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# Recognizing the Sites with Maximum Power Generation According to Typical Wind Patterns of New Zealand

Navid Majdi Nasab*, Jeff Kilby

School of Engineering, Computing and Mathematical Sciences, Auckland University of Technology, Auckland, New Zealand
navid.nasab@aut.ac.nz

This paper introduces the typical wind patterns in New Zealand recording by the National Institute of Water and Atmospheric Research (NIWA) and evaluates the optimized sites among them with higher amount of power generation. A comprehensive simulation model has been set up, using several available commercial software packages to test the performance, capacity and efficiency of the results. Available wind records have been used from NASA to conduct simulation model runs of them. Global Wind Atlas is used for showing wind patterns and WRPLOT software plots wind class of sites. Homer Pro software used to propose a microgrid design for each site and calculate power. Generation of electricity from wind turbines depends on the wind speeds and cut-in speed of the wind turbines. In other words, to reach maximum efficiency from wind power, the first step is to analyse the wind speeds of the site where turbine will be located and then estimate the generated power from that turbine. To do it, it is necessary to find the range of wind speeds and the wind directions with demonstrating wind rose and the percentage of year a turbine is working in more than cut-in speed. Based on current wind patterns, Dunedin and Bluff sites found the areas with maximum power generation.

## 1. Introduction

Wind energy is one of the renewable energy sources already being used to meet the world's massive demand for electricity and reduce use of its fossil fuels. Historically in New Zealand the main renewable energy sources have been geothermal and hydro power. However, in the future most incremental growth in renewable energy are forecasted to come from wind energy and geothermal energy capacity (New Zealand Energy Strategy 2011–2021, 2011).

The percentage of generation electricity from wind in the decade 2011-2020 in comparison to total renewable sources used shown in Figure 1 (GOVT.NZ, 2022).

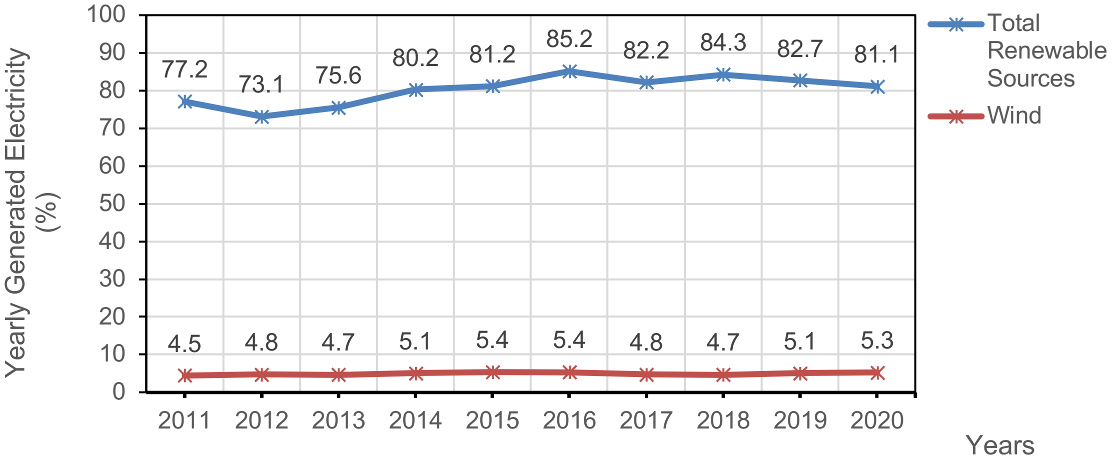


*Figure 1: Percentage of electricity generation in New Zealand 2011-2020, source (GOVT.NZ, 2022)*

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Wind provided 2,232 GWh of electricity, or 5.1 %, of total electricity supply in 2019 which was 37 % of the capacity factor. Capacity factor for wind is the amount of electricity generated in relation to the maximum output capable of being generated by installed wind turbines over a period of time assuming no downtime for maintenance (GOVT.NZ, 2020a).

By 2030 it is predicted that wind generation in New Zealand will increase six-fold, producing as much as 20 % of all electricity. Wind farm capacity can be built as it is essentially the most cost-effective form of electricity generation, being predictable, dependable and the costs of fuel are known (wind is free) (GOVT.NZ, 2011). The Ministry of Business, Innovation and Employment (MBIE) report issued on June 2020 (GOVT.NZ, 2020b) describes the desired wind generation growth between 2020 and 2060. It shows that 2,500 MW of new wind generation is required between 2020 – 2030, 1,500 MW between 2030-2040, 2,000 MW between 2040-2050, and 2,000 MW between 2050-2060. To put this in context, there is currently only 690 MW of wind generation in New Zealand – and the majority of this total has taken the previous 20 y to develop and construct (GOVT.NZ, 2020b).

To reach the targeted wind generation growth, wind energy needs to be investigated from different aspects. The effects of configuration parameters on the performance of wind turbines have been thoroughly investigated (Esteban et al., 2011). RETScreen software was used to identify which of the harbour/estuary sites in New Zealand appear to have potential for wind power generation (Nasab et al., 2020) However, to ensure their better operation in an environment, some technical challenges remain to be resolved.

Historically, wind directions determined from eolian sandstones (Parrish et al., 1988). In modern wind turbines, control mechanisms and operation of yaw systems maximize wind power extraction from different wind directions (Song et al., 2018). But no one has used climate models for predicting generated wind power in different wind patterns. To do this, Global Wind Atlas (2022) is used to plot wind rose of current wind patterns in New Zealand and in the next step, wind speeds data from each site imported from NASA database (NASA.GOV, 2019) to WRPLOT view software (WRPLOT, 2018) and Homer Pro (2022) to find wind frequency distribution and output power in each site.

What is novel about the project described in this paper is that it investigates the technical feasibility of wind generation directional-wise. So, based on current wind patterns, the results will be enabled to propose in which wind patterns the maximum electricity can be achieved.

The paper is organized as follows: After the Introduction Section, Section 2 presents the methods used to evaluate the strength of wind energy in different wind patterns, Section 3 presents the Results of generated powers, and finally, the Conclusions are given in Section 4.

## 2. Methods

Westerly wind patterns prevail in most parts of New Zealand. National Institute of Water and Atmospheric Research (NIWA) recording sites in 2014 summarize every hourly measurement, illustrating patterns of turbulence and calm in different places shown in Figure 2.

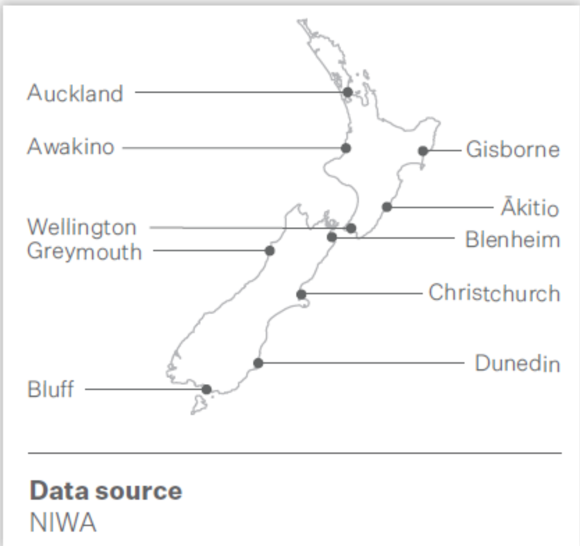


*Figure 2: NIWA recording sites, selected to show typical wind patterns in 2014 (McDowall, 2019)*

Entering the geographical coordinates of above sites in Global Wind Atlas (Global Wind Atlas, 2022) updates NIWA wind patterns as shown in left sides of Figures 3 to 12. Global Wind Atlas (Global Wind Atlas, 2022) is a tool for estimating the potential of wind energy in an area (Nasab et al., 2021) For each site selected, scatter charts show how often and how strongly winds blow from different directions during 2021. The centre of each plot represents calm conditions. Wind strength is shown by the distance from the chart centre, in 1 m/s steps. The further a tick is from the calm centre, the stronger the wind. Wind direction is determined by angle from the centre. Northerly winds are at a 12 o'clock position; easterlies at 3 o'clock. The duration for which wind blew from a particular direction at a certain strength is shown defining wind class frequency distribution graphs. WRPLOT view software (WRPLOT, 2018) was used to plot wind frequency distribution downloaded from NASA Surface Meteorology and Solar Energy database (NASA Surface Meteorology and Solar Energy Database, 2019). Totally 8760 wind speeds for 12 months in 1 h interval imported to software to introduce wind class of sites. Assuming a typical cut-in speed of 4 $ms^{-1}$, WRPLOT (2018) enables the percentage of power generation for each site when wind blows over cut-in speed as presented on right sides of Figures 3 to 12. It shows in how much percentage of year, wind blows more than 4 $ms^{-1}$.

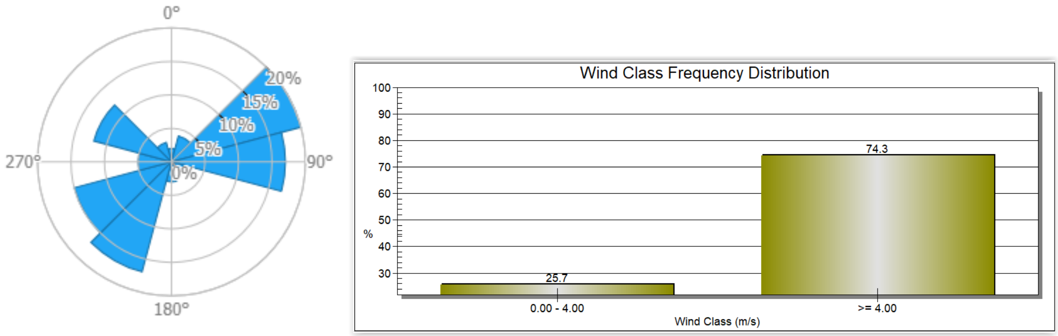


*Figure 3: Wind patterns of Christchurch: gentle winds from most directions*

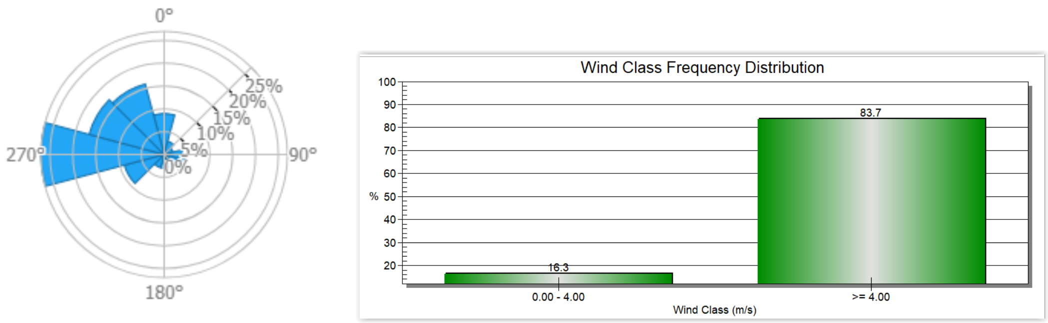


*Figure 4: Wind patterns of Bluff: strong westerlies, moderate easterlies and southerlies*

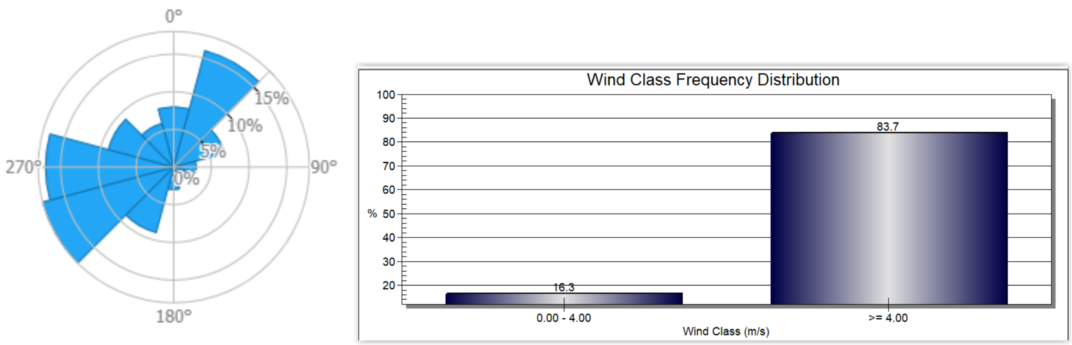


*Figure 5: Wind patterns of Dunedin: wind from most directions except the north-east and south*

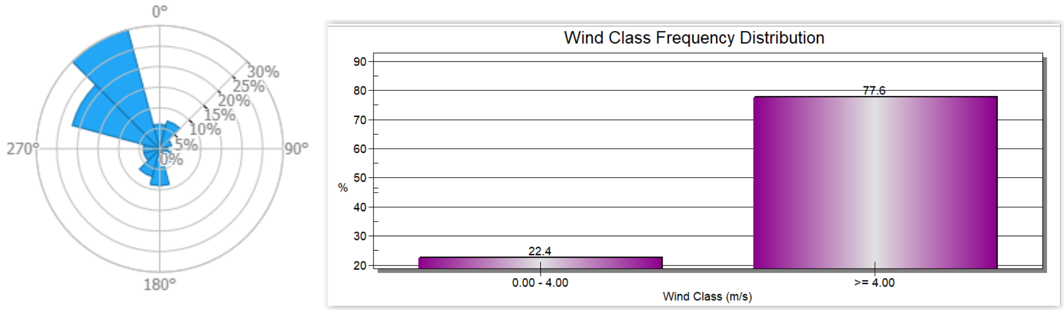


*Figure 6: Wind patterns of Greymouth: strong south-westerlies and easterlies*

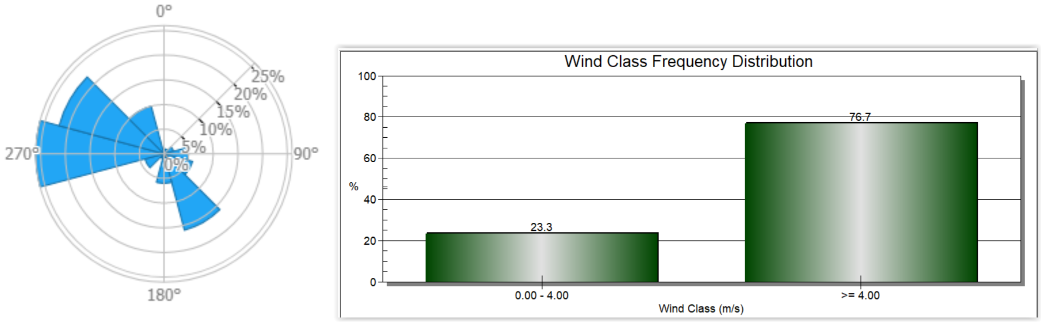


*Figure 7: Wind patterns of Blenheim: moderate westerlies and north westerlies*

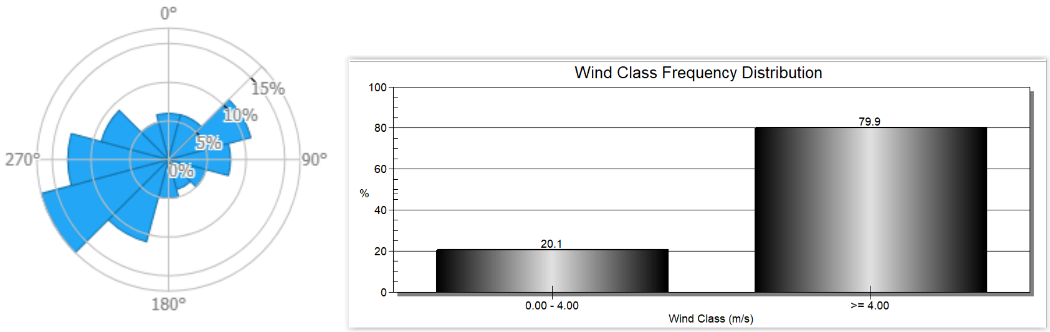


*Figure 8: Wind patterns of Auckland: dominated by westerlies, south westerlies, and north easterlies*

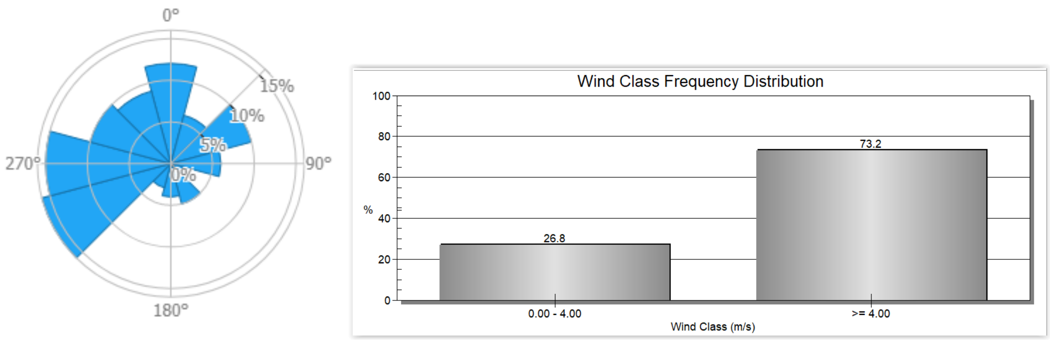


*Figure 9: Wind patterns of Awakino: strong westerlies and moderate south-easterlies*

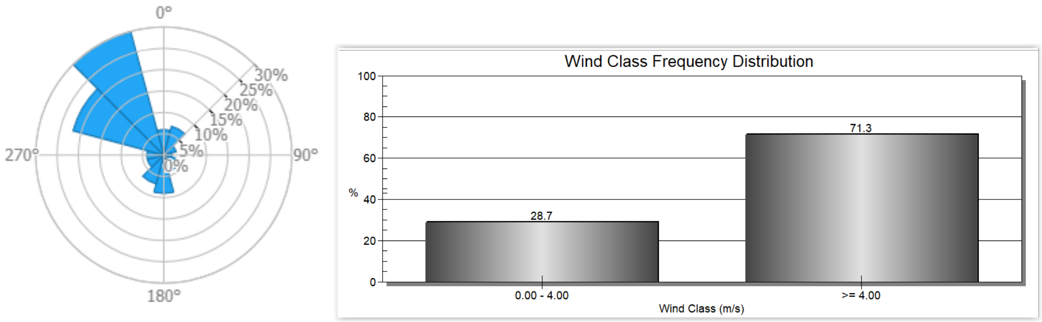


*Figure 10: Wind patterns of Gisborne: a calm year of mostly gentle winds*

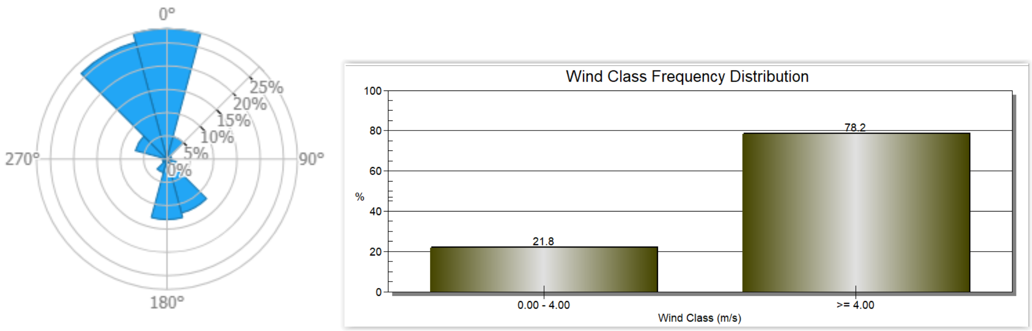


*Figure 11: Wind patterns of Wellington: strong northerlies and southerlies*

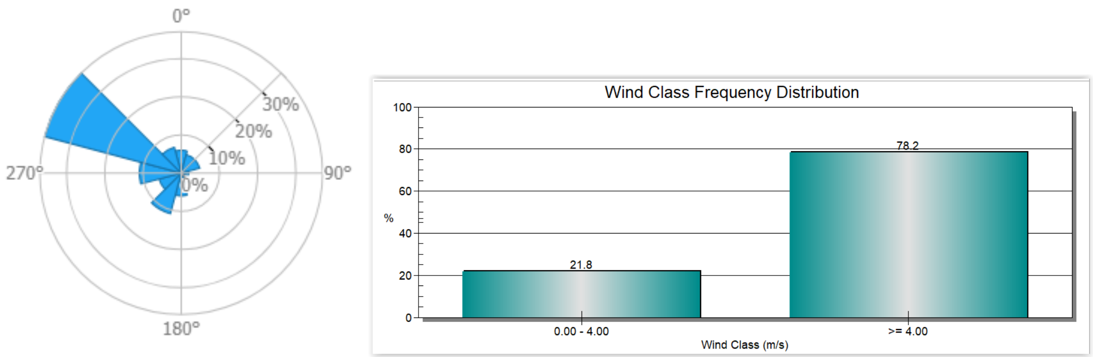


*Figure 12: Wind patterns of Akitio: wind from all directions, with especially strong north-westerlies*

## 3. Results

Homer Pro imports wind speeds from NASA database to calculate annual generated power ("Homer Pro,"2022). To do so, Homer needs at least 8,760 value for 12 months. So, if there be a value for 1 h, a total of 8,761 (total number of hours in a year) values of wind speed can be gathered and imported to software to help Homer calculate the annual average water speed. Based on the geographical coordinates of above sites, their annual power is summarised in Table 1. The maximum efficiency can be seen in Dunedin and Bluff sites respectively. In both sites, wind blows over 4 $ms^{-1}$ in 83.7 % of a year. The minimum wind power is in Gisborne and Awakino shows east of north island is not a good area for investment at all. While percentage of power generation in Gisborne and Awakino is good values of 71.3 % and 73.2 %, the speed of wind is still far from cut-out speed to generate enough electricity.

*Table 1:The power generation in typical wind pattern sites*

| Location | Latitude (deg) | Longitude (deg) | Annual Power (MW) | Power Generation share (%) |
|---|---|---|---|---|
| Christchurch | -43.510962 °S | 172.581139 °E | 137,550 | 74.3 |
| Bluff | -46.60228 °S | 168.339729 °E | 225,076 | 83.7 |
| Dunedin | -45.852222 °S | 170.50027778 °E | 237,060 | 83.7 |
| Greymouth | -42.474123 °S | 171.208191 °E | 161,884 | 77.6 |
| Blenheim | -41.521174 °S | 173.959236 °E | 155,116 | 76.7 |
| Auckland | -36.54164 °S | 174.550781 °E | 172,315 | 79.9 |
| Awakino | -38.659778 °S | 174.624939 °E | 131,836 | 73.2 |
| Gisborne | -38.643691 °S | 178.015594 °E | 117,517 | 71.3 |
| Wellington | -41.252774 °S | 174.718323 °E | 168,325 | 78.2 |
| Akitio | -40.618122 °S | 176.412964 °E | 168,889 | 78.2 |

## 4. Conclusions

While wind patterns in New Zealand can be analyzed with wind roses, the main issue is recognizing the superior wind patterns based on their generated power. The results of reviewing information about wind speeds and directions on the New Zealand coastline reveals that Dunedin and Bluff can generate 237,060 and 225,076 MW power respectively in 83.7 % of year based on their wind pattern analyzed in Figures 4 and 5.
Investment on wind power considering wind rose is crucial to increase the capacity of wind generation to an optimized level. The future work in this aspect can be estimating the cost of electricity in terms of wind rose and analysing the wind patterns which can generate electricity with lower cost for customers.

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