Renewable energy for Scott Base. A win-win situation

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Abstract

Antarctica New Zealand and the Electic Power Engineering Centre at the University of Canterbury are currently investigating future renewable energy alternatives for Scott Base. The aims are to investigate the current energy requirements, and then conduct a feasibility study on the suitability of alternative energy systems, including wind and solar energy.   The overall goal is to reduce the quantity and dependency of fossil fuels and their associated impact on the environment.   This paper presents an initial outline of the various energy issues and provides a basis for identifying possible directions for future work.

Introduction

Scott Base located at S77.85°, E166.800°, is New Zealand's main Antarctic scientific research base located on the southern end of Hut Point Peninsula, Ross island in McMurdo Sound. The station has been continually inhabited since 1957 and now regularly accommodates up to 70-80 people during the summer months and around 10-15 people over winter months.

Almost all energy needs are met from the burning of fossil fuels for both heating and electrical generation for lighting, power, water desalination, etc. Each year around 450000 litres of fuel are purchased from the United States Antarctic Program (USAP) McMurdo station of which 370000 litres are used for the generation of electrical energy (with thermal heat recovery) and a futher 53000 litres used to run diesel fired boilers for additional thermal energy. The remaining fuel is used for transportation.

The associated environmental impacts of burning fossil fuels and the risk of spillage are good incentives for reducing fossil fuel energy use.   By harnessing cleaner forms of renewable energy such as wind and solar power, a cleaner environmentally friendly form of energy can be utilised with not only possible savings in the medium to long term, but with much reduced environmental impact on the Antarctic's sensitive environment.

At least one station on the east coast of Antarctica, Australia's Mawson station, has led by example by installing three large ENERCON 300kW wind turbines to help reduce its fossil fuel consumption[1]. This paper, using recorded energy data, first examines the current energy demands and trends at Scott Base. Then, using meteorological records it provides an estimate into the likely performance from the installation of both wind powered turbines and photovoltaic solar panels.

Scott Base's current energy system

With recent extensions to the footprint of the base, including the stage 8 ablutions block and the waste water treatment plant, as well as with the current building of a new field store, energy trends are currently on the rise.

The heart of Scott Base's power system consists of three 225kVA Caterpillar diesel generators, two in the stage 2 power house and one in the stage 6 power house.   Only one unit is ever run at any one time with one on standby, ready to go, and one backup unit providing extra reduncy. Marine

manifolds, running through heat exchangers as well as exhaust heat exchangers, are used to capture heat from the stage 2 power house generators (stage 6 does not have heat exchangers). The heat recovered from the generators is carried through the base via a heating loop (an 80mm pipe) where it is distributed to the various plant rooms located in the different base buildings. Additional heat is added to the heating loop from within the power houses by four diesel-fired boilers, and two electric water heaters as required.

Table 1 shows the recorded and estimated energy figures for Scott Base. The assumptions made are a Lower Heat Value of 9.8kWh/litre for AN8 fuel, a boiler efficiency of 80%, and heat recovery of 30% of input energy in the generators.

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AN8 used in generators (litres)	368657
AN8 used in boilers (litres)	53830
Electrical Production (kWh)	1360335
Generator heat recovery (estimate 30% – kWh)	1083852
Boilers Production (estimate 80% – kWh)	422027
Total energy production (estimate - kWh)	2866214
Overall efficiency (estimate - %)	69.00%
Average electrical load (kW)	155
Average thermal load (estimate - kW)	172
Average Total load (estimate - kW)	327

Current Energy Trends

The required energy throughout the year is influenced by two main factors: the level of activity on the base which is highest in summer, and the lighting and thermal requirements that are highest in winter. The thermal heating and lighting requirement leads to maximum energy use through the use of the supplimentary boilers during winter.

Figure 1 illustrates the total amount of fuel used at Scott base during the period from December 2001 through to the end of November 2002. This is the fuel used in the generators and boilers. As a comparison, the lower graph shows the recorded temperture. A good inverted correlation can be seen between the two indicating that the thermal energy requirement is significant during the winter months.

This information was obtained from Antarctica New Zealand from the physical fuel meter readings as recorded at Scott Base by routine daily rounds and checks from the engineering staff. The data obtained has been adjusted to compensate for new fuel meters (installed during the 2001/02 year effectively adding a dc offset to the original meter readings) and also for several human induced errors that have been corrected with simple linear interpolation. The daily data was then subjected to a crude rolling average filter, providing a weekly rolling average. This makes the data more readable, however it should be noted that this results in a minor mis-alignment in the x-axis scale.

Figure 2 illustrates the total energy production at Scott Base from December 2001 through to the end of November 2002 with the estimated heating effects of the boilers and heat recovery from the diesel gen sets. To obtain the estimated power, a value of 9.8kWh/litre was used for the fuels Lower Heat Value (LHV)

Scott Base fuel use and temperature from December 01 to November 03 (weekly rolling average)
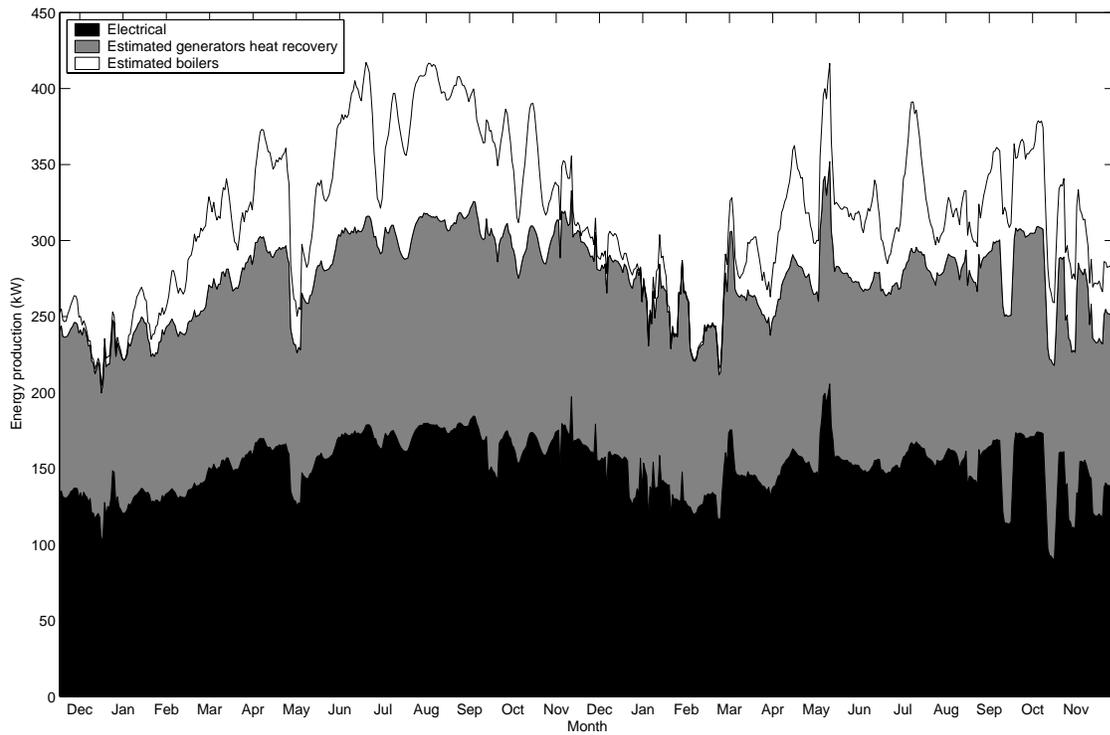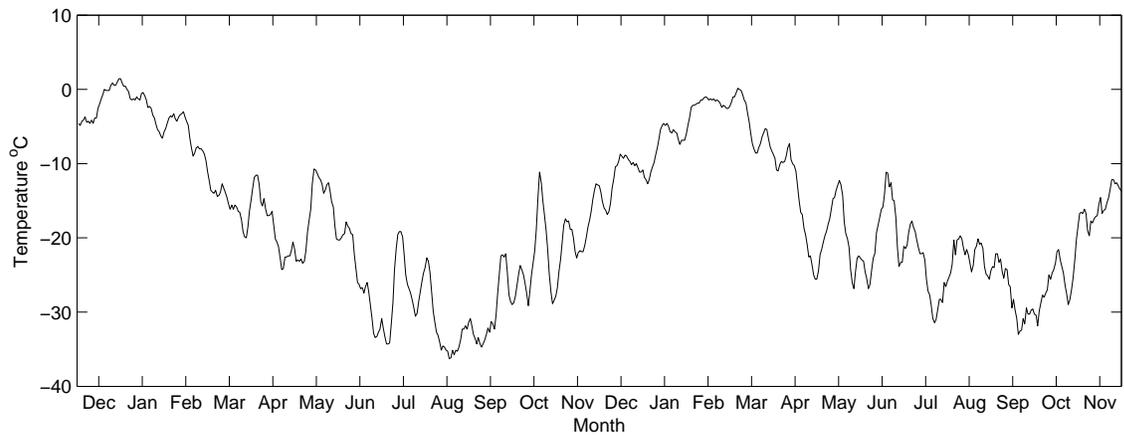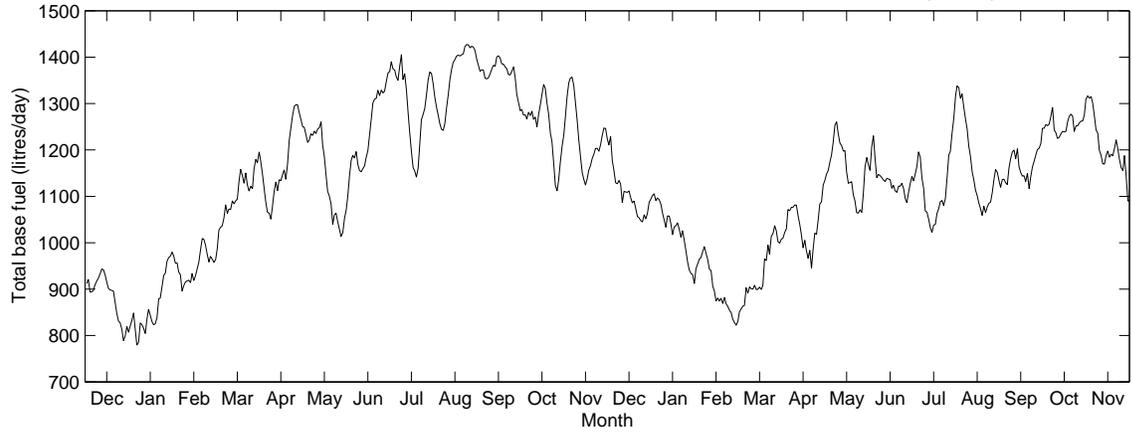
As shown, more energy is required during winter than summer due to the extra thermal and lighting requirements. This extra thermal energy is provided mainly through the use of the diesel fired boilers, however, both the electrical and thermal energy recovered from the generator sets are increased during the winter months. During the summer months, November through to March, the boilers are used only occasionally, with the thermal energy from the generator sets more than adequate to provide the base's heating requirements.

The average electrical load is 155kW with a maximum occuring during winter, near the generators capacity of 225kW. This is the same as the power used by over 130 average New Zealand households[1].

Renewable Energy Potential

The renewable energy potential for Scott Base can be assessed using past recorded metrological records of wind speed and solar insolation data. A system used to replace the generators will require, on average, 155kW of power to provide a significant reduction in fossil fuel usage. The likely canidates are wind power and solar power. Figure 3 shows the average monthly wind speed and global solar radiation at Scott Base. These plots were produced by averaging the monthly wind and solar data from 1997 through to 2003.
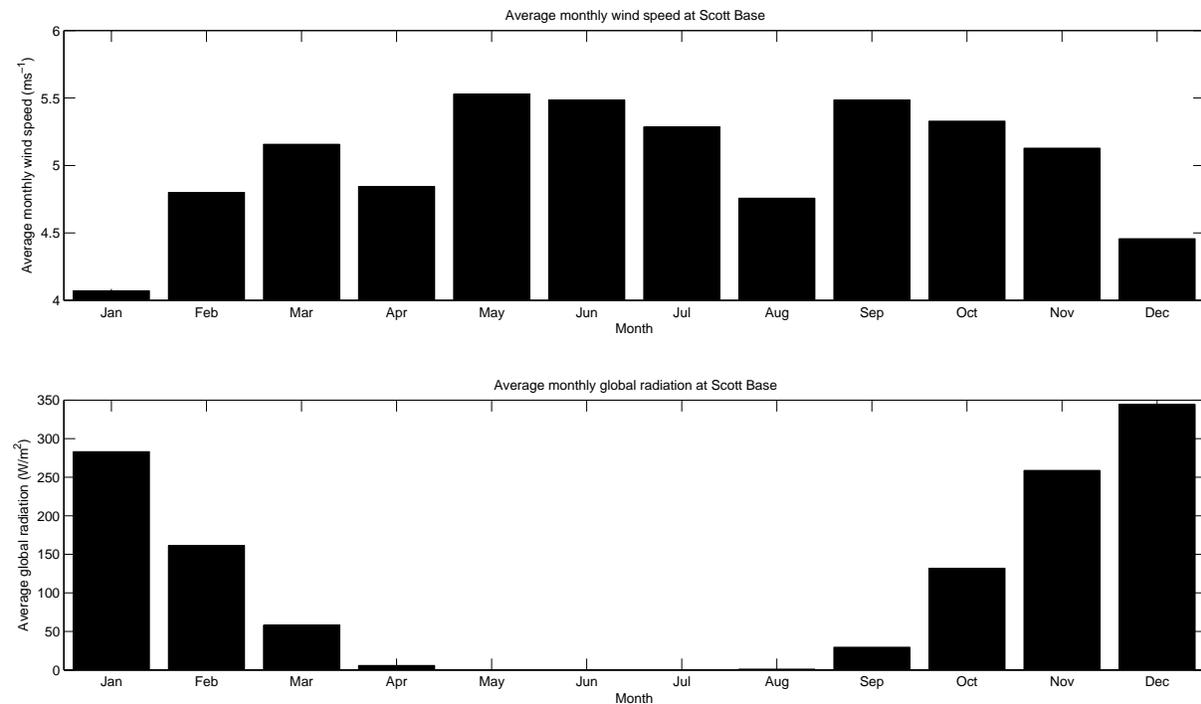
Solar radiation

As shown in Figure 3 global solar radiation has high seasonal variation from $0W/m^2$ during the winter months to a peak of over $300W/m^2$ during December. Hence, solar energy is inadequate for year round applications but very usefull for summer applications where there is 24 hours of sunlight. Photovoltaic panels transform solar radiation into direct current with a typical efficiency of around 10% and cost in the vacinity of $NZ\$1000/m^2$. Hence, using Figure 3 it can be seen that

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1Assumming the average NZ household consumes 10500kWh per year [4].

the maximum electrical power over December will be in the vacinity of 34.5W/m². The average over the summer months from November to January will be 29.5W/m² and the average for the typical year being 10.6W/m² . Hence, solar panels are generally limited to small summer field camps and field stations which generally range in size up to several hundred watts and are often coupled with small wind turbines. The authors are currently in the process of designing, with Antarctic New Zealand, such a small scale system at Cape Bird hut, a summer field station situated on the NW corner of Ross Island.
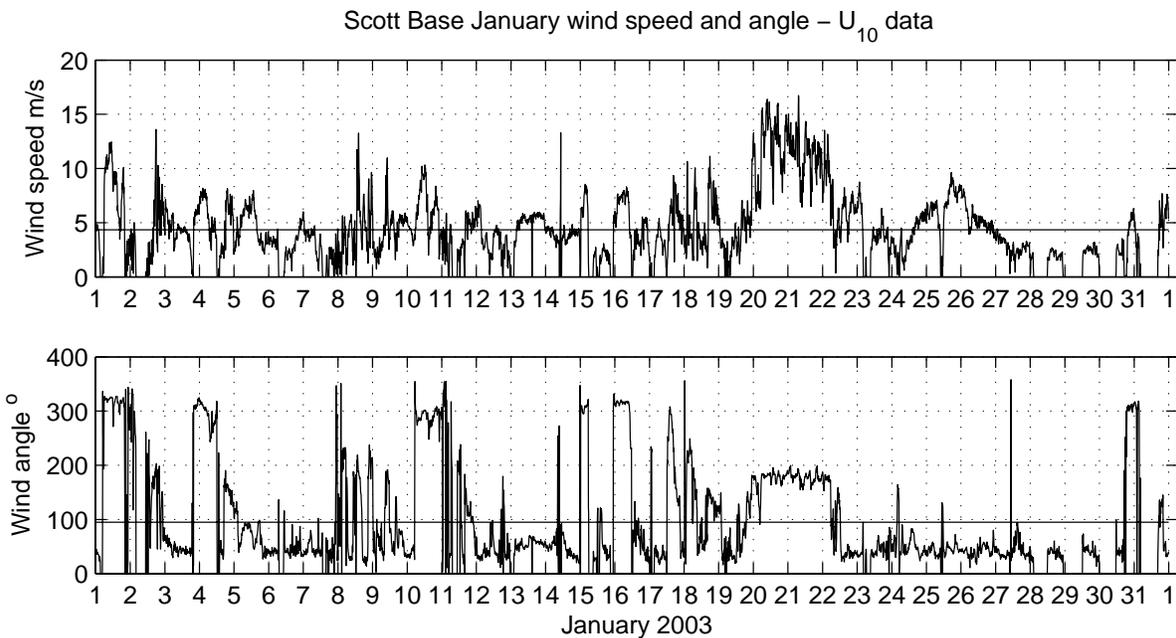
Wind turbines

As shown in figure 3, the average recorded wind speed at Scott Base is not high with a yearly average of only 5ms⁻¹. Most turbines are rated around 12-14ms⁻¹. The power from the wind is proportional to the cube of the wind speed, ie,

$$P_{wind}=kv^3 \qquad (1)$$

where, k is a constant dependent on the wind mass and sweep area of the turbine [5].
Hence, if the wind is constant, a typical wind turbine of rated capacity at 12ms⁻¹ would produce $(5^3/12^3)$x100=7.2% of its rated output. However, Figure 4 shows the typical 10 minute wind speed and direction of data recorded at Scott Base during January 2003[2].

Scott Base January wind speed and angle – U_{10} data

As shown, the wind speed varies greatly with a maximum of 16.7ms⁻¹. Assuming that a wind turbine will keep power to its rated power output at wind speeds above rated wind speed, and produce no power below rated wind speed, the data in figure 4 can be used with equation (1) to find the output power of a turbine. Hence, figure 5 shows the output power of a 300kW wind turbine rated for 12ms⁻¹ during January 2003 at Scott Base. January was choosen as the data was obtained free of charge from NIWA.
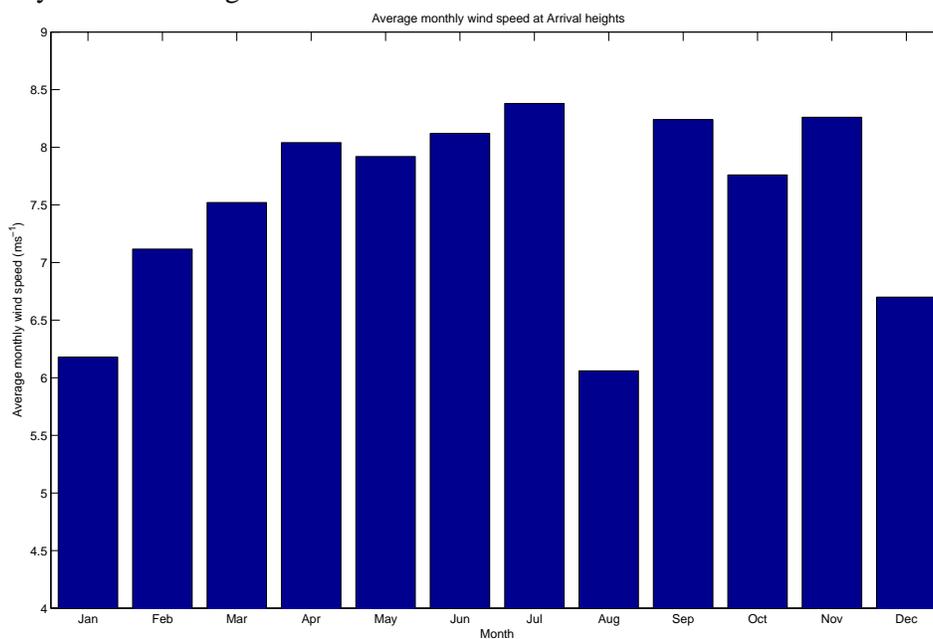

2Courtesy of NIWA.

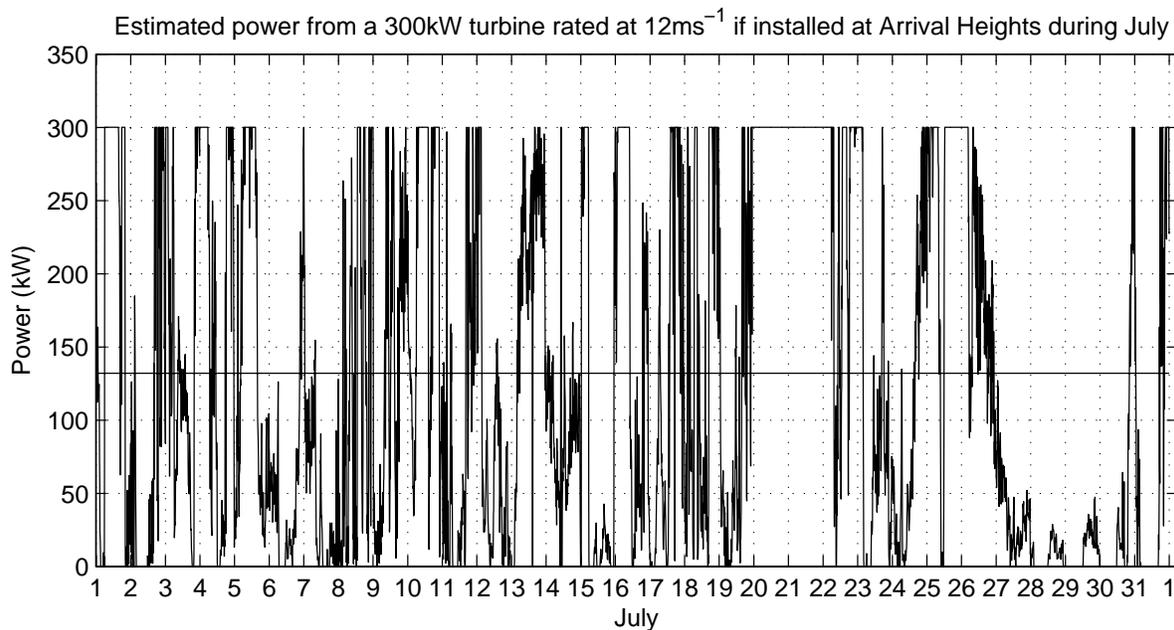Calculated power from a 300kW turbine rated at 12ms^{-1} if installed at Scott Base during January 2003
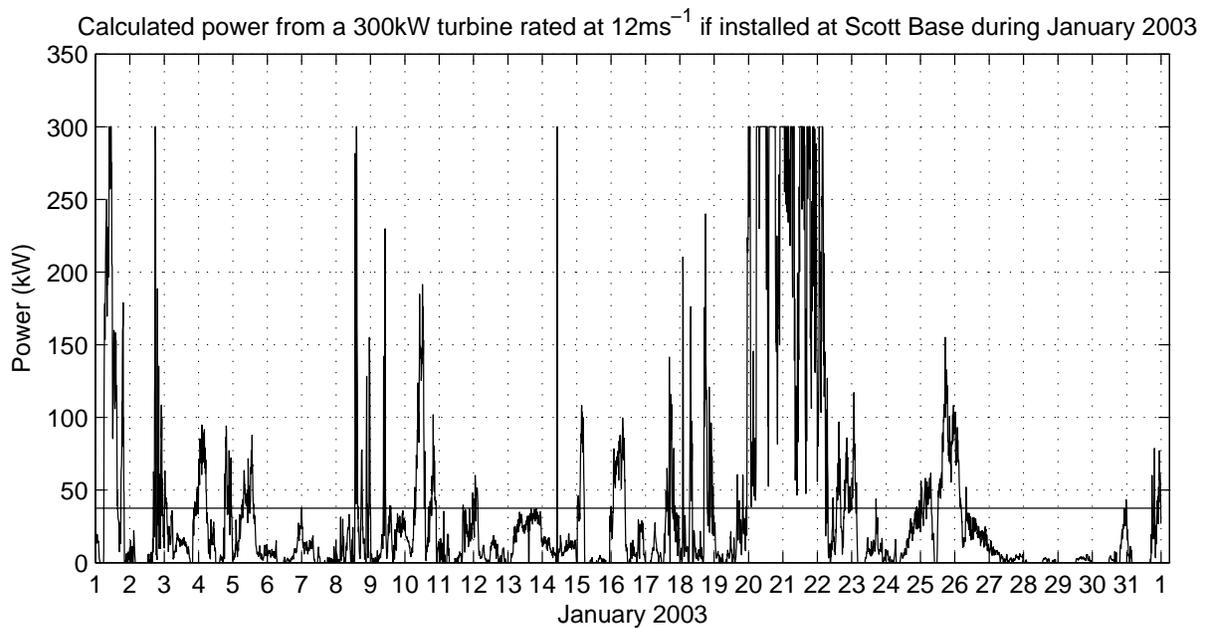
The average power produced during January is 37.4kW or 12.5% of rated capacity. Similarily, applying a scaling factor to the January wind data and repeating the calculations above gives an average power output of 68.5kW or 22.8% of rated capacity during May. These values are still low, and a site with a higher average wind speed is required.

Arrival Heights is located 6km from Scott base and has an average recorded wind speed of 7.5ms^{-1} with monthly averages shown in Figure 6 over the period from February 1999 to February 2004. This is 1.5 times as windy as Scott Base.

Applying the same calculations and scaling for the Arrival Heights wind speed data gives an average power output of 82.2kW or 27.4% of rated capacity during January and 132.0kW or 44% of rated capacity during July at Arrival Heights. Figure 7 shows the scaled January Scott Base data applied to July at Arrival Heights.

Average monthly wind speed at Arrival heights

Estimated power from a 300kW turbine rated at 12ms^{-1} if installed at Arrival Heights during July

Conclusions

Apart from thermal energy acquired from the wind, as proposed in [2], the most likely and readily availiable canidate for renewable energy at Scott Base is wind power. However, as shown, Scott Base is relatively sheltered, at least in terms of its average wind speed and an alternative site with a higher average wind speed is required. Arrival Heights shows resonable promise, being situated 6km from Scott Base and having an average wind speed 1.5 times greater than that of Scott Base. Other alternative sites nearby may also warrent further investigation.   The authors have yet to invesitagate the enconomics and costs of such a wind system. This will be presented at a later date.

Acknolodgements

The authors would like to acknowledge Antarctica New Zealand, and in particular Peter Brookman and Kevin Rigarlsford for their help in acquiring data and knowledge of Scott Base and the surrounding area. Also, thanks to NIWA for suppling weather data free of charge.

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