standard 6808:2010 for windfarm noise. The Fiordland Rakiura Zone General Standards (Rule FRZ.5) requires all activities to comply with the table (40dB day time and 30dB night time) at the property boundary. Noise Rule NSE2 does state that noise shall be measured in accordance with NZS6801 and assessed in accordance with NZS6802, except where another standard has been referenced in the rules.

Without the necessary Resource Consents, Concession and landowner agreements, there is no wind farm project and if the wind option is going to be considered further, these would be the matters that require progressing and resolution.

10 Preferred Site

The wind flow modelling clearly shows the Mamaku Headland site and the Airport site to be significantly better than other locations identified and assessed in Section 5. In addition to the better wind speeds at these two sites, they are both capable of facilitating up to 4 turbines.

The Airport site has much easier access and has higher wind speeds than the Mamakau Headland site. The new connection line at the airport site is slightly longer, however that location will require much less of a line upgrade on the existing electrical network.

[redacted]

[redacted] however a concession will need to be sought, both for access and the siting of any turbines on DOC land. Given the requirement to gain a resource consent for any site, it is considered that a concession application could be progressed at the same time as a resource consent, [redacted]

Issues around the placement of wind turbines close to an airstrip will need to be worked through with Stewart Island Flights (flight and airport operator) and Civil Aviation Authority (CAA). The locations identified are not within the airport exclusion zone identified by the Stewart Island/Rakiura Airport Approach Vectors included within Section 5.5 of the District Plan. CAA Advisory Circular AC139.6 and AC139.7 outline obstacle limitation surface dimensions (OLS) which indicate that structures within 2.5 km of the airport, which have a height of more than 45 m above the height of the airstrip, are considered an obstacle. Depending on the height of the turbines selected and the final locations of those turbines, they may be considered as obstacles and require some sort of mitigation. It is noted that the Stewart Island aerodrome is a non-certificated aerodrome and there are other certificated airports around New Zealand which have many obstacles within the OLS, for example the hills around Wellington airport.

On consideration of requirements for a successful wind farm, Roaring40s Wind Power consider the Airport site to be the preferred site and have provided indicative costs for that site in Section 11 of this report.

11 PROJECT COSTS

Project costs have been compiled for the following turbine configurations.

- NPS 100-24 37 m free standing hub height
- XANT M24 38 m free standing hub height
- XANT M24 32 m tilt-up hub height
- XANT M21 55 m tilt-up hub height

The capital costs were summarised into to following broad categories:

- Pre-development costs (resource consents, geotechnical survey, wind measurements, etc.)
- Project civil costs (foundation, roads, etc.)
- Project electrical costs (turbine inter-connection, connection to grid, grid upgrade, etc.)
- Turbine costs (turbine, transport, installation, crane, etc.)

For each option the base case has been represented using discounted cash flow assumptions largely similar to those used in the McCutcheon Report, which are listed in Table 11.1. A variation in the depreciation rates was included.

Parameter	**McCutcheon Report**	**Roaring40s**
Discount rate	8.5%	8.5% / 6.5% / 5.5%
Inflation rate	3.0%	3%
Depreciation rate: • Civil • Electrical • Mechanical		 4% 8% 20%
Debt funding	0%	0%
Tax rate	28%	28%
Lifecycle	40 years	40 years

Table 11.1. Summary of discounted cash flow economic parameters

In order to optimise a wind-diesel-battery system, a detailed study would be required to solve for the best solution but is very dependent on the input drivers. If total reliance on renewable energy is required, it would return a different solution to one which results in the lowest cost of wind generated electricity. In general terms, the installation of the first wind turbine or two will provide the biggest benefit in terms of diesel reduction and as more turbines are added, the amount of diesel displaced per turbine will decrease unless battery storage is added. Constructing more than one turbine initially presents some capital savings and has benefits from that perspective. The options available are significant and an optimization analysis will solve for a solution based on the drivers selected. Roaring40s Wind Power considers that the best starting point is the installation of 2 x 95/100 kW wind turbines however this configuration will require diesel generation to always run in addition to any wind generated electricity. The installation of such a system would require a controller and dump load. If more wind was to be installed, a more sophisticated control and load management system would need to be installed together with a battery storage system.

11.1 Pre-development Costs

Table 11.2 lists a summary of the pre-development costs associated with the project.

Development Cost Summary	Cost
Development cost total	

Table 11.2. Pre-development cost assumptions.

11.2 Civil Construction Costs

Table 11.3 lists the costs associated with the civil aspects of the wind farm construction which have been used in the evaluation of the project economics.

Table 11.3. Civil cost assumptions.

11.3 Electrical Construction Costs

Table 11.4 lists the costs associated with the electrical aspects of the wind farm construction which have been used in the evaluation of the project economics.

Table 11.4. Electrical cost assumptions.

11.4 Turbine Costs

Indicative turbine costs have been provided by two wind turbine manufacturers together with the cost of shipping to New Zealand. Roaring40s Wind Power has added crane and barge costs where required and based some of the installation man hour rates on local New Zealand rates. Included in the turbine costs are special tooling, where needed and initial purchase of spares. A contingency of 5% on the turbine supply and 15% on the barge and crane has been included. Exchange rates of NZD-USD = 0.66 and NZD – EUR = 0.60 have been used.

11.5 Overall Project Costs

Table 11.5 lists the summary of the civil, electrical and turbine costs and gives the overall project costs with and without the development costs.

Construction Cost Summary	NPS 100-24 Std 37m	XANT-24 Std 38m	XANT-24 Tilt-up 32m	XANT-24 Tilt-up 55m
Total, excl pre-development costs				

Table 11.5. Summary of project costs.

11.6 Project Generation and Configuration

Table 11.6 lists the main characteristics of the each of the wind farm options considered along with the energy generation.

Assumptions & Summary	Units	NPS 100-24 Std 37m	XANT-24 Std 38m	XANT-24 Tilt-up 32m	XANT-21 Tilt-up 55m
Number of turbines		2	2	2	2
Capacity of turbines	kW	95	95	95	100
Annual Output per turbine	MWh p.a.	369.9	365	352.3	381.1
Total wind farm output	MWh p.a.	739.8	730	704.6	762.2
Annual availability	efficiency	95%	95%	95%	95%
Other losses	efficiency	94%	94%	94%	94%
Net output	MWh p.a.	660.6	651.9	629.2	680.6
Net capacity factor	% at full power	39.7%	39.1%	37.8%	38.8%

Table 11.6. Summary of main wind farm parameters and output.

11.7 Unit Cost and Sensitivity

Given the updated wind speed modelling at the preferred airstrip site, it is likely that the levelized cost of wind generated electricity (LCOE) would be in the 31 c/kWh to the 47 c/kWh range. This range is based on project capital costs and excludes any pre-development costs. While the lower end of this range is slightly greater than the cost of the diesel cost per kWh, the wind generation cost will be essentially fixed for the next 20 years and not subject variation in operational costs as with diesel fuel. Table 11.7 summarises the LCOE for the four different wind turbine configurations considered for a range of discount rates.

Discount Rate	NPS 100-24 Std 37m	XANT-24 Std 38m	XANT-24 Tilt-up 32m	XANT-21 Tilt-up 55m
	c/kWh	c/kWh	c/kWh	c/kWh
8.50%	46	47	44	41
6.50%	38	39	37	**34**
5.50%	35	35	33	31

Table 11.7. Summary of LCOE's using a range of discount rates.

Figure 11.1 presents the sensitivity of the civil, electrical, turbine and discount rate to the unit cost of wind power generation. The change in unit cost is represented as a function of the % variation of that item alone and using the 55 m tilt up XANT turbine as the base case. The variation is from a base case value of 34 c/kWh shown in Table 11.7. All unit costs exclude any pre-development costs. As can be seen from the figure, any changes in the turbine cost or discount rate assumption have a greater impact on the unit cost assessment than the civil and electrical costs.

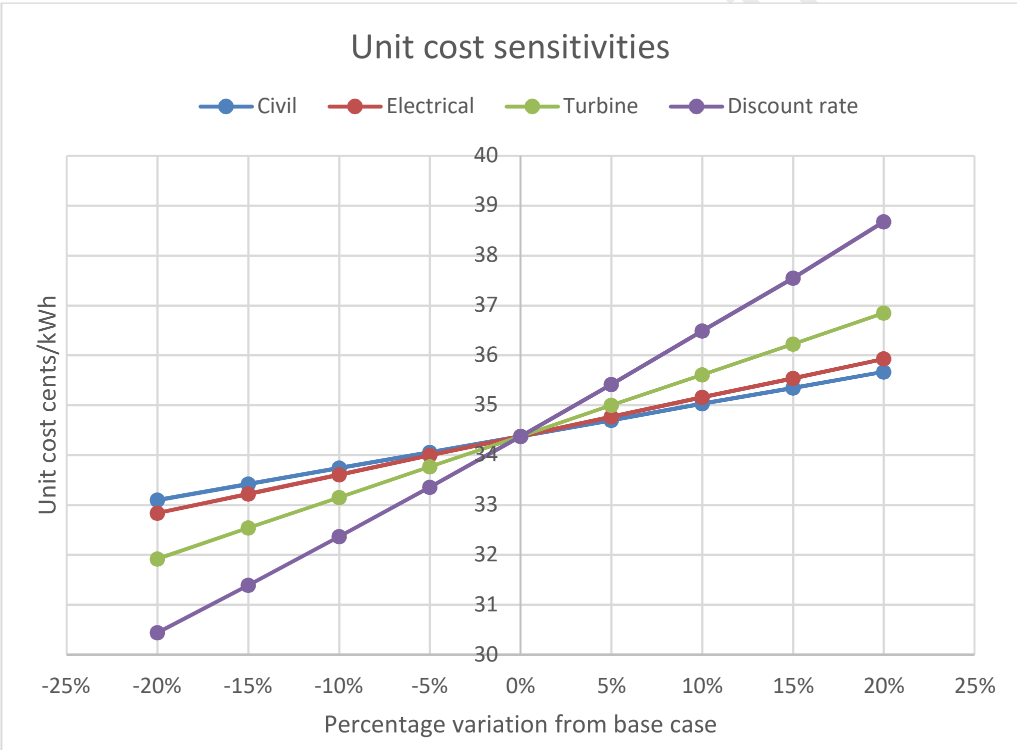


Figure 11.1. Sensitivity analysis

Changes in the turbine capital cost (including ex-works cost, exchange rate, international shipping, barging and installation) have a far greater impact on the cost of energy than the civil and electrical. These costs are all directly related to the choice of wind turbine technology selected which may be reduced through a competitive tendering process.

Roaring40s Wind Power notes that the balance of plant civil and electrical costs are very high for a wind project. This is primarily due to the logistics in undertaking construction on Stewart Island. The civil and electrical works together account for approximately 55% of the project capital costs while the turbines make up the remaining 45%. For large scale commercial wind farms in more accessible locations in New Zealand, the balance of plant costs are typically in the order of 30% of the project costs. Roaring40s Wind Power believes that there is scope to reduce the balance of plant costs by taking whole of project approach during the design and procurement phases.

If financial assistance is gained for the project (through development funds or grants), particularly through lower cost of capital, that has a major impact on the cost of energy. For example, there the discount rate is changed from 8.5% to 5.5%, the LCOE of the XANT 55m tilt-up wind turbine option changes from 41 c/kWh to 31 c/kWh.

12 CONCLUSIONS

While numerous studies and reports precede it, this report is still only at a pre-feasibility level status. Roaring 40s Wind Power notes that for up to 200 kW of installed wind generation, the levelised cost of energy is 31c/kWh to 47c/kWh depending on a number of assumptions. The wind turbines would provide about 41% to 44% of the generation, assuming 7.8% line losses. This LCOE is lower than the value of 47 c/kWh to 59 c/kWh in the McCutcheon report and is primarily due to the increased wind speed at the airport site. We estimate the capital cost of a 200 kW wind turbine installation to be in the order of $2.4m to $2.7m, excluding the project development costs.

The McCutcheon report concluded that the capital cost of a hydro generation facility would be in the order of $8.7m which includes $1.6m for an access track and $1.5m for an 11 kV electrical connection. The hydro plant was estimated to have a LCOE of 92 c/kWh and provide approximately 62% of the load. An augmented scheme was costed at $9.6m and had a LCOE of 74 c/kWh providing 83% of the load. Roaring40s Wind Power notes that, based on the road construction rates it has received, a 9.5 km road would cost significantly more than the $1.6m estimate.

An undersea cable, connecting Stewart Island to Bluff was costed in the McCutcheon report and depending on the route and number of cables, was costed at $10m to $20m. A single cable on the shortest route (through the oyster beds) was costed at the low end, while a twin cable east of Green Island was at the $20m end of the range.

From the work undertaken by Roaring40s Wind Power we make the following comments:

- Wind energy production estimates are based on modelled wind speeds which in turn rely on wind data measured at another site. While we have reasonable levels of confidence in the results, there is a need to improve that confidence with more accurate measurements on the preferred site to justify investment.
- Ground conditions for foundations at the site are unknown, and geotechnical investigations will be required to determine foundation design.
- Construction costing for a work of this scale on the Island is difficult as materials and equipment will have to be transported there in relatively small loads. From indicative costs that we have been provided, there is a significant premium to undertake work on the island.
- Turbine prices have been provided by the manufacturers who appear keen to be involved, but have not yet been subject to competitive tension (i.e. costs could get better).
- Two quite different types of turbine have been investigated, the pros and cons of which have yet to be fully determined and compared through competitive pricing, including barge and crane costs.
- While landowners have been open minded to the possible project, no formal access to land has been secured.
- No consultation with the community other than the Community Board and a few individuals has yet taken place. Nor has there been any consultation with the iwi. This is because there is little point going far afield without real information on a proposal.
- [redacted] there is a formal process to go through with them in the form of a Concession application, as it appears that the preferred site will seek to use a small part of a property owned by them.

- The preferred site will require further discussions with Stewart Island Flights and Civil Aviation Authority to work through the issues around siting turbines close to the airstrip.
- The Resource Consent Process will require careful management to meet the requirements of the District Plan with wind generation being a Discretionary Activity. Provisions for renewable energy and particularly Community Scale Projects in the District Plan are encouraging.
- The economic evaluation of the Project is subject to a number of variables – some more sensitive than others. There are many ‘avenues’ that could be explored to provide financial assistance to the development of this project.

The objective of this report was to provide a reasonable indication of the viability of a wind generation project on Stewart Island to replace or off-set the current diesel generation. The report achieves this objective by demonstrating

- That a wind option can be implemented at about the same LCOE as the current marginal cost of generation (i.e. the current cost of diesel)
- That a wind option would provide long term electricity cost stability for the Island
- That innovation and cooperation has the potential to reduce capital costs
- That grants and other venture funding has the potential to improve the LCOE

This study concludes that a wind generation option is on the threshold of providing Stewart Island with a renewable source of electricity supply at comparable rates to that of the cost of the diesel fuel and higher certainty of future electricity prices.

[redacted]

13 RECOMMENDATIONS

There are a number of reasons for considering the installation of wind turbines on Stewart Island which include:

- Cheaper electricity
- Fixing electricity prices going forward
- Diesel consumption reduction - CO2 reduction
- Using renewable energy rather than fossil fuels to provide electricity to the residents in this ecologically sensitive area.

If on balance, it decided to proceed further with this project, a number of tasks need to be progressed which are listed below:

1. Gain land access agreements for turbines and turbine access track and electrical network connection. Gain agreement with Stewart Island Flights / CAA on proximity and height of possible turbines.
2. Gain a resource consents and DOC concession for the installation and operation of the wind turbines and supporting infrastructure. This will require environmental effects studies and a planning report to be completed. It is considered the focus of these studies will be a planning report, landscape, ecology, noise, cultural and consultation.
3. Undertake wind monitoring on the selected site, in order to reduce the uncertainty in the estimate of the cost of energy and specify the wind flow conditions. The wind monitoring would require some vegetation clearance for access and installation.
4. Undertake geotechnical investigation at the selected turbine locations.
5. Undertake a detailed system optimisation analysis to determine the optimum number of wind turbines, battery size and system control requirements to maximise diesel reduction and minimise capital cost.
6. Complete a grid integration and stability study.
7. Tender turbine supply, install, commission and service. Select turbine.
8. Finalise design based on selected turbine.
9. Tender balance of plant, civil and electrical
10. Proceed to construction phase.

Roaring40s Wind Power recommends that in the first instance, all activities be completed to gain a resource consent (i.e. 1 and 2 above). Without land access and resource consents there is no wind project. It is possible that tasks 3, 4, 5 and 6 could be completed while the consenting was being undertaken as they will need to be completed prior to proceeding to construction. Roaring40s Wind Power recommends that at a minimum, additional wind speed measurements be undertaken.

APPENDIX A – VORTEX WIND MODELLING RESULTS AT 30 M.A.G.L

Note that “Point 1” in the Vortex results refers to the Mamaku Point Headland site while “Point 4” refers to the Airstrip site. Results have been modelled for both 30 m.a.g.l and 50 m.a.g.l but only the 30 m.a.g.l results are included here.

FARM Report 72621
Run 193087, Stewart Island, New Ze at 30 m

Created for Roaring40s Wind Power Limited
September 18, 2018

Point 1
Lat. -46.864452
Lon. 168.137246

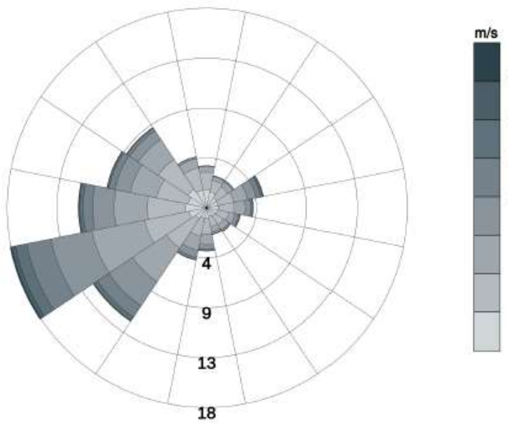


Figure 1: Wind Direction Rose. The radius of each sector is proportional to its frequency in the total wind speed distribution. The color of each bin depends on the wind speed as referred in the legend.

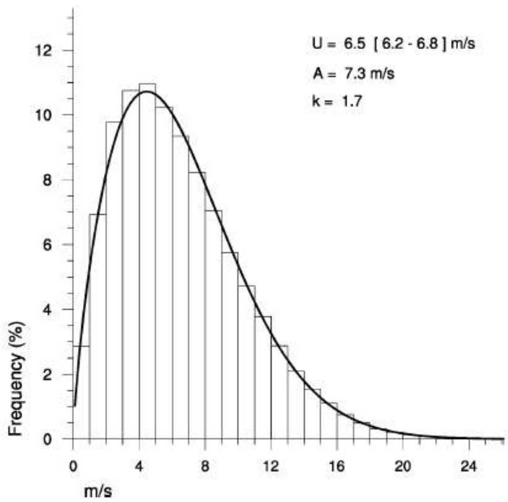


Figure 2: Wind Speed Histogram. A, K parameters indicate Weibull fitting for total (all-sector) histogram. The grey band along histogram bars is the result of different ensemble model configurations which also result in the shown uncertainty range for the mean wind speed.

FARM Report 72621
Run 193087, Stewart Island, New Ze at 30 m

Created for Roaring40s Wind Power Limited
September 18, 2018

Point 1
Lat. -46.864452
Lon. 168.137246

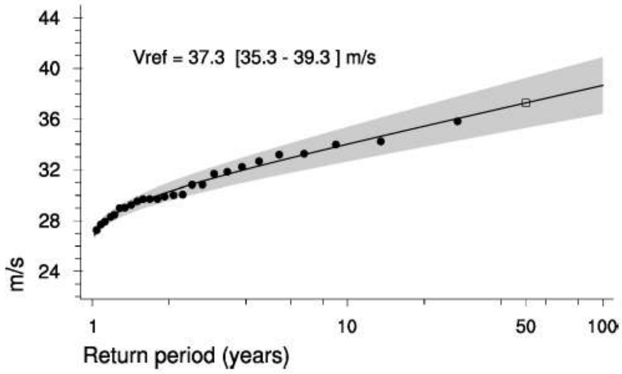


Figure 3: Extreme Events Gumbel Fit. 50-year return period extreme wind speed (Vref) is marked as en empty square. The grey band indicates Gumbel fitting uncertainty which also provide the shown uncertainty range for the Vref.

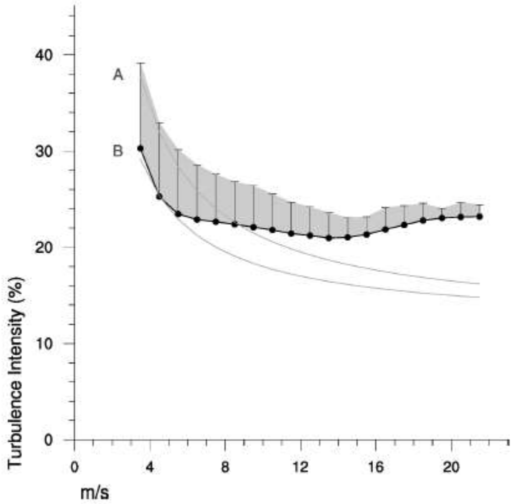


Figure 4: Tubulence Intensity Plot. Vertical thin lines at each point indicate the standard deviation of turbulence intensity showing the characteristic turbulence intensity. A & B curves are the thresholds from IEC 61400-1 Second Edition 1999-02.

FARM Report 72621
Run 193087, Stewart Island, New Ze at 30 m

Created for Roaring40s Wind Power Limited
September 18, 2018

Point 1
Lat. -46.864452
Lon. 168.137246

m/s - deg	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5	%	TI	STI
0 - 1	21.9	26.0	14.0	12.8	14.1	15.0	12.4	9.9	11.0	9.8	8.5	13.8	21.3	17.5	23.9	18.2	2.9		
1 - 2	49.2	45.3	33.2	31.1	30.9	27.7	24.3	23.4	27.4	26.3	31.9	45.3	53.7	49.5	59.0	48.2	6.9		
2 - 3	64.5	47.9	44.3	39.8	40.1	34.1	33.0	28.7	36.4	39.5	55.4	76.6	82.7	74.6	88.0	70.0	9.8		
3 - 4	58.6	42.1	41.3	43.0	43.9	33.9	31.9	29.5	41.7	48.9	79.1	99.8	98.7	84.0	98.9	66.8	10.8	30.3	8.9
4 - 5	50.0	32.3	36.2	43.7	43.2	34.4	29.0	28.8	43.6	49.7	96.2	121.6	104.6	87.1	97.4	61.6	11.0	25.3	7.7
5 - 6	34.4	22.0	26.4	41.9	38.7	27.3	25.1	24.6	40.9	47.1	104.6	137.4	102.8	83.3	89.0	51.3	10.2	23.5	6.7
6 - 7	21.7	14.9	21.1	39.5	32.7	21.3	20.8	19.1	34.1	47.1	112.4	145.8	95.6	79.2	77.2	35.9	9.3	22.9	5.7
7 - 8	13.2	9.4	14.5	39.4	30.6	16.8	15.3	14.3	29.3	37.9	107.5	144.6	87.1	73.0	64.0	24.0	8.2	22.7	4.9
8 - 9	7.5	5.9	10.5	32.9	24.6	13.5	10.5	10.8	22.6	30.5	104.1	137.1	79.9	62.8	49.1	15.2	7.1	22.4	4.4
9 - 10	4.0	3.7	6.3	25.6	17.3	11.5	7.7	8.0	15.9	24.0	89.4	124.0	69.6	51.2	36.9	8.4	5.8	22.1	4.3
10 - 11	2.1	2.1	4.4	23.1	15.2	8.7	5.3	5.0	11.6	18.3	76.2	112.9	56.0	41.7	25.5	4.8	4.7	21.8	3.8
11 - 12	1.3	1.5	2.3	22.0	10.3	7.6	3.2	3.6	8.0	14.3	63.0	95.6	45.2	32.1	18.3	2.8	3.8	21.4	3.3
12 - 13	0.0	0.0	1.0	16.7	7.0	5.2	2.0	2.6	6.1	10.3	47.5	81.6	34.1	23.1	13.2	1.3	2.9	21.2	3.0
13 - 14	0.0	0.0	0.0	12.0	6.1	4.2	1.1	1.2	4.5	6.2	34.7	64.4	24.6	16.2	8.3	0.0	2.1	21.0	2.6
14 - 15	0.0	0.0	0.0	8.9	3.8	3.9	0.0	0.0	2.4	3.8	26.5	51.5	17.8	10.9	5.5	0.0	1.5	21.0	2.0
15 - 16	0.0	0.0	0.0	8.8	2.8	2.0	0.0	0.0	1.3	2.0	17.4	39.9	12.5	6.8	3.1	0.0	1.1	21.3	1.8
16 - 17	0.0	0.0	0.0	5.1	1.5	1.2	0.0	0.0	0.0	1.3	10.5	29.5	9.5	4.6	2.3	0.0	0.8	21.9	2.3
17 - 18	0.0	0.0	0.0	3.5	0.9	0.0	0.0	0.0	0.0	0.0	7.1	21.7	6.6	2.4	1.2	0.0	0.5	22.3	2.0
18 - 19	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	3.9	14.8	4.4	1.6	0.0	0.0	0.3	22.8	1.8
19 - 20	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	2.1	10.4	3.0	1.0	0.0	0.0	0.2	23.0	1.0
20 - 21	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.1	7.4	2.0	0.0	0.0	0.0	0.1	23.2	1.5
21 - 22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.5	0.0	0.0	0.0	0.1	23.2	1.2
22 - 23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0		
23 - 24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0		
24 - 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0		
25 - 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
%	3.8	2.9	2.9	5.2	4.2	3.1	2.5	2.4	3.8	4.8	12.3	18.1	11.6	9.2	8.7	4.7		23.8	5.6
Inflow (deg.)	2.9	2.9	2.5	1.5	0.2	-0.5	-1.1	-1.5	-1.9	-1.9	-1.5	-1.0	-0.4	0.8	2.0	2.7	0.1		
Shear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Figure 5: Bin/Sector Ocurrence Table. Ocurrences are expressed in hours per year. Rows and Columns totals are expressed in percentages. Turbulence intensity and its standard deviation are shown in the last two columnns. Inflow angle (vertical wind) is shown for each direction sector at the next-to-the-last row. Shear "exponent" shown in the last row is the result of a potential fitting of wind speed versus height above ground. Total turbulent intensity, inflow angle and shear are a weighted average of these magnitudes according to the percentages of wind speed bins and wind direction sectors respectively.

Temperature (C)	Density (kg/m3)
9.4	1.23

Figure 6: Mean Air Characteristics Table. Mean temperature is expressed in Celsius degrees and mean density is expressed in kilograms per cubic meter.

Roaring40s
Wind Power

FARM Report 72621
Run 193087, Stewart Island, New Ze at 30 m

Created for Roaring40s Wind Power Limited
September 18, 2018

Point 4
Lat. -46.90462
Lon. 168.098195

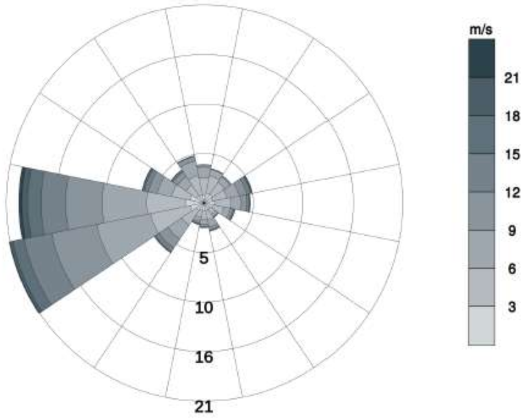


Figure 19: Wind Direction Rose. The radius of each sector is proportional to its frequency in the total wind speed distribution. The color of each bin depends on the wind speed as referred in the legend.

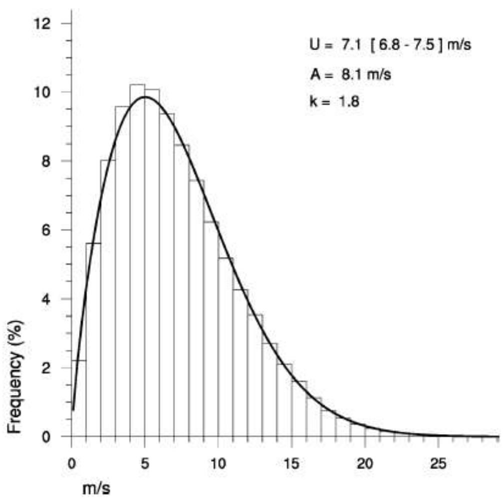


Figure 20: Wind Speed Histogram. A, K parameters indicate Weibull fitting for total (all-sector) histogram. The grey band along histogram bars is the result of different ensemble model configurations which also result in the shown uncertainty range for the mean wind speed.

Point 4
Lat. -46.90462
Lon. 168.098195

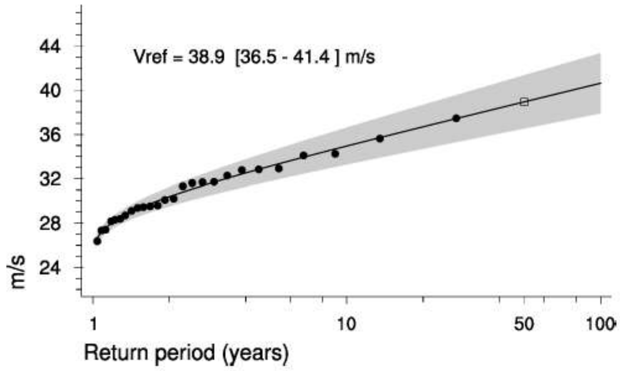


Figure 21: Extreme Events Gumbel Fit. 50-year return period extreme wind speed (Vref) is marked as en empty square. The grey band indicates Gumbel fitting uncertainty which also provide the shown uncertainty range for the Vref.

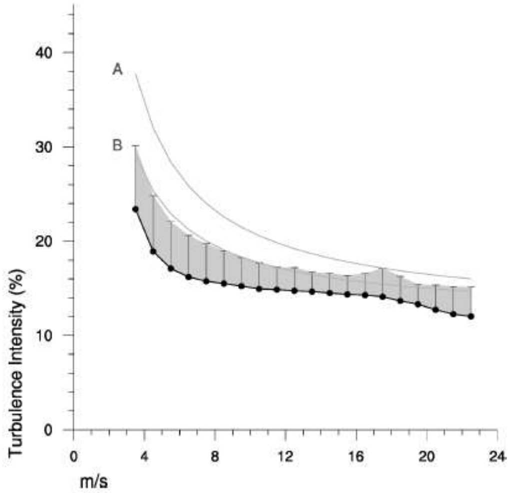


Figure 22: Tubulence Intensity Plot. Vertical thin lines at each point indicate the standard deviation of turbulence intensity showing the characteristic turbulence intensity. A & B curves are the thresholds from IEC 61400-1 Second Edition 1999-02.

FARM Report 72621
Run 193087, Stewart Island, New Ze at 30 m

Created for Roaring40s Wind Power Limited
September 18, 2018

Point 4
Lat. -46.90462
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m/s - deg	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5	%	TI	STI
0 - 1	5.9	9.7	11.9	10.5	14.6	15.5	11.6	9.8	12.7	13.0	9.9	9.6	19.6	20.9	12.2	6.4	2.2		
1 - 2	22.9	31.3	32.1	26.3	33.0	29.1	21.4	23.2	24.0	23.8	27.3	39.7	58.6	47.8	27.9	23.1	5.6		
2 - 3	40.5	49.2	45.6	36.9	46.3	36.6	26.0	29.7	28.6	25.5	40.6	73.9	88.1	58.3	36.3	41.5	8.0		
3 - 4	52.3	60.4	54.0	47.0	54.8	40.3	24.1	31.7	28.2	24.9	49.6	106.1	109.9	60.9	40.0	54.8	9.6	23.4	6.7
4 - 5	58.0	58.3	49.2	48.3	50.9	37.9	21.0	34.0	26.7	24.0	58.6	133.3	127.9	60.2	41.6	64.3	10.2	18.9	5.9
5 - 6	53.3	48.1	39.4	46.3	47.1	30.4	18.0	31.1	23.9	19.7	62.0	154.0	140.1	58.6	40.8	68.8	10.1	17.1	5.0
6 - 7	46.7	32.3	27.8	43.1	38.5	25.8	12.9	26.3	20.9	16.7	60.2	171.2	145.1	54.8	37.9	60.2	9.4	16.2	4.4
7 - 8	34.8	20.6	21.1	40.4	33.9	19.9	9.0	22.2	18.4	13.6	53.9	178.9	145.5	46.5	34.0	48.7	8.5	15.8	4.0
8 - 9	22.3	10.8	13.8	36.8	30.4	15.4	6.3	17.7	14.2	10.9	48.2	180.4	139.7	41.6	27.7	35.4	7.4	15.5	3.4
9 - 10	12.8	5.2	7.7	27.8	23.7	11.8	5.4	13.5	9.3	9.0	42.2	165.8	130.1	35.7	22.7	23.1	6.2	15.2	3.0
10 - 11	6.0	2.2	4.1	24.3	17.8	9.6	3.6	10.0	7.2	7.0	34.4	148.7	118.6	28.2	17.5	14.0	5.2	14.9	2.8
11 - 12	3.1	0.8	2.0	22.6	15.0	7.2	1.8	6.9	5.3	5.8	26.8	129.2	103.8	23.4	11.9	7.8	4.3	14.9	2.4
12 - 13	1.1	0.0	0.8	16.5	9.7	5.8	1.2	6.6	3.7	4.8	20.6	113.1	94.9	18.3	8.5	4.0	3.5	14.7	2.5
13 - 14	0.0	0.0	0.0	12.3	7.7	3.7	0.0	3.7	3.3	3.1	14.2	89.8	78.3	13.4	5.6	1.7	2.7	14.7	2.1
14 - 15	0.0	0.0	0.0	9.9	6.2	4.0	0.0	2.0	2.1	2.0	9.0	69.7	65.4	10.0	4.0	0.0	2.1	14.5	2.1
15 - 16	0.0	0.0	0.0	6.5	3.8	3.1	0.0	1.2	1.3	1.3	5.9	53.8	52.9	7.3	3.2	0.0	1.6	14.4	2.0
16 - 17	0.0	0.0	0.0	3.6	3.5	1.5	0.0	0.0	0.0	0.9	3.8	35.0	42.9	5.4	1.9	0.0	1.1	14.3	2.3
17 - 18	0.0	0.0	0.0	2.6	1.3	0.0	0.0	0.0	0.0	0.0	2.3	22.4	32.6	4.0	1.0	0.0	0.8	14.1	3.0
18 - 19	0.0	0.0	0.0	1.6	1.0	0.0	0.0	0.0	0.0	0.0	1.3	14.9	24.8	3.1	0.0	0.0	0.5	13.7	2.6
19 - 20	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	19.2	1.9	0.0	0.0	0.4	13.3	2.1
20 - 21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	14.6	1.3	0.0	0.0	0.2	12.7	2.6
21 - 22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	10.4	0.0	0.0	0.0	0.2	12.3	2.9
22 - 23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	7.1	0.0	0.0	0.0	0.1	12.0	3.1
23 - 24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	4.5	0.0	0.0	0.0	0.1		
24 - 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0		
25 - 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0		
26 - 27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0		
27 - 28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0		
28 - 29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
%	4.1	3.8	3.5	5.3	5.0	3.4	1.9	3.1	2.6	2.4	6.5	21.8	20.3	6.9	4.3	5.2		16.9	4.1
Inflow (deg.)	5.3	5.3	5.0	3.2	0.8	-1.1	-2.9	-4.6	-5.6	-5.1	-3.6	-2.1	-0.2	1.5	3.0	4.8	0.1		
Shear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Figure 23: Bin/Sector Ocurrence Table. Ocurrences are expressed in hours per year. Rows and Columns totals are expressed in percentages. Turbulence intensity and its standard deviation are shown in the last two columnns. Inflow angle (vertical wind) is shown for each direction sector at the next-to-the-last row. Shear "exponent" shown in the last row is the result of a potential fitting of wind speed versus height above ground. Total turbulent intensity, inflow angle and shear are a weighted average of these magnitudes according to the percentages of wind speed bins and wind direction sectors respectively.

Temperature (C)	Density (kg/m3)
9.7	1.23

Figure 24: Mean Air Characteristics Table. Mean temperature is expressed in Celsius degrees and mean density is expressed in kilograms per cubic meter.

APPENDIX B - SITE PHOTOS

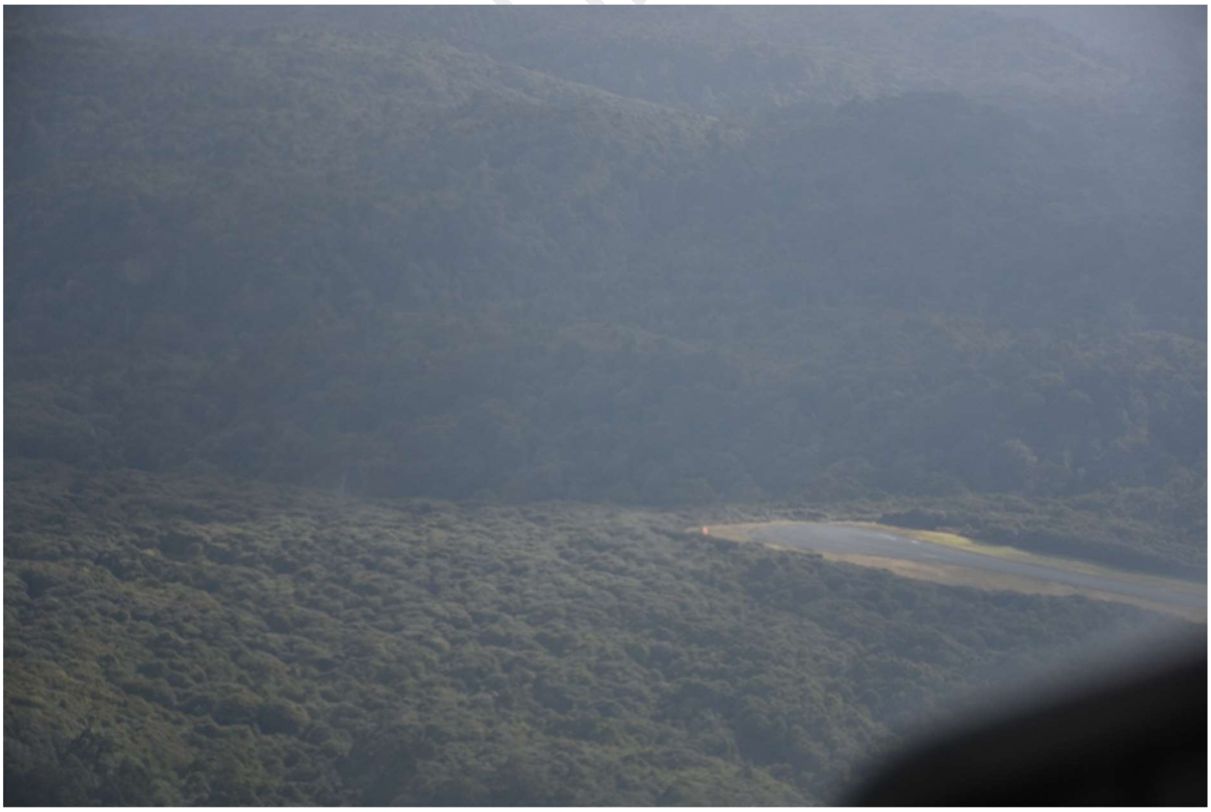
Site photo 1. Mamaku Headland site – looking south west

Site photo 2. Mamaku Headland site – looking north east

Site photo 3. Airport site. Looking south west. (knob to left of airstrip)

Site photo 4. Airport site. Looking south west. (knob to left of airstrip at edge of photo)

Site photo 5. Airport site. Looking south west. (knob to left of airstrip at edge of photo)



Site photo 6. Airport site. Looking north. (Between end of runway and left of photo)

Site photo 7. Sewage pond site. Higher ground behind sewage ponds.

Site photo 8. Location of previous 30m wind monitoring mast. Looking south west.

Site photo 9. Rockfill wharf. Possible landing site for barge.

Site photo 10. Oban wharf

Roaring40s Wind Power

APPENDIX C – ACKNOWLEDGEMENTS

Roaring40s Wind Power has spoken to a vast range of third parties and wishes to acknowledge the time and assistance that they have provided.