Wellington Registry **ENV-WLG-2024-001**
Te Whanganui-a-Tara Rohe

In the Environment Court
I Mua I Te Kōti Taiao O Aotearoa

Under the Resource Management Act 1991

and in the matter of the direct referral of an application for resource consents by Meridian Energy Limited in respect of the proposed Mt Munro wind farm under section 87G of the Resource Management Act 1991 (**RMA**).

Meridian Energy Limited
Applicant

and

Tararua District Council, Masterton District Council, Manawatū-Whanganui Regional Council and Greater Wellington Regional Council (**Councils**)
Consent Authorities

and

s 274 Parties

Statement of Evidence of Simon Andrew Faulkner on behalf of Meridian Energy Limited

24 May 2024

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INTRODUCTION

1. My name is Simon Andrew Faulkner. I hold a master's degree in mechanical engineering. I am a Chartered Professional Engineer and member of Engineering NZ.

2. I have worked in the renewables and wind energy industry for a continuous period of over 30 years. I have worked on wind energy projects in numerous countries including New Zealand, Australia, South Africa, and Asia. I am currently employed by Meridian Energy Limited (**Meridian**) as a Renewable Engineering Technical Expert.

3. I am responsible, in conjunction with my colleagues, for prospecting for new sites, developing wind monitoring programmes, designing the turbine layouts, providing technical input into the assessment of environmental effects, and undertaking wind data analysis and wind energy estimates of potential wind sites throughout New Zealand. I have undertaken similar roles on wind farms in NZ and other countries in my previous employment with international engineering consultancies.

CODE OF CONDUCT

4. I confirm that I have read the 'Code of Conduct for Expert Witnesses' contained in the Environment Court Consolidated Practice Note 2023. I agree to comply with this Code of Conduct. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

5. In my evidence I will address wind resource, wind energy and wind turbine related issues associated with the proposed Mt Munro Wind Farm (**Mt Munro** or **the Project**). My evidence covers the following matters:

   (a) The wind resource of New Zealand, in the region and at the Mt Munro site in particular.

   (b) The need to site wind turbines on hilltops and ridgelines rather than in valleys, and other technical considerations.

   (c) The relationship between site wind regime and energy production

   (d) Wind turbine technology and development history;

   (e) The turbine models being considered for Mt Munro; and

   (f) Shadow flicker and blade glint effects.

6. All figures referenced in my evidence are included within Appendix A at the end of my evidence.

THE NEW ZEALAND & MT MUNRO WIND RESOURCE

7. One of the most important considerations for a financially viable wind farm is the wind resource, since this determines how much energy is produced by the turbines, as discussed in more detail later in my evidence. The more energy that is produced, the lower the cost of the energy will be. The wind farm needs to generate sufficient energy to provide revenue that covers the cost of the investment and operating costs. The wind farm needs to be competitive with other generation, both wind farms and other forms of generation.

8. Other considerations which can determine the viability of a wind farm are the environmental effects, land availability (ownership and protected status), complexity of the terrain (which affects the construction costs and turbine wind loads), proximity to the grid (which

affects the grid connection cost), and grid capacity and proximity to loads (which affects the nodal pricing i.e. the value of the generated electricity at the grid connection location). Site selection is covered in more detail in Mr Bowmar's evidence.

9. The wind resource of a site is characterised mainly by the average wind speed, with other characteristics including the consistency of the wind (wind speed distribution), gustiness (turbulence intensity), and the extreme wind speeds. These are covered in more detail later in my evidence.

10. Aotearoa New Zealand has a wind resource that places it amongst the best in the world. The predominant westerly trade winds as well as the surrounding open ocean means that the country is very exposed to the wind with many areas having a higher wind resource than occurs in other countries. NZ has many mountain ranges, which accentuate the wind in areas such as the Manawatu Gorge, Cook Strait and Foveaux Strait; although they also block the wind in other areas. New Zealand has many areas with a wind resource that is comparable to or better than what has been extensively utilised overseas.

11. New Zealand has a small population and many areas that have low population density. However there are large areas of steep mountainous terrain and native forest that limit the amount of land that is available for development. Also, the existing electricity network (ie "the grid") does not extend across all parts of the country. New Zealand has an excellent wind resource with many areas that are suitable for wind farms, although not everywhere is suitable.

12. New Zealand's wind resource is presently under-utilised for the purpose of generating electricity, with the installed wind capacity (including Harapaki, once fully commissioned) being approximately 1,266 MW. This supplies about 10% of the country's electricity requirements.

13. The process of prospecting and selecting potential sites that meet all of the requirements of a wind farm is covered in Mr Bowmar's evidence. My evidence covers the wind resource aspect of this.

14. Figure 1**Error! Reference source not found.** shows a wind resource map of New Zealand. The map shows the general trend of average wind speeds over New Zealand and that there are good wind speed areas in many locations throughout the country. However, as already noted, large parts of these areas are not suitable for wind farms due to steep terrain, protected land, proximity to densely populated areas, and distance to a grid connection.

15. Figure 2 shows the wind resource in the Wairarapa/Manawatu region in the vicinity of Mt Munro. This shows the excellent wind resource in the Manawatu Gorge area where there are several existing wind farms, as well as at Mt Munro. The Mt Munro site meets other requirements of a viable wind farm site as discussed in the evidence on Mr Bowmar.

16. Wind maps such as these only provide an approximate indication of the wind resource. The wind resource must be proven by wind monitoring, which consists of wind monitoring masts and remote sensing devices such as vertical profiling SoDARs and LiDARs. At Mt Munro Meridian has installed an 80 m mast and a SoDAR, with the mast having collected 14 years of data. This is sufficient for a robust wind resource assessment with low uncertainty.

17. This wind monitoring has confirmed that the wind resource is excellent for a wind farm, with a high average wind speed, suitable wind speed distribution, low to moderate turbulence, and extreme wind conditions that are within the design parameters of available turbine models. The average wind speed at the mast is roughly equal to the design Class I (10 m/s) as defined by the IEC 61400-1 turbine design standard.

18. A wind direction rose for Mt Munro is shown in Figure 3. This wind rose shows how much of the time that the wind comes from each direction (radial axis) as well as the time in each wind speed range (coloured segments), and shows that:

    (a) The predominant wind direction is north-west, with the wind coming from this direction for about 44% of the time and having the strongest winds.

(b) The second most common wind direction is southerly which occurs about 22% of the time.

(c) The remaining 34% comes from a wide range of directions and is generally lighter winds.

19. To determine the local topographic effects over Mt Munro, Meridian modelled the wind flow over the site using the Computational Fluid Dynamics (CFD) model Meteodyn. The CFD modelling package models the effects of terrain, surface roughness (such as trees or buildings), and atmospheric stability on the wind speed, wind direction and turbulence over a particular area. This includes wind shear, i.e. wind speed variation with height above ground level. The inputs to the model include:

(a) Wind speed, direction, and turbulence data

(b) Digital terrain model (ie 3D model of the area being investigated)

(c) Surface roughness description (vegetation etc)

(d) Description of any obstacles in the vicinity of the wind measurements.

20. Data collected from Meridian’s wind monitoring mast at Mt Munro has been used in the flow model. The results of the numerical flow modelling have been represented in graphical form in Figure 4. The yellow to red areas have the highest average wind speeds and occur on the ridges and the blue areas have the lowest average wind speeds and occur in the valleys.

21. The wind resource found on the ridges of the Mt Munro site is excellent in both quality and quantity and is ideal for wind power generation. The wind resource on the surrounding flat land and valleys is substantially lower, and there is also much more turbulence and fluctuation in the wind in the valleys, making these areas unsuitable for wind turbines.

WIND RESOURCE AND ENERGY CHARACTERISTICS

The Relationship Between Wind Speed and Energy

22. The power in a free-flowing fluid such as wind is proportional to the cube of the wind speed (V^3). As an example, a doubling of the wind speed gives rise to an eightfold increase in available power. However, there is a theoretical limit on how much power can be extracted from a free flow of air, since the power is determined from how much air passes through the device capturing the power as well as how much it is slowed down. Slowing it down completely means that no air passes through the device and therefore the power extracted is zero. There is a theoretical optimum power extraction known as the Betz limit, equal to 59.3% of the power contained in the flowing air.

23. Wind turbines are designed to capture as much of the available wind energy as possible, with practical limitations to ensure that the turbines can withstand extreme wind conditions. They are designed to operate over a wide range of wind conditions, and most efficiently at the most common wind speeds. At high wind speeds when there is too much power available the turbine feathers its blades to spill the excess power and when the wind becomes extreme then the turbine will shut down. This is a sensible design philosophy since the strongest winds are rare and it is not cost-effective to design the turbine to capture them.

24. A turbine’s overall efficiency including blades, rotor, bearings, gearbox and generator is determined by comparing the net power output to the theoretical maximum power available, ie the Betz limit, and is typically about 75-80%. Turbine technology has been developed for several decades in a competitive international industry to produce the most cost-effective designs possible. As an example, Figure 6 shows the power curve (turbine power versus wind speed) and the coefficient of performance (Cp), which is the net power divided by theoretical power. The Cp peaks at 0.467 which is 79% of the Betz limit.

25. The energy production at a turbine location is determined from the wind speed distribution, the power curve, and wake and other losses.

26. A typical wind speed distribution is shown in Figure 5. Wind speed distributions often take on a shape similar to this, i.e. a 'Weibull' distribution that starts at zero, has most occurrences at the lower to medium wind speeds and a tail with increasingly rare higher wind speeds. The Weibull distribution is characterised by the 'size' factor A which is closely related to the average wind speed and the 'shape' factor k, which indicates how consistent the wind is. A k value of 2 is typical of many wind farm sites.

27. The turbine power curve shows the short-term response of the turbine to wind speed. A turbine power curve is shown in Figure 6 for the Siemens SWT-DD-130, which is typical of modern turbines. The turbine starts to generate at about 3m/s, reaches rated (full) power at about 13m/s, controls itself to rated power from 13m/s to 23m/s, and derates and shuts down progressively from 23m/s to about 28m/s.

28. The energy production over a long period, eg a year or the life of the project, is the result of combining the wind speed distribution with the power curve, and applying typical losses. The effect of the varying wind conditions is shown in Figure 7 for a range of average wind speeds and Weibull k values. The energy production of a wind farm is very sensitive to the site average wind speed as is shown in Figure 7.

29. The output from a wind farm or wind turbine is sometimes expressed in terms of a capacity factor. The capacity factor is the ratio of the turbine's average net power output to the turbine's rated (maximum) power, or in other words the net energy generated in a period of time divided by the energy that could be generated if the turbine operates at rated power for the whole period.

Topographic Effects on Wind Speeds

30. Wind speeds are generally highest close to the coast as a result of the low surface roughness of the sea (compared to land). As you move inland from the coast, the surface roughness increases and generally reduces the wind speed. Surface roughness has the added effect of increasing the turbulence intensity.

31. Wind flow directly off the sea is generally much more laminar (non-turbulent) than that at inland locations. The performance of offshore wind farms abroad has demonstrated that higher wind speeds and lower turbulence levels are found out at sea. While the wind off the coast of some of the flatter European countries may be higher than those experienced on land, in New Zealand there is significant topographical enhancement to the wind speed as a result of funnelling effects, which results in higher wind speeds over many parts of the land, such as the Cook Strait and Manawatu Gorge areas.

32. Ridges, hills and escarpments all have the ability to accelerate and decelerate wind speeds. Typically, the wind speed accelerations occur at the top of a hill and decelerations are experienced in front of and behind the hill. Wind speeds at the tops of hills and ridges can be significantly accelerated due to the shape of the hill. The acceleration effect also means that the wind is less turbulent and more consistent on top of the ridge, and more turbulent in the lee of the ridge.

33. Site elevation results in a decrease in air density and this results in a reduction in potential available energy. However, this energy reduction is generally small; for example, an increase of 500 m in elevation results in about a 1.5% reduction in energy due to the lower air density.

34. Mt Munro benefits from the funnelling effect of the Tararua and Ruahine ranges, as these are lower near the Manawatu Gorge, allowing the predominant westerly winds to funnel through. It also benefits from local terrain effects with enhanced wind resource due to the effect of the ridgelines which are orientated across the predominant wind directions. The resulting high average wind speed, low turbulence levels and consistent wind directions at Mt Munro make it a good wind farm site with respect to the wind resource.

35. The relatively steep profile of the seabed surrounding New Zealand, and the higher costs of constructing off-shore facilities means that building off-shore wind farms is presently much more expensive than on land. However, if there is sufficient electricity demand then offshore wind farms may be built in the future.

Turbulence and Extreme Gusts

36. The turbulence in the wind affects the operational performance of a wind turbine. The turbulence is also a key driver in the design of the wind turbine components. A good example of turbulent wind flow is landing at Wellington airport in a northerly wind. It is the turbulence from the hills to the north of the airport that causes the plane to be buffeted around. A kite also generally flies better at the top of a hill or at the beach where there is less turbulence.

37. The design of the majority of the components in a wind turbine is driven by fatigue loads, so the turbulence regime in which a turbine operates is a critical design parameter.

38. The turbulence in valleys is generally significantly greater than the turbulence at the top of a ridge or hill and this is a further reason why wind turbines are not usually sited in valleys. Wind turbines should only be sited in locations where the turbulence level is lower than that used in their design to ensure their long-term performance.

39. Mt Munro is characterised by turbulence intensity equal to category B to C as defined by the IEC 61400-1 turbine design standard, ie at the lower end of the range that turbines are designed for. The low turbulence means that more turbine models will be suitable, and they will have a longer design life.

40. Turbines are designed to withstand extreme wind conditions. The turbine model used will be able to withstand the 50-year extreme wind gust that is expected at the site. The wind data collected at site indicates that the extreme wind is within the design parameters for the models being considered. For example, in the IEC 61400-1 turbine design standard the Class I 50-year extreme 3s wind gust is 70m/s or 252km/h, which is very rare in NZ.

Mt Munro Energy Production

41. Mt Munro will produce about 300 GWh per year of electricity depending on the number of turbines and turbine model, which is the equivalent to

the electrical consumption of about 42,000 typical homes. This is an average that takes into account the intermittent nature of the wind and the variable load at the houses.

42. The capacity factor for Mt Munro is calculated to be 45-50% depending on the turbine model used. Capacity factor can be misleading as it is simply a measure of overall energy production. It is not a measure of the efficiency of the wind farm or a measure of how much of the time the wind farm operates. The capacity factor is dependent on the site wind speeds, the wind turbine design (in particular the rotor area and rated power, which determines the power curve), and wake and other losses.

43. Wind turbines obviously only generate electricity when the wind is blowing. At Mt Munro this is about 95% of the time. The time that the turbines are not generating includes periods when there is not enough wind and a small proportion of time when there is too much wind for the turbines to operate, as well as times when maintenance is completed. As the turbines are spaced over a significant area and individually experience different wind speeds, the wind farm will commence operation gradually in low wind speeds and stop operating gradually in high wind speeds, as each individual turbine progressively reaches its wind speed thresholds.

44. The annual variation in output from a wind farm is smaller that the variation in hydro power station output, as the wind is more consistent that hydro inflows (rain and snow melt). For the wind farms the annual variation has a standard deviation of about 4-6%, whereas the variation in output from some of New Zealand's hydro generation is about 10-12%. For example, Te Apiti Wind Farm has only a 5.3% variation in output due to wind resource variations and White Hill 4.0%. This is consistent with international figures and long-term wind records that Meridian holds from sites within New Zealand.

45. The output of a wind farm is dependent on the strength of the wind. However, the variability in the wind does not make a wind farm unreliable, it simply means the wind farm output is variable. Wind turbines are a reliable source of power and their success has been well established overseas and in New Zealand.

WIND TURBINE TECHNOLOGY

46. In planning a wind farm, after identifying and analysing the available wind resource, the next step is to assess the characteristics of available wind turbine models to see which would be most suitable for the wind resource and terrain.

47. Development in turbine design has proceeded very rapidly over the last 40 years. Although there are a number of established manufacturers, there are strong similarities between most turbines as a result of those manufacturers converging on the most cost-effective designs and technology.

48. Turbines are designed to standard specifications, however these can be refined, within limits, in both the mechanical and operational specifications to meet the requirements of a particular site. This means that turbines located where some operational elements such as noise levels or visibility are important can have specific features in their aerodynamics, markings, finish, or operational software to meet these requirements.

49. The operational control system will have one or more specified “power curves” or modes of operation of the turbine. Put simply, this “curve” plots the way the turbine will respond to the available wind by controlling the rotational speed of the rotor. In an area where turbine noise is required to be limited, the selected curve may include features such as a more gradual increase to full power, reduced rotational speed, or a later initial start. These give a trade-off between the energy captured by the turbine and the effects of the operation of the turbine.

50. Limitations on environmental effects of turbines are therefore best expressed by defining the limits or standards which must be met before generation can occur. This places the compliance onus on the wind farm operator, who must then make the technical and operational decisions to ensure compliance.

Main Features of the Turbine

51. The historical development of wind turbines covers about 40 years, and in that time there has been a huge increase in the size of the turbines, as well as improvements in the components and the design process. A range of manufacturers have progressively introduced new turbines to the market, as wind technology has become more established throughout the world. Most early wind turbines were fixed speed, fixed pitch, stall regulated with mechanical brakes. Most turbines today are variable speed, variable pitch and have both aerodynamic and mechanical brakes.

52. In the 20 years between 1985 and 2005 turbines increased in diameter from 15 m to about 126 m, and now (after another 20 years) turbines up to about 260 m diameter are available for offshore wind farms. For example in NZ the V27 installed in Brooklyn, Wellington in 1993 had a 27 m rotor diameter, Tararua Wind Farm (1999) turbines have a 47 m rotor diameter, WestWind (2009) and Mill Creek (2014) 82 m, Te Uku (2011) 101 m and the wind turbines installed at Meridian's most recent wind farm Harapaki have a 120 m rotor diameter. Comparing Harapaki to WestWind, in 15 years the rotor diameter has increased by nearly 50%, and rotor area and rated power have doubled. Bigger turbines are more cost-effective to manufacture, install, and maintain; and can access better wind resource since they are taller.

53. The main dimensions of a wind turbine are shown in Figure 8 and the major components of a wind turbine are shown in Figure 9. A typical wind turbine is made up of:

    (a) Blades, typically three, although one- and two-bladed turbines have been built in the past;

    (b) Hub, to which the blades are attached;

    (c) Rotor, ie the hub and blades;

    (d) Nacelle, which contains the rotor support and bearings, drive train, gearbox, generator, transformer, and turbine controller;

    (e) Tower, which supports the nacelle; and

(f) Foundation, which supports the tower.

54. As noted in the Application, the turbine proposed for Mt Munro is a horizontal axis – 3 bladed, upwind rotor machine, sometimes known as the “Danish Design”.

55. The whole nacelle rotates on the tower top so that the rotor points into the prevailing wind direction. This movement of the nacelle is known as yawing. Each individual wind turbine constantly monitors the wind direction and will yaw so as always to face into the wind in order to maximise the energy production and minimise the loads on the structure. The turbine will occasionally stop and turn in a full circle to unwind the power cables.

56. Each of the blades can rotate on the hub. This movement allows the blade pitch angle to be set between 90°, when the turbine is stopped, and 0°, when it is running in light winds. The pitching of the blades allows optimum power production at low wind speeds and controls the output at high wind speeds at a fixed level. The pitching also allows the turbine to be shut down as it acts as an aerodynamic brake.

57. The three major components in the nacelle are the low speed shaft (main shaft), the gearbox and the generator. Some turbines are direct drive, with the generator built into the rotor and not requiring a gearbox.

58. The main characteristics of the indicative wind turbines being considered for Mt Munro are listed in Table 1 and Table 2 below.

Table 1: Indicative turbine characteristics

Factor	**Siemens SWT-DD-120**	**Siemens SWT-DD-130**	**Vestas V136**
Rated output	4.3 MW	4.3 MW	4.2-4.5MW
Rotor diameter	120 m	130 m	136 m
Hub height	80-92 m	80-92 m	92 m
Specific rated power	380 W/m^2	324 W/m^2	289-310 W/m^2
Rotational speed	To be added	6.5 – 15.5 rpm	To be added

Table 2: Indicative turbine mass

Component	Mass
Blade	17 tonne
Hub	45 tonne
Rotor	96 tonne
Nacelle	103 tonne
Tower	260 tonne
Overall	460 tonne

59. The reliability of a wind turbine is generally measured by its availability, which is the proportion of time that the turbine is ready and able to generate. Typically, modern wind farms have availabilities of about 97%. The downtime when they are not available is a combination of routine servicing, occasional faults that require rectification, and operational requirements such as unwinding the power cables that hang down the tower. Because a wind farm is made up of a large number of individual turbines, scheduled servicing only limits the wind farm output by the number of turbines being serviced. This is unlike a thermal or hydro power station that has a small number of separate generation units, so that a shutdown of any one of those generators has a significant impact on the output from the station.

60. Routine servicing is done typically every 6 months, with additional work done as refurbishment typically at the mid-point of the turbine life. As a comparison we can consider a modern motor vehicle which requires a service every 20,000 km. Assuming an average speed of 50 km/h, the car is being serviced after every 400 hours of operation. A wind turbine on the other hand is being serviced every 4,380 hours. The service interval of a wind turbine is therefore 10 to 20 times greater than that of a modern motor vehicle.

61. I consider that when one looks at a wind turbine as a whole it is both efficient and extremely reliable.

Wind Turbine Spacing

62. Wind turbines require appropriate separation distances to operate successfully. Turbines placed too close to one another will have reduced power output and higher fatigue loads as a result of the

reduced wind speeds and increased levels of turbulence in the upwind turbine’s wake. Turbine separation distances are often referred to in terms of the number of rotor diameters, e.g. 5D would be a spacing between the turbines equal to 5 times the rotor diameter. This enables easy discussion of separation distances for a wide range of turbine size. To illustrate, a turbine with a 100 m rotor diameter which has a 5D separation means that there is 500 m between the turbine positions.

63. The spacing between turbines is a compromise between increasing spacing to minimise wake effects, reducing spacing to minimise the road and electrical costs, and reducing spacing to maximise the installed capacity to cover the fixed costs of the wind farm such as the grid connection. Small wind farms generally have turbines spaced at roughly 5D to 7D in the predominant wind direction (between rows) and 2D to 3D in the non-predominant wind direction (within rows). Larger wind farms with many rows of turbines may have larger spacing, since the wake effects accumulate.

64. A typical spacing of 7D x 2D has been adopted for Mt Munro, with some variations in spacing to suit the terrain. This close spacing within the rows is possible due to the consistent wind direction ie the strongly predominant north-west wind. Generally, this spacing puts the turbines at minimum spacing of about 260 m within rows (across wind) and 900 m between rows (down wind).

65. The spacing between turbines needs to vary with the size of the turbines being used. This is one of the main reasons for seeking an envelope approach in the consent, where an outer boundary is defined and turbines can be within this at a spacing that suits the turbine size. The envelope approach is covered in the evidence of Mr Bowmar.

Wind Farm Separation Distances

66. It is not appropriate or necessary to define a minimum distance between wind turbines and houses or property boundaries. The influence of turbines does generally reduce with distance, but this cannot be directly related to a specific distance or a distance that is based on the overall size of the turbine. It is necessary to consider the

environmental effects and define limits in relation to these effects. These effects have been assessed and appropriate limits (where applicable –e.g. shadow flicker and noise) have been proposed. This is the approach that has been adopted in the consenting process for NZ and overseas wind farms.

67. Although the effects need to be considered rather than the distances, the distances to neighbouring dwellings at Mt Munro are not unprecedented. There are two at 670-690m (MTMH02, 26), three at 915-990m (MTMH08, 09, 24), and the remainder more than 1km.By comparison, the closest neighbouring dwellings for some other NZ wind farms are as follows:

(a) Turitea has a dwelling at 550m (81 North Range Rd), another at 840m, 22 within 1km, and many more within 2km.

(b) Te Rere Hau repowering project (consented) has a house at 470m (81 North Range Rd, which was a neighbour at the time of consenting) and another at 780m.

(c) Aokautere extension to Te Rere Hau (in consent process) has a dwelling at 1.0km and several more at slightly larger distances.

(d) West Wind: one house at about 780m and two houses at about 880m (off Opau Rd, no line of sight) and several at about 1.0-1.1 km with line of sight.

(e) Mill Creek has dwellings in Makara Beach village at about 1.1km (not visible from some parts of the village).

(f) Harapaki has a dwelling at 1km.

(g) Brooklyn wind turbine: about 560 m. 60 houses within 750 m of the turbine and an additional 91 houses between 750 m and 1000 m of the turbine.

Wind Turbine Effects on Wind and Micro-climate

68. Wind turbines have a zone of wake downwind of them. This wake has lower average wind speeds and higher turbulence than the freestream or natural wind. However, the freestream wind is also turbulent, especially downwind of a ridge. The wake quickly mixes with the surrounding wind and dissipates. The wake is not noticeable at ground level either near the turbines or at a distance, and there is no discernible effect on airborne dust, air temperatures, rainfall, soil moisture, or other micro-climate parameters.

SHADOW FLICKER

69. The shadow flicker assessment for Mt Munro was undertaken by Boffa Miskell Ltd and is described in the statement of Mr Girvan. I will only discuss the proposed consent condition, its implementation, and some clarifications of the assessment.

70. Shadow flicker is easy to control to acceptable limits, since the time of day and days of the year that it occurs can be calculated exactly, and the relevant turbines can be shut down when required to achieve the limit that has been imposed. However, there are some complications related to what limits are relevant and how cloud and shielding is taken into account. I have covered these issues in detail below.

71. I have investigated the origins and implementations of shadow flicker limits, including a conference paper on the topic presented at an NZWEA conference in 2013[1]. The limits on shadow flicker duration are somewhat arbitrary but have been developed, refined, and widely utilised on wind farms around the world. There have been misinterpretations of the intended limits in the past, however, the Australian EPHC "National Wind Farm Development Guidelines" Draft July 2010, Technical Appendix E (the Guideline) provides a good explanation and a suitable assessment method and limits to ensure that shadow flicker effects are no more than minor. The Guideline limits have been used in recent NZ resource consents such as the Te Rere

[1] "Shadow Flicker Guidelines" Simon Faulkner & Julia Schmidmaier, NZ Wind Energy Conference 2013

Hau Repowering and the Aokautere Extension. I recommend that they form the basis of the consent condition for Mt Munro.

72. The Guideline defines two levels of limit: 30 h of “Modelled” (or theoretical) annual duration using a prescribed and conservative method, and 10 h of “Measured” (or realistic) annual duration using prescribed “mitigations” ie cloud, shielding, and turbine curtailment. It is important to note that all of these calculated shadow flicker durations are conservative, as they do not take account of several practical matters such as the turbine operation and rotor and blade orientations. With this limit imposed, the total length of time that shadow flicker actually occurs will be less than the 10 hours per year. However, this conservative method of calculation and the associated limits is well-established as a method to ensure that the effects are acceptable.

73. The consent condition proposed in the AEE is a limit of 30 hours per year, modelled in accordance with the Guideline (but to 10 times the turbine diameter), using a curtailment strategy to achieve the limit. I believe that this condition should be amended to be clearer and align more closely with the Guideline. In particular, the condition should:

(a) Include final layout and turbine model, and all applicable dwellings ie those that existed or were consented at granting of the consent.

(b) Specify an assessment distance limit of 265 x max blade chord, as per the Guideline and more directly related to the worst-case effect.

(c) Include limits on ”modelled” and “measured” duration and the associated mitigations including cloud and shielding by vegetation and structures. This is in accordance with the Guideline and avoids turbines being shut down unnecessarily.

(d) Clarify how shielding is taken into account in assessing compliance (see below).

(e) Inclusion of 30 minute daily duration limit. This was recommended in the s 87F Report, and is included as it provides greater certainty, although I note that it is not strictly necessary; the Guideline states that it “does not include a daily limit for shadow flicker exposure as this is inherently satisfied by the annual exposure limit”.

74. Proposed consent conditions SF1 to SF3 in the set attached to the evidence of Mr Anderson incorporates these recommendations. The modelled shadow flicker duration will be assessed for the final layout and turbine dimensions and compared to the limit of 30h annual and 30min daily. For dwellings that do not meet this limit, the measured duration will be assessed, taking into account cloud conditions (determined using a method equivalent to that stated in the Guideline) and shielding by any structures or vegetation present, and compared to the limit of 10h annual and 30min daily (noting that the cloud effect is not applied to daily duration). For dwellings that do not meet this limit, automated shutdown will be applied to achieve the limit of 10h annual and 30min daily. In summary the progressive limits are:

(a) “Modelled” (conservative theoretical) 30h annual and 30min daily.

(b) “Measured” pre-assessment (conservative realistic) 10h annual (include cloud and shielding) and 30min daily.

(c) “Measured” operational (conservative actual operation) 10h annual and 30min daily (include cloud, shielding and automated shutdown).

75. The proffered consent conditions propose that shielding by vegetation such as trees or hedges and structures such as fences or nearby buildings will be applicable if, at the time that the shadow flicker occurs, the shielding blocks the sun at the windows of any habitable room of a dwelling to the turbines that cause the shadow flicker. This means that the moving shadow of the turbine blades does not fall on the windows of the dwelling. The Guideline requires assessment of the shadow flicker at a distance of up to 50 m from the centre of each dwelling. However, this is not appropriate for shielding since this effect is highly localised. Also, shadow flicker has more effect when it occurs at the window of a naturally lit room than it does outdoors, as the lighting in the room provided by the sun is affected by the intermittent shadow. A

building or row of trees may provide complete shielding of the dwelling's windows but not be able to considered because there is a location somewhere within the 50 m threshold where no shielding occurs. For many dwellings the 50m threshold falls outside of substantial shelterbelts and even in some cases outside of the property boundary and across a public road.

76. The curtailment, if needed to meet the shadow flicker limit, will be automated. The turbine manufacturers being considered for the project provide this automation capability as part of the wind farm SCADA (operation and control) system. For dwellings that do not meet the limit for pre-construction Measured duration, the SCADA will be programmed to shut down the relevant turbines at enough of the relevant times (ie when the sun is in the position to cause shadow flicker and is not behind a cloud or shielding) to meet the limit for Measured shadow flicker. There are two main methods:

(a) Continuous: track the accumulated shadow flicker duration, ie record the accumulated time that the shadow flicker is modelled to occur <u>and</u> there is not cloud obscuring the sun, over a rolling one-year period, and shut down the relevant turbines when the accumulated duration reaches the limit.

(b) Predetermined: Calculate the amount by which the <u>Modelled</u> shadow flicker (ie not considering cloud conditions) is in exceedance of the 30 h limit, and allocate sufficient curtailment periods throughout the year to achieve the limit on theoretical duration; then shut down the turbine during these periods unless there is cloud obscuring the sun. It may be possible to some extent to apply the curtailment periods to the times when the landowner finds the effects to be most noticeable. For example, for a site that is cloudy for two thirds of the time relevant to shadow flicker and has Modelled duration at a dwelling of 45 hours, then the Measured duration will be 15 h and 5 h of curtailment is required. Using Modelled duration, a total of 15 hours of curtailment is required to be identified. Suitable periods of Modelled shadow flicker on various days throughout the year are identified, and the relevant turbine is shut down during these curtailment periods; two thirds of the time the curtailment will not be required due to cloud, resulting in 5 h of actual curtailment.

BLADE GLINT

77. Another effect that can be caused by the rotating turbine blades, is their ability to reflect sunlight off their surfaces. I have observed this effect in rare cases with new wind turbines, and it has the appearance as a slight “twinkling” as the blades rotate. I have not observed older turbines to produce this effect.

78. It is not possible to calculate the extent to which this effect will occur. However, there are a number of measures which can be taken to minimise the potential for this phenomenon. The extent to which blade glint may be apparent from a particular location will depend on a number of parameters including:

   (a) Position of the viewer, the sun and the turbine

   (b) Surface finish of the blades.

79. In accordance with international best practice it is proposed that for Mt Munro the wind turbine blades will be painted the same light grey or off-white colour and have a light reflectance value of no greater than 30%. This will reduce the potential for the turbines to cause blade glint. As the turbines age, this aging process will further reduce the ability of the blades to reflect sunlight. Therefore the effect will be insignificant.

RESPONSES TO ISSUES IN SUBMISSIONS

80. *Several submissions raise concerns about the distance from turbines to neighbouring houses and suggest setback distances.*
My evidence discusses this issue, and I make the point that a distance-based limit is not an effective way to limit effects and instead the actual effects of the turbines should be considered. I cover shadow flicker and others cover noise and visual effects. I also have provided some

examples of existing wind farms that have similar or closer spacing between turbines and dwellings.

81. *Several submissions raise concerns about shadow flicker.*
Shadow flicker will be kept within acceptable limits as covered in my evidence and as provided for in the proposed consent conditions. Only a few nearby dwellings will experience significant shadow flicker, as covered in the Landscape and Visual Assessment attached to the AEE as Appendix K, and in the evidence of Mr Girvan.

82. *Several submissions raise concern about the wind turbines affecting the wind or having other climatic effects in the vicinity of the wind farm.*
As covered in paragraph 68, apart from the wake, the wind turbines have no discernible effect on wind, rain, or other micro-climate factors. The turbine wake is a zone of reduced average wind speed and higher turbulence downwind of the turbines. This wake is less than the effects of trees and hills, and is located high above the ground with no discernible effect at ground level.

83. *Several submissions raise concern about dust and pollen caused by the wind farm construction and operation and the effect on air, water, pasture, solar panels, etc.*
The wind turbines will not cause any additional dust creation or pollen movement during operation as mentioned in paragraph 68 of my evidence. The control of dust to acceptable levels during construction is covered in Mr Van de Munckhof's evidence and the proposed consent conditions, including an Air Quality Management Plan under proposed conditions AQM1 -AQM2.

84. *Several submissions raise concern about the ability to do aerial topdressing and weed spraying on wind farm land and neighbouring land.*
The airstrip near the turbines is on land owned by one of the wind farm landowners, and its prior use was determined by the landowner. Future use may still be possible, depending on the final design of the wind farm, which will be confirmed at detailed design stage. The management of the underlying wind farm site for continued farming use is the responsibility of the landowner, subject to operational wind farm

and other constraints. Regardless of the availability of the airstrip, Meridian expects farming practices to continue in a similar manner.

85. *Several submissions suggest that Meridian should develop other areas or other sites instead of Mt Munro.*
As explained in the evidence of Mr Bowmar and Mr Anderson, Meridian has gone through a considered and fit for purpose site and feasibility analysis process for Mt Munro, and actively considers multiple potential sites for development across the country and region. As noted earlier in my evidence, the Mt Munro site has an excellent wind resource.

86. *Submission 11 questions Meridian's description of the wind profile as Grade 1 [Class I] and notes that at the submitter's site the wind is "very gusty and frequently seems above wind turbine operating parameters, possibly causing noise and gearbox wear resulting in more noise."*
The wind resource on the wind farm site is approximately Class I with low turbulence and well-suited to wind turbines as covered in paragraph 17 of my evidence. Turbulence and gustiness is expected to be higher downwind of the ridgeline where this submitter lives, as mentioned in paragraph 68. The increased turbulence at this location is a result of the terrain rather than the wind turbines.

87. *Submission 33 queries why Meridian doesn't fix the broken wind farms on Saddle Road and Pahiatua Track first."*
Meridian's Te Apiti wind farm is located on Saddle Road. The turbines are kept running as much as possible since any downtime represents lost revenue. The wind farm had a mid-life refurbishment recently that resulted in some additional downtime. However, the overall availability of the turbines is good. Meridian does not have a wind farm on Pahiatua Track, although we are investigating a possible repowering of the Te Rere Hau wind farm in conjunction with the site owner, NZ Windfarms. Some of the existing turbines are at the end of their economic life and are not cost-effective to maintain. As noted in Mr Bowmar's evidence, Meridian is investigating multiple development options and this site is among the very best Meridian is aware of in New Zealand.

88. *Submission 61 recommends turbines not larger than those of Pahiatua Track wind farm.*

The new Turitea wind farm south of Pahiatua Track has turbines nearly as big as those proposed for Mt Munro, and the consent for the repowering of the Te Rere Hau wind farm allows turbines of about the same size as proposed for Mt Munro. The wind turbine manufacturers continue to develop their turbines, making them more cost-effective and in many cases larger, with older, smaller turbines going out of production. It is important for a cost-effective project to be able to install the turbines that are available at the time of construction. The proposed maximum size of turbines is a balance between the effects and the expected sizes of turbines that will be available. Further, an increase in wind turbine size often is associated with a reduction in the number of turbines overall.

CONCLUSIONS

89. New Zealand has one of the best useable wind resources in the world, although not every site with a good wind resource is suitable for wind farms, given the number of other factors which can affect feasibility.

90. Wind speeds are significantly greater and the wind is smoother and more consistent at the summits of hills and along ridgelines due to both the shape of the hill and the elevation itself.

91. Wind farms have high capital costs with relatively low operating costs, so the cost of energy and financial viability are largely determined by how much electricity a wind farm will produce. The generation is in turn largely determined by the average wind speed at the site.

92. The Mt Munro site has a high average wind speed which will result in a good level of energy production. This is partly why the site is a good location for a wind farm.

93. Modern wind turbines will not operate successfully in high turbulence areas such as gullies and valley bottoms. These areas also generally have significantly lower wind speeds.

94. Wind turbines require significant separation distances from each other to operate efficiently, otherwise wake will cause excessive loss of energy and fatigue loads.

95. The wind turbine model which will be used at Mt Munro will be a 3 bladed, upwind pitch-controlled machine.

96. Mt Munro will have a capacity factor of 45-50% and the turbines will generate electricity for 95% of the time. Mt Munro will generate the annual energy requirement of 42,000 homes.

97. It is not appropriate or necessary to define a minimum separation distance between wind turbines and houses or property boundaries, but rather to consider the environmental effects and define limits in relation to these effects. The separation distances between the wind turbines and houses surrounding the site are similar to separation distances of many other wind farms in New Zealand and around the world.

98. Some existing houses will be affected by shadow flicker. This will be limited to acceptable levels using the proposed consent condition, which is based on a well-established assessment method and limits.

99. Blade glint effects associated with the project will be negligible. The effect is generally not noticeable, and the wind turbines will be painted a light grey colour and have blades with a low gloss finish to minimise the potential for blade glint.

Simon Faulkner

24 May 2024

APPENDIX A

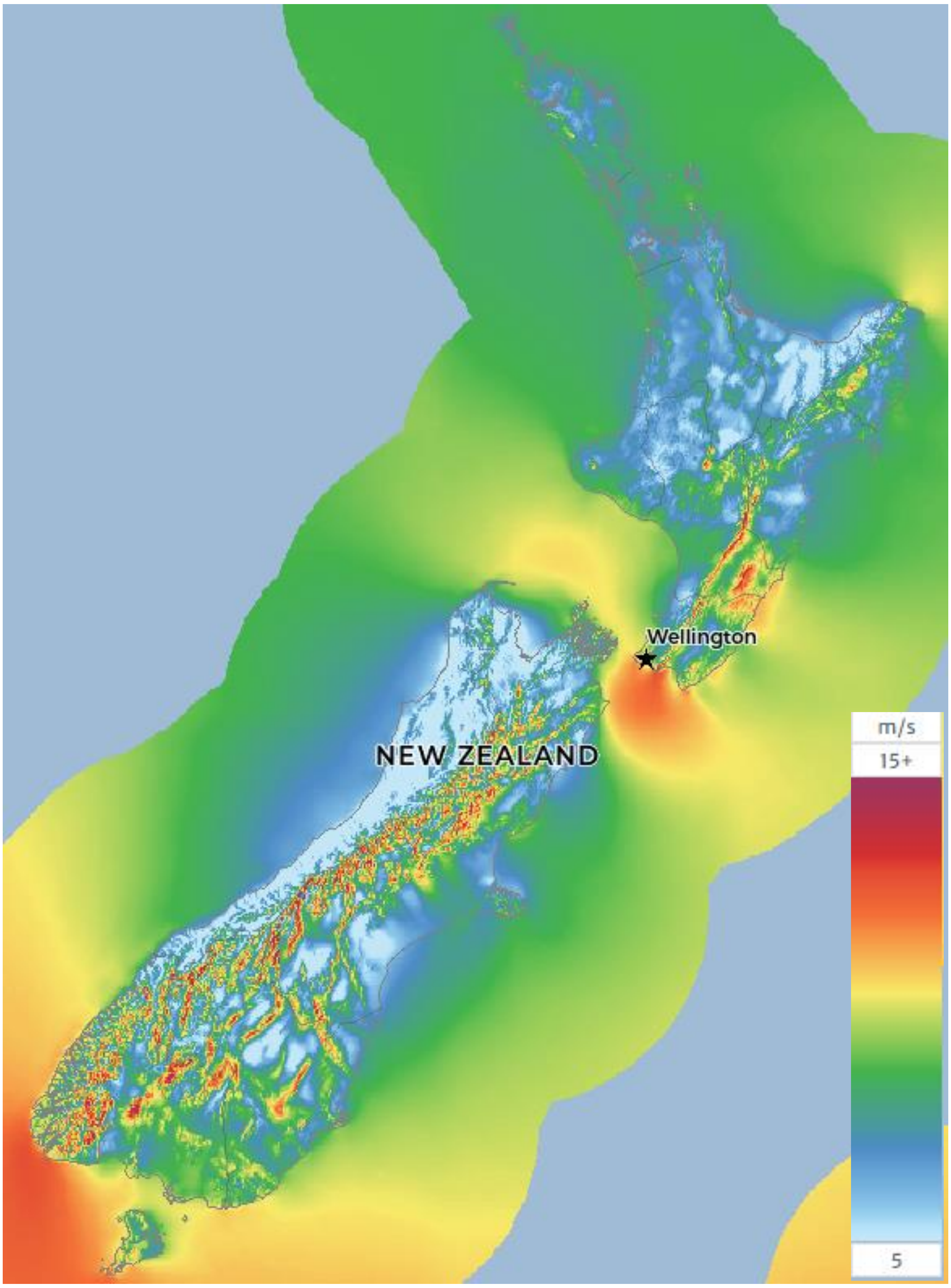

Figure 1: Wind map of NZ (source: Global Wind Atlas)

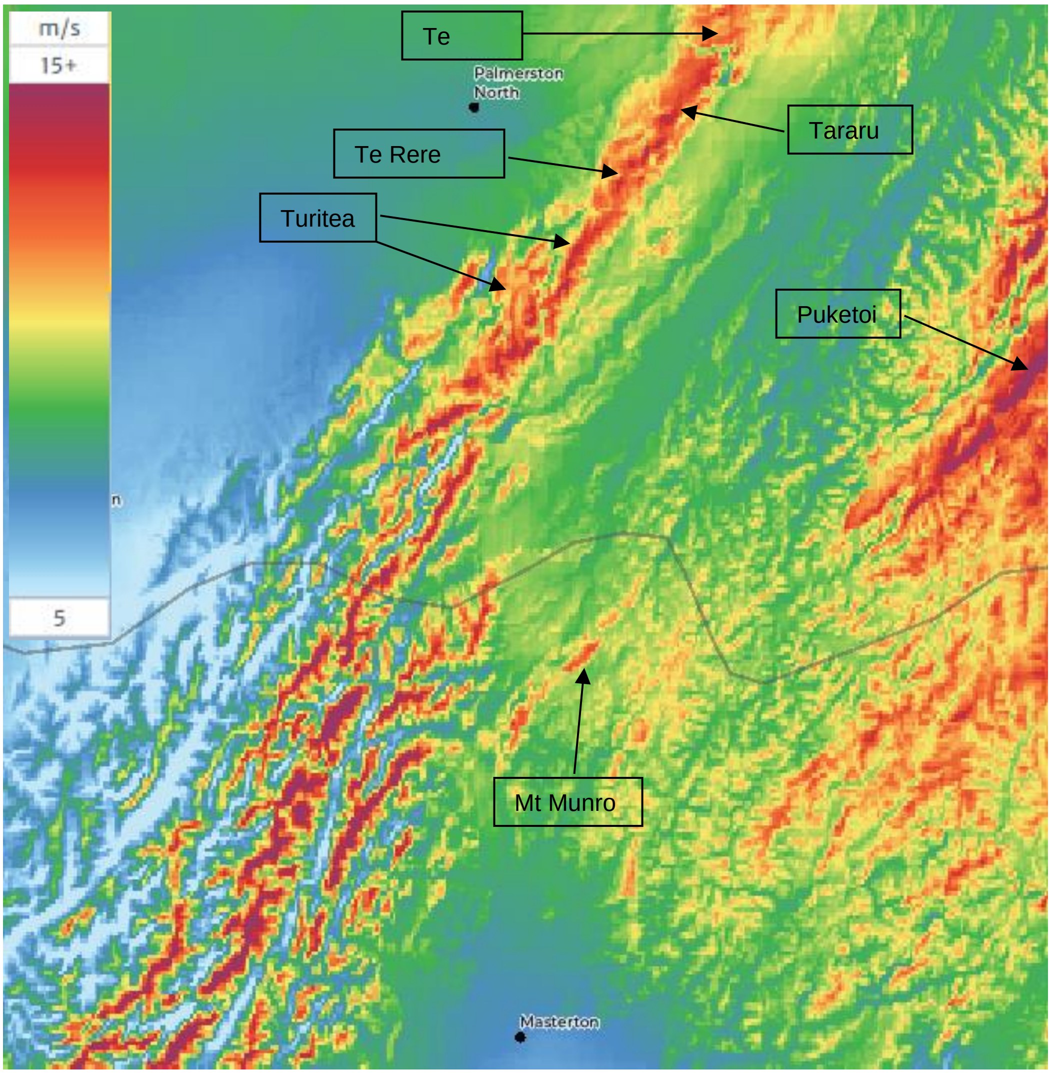

Figure 2: Wind map of Wairarapa/Manawatu region (source: Global Wind Atlas)

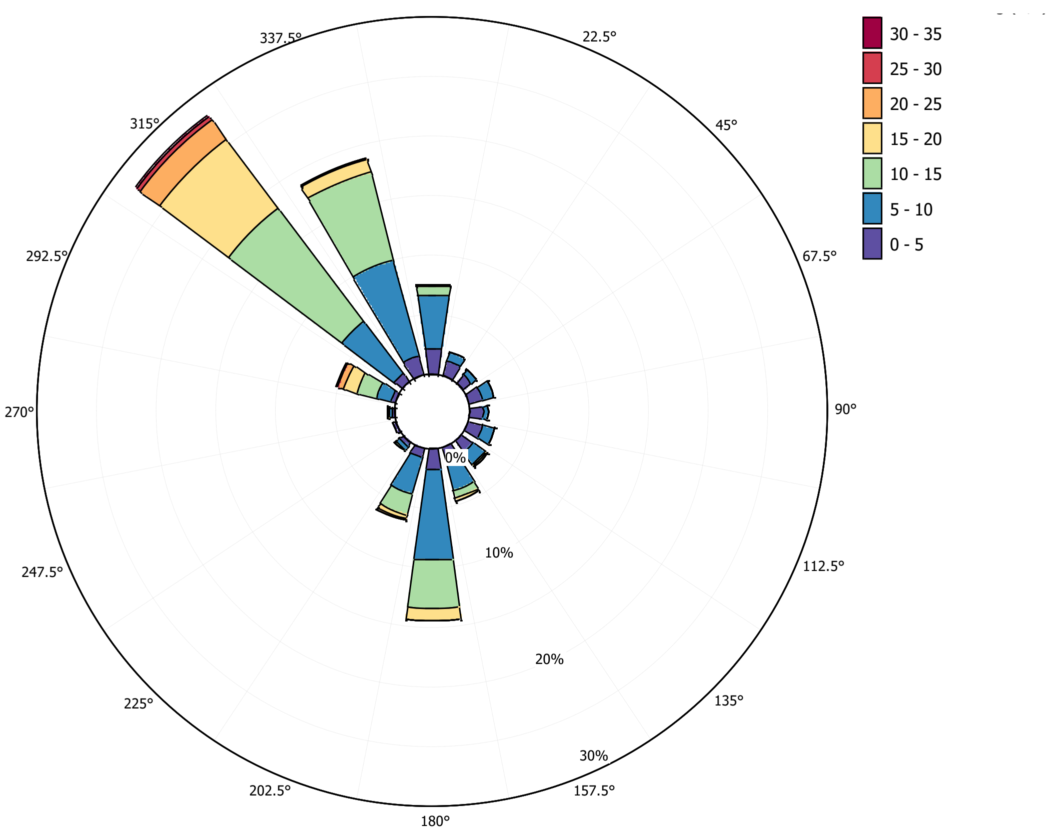

Figure 3: Wind rose for the site (colour bands indicate wind speed in m/s)

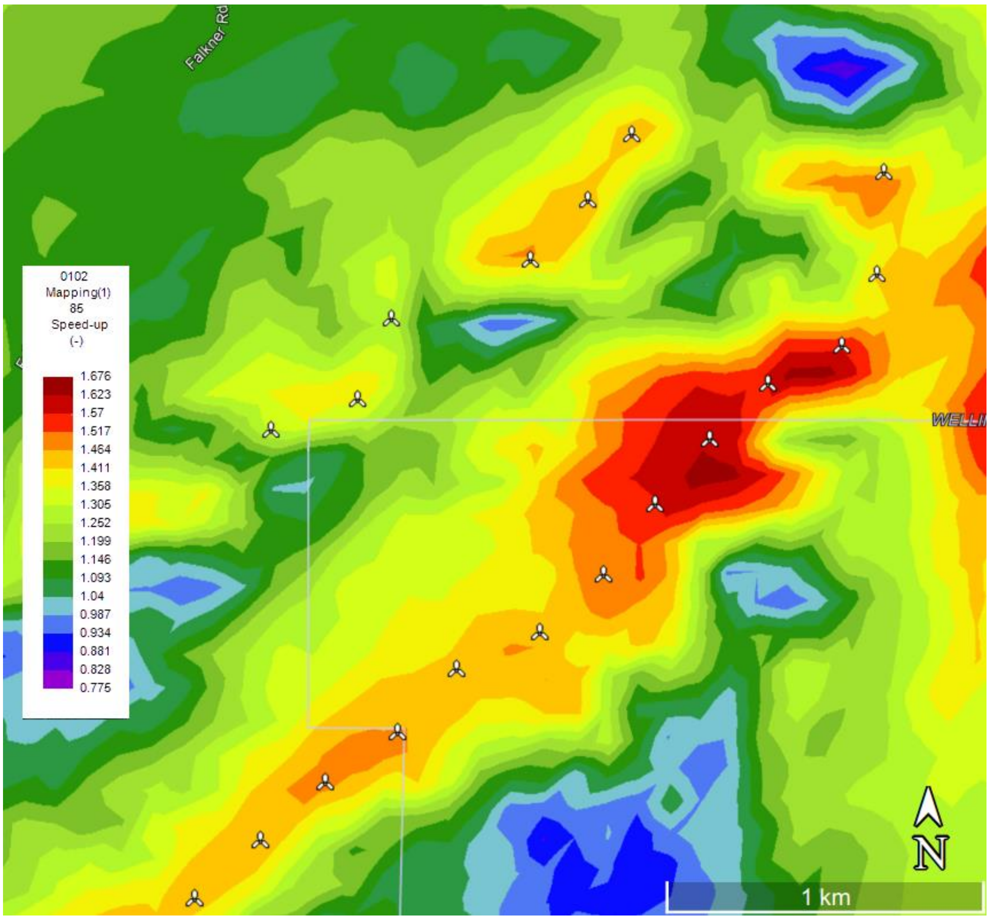

Figure 4: Wind speed map for the site (colour bands indicate average wind speed, from blue (low) to red (high))

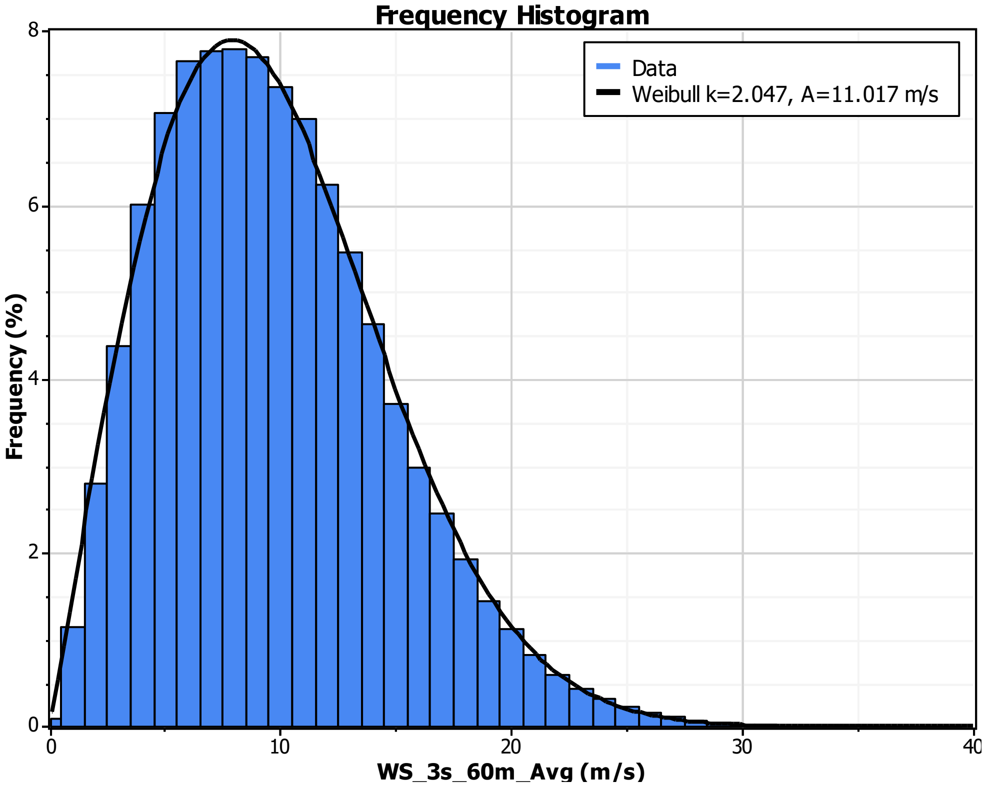

Figure 5: Wind speed distribution

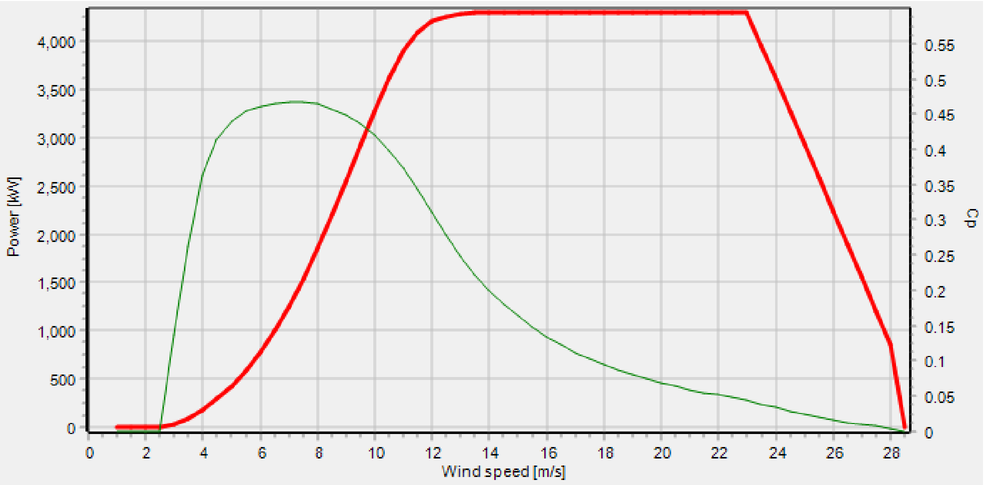

Figure 6: Typical turbine power curve (SWT-DD-130)

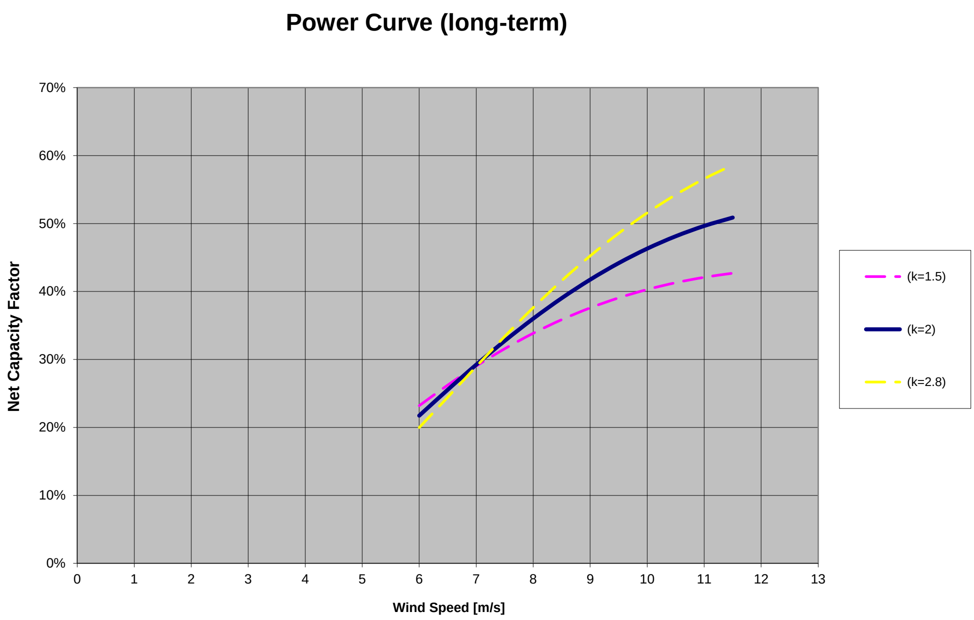

Figure 7: Typical wind farm long-term power curve

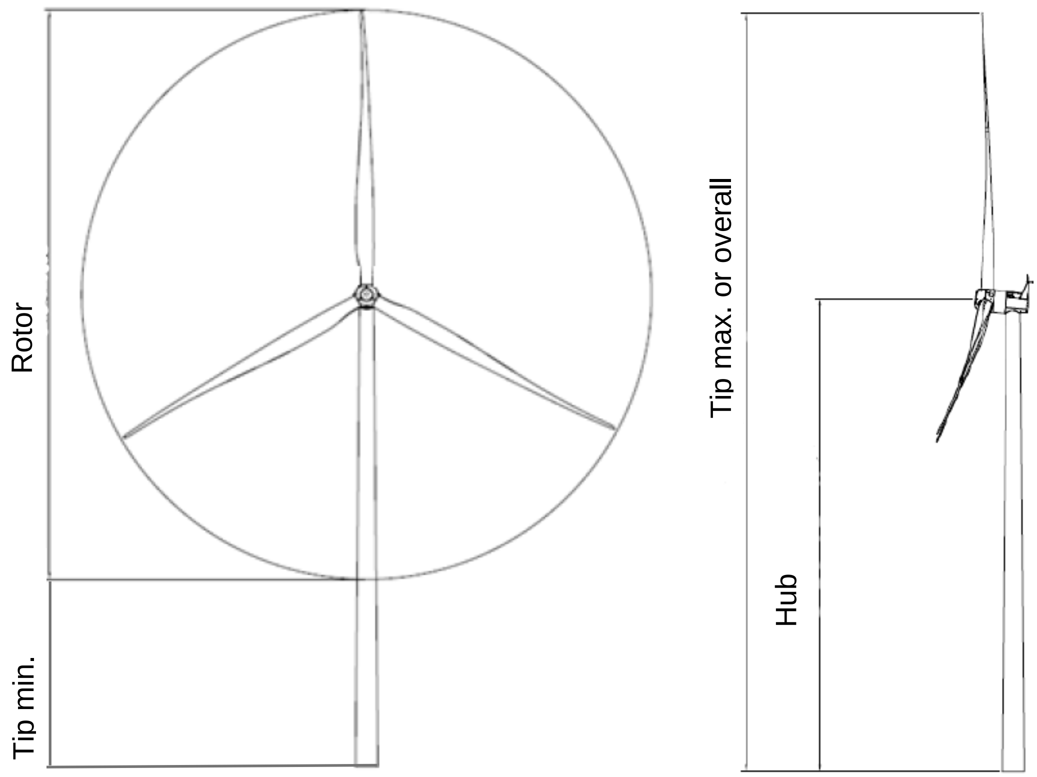

Figure 8: Wind turbine main dimensions

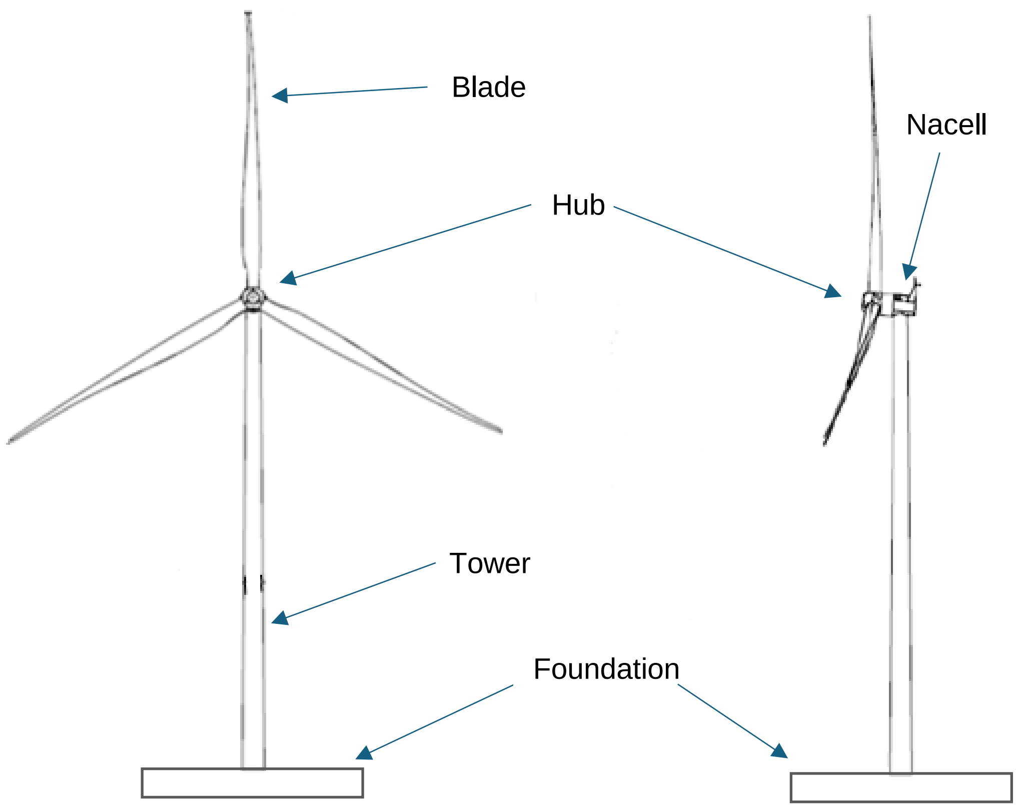

Figure 9: Wind turbine main components