BUTCHERBIRD RENEWABLE ENERGY RESOURCE REVIEW

Element 25

September 2021

VICE Engineering Pty Ltd on behalf of Element 25

Contents

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

Executive summary

Element 25 has engaged VICE Engineering Pty Ltd, refer Appendix 1 - Vice Engineering - Capability Statement, to process the data collected at the Butcherbird site for the purpose of evaluating the potential of the site to be able to utilise high levels of renewable energy in a novel application of electrowinning at the Butcherbird site.

The key findings of this report are that the major wind direction is from the East and has an annual average wind speed at 100 m of 6.89 m/s.

The solar resource has an annual climatology of 22.2 MJ/m^2. The data collected on site correlates well with that for the nearby Illgararie Bureau of Meteorology (BOM) station.
Longer term data collection will assist with reducing uncertainty associated with the data, however preliminary modelling can be performed with the initial data collection.

Background

Element 25 was successful in its funding application to ARENA to investigate the possibilities of using variable renewable energy resources to power its electrowinning process at the Butcherbird Manganese project located near Newman in the Pilbara, Western Australia.
Advisian, as a project partner, own and have installed a Vaisala sodar unit [1] and a pyranometer (solar radiance monitoring station) consisting of a Campbell Scientific CM106B tripod and Kipp & Zonen CMP 3 pyranometer[2] on site and have collected 462 days of data from the SODAR and 371 days of data from the pyranometer. The commissioning reports for these two items are attached as Appendix 3 - Sodar and Pyranometer Commissioning Reports.

Data

Data collection

The SODAR is located at grid reference Latitude -24.433079, Longitude: 119.715160 on the Western side of the Renewables area, shown in Figure 1below.

This area is typical of the land within the proposed Renewables area. There is a small tree (4 meters tall) 30 meters distant from the SODAR at 315 degrees and a small excavation (0.7 meters tall) at 55 degrees and 6 meters distant from the SODAR. Generally, the location is open and the surrounding terrain of low complexity. The SODAR was installed on 30/04/2019.

The SODAR is installed as per the supplier recommendations and the above description of obstacles is provided from the installation log and is provided for completion. The obstacles are shown in the two commissioning reports, Appendix 3 - Sodar and Pyranometer Commissioning Reports, and are not considered to be significant.

[1] https://my.vaisala.net/en/vaisalalists/Documents/TritonManualV2.pdf
[2] https://www.kippzonen.com/Product/11/CMP3-Pyranometer#.YUGOaX0RUaw

Figure 1 - Butcherbird Renewables Area (Proposed)

The Solar meteorological station is located at grid reference Latitude - 24.433180, Longitude 119.714828 near the SODAR on the same side of the proposed energy park.
The solar unit is located a short distance from the SODAR and has a similar surrounding landscape, which is open, and the surrounding terrain is of low complexity.
The solar monitoring station was installed on 29/07/2019.
The pyranometer is installed on a horizontal surface and is collecting solar data on the horizontal plane.

The Sodar and Pyranometers were pre-calibrated and no further settings were applied on site. No adjustments have been made since the installation of the units. Both monitoring stations have been installed in a location and manner that is appropriate and consistent with expectations. The area where the monitoring stations are located are appropriate for the proposed renewables area with no significant obstacles.

Data Availability

Data from the Sodar and Pyranometer is uploaded via separate satellite links to supplier web sites. Element 25 staff have retrieved the cumulative data from these web sites.

The websites are not shown as they require user access and passwords.

Data collected by the Sodar at each 10-minute collection point includes

- Date & Time
- Location
- At each 10m interval from 40-200m
  - Wind Direction
  - Wind Speed Horizontal
  - Wind Speed Vertical
  - Quality
  - Wind Turbulence
- Ambient Temperature
- Barometric Pressure
- Humidity
- Noise Level dB-A, dB-B & dB-C
- CPU Power, Modem Power, Speaker Power, PWM Power, Solar Power,
- Status
- CPU Temperature, Internal Temperature, Heater Temperature
- Battery Voltage
- Beep Volume
- Firmware Version

Data collected by the Pyranometer at collection point includes

- Date & Time
- Location
- 1 Minute Data
  - RadiantEnergy-kJ-m^2
  - SolarRadiation-Avg-W-m^2
  - SolarRadiation-Max-W-m^2
  - SolarRadiation-Min-W-m^2
  - SolarRadiation-StdDev-W-m^2
  - SolarData - BattVolt-Min
  - SolarData - PTemp-Avg
- 10 Minute Data
  - RadiantEnergy-kJ-m^2
  - SolarRadiation-Avg-W-m^2
  - SolarRadiation-Max-W-m^2
  - SolarRadiation-Min-W-m^2
  - SolarRadiation-StdDev-W-m^2
- 10 Minute Data
  - RadiantEnergy-kJ-m^2
  - SolarRadiation-Avg-W-m^2
  - SolarRadiation-Max-W-m^2
  - SolarRadiation-Min-W-m^2
  - SolarRadiation-StdDev-W-m^2

The data coverage and sample validity were checked to obtain the overall data availability
The data was screened for:

- Error values (Null, void, N/A, -999, etc.)
- Suspicious data was flagged for investigation and retained or discarded as appropriate.
- Data within/outside reasonable limits (temperature, battery voltage, speed)
- Suspicious trends (constant values or sudden changes)

The solar resource data collected indicated no null samples.

The SODAR data has an inbuilt function filtering the quality of the received signals. This study is based on quality data being equal or better than 85% which is a measure supplied by the sodar supplier assessing the validity of the data. The specific details of which are unknown.

The availability of the SODAR Data decreased with height as per the following table, which is a known characteristic of SODAR devices:

Samples vs up time at various heights										
Height (m)	40	50	60	80	100	120	140	160	180	200
Availability @ 90 % quality	99.30%	99.01%	98.01%	93.67%	86.01%	73.73%	58.43%	43.63%	30.85%	20.95%

For this study, the 100 m data was used as it is considered the most likely design height for a 4-5MW wind turbine at the date of the commissioning of the units. The highest quality data also resides in the 80 -120m levels, outside these elevations the data quality deteriorates.

Generally, data quality above 85 % is regarded as good.

The Power law using the wind shear was used to extrapolate the wind speed to other potential hub heights as it is considered more accurate than using poorer quality data for such early-stage evaluations. Wind shear calculations can vary with elevation, time of day, season, temperature, terrain, and atmospheric stability. To account for these variations, wind shear has been calculated monthly and applied when extrapolating data for comparison. The extrapolated data was checked against the retrieved data.

Assessment method

Data Correlation

Solar Resource

The solar data was correlated to the long-term daily exposure data from the Illgararie BOM meteorological station which is located 16 km from the Butcherbird site.
Using a scatter in Figure 2 the data shows there is some correlation between the two sites. Figure 2 and Figure 3 both show the daily, monthly correlation. The first graph shows the daily correlation by month and the second shows the same graph with a line of best fit. The R^2 value is 0.488, which indicates some, albeit poor, correlation. It appears that outliers in the data are is impacting the correlation although this is visual and may be related to low quality data points have not studied further. This may be due to seasonality and the comparison of one year to several years of data as well as local topographic and vegetation differences effecting the two different sites.

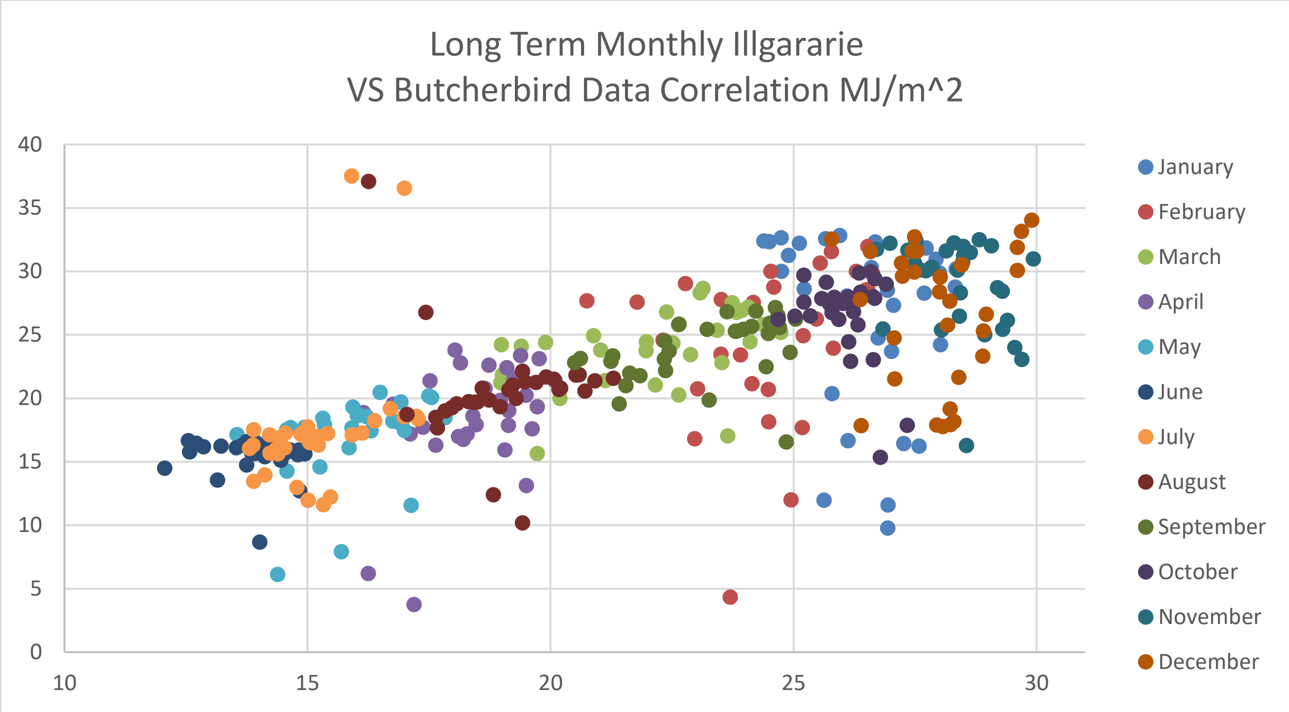


Figure 2 - Illgararie and Butcherbird correlation

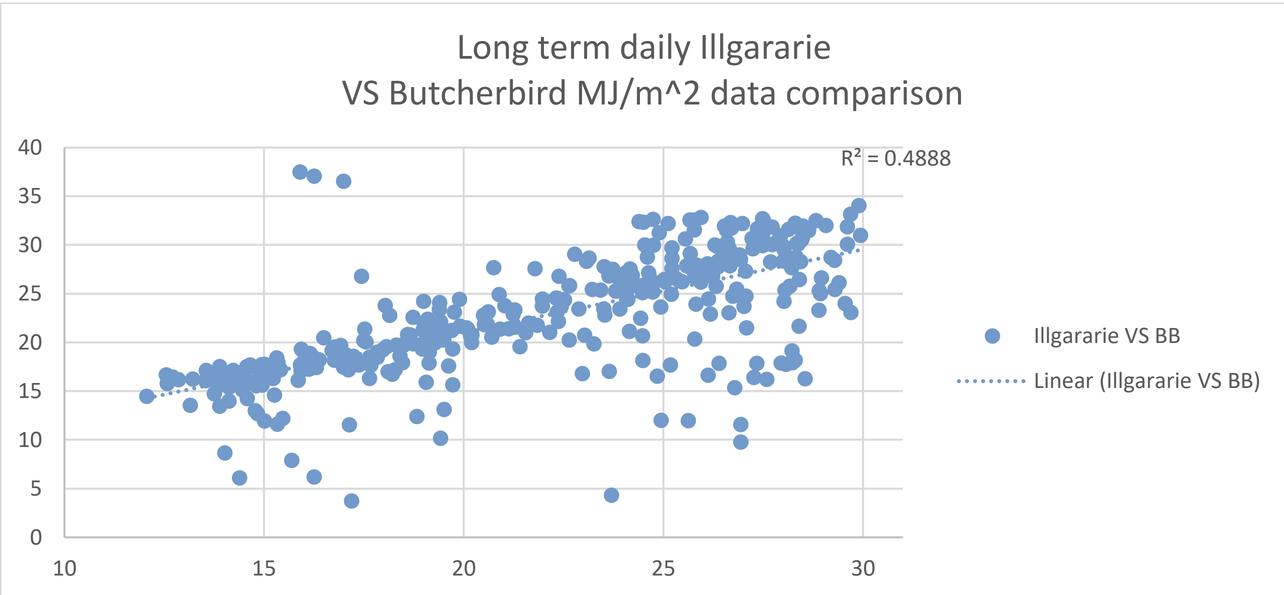


Figure 3 - Butcherbird and Illgararie Daily Correlation

The data from Illgararie is the long-term average from almost 30 years of observations. To address the intra year differences and the effect on the long-term average, the data was matched to the same timestamp as that collected at Butcherbird and compared in Figure 4. This graph shows a better correlation between the two sites. The R^2 value represents how well the sampled data fits the reference data. In this case the R^2 is 0.925, which indicates there is correlation between the Butcherbird and Illgararie sites.

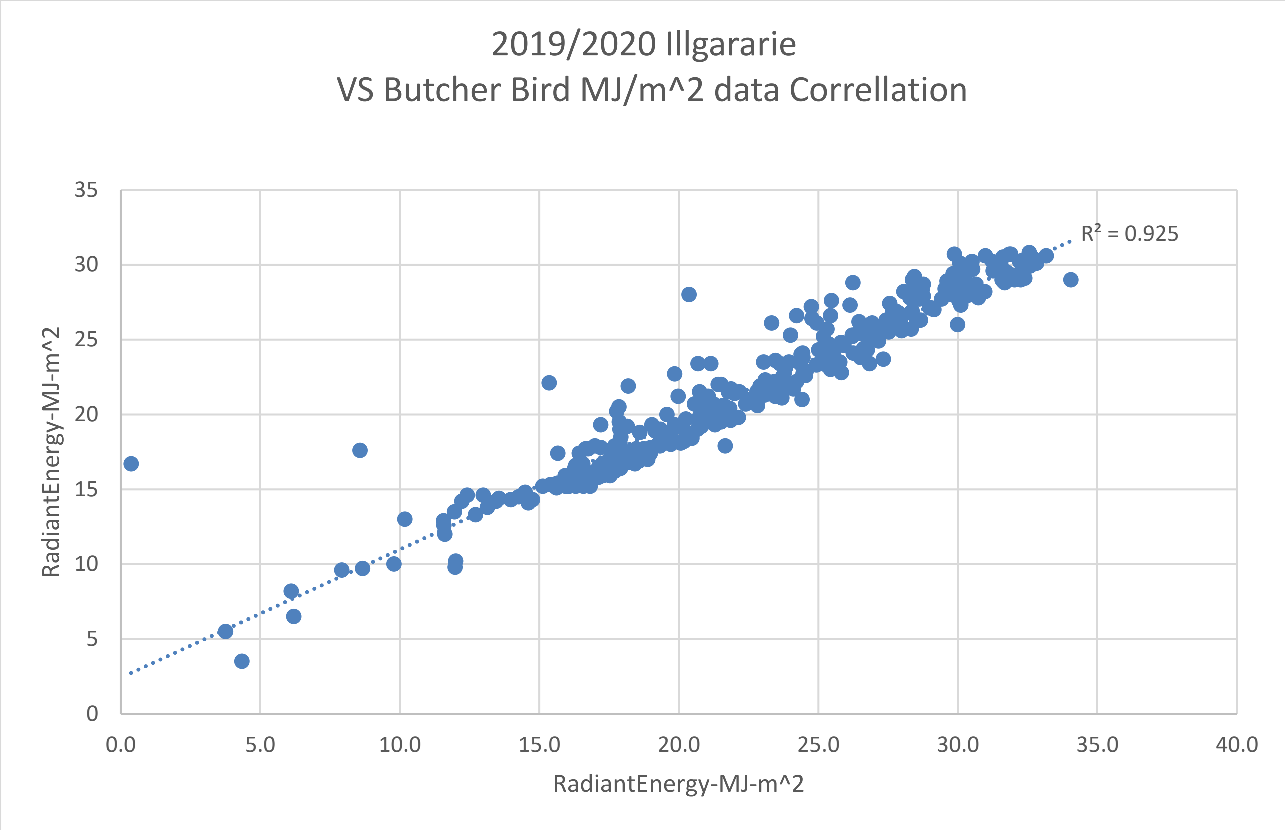


Figure 4 - Matching period solar data correlation

The correlation between the two sites can also be shown in as a time base plot as shown in Figure 5. Figure 5 indicates that the Butcherbird site is logging a higher solar resource in comparison to the Illgararie.

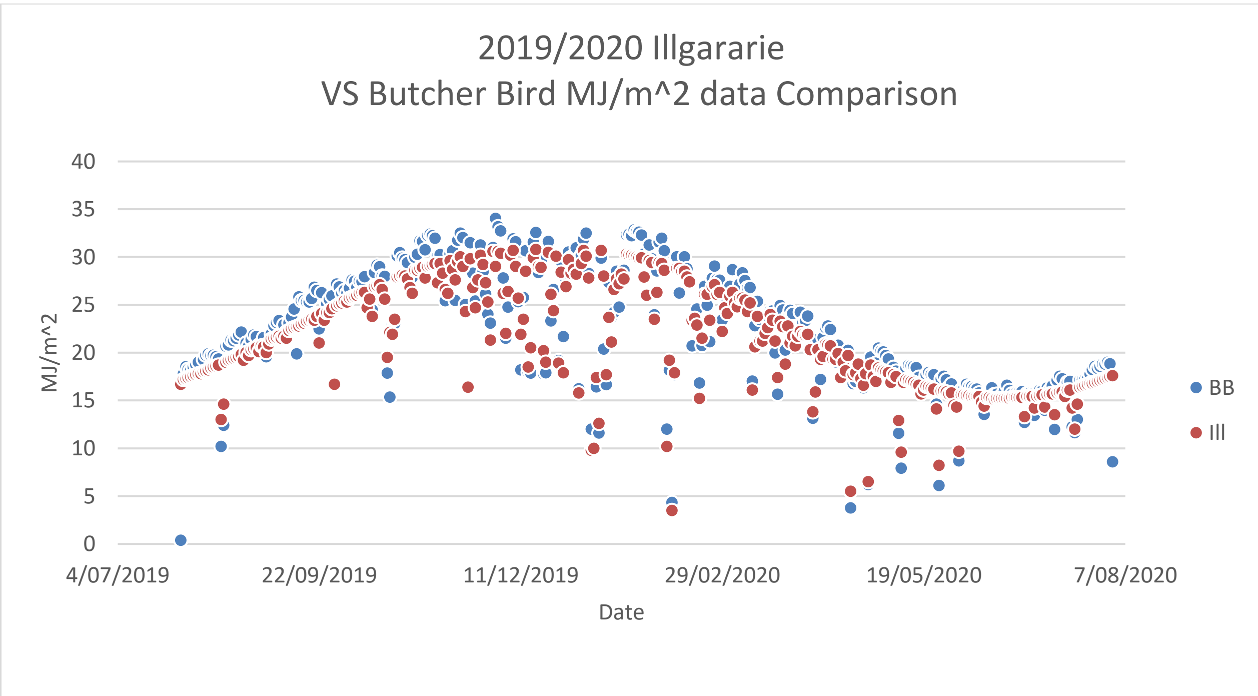


Figure 5 - Illgararie VS Butcherbird MJ/m^2 as sampled comparison

Wind resource

There are several wind resource data sets, that are typically used to correlate long term wind data that are often used for early design and evaluation considerations, where a measured wind resource is not available locally.

The wind data was correlated to the Merra2 data set, the Modern-Era Retrospective analysis for Research and Applications. Retrieved from National Aeronautics and Space Administration (NASA), available at https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/, between 2012 to 2019 centered around latitude: -24.433079 and longitude: 119.715160 using 3x3 (3-day, 3 Hour data averaging) Merra2 dimensions. Normally data correlation is performed using 2-3 years of data to 10 – 20-year long term data set, however the Merra2 database at this location at time of writing did not have more than 7 years of data available and hence the study has been limited to 7 years.

The relative locations to the Butcherbird site are shown in Figure 6. The two southern points are the closest, however the overall characteristic across the four points is relatively consistent

The Merra2 data is collected at 50 meters and has been compared to the 100 m annual data from Butcherbird. Figure 7 shows a low level of correlation in months July to December. Increasing the data collection length will assist with any sampling bias and resulting uncertainty that has influenced the comparison.

Figure 6- Locations of the Merra2 data points and Butcherbird

The Merra2 data over 2019 has an annual mean wind speed of approximately 16.7 % higher than that recorded by the SODAR at 50 meters. This could be due to intra year differences as the collected data set is for only one year and has missing samples, whereas the Merra2 data is from a longer data set. Comparing the 100 m SODAR data to the 50 m Merra2 data and applying the log law scale method to extrapolate the Merra2 to 100 m, reduces this difference to 4.3 %. A longer term and more rigorous data collection regime will assist with reducing the uncertainty associated with the wind resource. This is discussed further in the Recommendations.

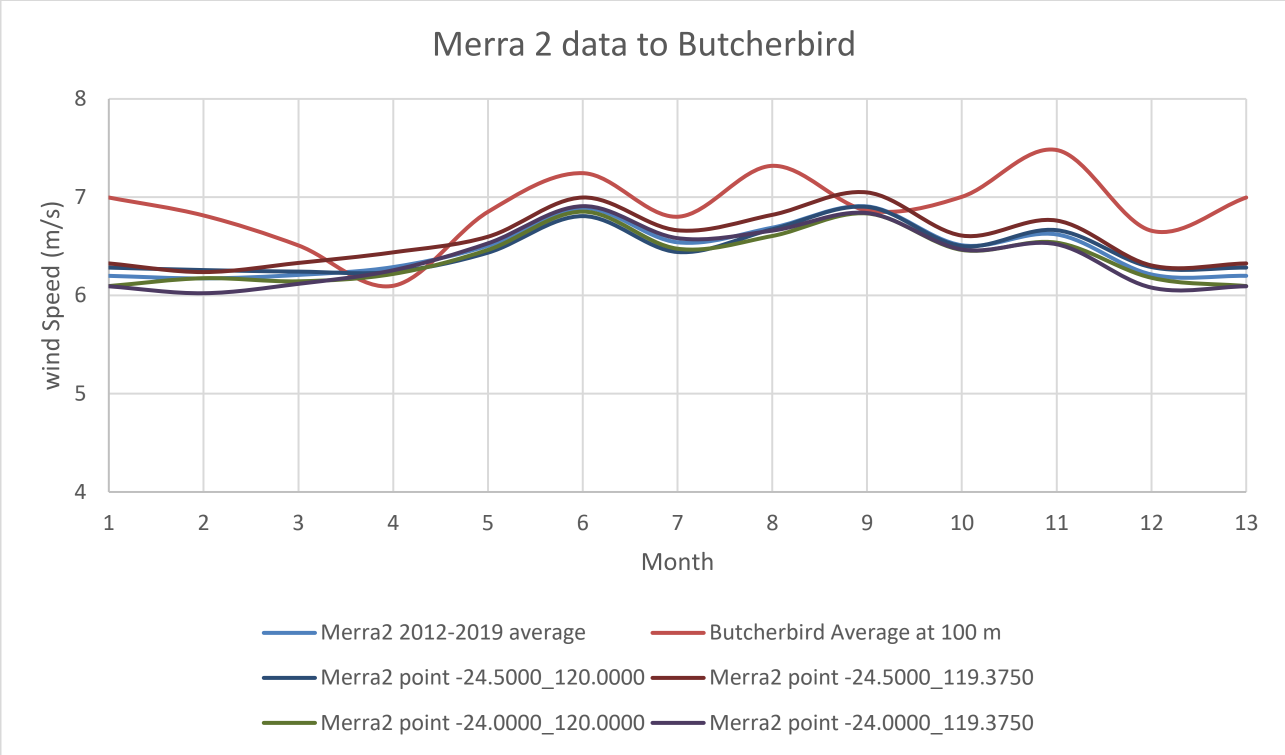


Figure 7 - Merra2 vs Butcherbird

Solar and Wind Resource Correlation

Using the collected data on an annualized daily basis, the average annual wind speed at 100 m was compared to the solar resource and is shown in Figure 8
From this analysis generally the two resources coincide, and the wind resource has a pronounced dip in the early morning. The dip is more pronounced in the Autumn months, indicating that the wind resource has some seasonality.
This characteristic wind dip is more pronounced through the middle of the year, which with a lower solar resource will reduce the available power from these sources.
Please see Appendix 2 - Monthly Solar and Wind Data vs Time Charts for the individual monthly correlation graphs.

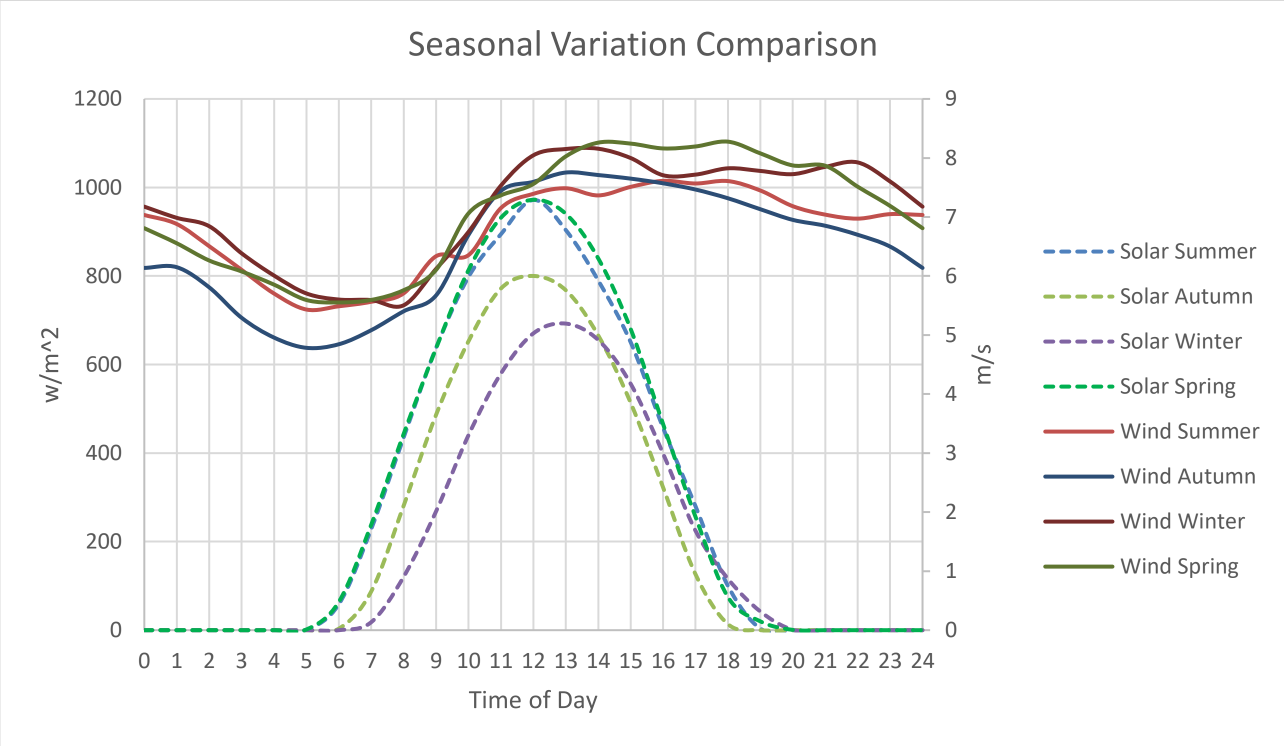


Figure 8 - Seasonal Diurnal wind and solar comparison

Resource Assessment

Solar

The annual solar trends were reviewed and are displayed in the Figure 9. The reason for the deviation in the August data is not known. It appears that there may have been a shading issue, such as sustained poor weather, morning fog or a time stamping issue in August. Longer term data should be able to identify if this is a local trend, or an instrumentation issue. The correlation data with the Illgararie BOM station indicated that there was reasonable correlation as evidenced by the R^2 value of 92.5 %.

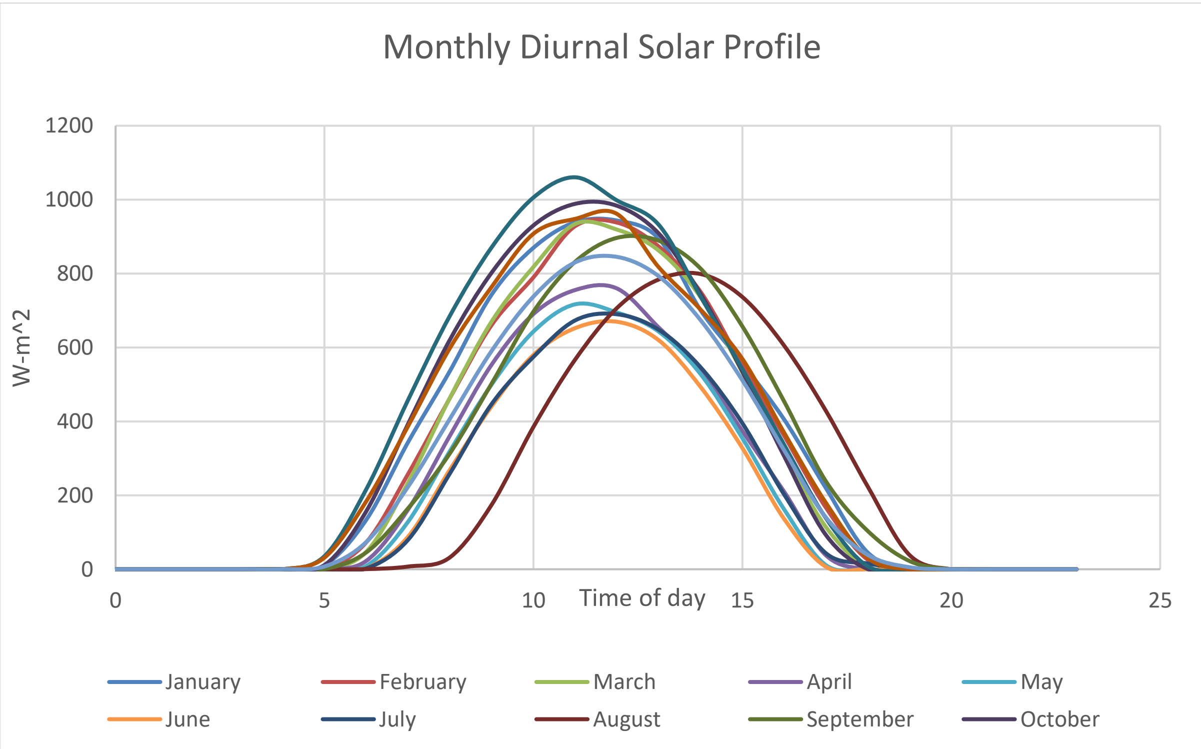


Figure 9 - Monthly Diurnal Solar Profile

The solar resource ranges throughout the year from 650 W/m^2 and 1050 W/m^2 at midday.
The analysis evaluates the Global Horizontal Irradiance on a flat (i.e., horizontal) surface. In practice this means that by aligning the solar farm towards the sun and tilting to receive more direct radiation (and reflected/diffuse etc.) will increase the energy received beyond the levels represented in this analysis.
Using the NREL System Advisor Model, VICE Engineering used a 1 MW DC PV system and varied the tilt and tracking to estimate the difference in annual energy production as a percentage.

Table 1 - Effect of tilting and tracking on annual energy output as a percentage

Efficiency gain for 1 MW DC system	**Annual production (kWh)**	**Efficiency gain (%)**
Base annual production	1,678,916	0
Annual production by tilting to 20 degrees	1,802,060	7%
Annual production by single axis tracking	2,191,851	31%

Table 1 Shows that there is significant benefit to be gained from single axis tracking. The gains from tilting are more pronounced for systems that have a lower latitude. Locations such as Butcherbird will receive some benefit from tilting to near the latitude angle, but it will be less pronounced compared to a project in Tasmania. The benefit directly relates to the height of the sun in the sky and hence locations with a higher latitude see less benefit.

Figure 10 - AREMI Annual climatology for Butcherbird 22.005 MJ/m^2

The Australian Renewable Energy Mapping Infrastructure (AREMI) shows Butcherbird to have an indicative annual solar radiance resource of 22.0 MJ/m^2. The collected solar data indicates the site value to be 22.2 MJ/m^2, which is marginally higher.

Wind

Wind speed varies with height with increased wind speeds expected and recorded at increasing distance from the surface of the earth. The wind speed at lower heights is influenced to a greater extent from the earth surface and the obstacles which the wind is required to pass over (vegetation, buildings, etc.).
To analyze the wind speeds and characterise the resource on the site the following data sets were interrogated:
100 m, 120 m, 140 m, and 160 m.
The monthly annual average wind speed is shown in Figure 11. This graph shows the annual monthly mean characteristics of the wind profile.

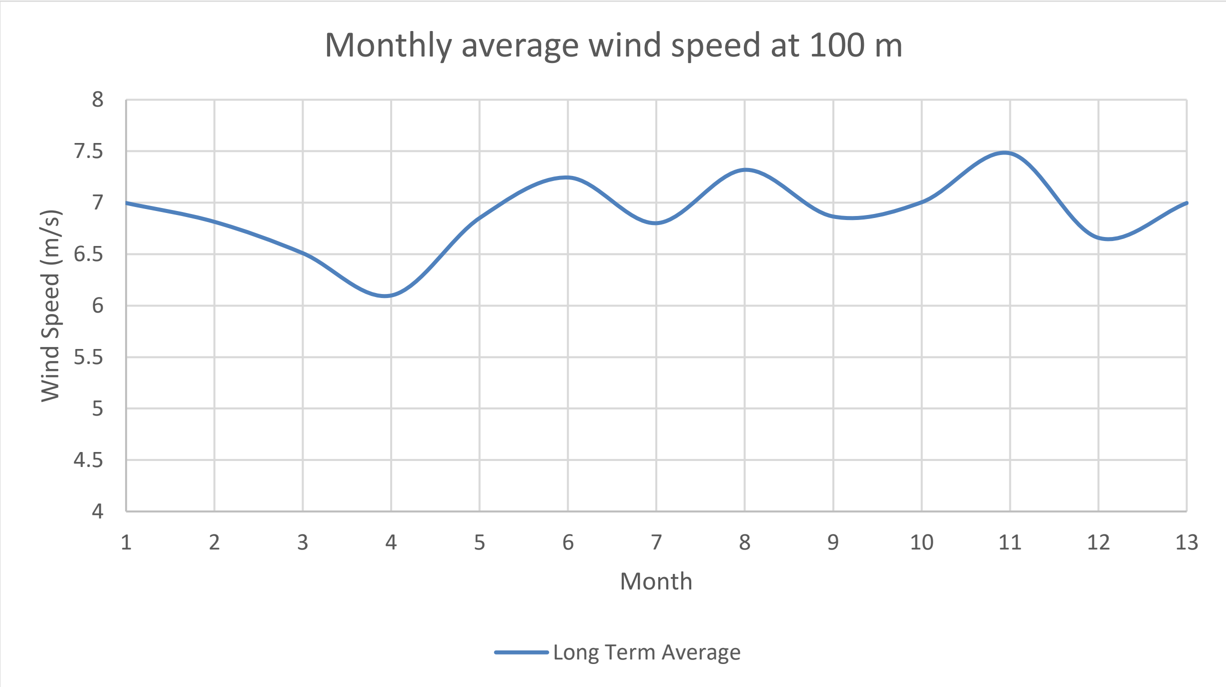


Figure 11 - 100 m Annual Average Wind Speed

The International Electrotechnical Commission (IEC) sets standards for the wind speed measurement. Each wind class must withstand based on the annual average wind speed, maximum extreme gust, and turbulence intensity (calculated at 15m/s), as well as a number of other parameters.

Table 2 shows the IEC wind turbine classification by wind speed and turbulence. Table 3 contains the measured wind turbulence at the Butcherbird site and it should be noted that due to the low amount of data at higher wind speeds the turbulence intensity should be treated as indicative. Further data would reduce the uncertainty.

The data in Table 3 indicates that the turbulence intensity recorded by the SODAR is in the lower regions and generally the Butcherbird site would be considered to be a low complexity site with a low level of turbulence intensity. It should be noted that due to the limited amount of data available there is a level of uncertainty associated with the wind turbulence intensity. This would best be evaluated by analysing multiple years of data where local variance can be smoothed out.

Table 2 - IEC Wind Turbine Classification

IEC Wind Turbine Classification		
Wind Class/Turbulence	**Annual average wind speed at hub-height**	**Extreme 50-year gust**
Ia High wind - Higher Turbulence 18%	10 meters per second (36 km/h; 22 mph)	70 meters per second (250 km/h; 160 mph)
Ib High wind - Lower Turbulence 16%	10 meters per second (36 km/h; 22 mph)	70 meters per second (250 km/h; 160 mph)
IIa Medium wind - Higher Turbulence 18%	8.5 meters per second (31 km/h; 19 mph)	59.5 meters per second (214 km/h; 133 mph)
IIb Medium wind - Lower Turbulence 16%	8.5 meters per second (31 km/h; 19 mph)	59.5 meters per second (214 km/h; 133 mph)
IIIa Low wind - Higher Turbulence 18%	7.5 meters per second (27 km/h; 17 mph)	52.5 meters per second (189 km/h; 117 mph)
IIIb Low wind - Lower Turbulence 16%	7.5 meters per second (27 km/h; 17 mph)	52.5 meters per second (189 km/h; 117 mph)
IV	6.0 meters per second (22 km/h; 13 mph)	42 meters per second (150 km/h; 94 mph)

Based on the presented data, Butcherbird, depending on the height of wind could expect to see proposals using machines from Classes II to IV suitable for lower turbulence sites.

Table 3 - Turbulence

Measured Average Turbulence at Height		
60 m Wind Turbulence Intensity Average	80 m Wind Turbulence Intensity Average	100 m Wind Turbulence Intensity Average
15.9%	14.6%	14.0%

The Figure 12 indicates that the predominate wind direction is from the East, with the predominant wind speeds being between 6 and 10 m/s.
High wind speeds yield more power because wind power is proportional to the cube of wind speed. Hence with modern wind turbines and higher hub heights greater power can be harnessed.

The Sodar takes measurements every 2 minutes. The Sodar averages the 2 minutes data up to a 10-minute average. This means that instantaneous wind speeds of under 2-minute duration are not adequately measured or available for assessment. Local, short-term gusts could be substantially higher than the 10 minutes average data.

This is not considered a large issue as wind turbines have a lot of stored rotational energy and can smooth over short duration wind lulls and ride through short duration gusts whilst maintaining generating capacity especially as part of a larger wind farm of potentially 20 or more wind towers, local variations will be also covered by the wind farm as a group.

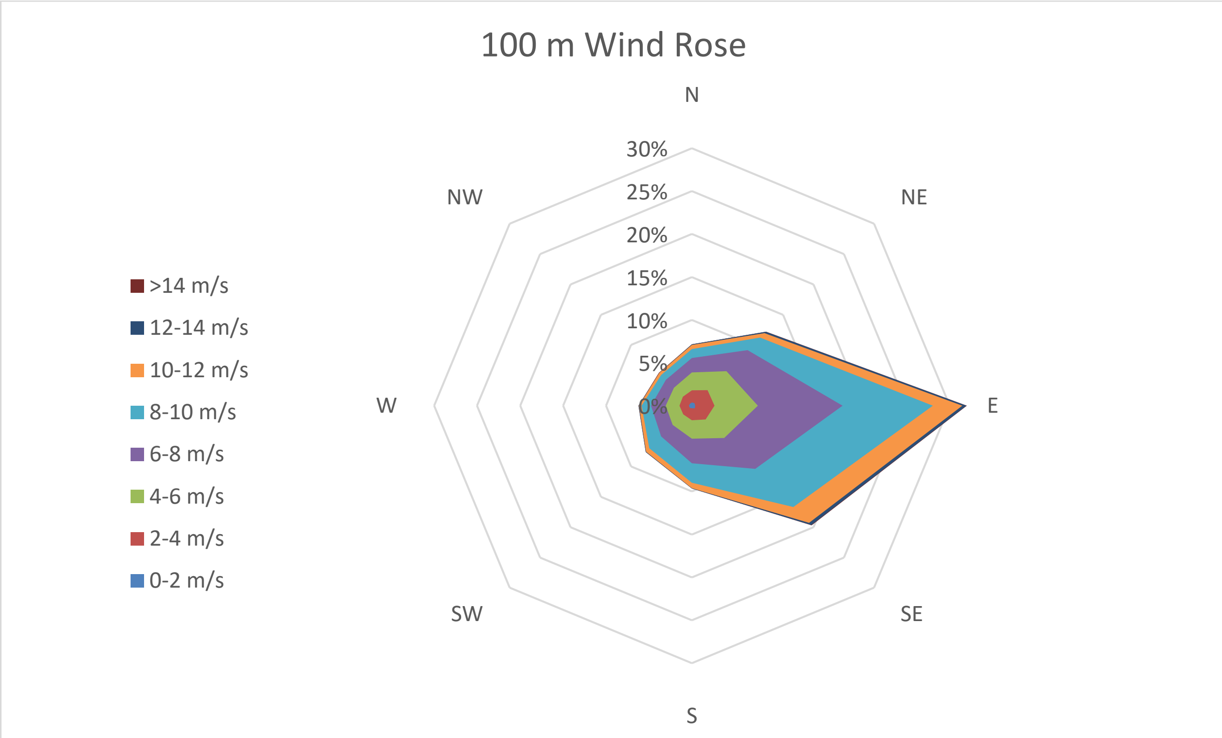


Figure 12 - 100 m Wind Rose

The wind rose shows that the dominate wind is from the East and is between 6 and 8 meters per second. The impact of this is that the wind farm could be orientated to capture more of the Easterly winds, resulting in a North/South layout being optimal.
The spacing of the wind turbines depends on the blade lengths and the turbulence. As a rule of thumb parallel turbine spacing is based on a minimum separation distance of between 4 to 5 rotor diameters to the predominant wind direction and for perpendicular spacing between 3 to 4 rotor diameters to the predominant wind direction. This means that the wake effects and shielding from other turbines can be optimized.

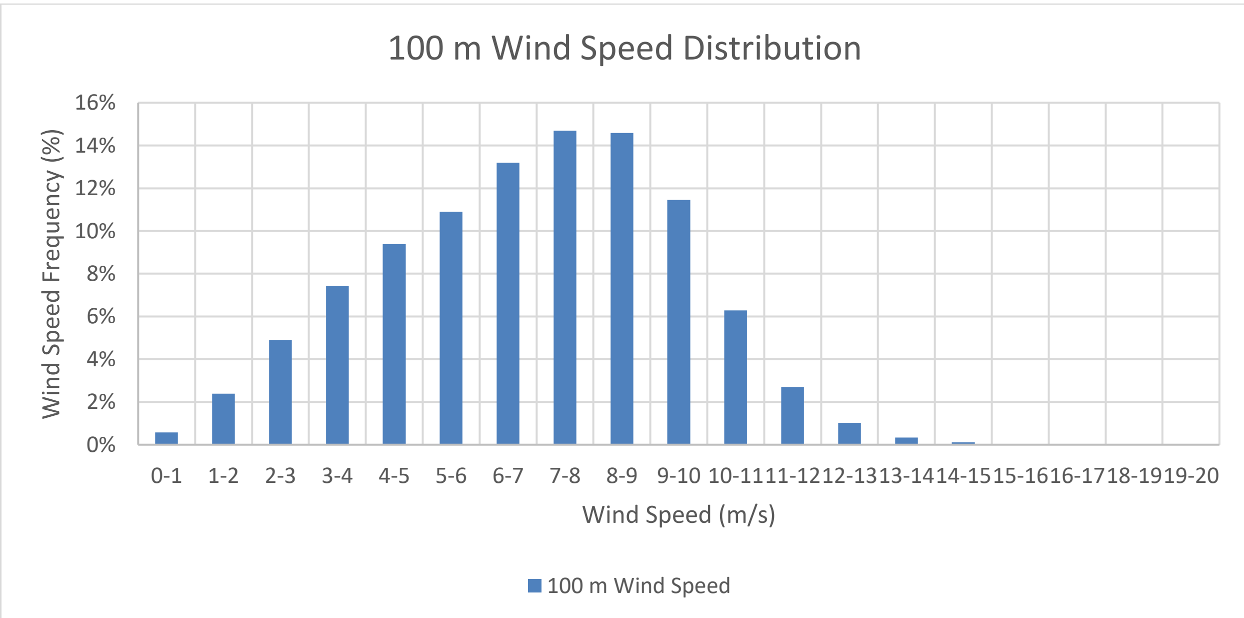


Figure 13 - 100 m Wind Frequency

Figure 13 Shows the distribution of the wind speed at 100 m.

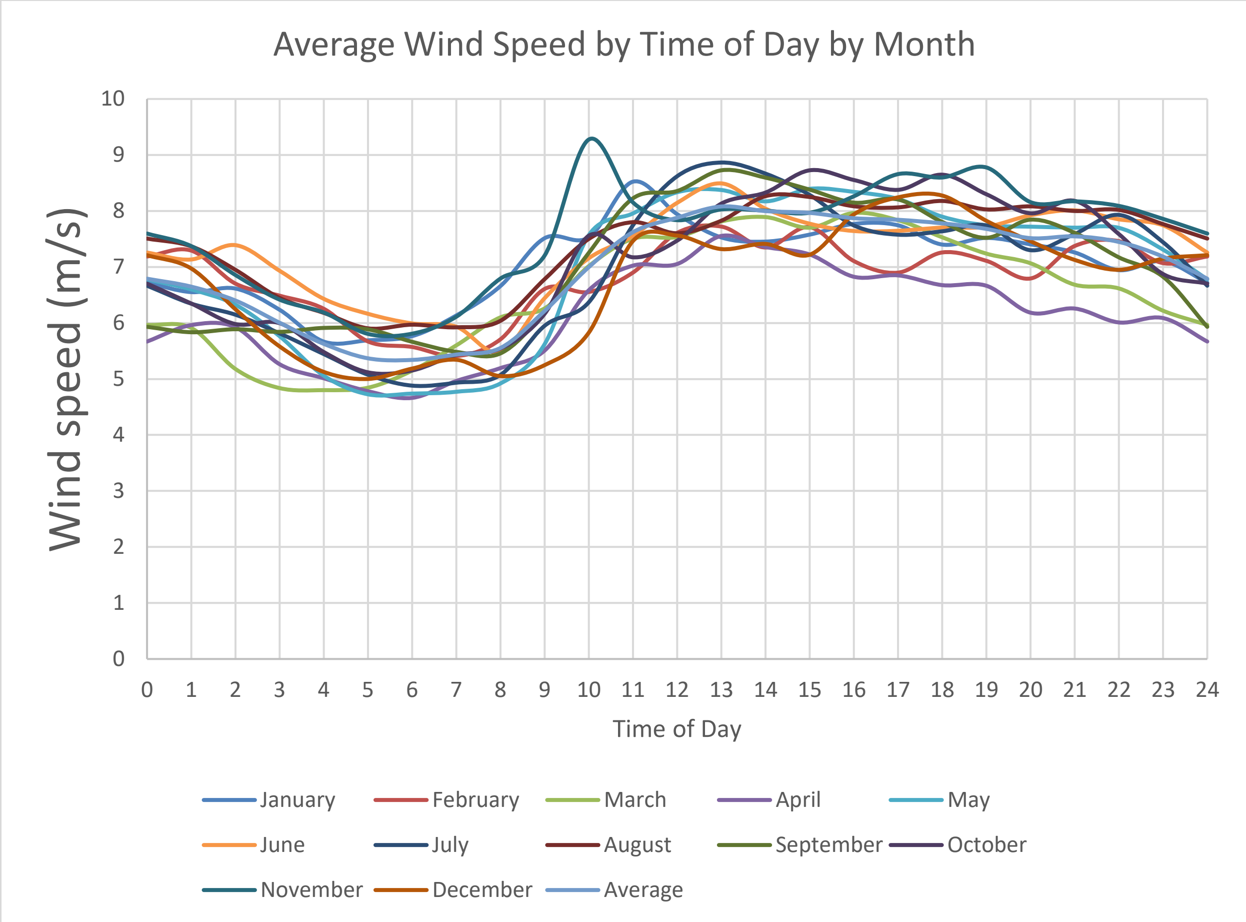


Figure 14 - Monthly Average Diurnal Wind Speed

Figure 14 - Monthly Average Diurnal Wind Speed shows the monthly average daily wind speed characteristics. This indicates that generally there is reasonably consistent wind throughout the months, with a clear characteristic dip in the early morning.

Comparison at Height

The data above 100 m is of lower quality and hence has a lower useable sampling rate, which results in incomplete data sets at higher elevations. However, given the higher sampling rate at 100 m, and 120 m, a strong correlation can be observed in the monthly profile between the quality data that was collected at 100 m and the various higher heights. Sampling over a longer period will reduce the uncertainty.

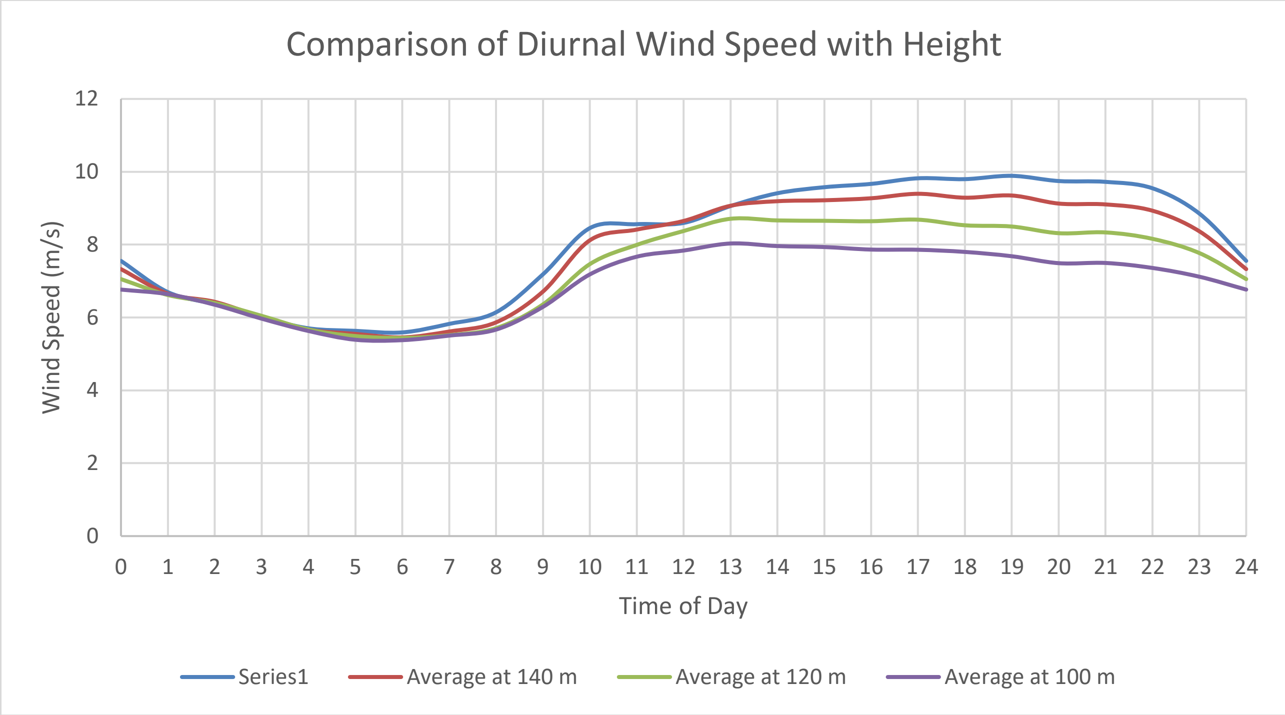


Figure 15 - Diurnal Wind Speed Variation with Height

The frequency of occurrence is a graphical representation of how often the wind blows at a certain speed as an overall percentage. The below graph shows the difference frequencies against the height. A clear trend of increasing wind speed with height can be seen.

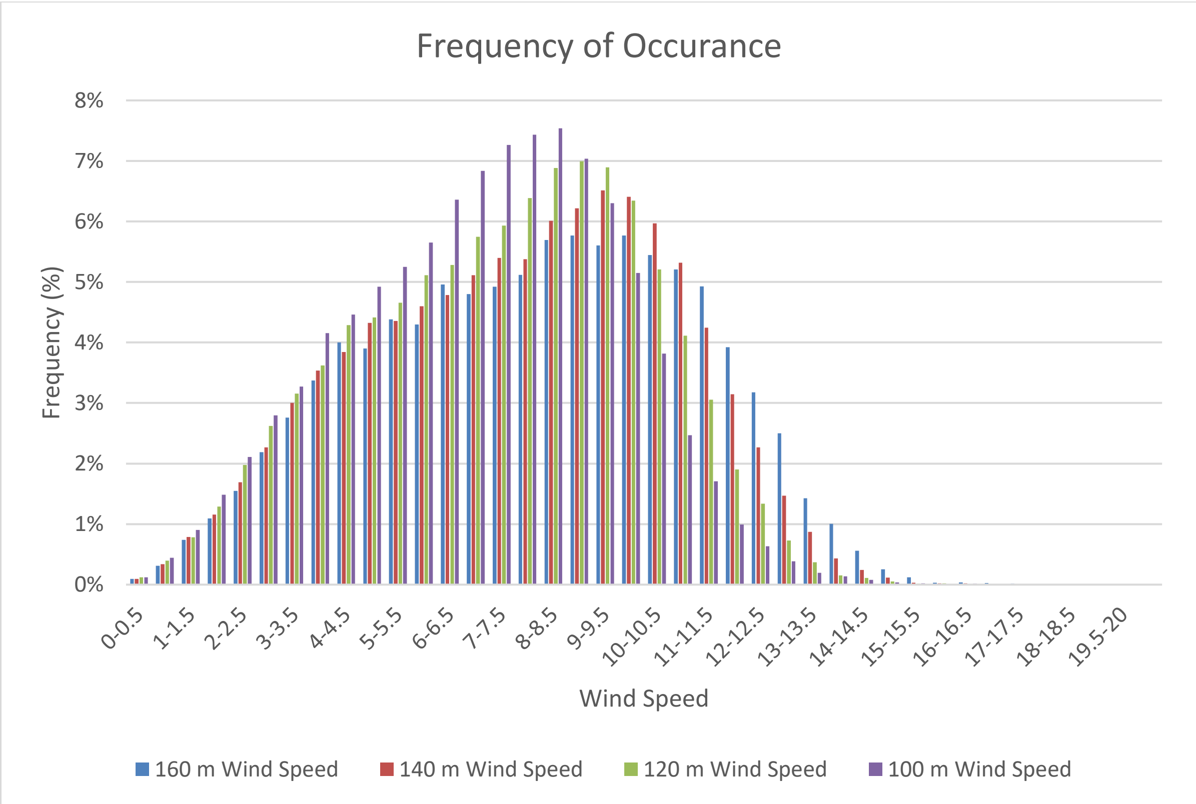


Figure 16 - Wind Speed frequency of Occurrence with Height

Wind speed frequency can also be displayed in a cumulative representation. Again, a clear representation that the wind speed increases with height can be observed.

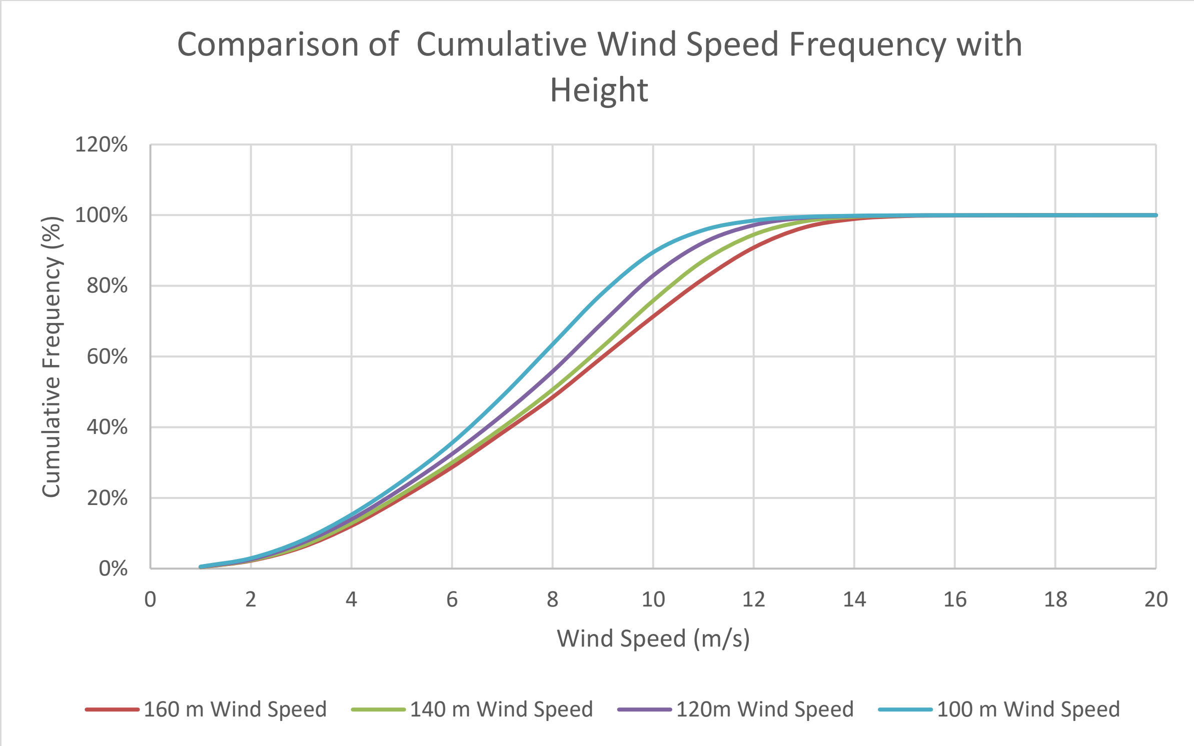


Figure 17 - Cumulative Frequency of Wind Speed with Height

By analysing the wind shear components across the different heights, a monthly average wind shear characteristic was a developed and applied to the 100 m data to extrapolate this to 160 m for comparison. The resulting comparison between an extrapolated from 100 m to 160 m and measured 160 m is shown in Figure 18 along with measured data from the other heights. The resulting graph indicates a reasonable fit, however there is an outlier in September, which is due to the averaging effect across the heights. This is likely due to the lower availability of data at 160 m.

Figure 18 indicates that there is a seasonal pattern, with lower wind speeds in the warmer months and higher wind speed during the cooler months. This combination could be beneficial as the cooler months typically have a lower amount of solar energy available.

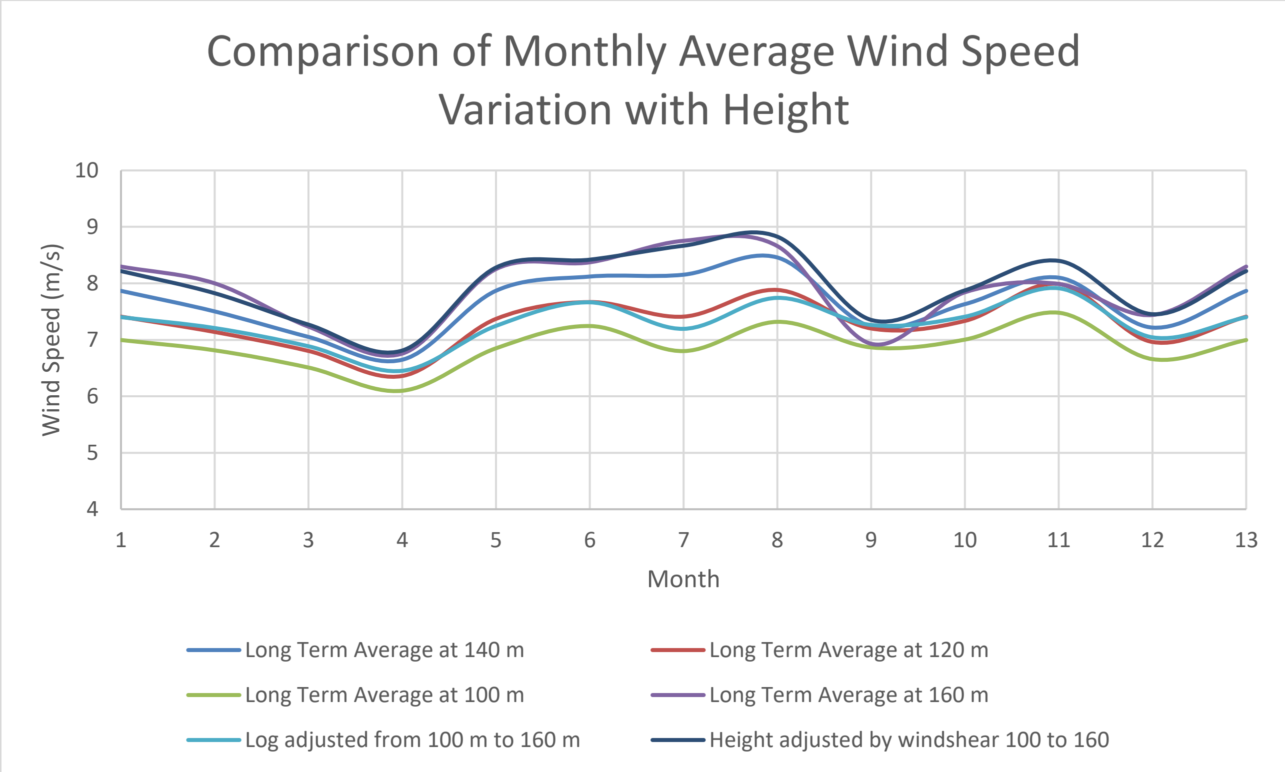


Figure 18 - Comparison of Monthly Average Wind Speed with Height

Using the filtered data from site an average annual windspeed was calculated. These values are shown in Table 4. Due to the limited data set, the 100 m dataset should be regarded as the most reliable for longer term modeling scenarios. Current wind turbine projects are deploying machines with up to 150 m hub heights. Based on the below table, pending further data collection, wind speeds in the region of 7.7-7.9 m/s at a hub height of 150 m could be expected.

Table 4 - Annual Average Wind Speed at Height

Annual Average Wind Speed with Height				
Height (m)	100	120	140	160
Wind Speed (m/s)	6.89	7.30	7.68	7.94

Change in Wind Speed

Element 25 is undertaking the IDE study to evaluate the impact of changes in power supply from a wind resource and its impact on the EMM plating and EMM morphology of the plated metal.

To understand this the company will study in a laboratory, changes in power supply vs time, known as ramp rate.

To evaluate this the 100m wind speed data was reviewed and analysed to determine the distribution of the changes in wind speed. This was measured as m/s per minute. That is the sequential data points were evaluated to determine the change in wind speed per minute.

The distribution of the data is shown below:

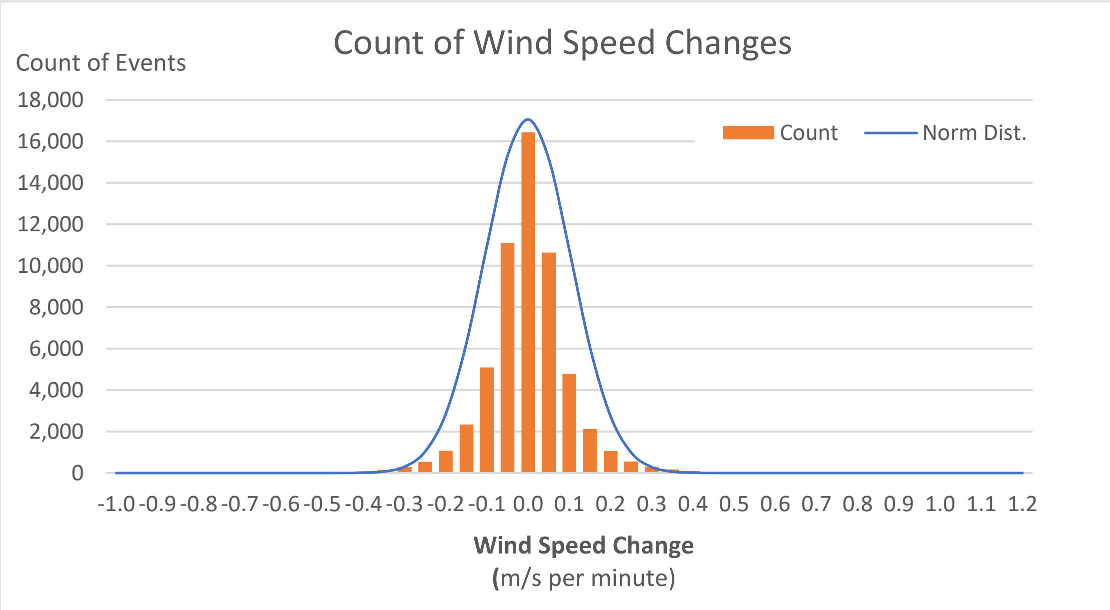


Figure 19 - Wind Speed Change Distribution

The average wind speed change is 0 (average 0.0011 m/s per min) with a standard deviation of 0.1052 m/s per min.

That is 99.73% of wind speed changes should fall with 3 standard deviations from the mean being between -0.3145 and +0.3167 m/s/min.

Using a Normal Distribution allows the determination of the large positive or negative wind change events.

This is shown in the following table

Table 5 - Wind Speed Change Cumulative Distribution Summary

Cum. Probability (%)	Wind Speed Change (m/s per Minute)
0.01%	-0.39
0.10%	-0.33
0.50%	-0.27
1.00%	-0.25
10.00%	-0.14
25.00%	-0.07
50.00%	0.00
75.00%	0.07
90.00%	0.13
95.00%	0.17
99.00%	0.24
99.90%	0.32
99.99%	0.39

This table and the Normal Distribution statistics can be used to estimate the percentage of time that an event takes place.

Examples:

- The wind changes Negatively by less than 0.25 m/s/min approximately 1% of the time
- The wind changes Positively by greater than 0.24 m/s/min approximately 1% of the time

From the above table although very rare, with a likely incidence rate of 1 in 10,000, we can see that the ramp rate has a lower negative limit of -0.39 m/s/min and a positive upper limit of 0.39 m/s/min. These limits should be reviewed as limits for testing purposes to evaluate EMM performance when converted back to a wind powered process power supply.

Temperature

Temperature is an important consideration for any power system. All generators have de-rating profiles associated with temperature.
The effect of derating on solar is two-fold, firstly the modules have a derating and then the inverter also has a derating characteristic. Generally, the inverter is the prominent characteristic.
Wind turbines are mostly inverter connected and have a similar derating characteristic. Most market offerings have a derating factor that comes into effect between 40-45 degrees Celsius. This risk can be addressed by appropriate system definition during the tender process, such as mandating high temperature tolerance in the technical specification during the system procurement.
Temperature also effects the density of the air, which influences the amount of energy available to the wind turbine.
The most significant effect of temperature on any generating system (thermal or renewable) is the temperature at which derating occurs. This should be considered carefully in the system design for Butcherbird.

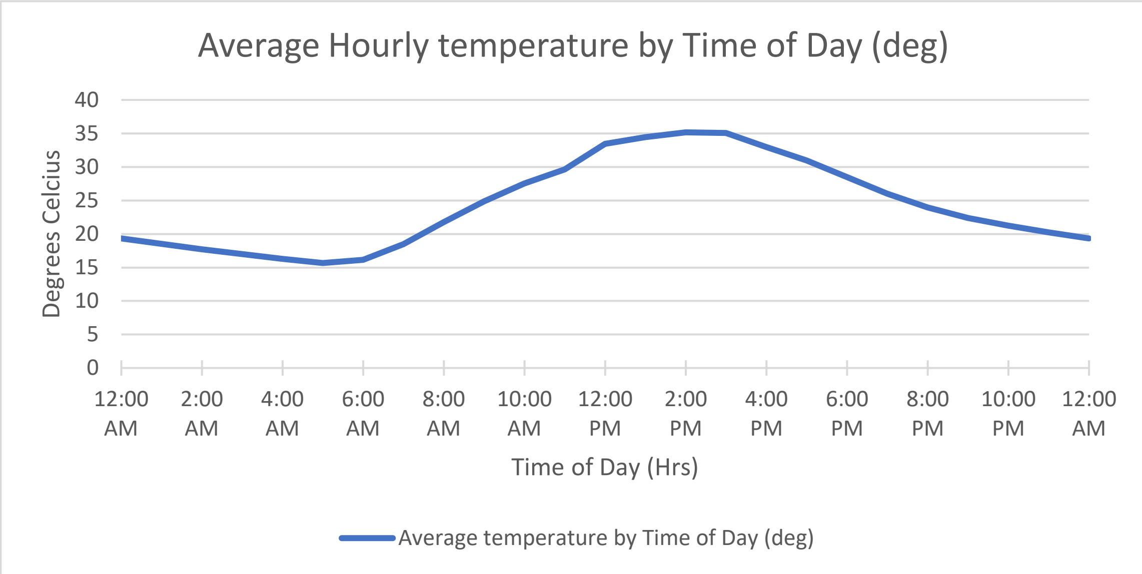


Figure 20 - Butcherbird Annual Average Diurnal Temperature

Value

The viability of a project depends on the business case and power source alternatives. Power usage has been estimated at approximately 40% of total operating costs for the EMM Plant. In this scenario, the wind and solar resources represent a viable alternative to bringing in fuel, which generally results in a high cost of electricity.

Based on the preliminary data assessed, there appears to be a suitable wind and solar resource at the Butcherbird site to support the development of a wind and/or solar project. Further data monitoring will further refine and reduce uncertainties around the level resources.

To be able to provide a consistent power output a third power supply will be required. There are several alternatives available to Element 25. The integration between the power demand, alternative generation, and wind and solar power generation will need careful consideration. There are several projects across Australia that have successfully integrated renewable resources into their projects and achieved significant levels of renewable penetration.

Discussion and Interpretation

VICE Engineering understands that Element 25 is considering the implications of combining the various renewable energy resources together with a dispatchable generator and demand management.
This section is provided as commentary on observations obtained from the data and is provided for discussion.
The wind resource shows a dip in the early morning before the solar resource is available. It is likely that an alternative generator, such as a gas reciprocating engine or a diesel engine may be required to cover shortfalls at certain times.
Depending on the ability of the load to be managed dynamically, it may be possible that this dip in resources could be demand managed out or minimised.
Generally, the wind resource appears to be more consistent and has a higher capacity factor (and is available at night), which would indicate that wind and a dispatchable generator may be the base combination.
Synergy in Western Australia has operated wind diesel hybrid power stations (such as Coral Bay, Denham and Bremer Bay for over 10 years, successfully integrating a high level of intermittent wind and low load diesel generators.

A second alternative may be to consider using excess renewable energy to produce a combustible fuel, such as Hydrogen gas, for use in the dispatchable generator to further reduce the reliance on imported fuel.

VICE Engineering developed a simulator based on one year's data and an assumed fixed load of 80 MW. This simulator was used to examine a basic scenario assuming that at least 10 % of generation was required to be from conventional generation.
Figure 21 indicates that most of the energy could be provided by wind, with smaller amounts of solar and conventional generation as per the above discussion.

DASHBOARD						Percentage
Wind Farm Capacity (MW)	139.5	Conventional Generation (MW)	19.64	Max required generation (MWh)	702,720	91%
Wind Capacity factor (%)	41.1%	Capacity Factor	18.2%	Annual generation (MWh)	637,730	100%
Solar Farm Capacity (MW)	56.9	Load (MW)	80	Annual Conventional Gen (MWh)	31,458	5%
Solar Farm Capacity Factor (%)	19.4%			Annual Wind (MWh)	509,281	80%
				Annual Solar (MWh)	96,991	15%

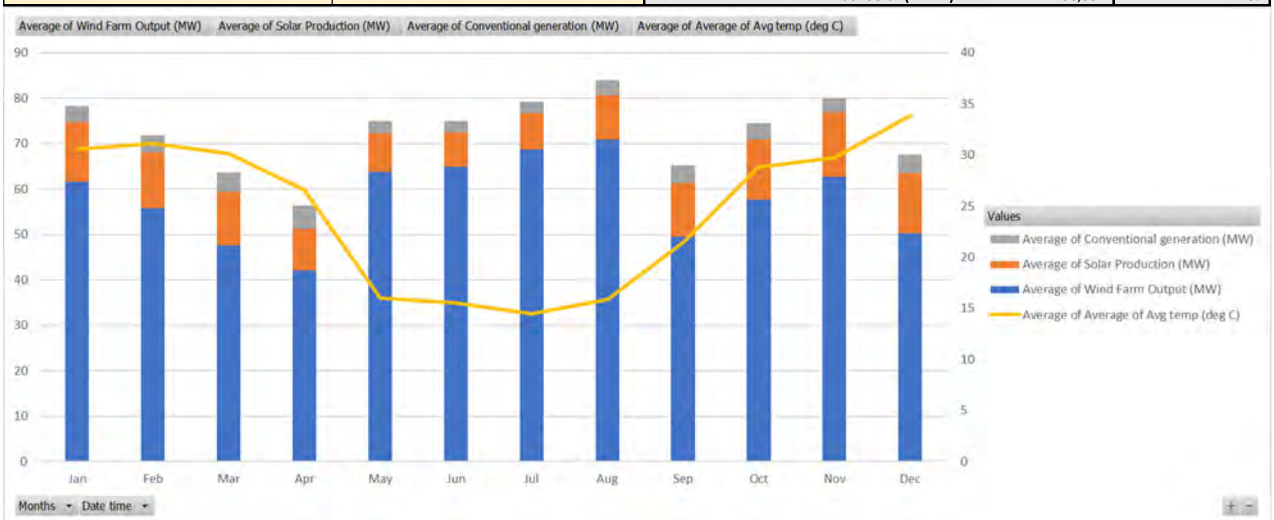


Figure 21 - Simulation Results

High renewable penetration systems can have extreme ramp rates in their renewable components. In the wind resource, large changes in power output can be caused by natural atmospheric phenomena, such as wind gusts, storms, and cyclones.
Fluctuations in the solar irradiance beyond the daily cycle are caused by short-term microclimates,

such as the passing of the clouds can result in the inverter ramping down very quickly. There are several studies about power stations that have successfully integrated high levels of renewables such as, Coral Bay, Denham and Bremer Bay Power stations. By integrating fast acting power systems, such as lithium battery storage and diversion loads, high levels of renewable power can be achieved without compromising on system reliability.

Tools are being developed for addressing the short-term microclimate challenges and have been demonstrated to be effective.
For example, Karratha Airport with support from ARENA has combined cloud predictive technology and a battery system to control the up and down ramp rates at the hybrid power station successfully.
Synergy, at the wind diesel hybrid (Coral Bay, Denham .etc.) stations took another route, using low load diesel generators to provide reference power and control the grid, with wind providing fill in power and high wind gusts controlled by diverting excess wind power to the diesel generators cooling system as heat.
Several trials using LIDAR to monitor the approaching wind for gusts have shown potential to allow the turbines to anticipate the gust and react accordingly.

Recommendations

There are several actions that can be undertaken to reduce the uncertainty associated with the data collected at the Butcherbird site, these items are:

1. Longer monitoring campaign.
   A longer data campaign will assist by having more data points to be compared to the long-term averages, which means that overall effect of seasonal and irregular variations is reduced.
   Longer term collection also to reduce the uncertainty of long-term resource forecasts for the site

2. Hub height wind monitoring tower for 18-24 months with a fixed meteorological mast.
   Hub height monitoring directly measures the wind at the hub height and reduces the uncertainty associated with extrapolating wind speed from one height to another, which while useful for indicative inspection is known to be subject to approximation, seasonal, topographical and weather influences.

3. Validation of the SODAR against the meteorological tower.
   Validating the SODAR against the meteorological tower accounts for the individual characteristics between the two instruments and allows calibration of the Sodar data against more precise measurements made at varying heights on a tower. Once calibrated, Sodars can be redeployed quickly to multiple sites to measure local wind measurements. This is impractical using masts.

4. Relocating the SODAR to another part of the site at regular intervals (3-6 months).
   Increases the wind profile across the site, and once the SODAR is correlated to the met mast allows for an overall wind map of the site to be approximated, which reduces the intra site layout uncertainty.

5. Cleaning of the solar monitoring equipment every second day.
   Reduces the impacts of soiling and short-term localised weather impacts on the data set.

6. Recalibration of instruments at recommended intervals.
   Ensures that the collected data is not being subjected to instruments that have drifted from their calibration and hence reduces the uncertainty associated with the collected data.

Conclusion

Element 25 is collecting wind and solar data to inform their investigation into the potential for renewable energy to provide energy to their facility.

The project is investigating the viability of using high levels of variable energy supply from wind and solar. This study has evaluated the collected data against BOM and MERRA 2 data sets to highlight the characteristics of the renewable energy resources at the Butcherbird site.

The findings show that the solar resource correlates well with the Illgararie BOM collected data and annual GHI of 22.173 MJ/m^2 is expected at the site.

The annual average wind resource at 100 m is 6.89 m/s, however the available data from higher altitudes indicates that at higher hub heights, such as 150 m; then the wind resource is expected to be between 7.68 m/s to 7.94 m/s. The SODAR collected data indicates correlation with the Merra2 data set.

The wind and solar resources have some level of co-occurrence and some seasonal variation, with an evident morning dip in the wind before the solar resource is available.

It is recommended that the data collection regime is continued as more valid data points will reduce uncertainties associated with the resource.

Generally, the data collected indicates that the solar and wind resource on site would support the development of a wind and or solar project and could be further evaluated as part of the energy solution for the electrowinning process.

Appendix 1 - Vice Engineering - Capability Statement

VICE ENGINEERING

Key Personnel

The engagement will be performed by Antoine Le-Ray as director of VICE Engineering

Antoine has extensive experience in the development, financing and operation of wind, solar, gas and solar thermal power systems. His experience on these projects includes, conceptual design, business case, feasibility studies, development, operations and maintenance, due diligence, auditing, maintenance planning and delivery and project management

Over the years Antoine has been involved in a range of developer support operations for green and brownfield sites. Activities such as PV infill modelling for a windfarm, solar thermal, PV, wind and solar thermal site selection modelling and preliminary site selection and performance analysis.

Antoine has experience with the very early blue sky modelling from a utility and developer perspective.

Antoine also has also undertaken end of warranty and pre-sale performance analysis on several projects.

Antoine has a bachelor's degree in electrical engineering with double majors in renewable energy and power systems.

Relevant experience and key roles include:

1. Provide preliminary modelling and options analysis for a 5 MW solar farm in South Australia - ongoing support for PV project development.
2. Full development support services for a 250 MW windfarm in South Australia.
3. Development manager for SolarReserve Australia.
    a. Develop Australian solar thermal pipeline, including preliminary site selection and resource modelling.
4. Renewable energy engineer for Mumbida Windfarm and Greenough River Solar Farm
    a. Develop a solar PV infill model for Mumbida windfarm.
    b. Develop Greenough River Solar Farm stage 2.
5. Synergy Renewable Energy Engineer
    a. Develop the renewable energy portfolio including:
        i. Formation of Synergy Renewable Energy Developments and Bright Energy Investments.
        ii. Warradarge wind farm.
        iii. Greenough river solar farm stages one and two.
        iv. Modelling of synergy renewable energy mix and future strategy.
    b. Support the Operation and Maintenance of the Synergy's Gas turbine and Sustainable Operation portfolio including: 8 windfarms, 1200 MW of gas turbines and two solar farms

Appendix 2 - Monthly Solar and Wind Data vs Time Charts

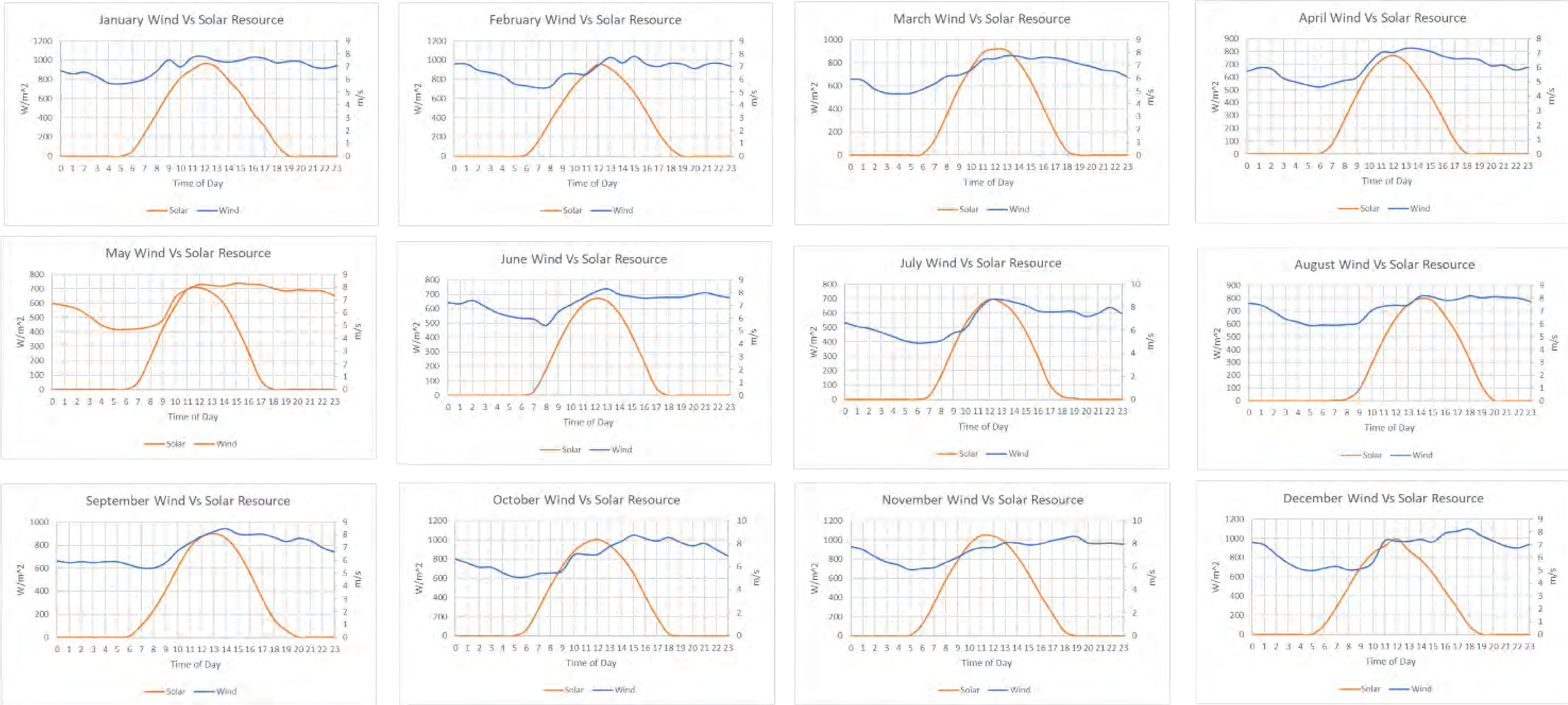


Figure 22 - Monthly Wind and Solar Correlation

Appendix 3 - Sodar and Pyranometer Commissioning Reports

Important note:

Please note that product brochures for those products referred to in the commissioning reports are available at the links below:

Sodar product brochure: https://my.vaisala.net/en/vaisalalists/Documents/TritonManualV2.pdf
Pyranometer product brochure: https://www.kippzonen.com/Product/11/CMP3-Pyranometer#.YUGOaX0RUaw

V

Triton Installation Report

T1086 Installation Newman 30.04.2019

Lat: **-24.433080** | Lon: **119.715176** | Elev: **610.9m**

Site Information Form & Checklist

1. Triton Information				
Triton Site Name:	T1086			
Triton Owner:	Advisian			
Install Date:	30/04/2019			
Triton Serial #:	T1086			
Triton Model:	Circle/Highlight:	Legacy	**TPU**	
Personnel Present:	Paul Deakin			
2. Site Information				
Surrounding Site Description (i.e. Windfarm, Forest, Field etc.)	900m from Great Northern Highway. Bushland clearing; scattered shrubs. See photos below for site characteristics.			
	Client: Advisian, WorleyParsons Group. Primary contacts: E: veronica.fok@advisian.com			

3. Fixed Object Vista Table					
Description of Object	**Azimuth (Deg)**	**Distance (m)**	**Height of Object (m)**	**Relative Elevation to Triton (m)**
Small excavation	55	6m	0.7m	-1.3m
Small tree	315	30m	4m	2m
Other	See photos and google earth at given co-ordinates			

V

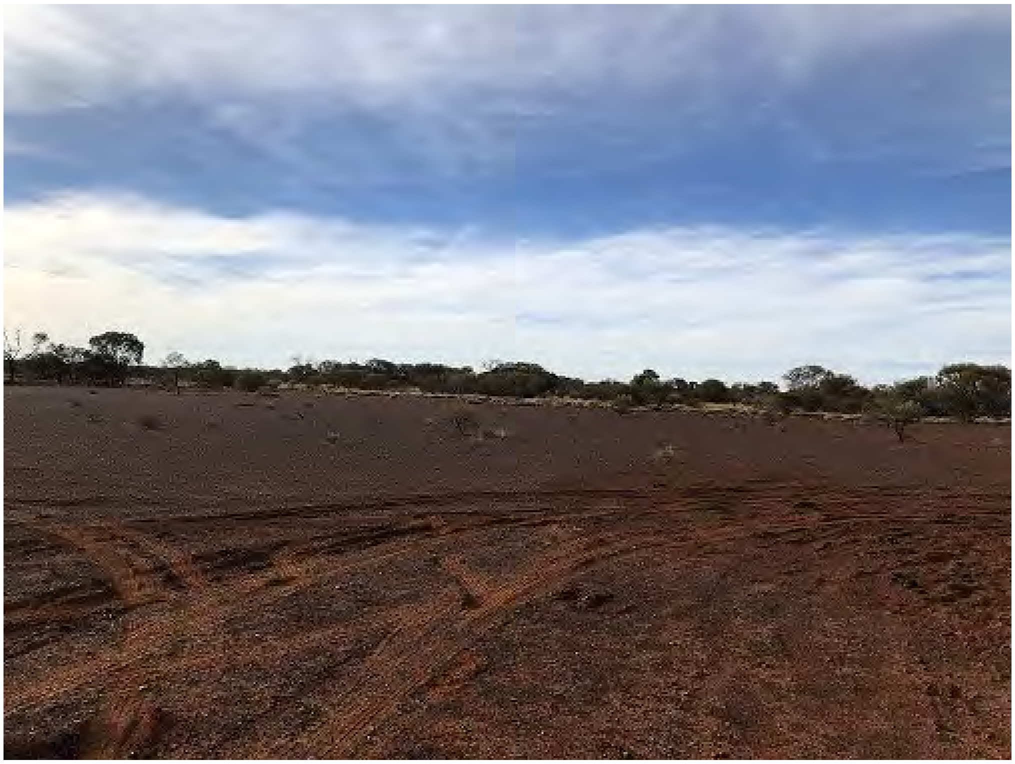
Triton Installation Report

4. Installation Checklist			
Item		**Unit**	**Value**
General Triton Checklist			
Mechanical Inspection		List Damage/Defects	None
Magnetic Declination			*1.04°*
Triton Properly Oriented		Record Azimuth of B-Beam (deg mag)	359° M
Triton Secured		Method (i.e. earth anchors, trailer, snow platform, etc.)	Star pickets and chains.
Batteries Charged (>12.7V)		Record voltage level, V - DC	12.8V
Solar Panels Installed, Connected		# of Panels	2
Solar Panels Charging		V - DC	Yes 17.6V
Operator Panel: GPS		Red/Green/Rapid/Off	Green
Operator Panel: SENSORS		Red/Green/Rapid/Off	Green
Operator Panel: SUPPLIES		Red/Green/Rapid/Off	Green
Operator Panel: SD CARD		Red/Green/Rapid/Off	Green
Operator Panel: NOTA (self-test)		Red/Green/Rapid/Off/NA	Green
Operator Panel: ARRAY		Red/Green/Rapid/Off	Green
Operator Panel: SODAR		Red/Green/Rapid/Off	Green
Operator Panel: SNR		Red/Green/Rapid/Off	Green
Operator Panel: INTERNET		Red/Green/Rapid/Off	Green
Operator Panel: TSP		Red/Green/Rapid/Off	Green
Operator Panel: SKYSERVE		Red/Green/Rapid/Off	Green
Take Photos or Videos		Pictures of 360deg site and Anchored Triton	Yes see below
Ambient Noise Description		(i.e. Birds, Crickets, Highway)	Quiet
Triton Information (1) Section Complete		none	Yes
Site Information (2) Section Complete		none	Yes
Fixed Obstacle Vista Table (3) Complete		none	Yes

Installer's Signature: Paul Deakin Date: 30/04/2019

Triton Installation Report

Installation Photos



T1086 to N

T1086 to NE

Triton Installation Report

T1086 to E

T1086 to SE

Triton Installation Report

T1086 to S

T1086 to SW

Triton Installation Report

T1086 to W

T1086 to NW

Triton Installation Report

Towards T1086 from N

Towards T1086 from E

Towards T1086 from S

Towards T1086 from W

Strategic Renewable Procurement Phase 2

Pyranometer Deployment

Element 25

12 August 2019

Signet House
Ground Floor, 600 Murray Street
West Perth WA 6005

201320-00737-EN-REP-0001

advisian.com

Disclaimer

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201320-00737-EN-REP-0001 – Strategic Renewable Procurement Phase 2: Pyranometer Deployment

Rev	Description	Author	Review	Advisian approval	Date
A	Issued for Internal Review	G. Hickson	V. Fok	N/A	09/08/2019
0	Issued for Use	G. Hickson	V. Fok	V. Fok	12/08/2019

Table of contents

1 Pyranometer Deployment Summary

This report details the deployment of the pyranometer within the Element 25 land tenement.

1.1 Site Information

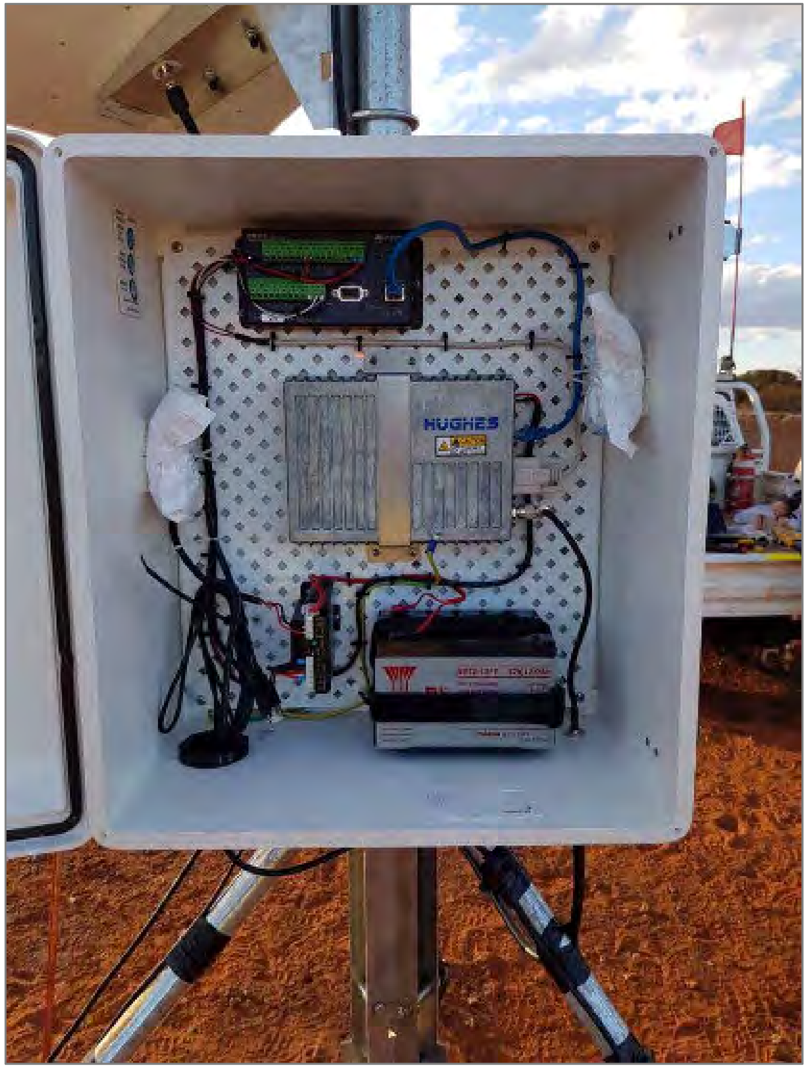
General Information				
Sensor Model:	Kipp & Zonen CMP 3 pyranometer			
Support Structure:	Campbell Scientific CM106B Tripod with guy ropes and crossarm mount - Staked to the ground			
Install Date/Time:	Monday 29 July 2019 5:00pm			
Location Coordinates:	**Lat:** 24.433180° South	**Long:** 119.714828° East		
	UTM:	**Zone:** 50 J	**Easting:** 775264 m	**Northing:** 7295114 m
Access Information				
General Location:	Approximately 120 km due south of Newman township (135 km via Great Northern Highway)			
Surrounding Site Description:	Approximately 900 m east of the Goldfields Gas Pipeline booster station.			
Road Access Description:	Accessible by 2WD vehicles, except if wet, via gravel station tracks. Access through a cattle gate which was unlocked at the time of installation.			
Gate Key Requirements:	No locked gates for access.			
Enclosure Access:	Enclosure is sealed from the environment by latches, no key access required.			
Property Management Contact:	Advisian Primary contacts: **Brett Giroud** Executive Consultant T: +61 8 9289 5824 E: Brett.Giroud@advisian.com			

1.2 Photographic Records

See following pages.

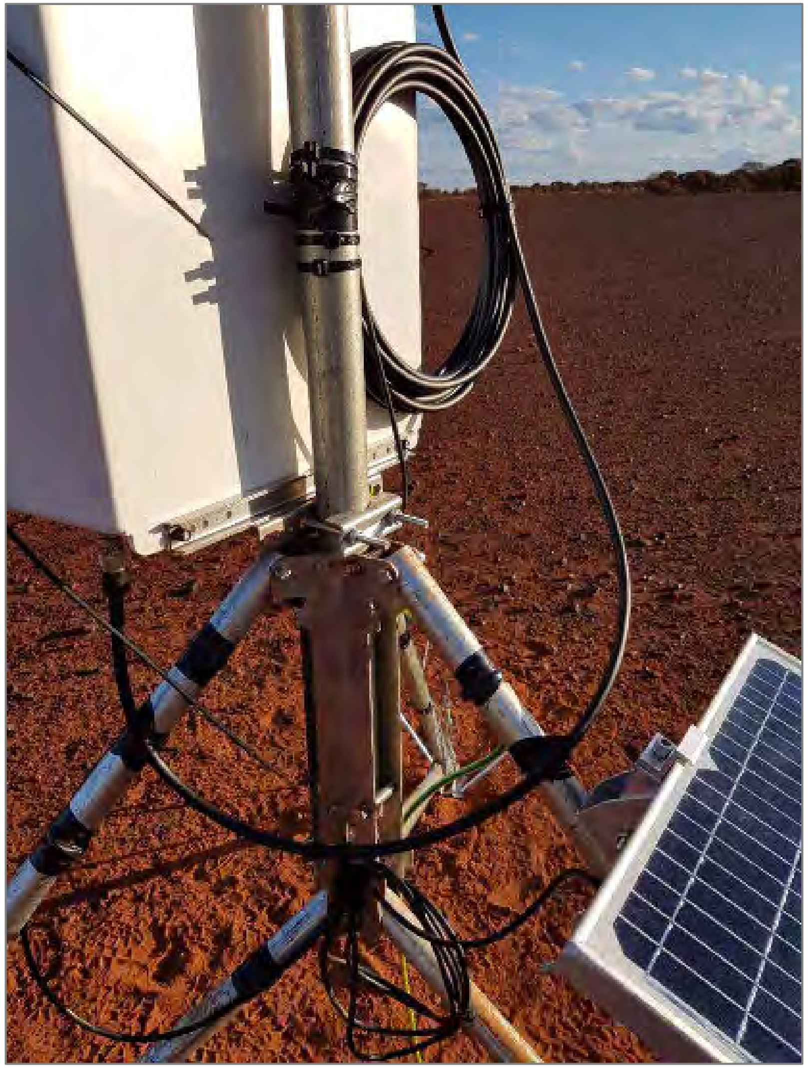
Whole assembly (facing SE) SODAR Unit in background

CMP 3 Pyranometer Sensor with Lightning Rod



Data Logger/Modem/Battery Enclosure

Solar Cell oriented facing North



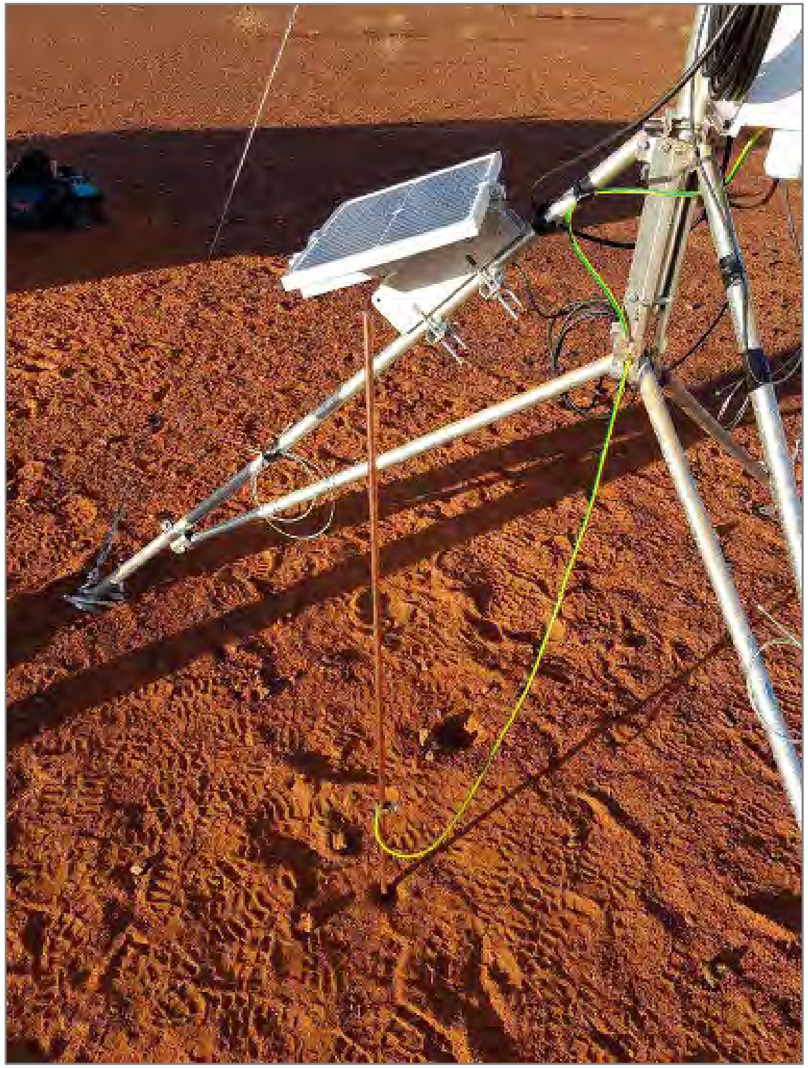
Satellite Communications Antenna Wiring

Enclosure Latches

Securing of External Wiring

Wiring below Enclosure

Satellite Communications Antenna

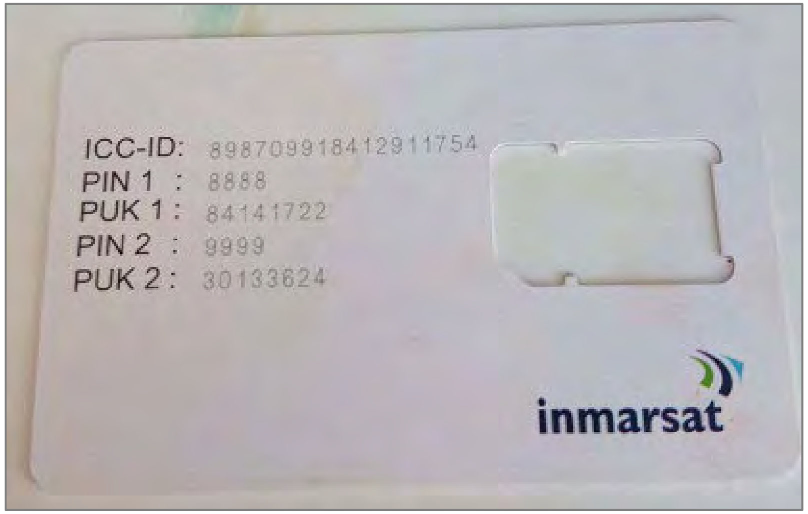


Earthing Rod

Stakes securing Tripod Feet

Stakes securing Tripod Feet

Stakes securing Tripod Feet



SIM Card Details

Disclaimer, Notes and Assumptions

1. This report does not qualify as a site classification or resource assessment and it is recommended that machine suitability for site is confirmed by the turbine supplier.
2. The as provided data by the client with pre applied pre monitoring settings are appropriate and correctly applied.
3. The data is representative of the general trends one could expect for the site, given the limited amount of data available.
4. Maintenance to the data monitoring equipment has been performed as expected for this type of installation.
5. VICE Engineering derived the data in this report from information sourced from Element 25 and available in the public domain at the time outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations, and conclusions expressed in this report. VICE Engineering has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.
6. This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by VICE Engineering for use of any part of this report in any other context.
7. The discussion and interpretation section are provided as commentary and not advice. The section is provided to add context to what a suitable combination of energy mix may be. It is based on limited assumptions and subject to change with additional information.

References

ARENA, Data61 CSIRO and Geoscience Australia. (2020, 09). Retrieved from Australian Renewable Energy Mapping Infrastructure: https://nationalmap.gov.au/renewables/

National Aeronautics and Space Administration. (2020). *The Modern-Era Retrospective analysis for Research and Applications*. Retrieved from National Aeronautics and Space Administration: https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/