Sub-Project 1

Wind Resource Monitoring Trial
Technical Report #2 (Public)

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Prepared for	ARENA

About Alice Springs Future Grid

Alice Springs Future Grid is led by the Intyalheme Centre for Future Energy, on behalf of Desert Knowledge Australia (DKA). Intyalheme is proudly supported by the Northern Territory Government.

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Acknowledgement of project partners

The Alice Springs Future Grid project is delivered by the Intyalheme Centre for Future Energy on behalf of Desert Knowledge Australia. The direction of the Future Grid project is guided by a Steering Committee comprising individuals from Consortium Member organisations. These are: Desert Knowledge Australia, Power and Water Corporation, Ekistica Pty Ltd, and Power Generation Corporation t/a Territory Generation. The Steering Committee is observed by ARENA, the NTG and CSIRO. Other Project Partners include the Arid Lands Environment Centre Inc (ALEC) and the Power Retail Corporation t/a Jacana Energy. A list of Project Partners can be found at alicespringsfuturegrid.com.au.

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Executive Summary

The Alice Springs Future Grid project conducted a twelve-month Wind Resource Monitoring Trial (Wind Study), providing insights for the development of renewable energy systems in Alice Springs. This report provides baseline information to stakeholders on the wind resource in Alice Springs and its potential to be developed into a useable electricity resource.

Data was collected at two locations in Alice Springs over 2021 and 2022, using mobile wind monitoring units. The units, known as SODARs, were constructed by Fulcrum 3D and rely on sonic detecting and ranging (SODAR) to estimate the wind speed and direction at up to 200 metres above ground. This data was also correlated to long-term meteorological datasets.

To further understand the potential value of wind energy an analysis was undertaken on the potential generation from a 3 megawatt (MW) turbine and compared to the potential of solar PV generation. Cost factors for both large-scale solar PV and wind generation were also reviewed in order to present the levelized cost of electricity (LCOE) of both resources.

This report includes the summary statistics from the SODAR units, a description of the interannual variation in average wind speed, the annual energy generation, LCOE and total system cost.

The analysis found that, in Alice Springs:

- Wind generation is significantly more expensive than the typical cost of wind generation in Australia, due to the poorer overall wind resources.
- The LCOE for wind generation is five times the cost of large-scale solar PV in Alice Springs.
- Notwithstanding the higher cost, there may be opportunity for wind generation due to a notable degree of solar/wind resource complementarity – that is the wind resource is most abundant in the late afternoon and evening, when the solar generation potential is significantly below maximum demand.

Furthermore, wind energy was used in optimised design scenarios of the future Alice Springs system, where 50 percent of the annual electricity usage was met by renewables in 2030. That is, wind generation was included alongside solar PV, and battery energy storage systems (BESS), with the resulting total system cost calculated in present value. With respect to the likely degree of accuracy, and development opportunities, it was found that the cost effective system included 15 MW of wind turbine generation and had a present value cost of $171 m. The results showed that including wind generation into the fleet, was significantly beneficial on the final costing, as 0 MW of wind turbine generation came at a present value cost of $187 m.

The results of the study will be used in the highly centralised case in the Alice Springs Future Grid Roadmap to 2030. This may show there is potential for investment in wind generation. Further investigation to the system, as a whole, should be completed before any introduction of wind generation in Alice Springs.

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Glossary of Terms

Term	Definition
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ARENA	Australian Renewable Energy Agency
BOM	Australian Bureau of Meteorology
DER	Distributed Energy Resource
DKASC	Desert Knowledge Australia Solar Centre
E-box	Energy-Box
LCOE	Levelised Cost of Energy
MCP	Measure-correlate-predict
OSPS	Owen Springs Power Station
PV	Photovoltaic
REF	Renewable Energy Fraction
SODAR	Sonic Detection and Ranging
TMY	Typical Meteorological Year

Introduction

The Alice Springs Future Grid is a collaborative project involving organisations across the Northern Territory (NT) and Australia. It is a system-wide project that is considering how Alice Springs can reach 50% renewable energy penetration by 2030.

The Wind Resource Monitoring Trial is part of Future Grid Sub-Project 1: Modelling. Its purpose is to supply baseline information to inform future wind power opportunities and quantify the extent that wind power can complement solar power in Alice Springs.

This trial is the first of its kind for Alice Springs. That is, studies undertaken previously on the wind resource in Central Australia have not considered wind resources in Alice Springs itself. As such, no historical reference exists for cost of generation comparison. It is intended that this report on the trial findings will help establish to what degree wind power may be integrated into the Alice Springs electricity system to realise an increased renewable energy fraction, accounting for the increases in technical efficiency and cost of wind power deployment seen across the industry nationally and internationally.

Wind Resource Measurements

Two mobile wind monitoring devices were deployed just south of Alice Springs in the second half of 2021. The two monitoring locations were: the Desert Knowledge Australia Solar Centre – referred to by Site 1 – DKASC; and the Owen Springs Power Station – referred to by Site 2 – OSPS. The exact locations are depicted in Figure 1 to Figure 3.

The units are constructed by Fulcrum 3D and rely on sonic detecting and ranging (SODAR) to estimate the wind speed and direction relevant to turbine height. SODARs have a range of applications; in this project they have been utilised for resource assessment – i.e. prospecting for sites and proving wind resource before any project development. The Fulcrum 3D SODARs perform well in complex terrain due and are housed in a robust, portable unit – important for the semi-arid climate of Alice Springs. The units can be seen in Figure 1 and Figure 2.

Measurements relevant to wind speed monitoring include heights (which emulate a wind turbine – thus various heights above ground level), location, windspeed, wind direction and generation capacity of a reference wind turbine. The measurements utilised for this study are summarised in Table 1.

Table 1 Summary of wind characteristics which have been taken into consideration for the Wind Resource Study.

Characteristics	Measurements Analysed
Height	50 meters, 100 meters, 150 meters [1]
Location	Site 1 – DKASC, Site 2 - OSPS
Windspeed	0 – 40 m/s
Wind direction	0 - 360°
Size of Wind Turbine	3.5 MW turbine

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[1] These identified heights allow assessment for a reference hub heights as well as potential nearby obstructions. SODAR's have data availability up to 200 m above ground, although it is only relevant to the chosen reference hub height to analyse up to 150 m.

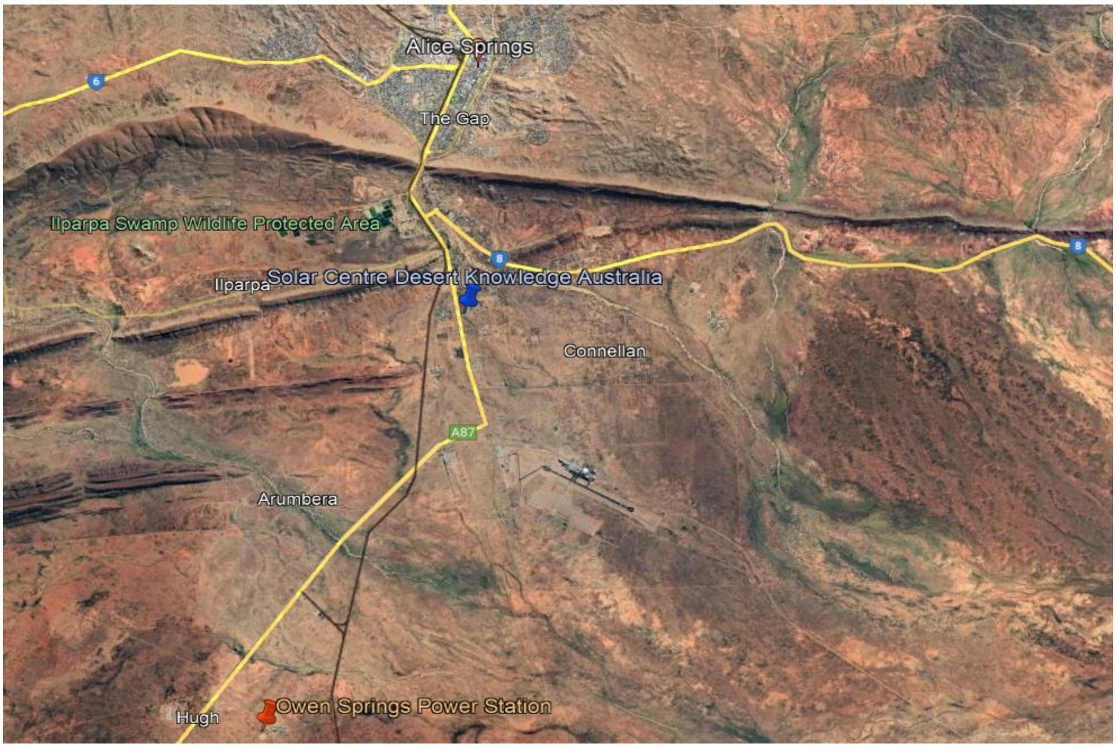

Figure 1 Regional map showing both SODAR locations amongst Alice Springs broader surroundings.

Figure 2 Location of Site 1 - DKASC

Figure 3 Location of Site 2 - OSPS

Data Collection Period and Availability

Wind speed and wind direction data have been collected from SODAR monitoring units at Site 1 – DKASC since 20 August 2021, and at Site 2 – OSPS since 09 September 2021. The data analysed throughout this report is for one year of data: from 1 November 2021 – 1 November 2022.

One year of wind data is sufficient in making informed conclusions on available wind resources based on wind characteristics [1], hence the duration of the Wind Study and where the period of time for the main analysis occurs.

During the data collection period, an atypically high rate of data unavailability was observed from the Owen Springs SODAR monitoring unit, suggesting that measurement uncertainties were frequently outside of tolerance. This was eventually resolved by the replacement of the unit's E-Box (central processor). However, this resulted in a data outage from 10 May 2022 – 10 July 2022, which can be observed in Figure 4.

Ekistica coordinated with Fulcrum3D to establish the degree to which data unavailability was correlated, and the appropriate remediation methodology. A measure-correlate-predict (MCP) approach (detailed in Appendix 1 – Variance Based MCP Methodology) was used for missing data imputation – for the outage period and for intermittent data unavailability prior to 10 May 2022. This resulted in a "corrected" dataset for Site 2 – OSPS, demonstrated in Figure 4 and Figure 5.

Note that for all analysis, the corrected OSPS data set will now be referred to as 'Site 2 – OSPS' based on its validity with respect to the MCP method.

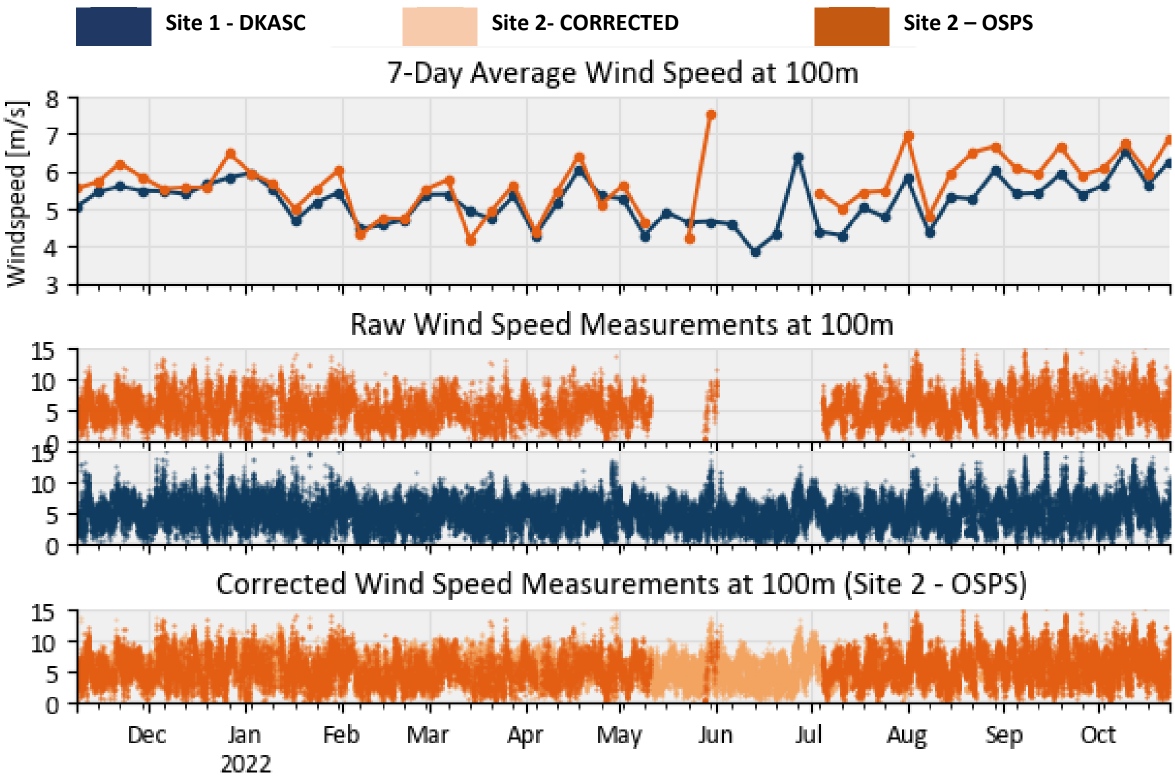

Figure 4. Average 7-day wind speed at 100m, and raw measurements at the two sites.

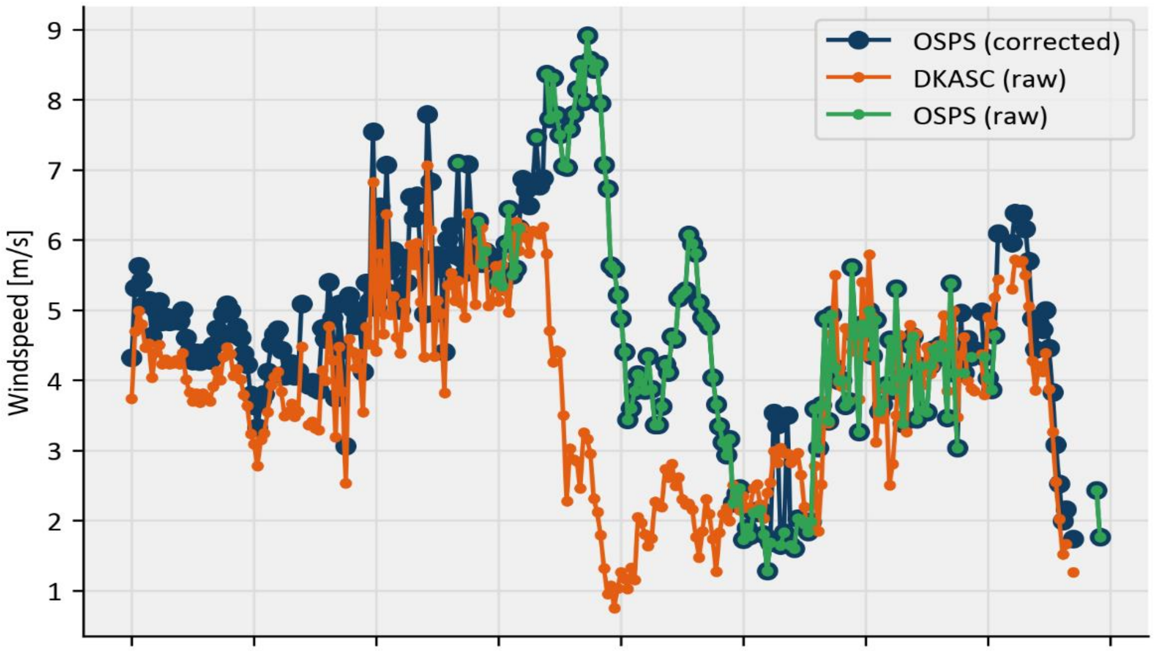

Figure 5 Comparison of DKASC and OSPS raw data with OSPC corrected data (04-07-2022 – 06-06-2022)

Wind Resource Results

The following sections summarise the collected meteorological data based on the observable wind characteristics (stated in Table 1).

Wind characteristics have been presented in a windspeed distribution plot (Figure 6 and Figure 7) and a wind rose (Figure 8 and Figure *9*). A wind rose represents wind direction averages at the identified heights, whilst a windspeed distribution plot represents windspeeds received at a range of heights.

Received wind data from both sites have been compared with historical wind resource data (see section on Consideration to Interannual Variance)to determine the long-term interannual variance of wind speed. This review was undertaken to determine if the duration of the wind monitoring period was of a typical or atypical year, and potentially skewing any results and future projections.

One-Year Wind Resource

Average yearly wind speeds for both locations are summarised for the identified heights in Table 2. Referring to the table, it is evident that Site 2 – OSPS has significantly higher average yearly windspeeds for all the identified heights.

Based on the one-year wind resource from both locations, it was determined that no further investigation would only be undertaken on Site 2 – OSPS. This was decided based on the poor wind resource results at Site 1 – DKASC.

Table 2. Average yearly wind speed in [m/s] for data analysis period

Height[2]	Site 1 - DKASC	Site 2 - OSPS
50m	3.92	4.58
100m	5.19	5.63
150m	5.94	6.44

Comparing Site 1 – DKASC windspeed distribution plot, Figure 6, with the Site 2 – OSPS windspeed distribution plot, Figure 7, it can be observed that Site 2 – OSPS has a greater average mean windspeed at all heights (as also confirmed by Table 2). However, Site 2 windspeeds also vary more, with greater standard deviations – which determines how far from the mean windspeeds individual measurements tend to fall (or rise).

Comparing Site 1 – DKASC wind rose plot, Figure 8, with the Site 2 – OSPS wind rose plot, Figure 9, it can be observed that Site 2 – OSPS has a greater number of wind directions with higher windspeeds. This is notably evident when comparing the two locations at the height of 50m – where at Site 1 – DKASC no directions appear to have received windspeeds over 5 m/s, unlike Site 2 – OSPS which received multiple directions with windspeeds over 5 m/s at 50m.

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[2] Height above ground.

Windspeed Distribution Summary

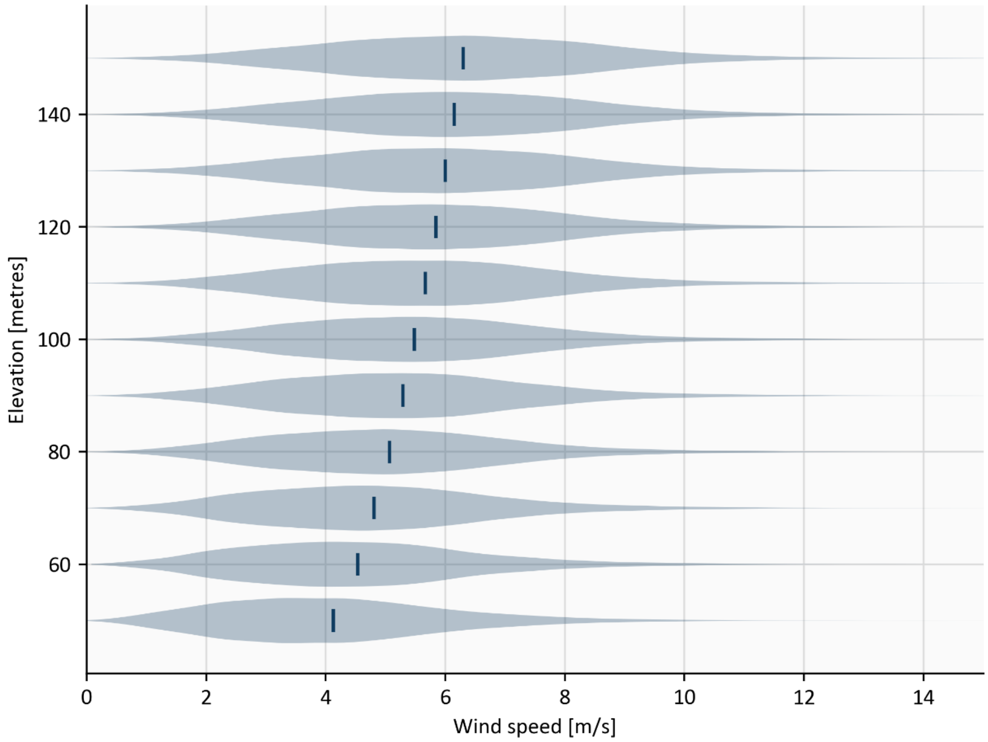


Figure 6. Windspeed distribution plot: Site 1 – DKASC

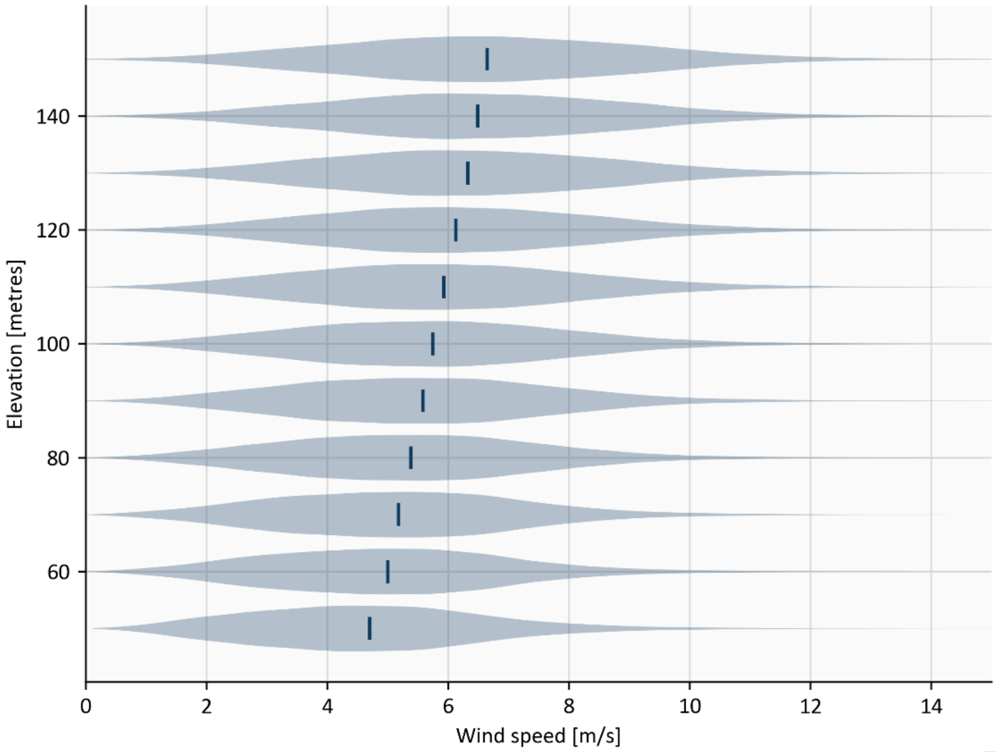


Figure 7. Windspeed distribution plot: Site 2 – OSPS

Wind Rose Summary

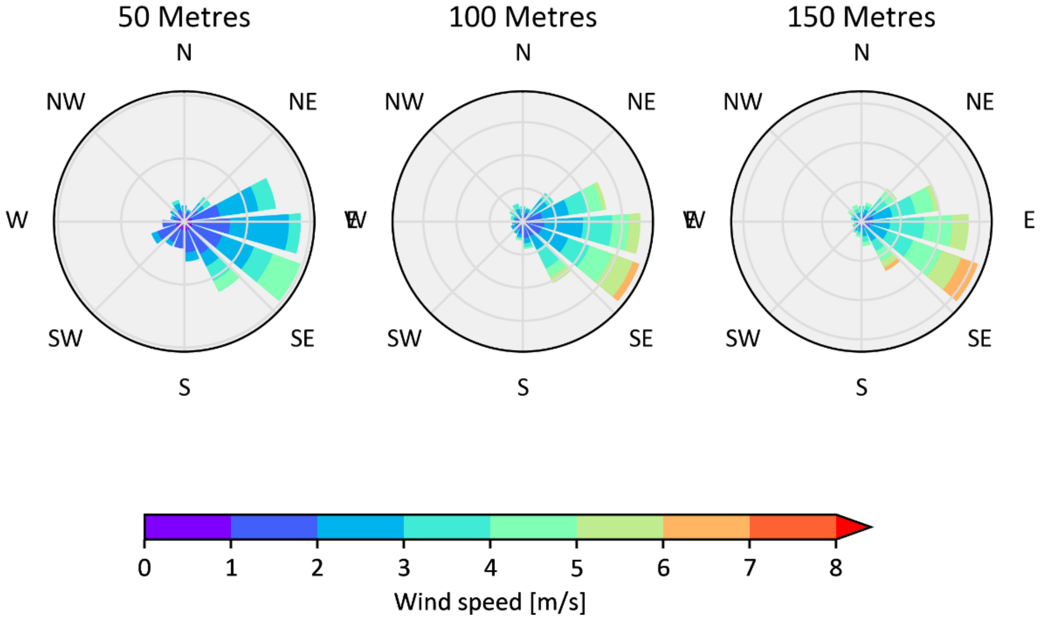


Figure 8. Wind rose for heights of 50m, 100m, 150m: Site 1 – DKASC

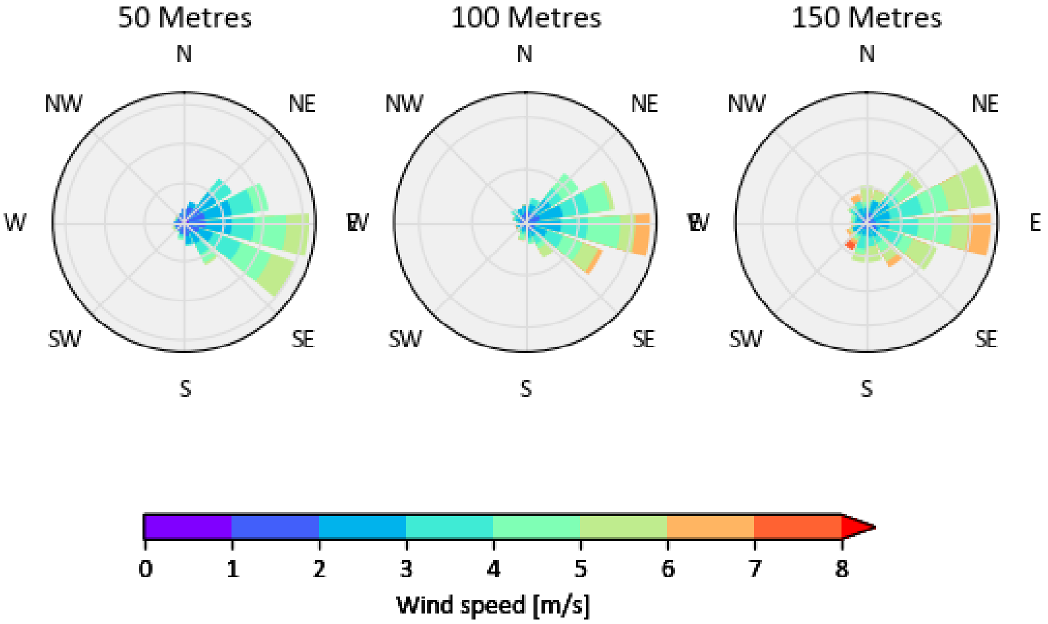


Figure 9. Windrose for heights of 50m, 100m, 150: Site 2 – OSPS

Consideration to Interannual Variance

To determine if the wind measurements taken over the data capture period were typical or atypical of historical wind data, an analysis of interannual wind-speed variance was undertaken on existing longer term wind data sets. This was compared to the data set from Site 2 – OSPS, to determine how a long-term data set for this site could be extrapolated for the site.

From this cross-analysis, a predicted long-term data set was developed for Site 2 – OSPS, based on its one year of results.

Comparative datasets

Three long-term historical wind datasets were initially assessed for suitability for this purpose. The source of these datasets and an analysis of their suitability is below:

1. Data collected from ground-based weather stations located at the ***DKASC*** [2] [3]. While this was deemed to be preferable due to its proximity with Site 1 – DKASC SODAR unit, it included a significant period of missing data. This data was deemed unsuitable for cross-analysis
2. Data collected from the ***Bureau of Meteorology's (BOM)*** [2] ground-based weather station adjacent to the Alice Springs Airport, some 8 kilometres (km) from Site 1 – DKASC and 15 km from Site 2 – OSPS. Preliminary analysis of this data noted statistically low average wind speed for 2022 due to a larger volume of 0 m/s readings in that period. Ekistica are in consultation with the Bureau of Meteorology but are yet to establish a suitable approach for use of this dataset. Since using the data as-is would have a significant impact on the study conclusions, this data was deemed unsuitable.
3. Satellite-derived dataset purchased from ***Solcast*** [4], which includes estimated wind speed and wind direction at 10 meters elevation. This long-term dataset was ultimately used for the long-term variability analysis, based on its similar mean windspeed results to Site 2 – OSPS as well as its high availability.

For reference, Table 3 shows the annual average windspeed for each long-term dataset listed above.

Table 3 Average annual wind speeds [m/s] for long-term datasets

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Mean
DKASC	3.15	2.38	2.21	2.41	-	-	-	1.63	1.28	1.34		2.10
BOM	3.65	3.64	3.70	3.61	3.68	3.56	3.76	3.74	3.79	3.60	3.35	3.64
Solcast	4.42	4.36	4.38	4.48	4.23	4.16	4.42	4.63	4.70	4.75	4.68	4.47

Site 2 – OSPS long-term data set creation

To create the predicted long-term data set for Site 2 – OSPS, the variance-based MCP method was used; with Site 2 – OSPS dataset as the "target", and the long-term Solcast dataset as the "reference", then resulting in 10 years of predicted historical data for Site 2 – OSPS. The resultant average windspeed for each year is presented in Table 4. The MCP method and its validity for creating long-term data sets with historical data sets is addressed in Appendix 1.

Table 4 Average annual wind speeds [m/s] of long-term data set compared to predicted long-term data set

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Mean
Solcast	4.42	4.36	4.38	4.48	4.23	4.16	4.42	4.63	4.70	4.75	4.68	4.47
Long term Site 2 – OSPS	4.93	4.86	4.89	4.99	4.71	4.63	4.93	5.17	5.24	5.31	5.18	4.98

With reference to Figure 10, it is evident that the long-term Site 2 – OSPS data (Table 4) sits well within the normal distribution plot bell curve.

This means that the 12-month wind speed data at Site 2 – OSPS was of a typical year. A ‘typical year’ of data allows for reliable assumptions to be made for future projections.

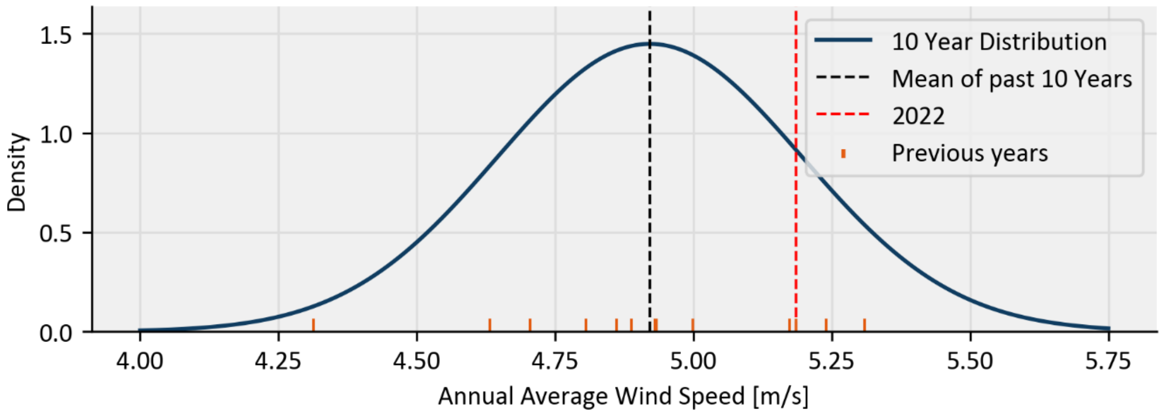


Figure 10. Distribution of historical annual average wind speed.

Note: Values have been estimated using the variance-based MCP methodology, and represent predicted historical measurements for the Owen Springs SODAR monitoring unit. The 10-year distribution is a normal curve fitted to the data. The dashed black line shows the distribution mean, while the dashed red line shows the measured wind speed for the 2022 data collection period.

Estimated Wind Turbine Generation

Overview

Potential wind power generation for Site 2 – OSPS has been calculated by modelling the likely performance of a Vestas V126/3000 3.5 MW wind turbine. This was completed using a wind turbine generation simulation software library, windpowerlib [5].

The datasets from Site 2 – OSPS at 100m (height, windspeed, wind direction, air temperature) were also used. This was considered the most suitable as the 3.5 MW reference wind turbine has a hub height of 119m. More of the referenced wind turbine's specifications can be viewed in Table 5.

Table 5 Vestas V126/3000 3.5MW wind turbine specifications.

Specification	Description
Manufacturer – Model	Vestas – V126/3000
Rated Power	3.5 MW
Rotor Diameter	126m
Number of Blades	3
Cut in/cut out wind speed	3 [m/s] / 22.5 [m/s]
Rated wind speed	10.5 [m/s]
Hub Height	119 m

Wind Generation

Based on the referenced wind turbine specifications, we can calculate the wind power generation from Site 2 – OSPS. The distribution of windspeeds observed are overlayed with the referenced wind turbine power curve in in Figure 11.

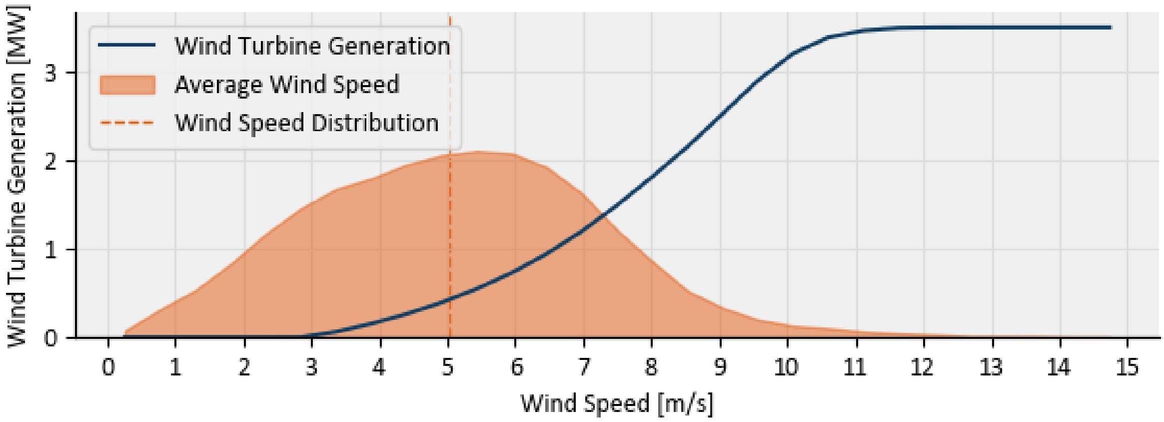


Figure 11 Modelled power curve with distribution of windspeeds.

The power curve dictates that the turbine will generate power when wind speeds are greater than 2.8 m/s and less than 14.7 m/s. Higher wind speeds allow for faster rotation of wind turbine blades, thus significantly greater power generation when compared to slower rotations (and slower wind speeds).

Observed in Figure 11, are wind speeds at the lower end of the referenced wind turbines power curve. This means it is likely to be an undersized wind resource, but the wind turbine will operate.

Using average monthly wind speed and the referenced wind turbine power curve, monthly average generation is plotted (Figure 12). From this, it is understood that monthly average wind speeds are higher than monthly average generating power available from the referenced turbine.

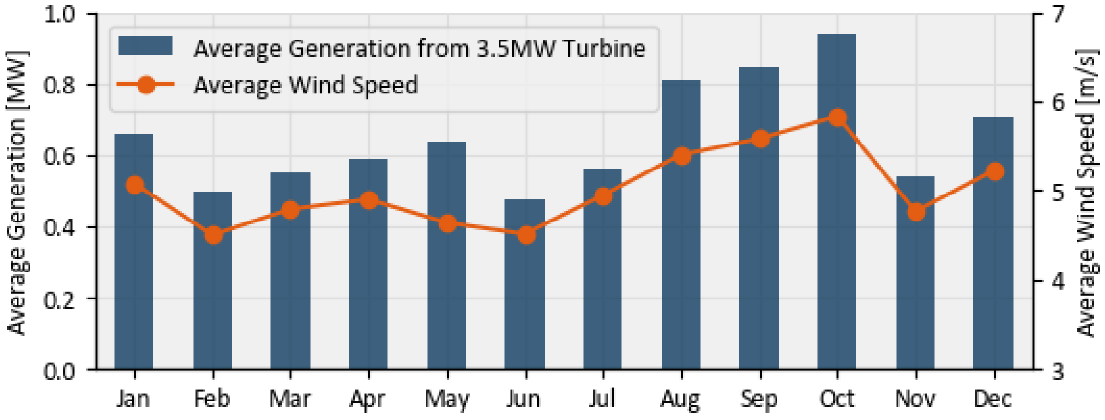


Figure 12. Monthly average windspeed for each calendar month, and estimated average power generated by the referenced 3.5MW wind turbine at identified height of 100m.

Power generation from the referenced turbine has been calculated for a 10 year period using the Site 2 – OSPS – long term wind data. The results, as a distribution, are shown in Figure 13. This historical distribution plot shows the likely power generation of a typical year. Figure 13 Distribution of historical total annual energy generation.

Note: Values have been estimated using the variance-based MCP methodology, and represent predicted historical measurements for Site 2 – OSPS. The 10-year distribution is a normal curve fitted to the data. The dashed black line shows the distribution mean, while the dashed red line shows the measured energy for the 2022 data collection period.

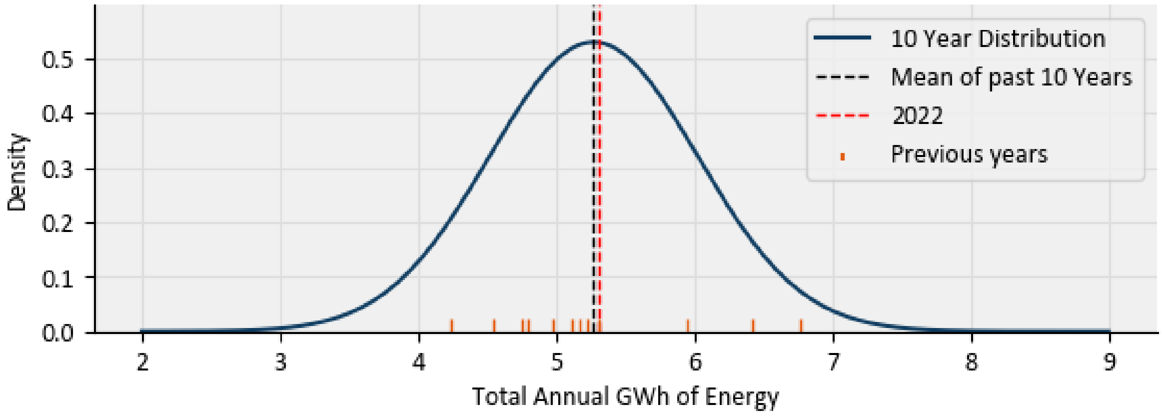


Figure 13 Distribution of historical total annual energy generation.

Note: Values have been estimated using the variance-based MCP methodology, and represent predicted historical measurements for Site 2 – OSPS. The 10-year distribution is a normal curve fitted to the data. The dashed black line shows the distribution mean, while the dashed red line shows the measured energy for the 2022 data collection period.

Correlation to Solar Generation

To date solar generation has been assumed to be the only renewable energy resource economically viable in Alice Springs. However, a purpose of the Wind Resource Monitoring Trial is to explore this assumption. It could be seen that initial review of wind data that there were some complementary aspects of the wind profile to the solar PV profile.

To quantify this, both solar and wind generation were modelled, overlayed and compared. The modelled wind power generation, as referenced in the previous section, is based on Site 2 – OSPS data and the referenced 3.5MW wind turbine. Solar generation was modelled on a similar sized PV array. The available generation from a 3.5MW fixed-tilt PV array was simulated using the pvlib [5] photovoltaics simulation software library was used. The source of solar irradiance data was the DKASC weather-monitoring station.

In addition, days of solar and wind data were categorised according to the weather conditions (sunny, cloudy, windy), which was based on the clearness index and wind speed recordings. This was undertaken to complete simulations that analyse the extent to which solar and wind are/ are not complementary.

The constraints for categorisation are as follows:

- Days with a clearness index [6] of greater than 0.8 were categorised as Sunny.
- Days with a clearness index of lower than 0.7 were categorised as Cloudy.
- Days with an average wind speed of at least 5 m/s were categorised as Windy.

From these categorisation results, the average daily generation was then produced for both Solar PV and wind turbine generation – as shown in Figure *14*.

From these diagrams, and the assessment of the data, the following conclusions can be made:

- Early mornings, in all weather, categories have a notable dip in wind generation. This is occurring as solar generation commences.
- Wind generation tends to be greater in the evenings, in all weather. This is complementing solar generation – which consistently diminishes at approximately 6:00pm (as the sun sets).
- On windy days, solar generation tends to be reduced, with wind generation having a predictably significant increase.
- On days with high cloud coverage, both solar and wind generation reduce in comparison to the other weather categories; although still follow the trends mentioned above (wind generation reducing early morning, wind generation peaking early evening).

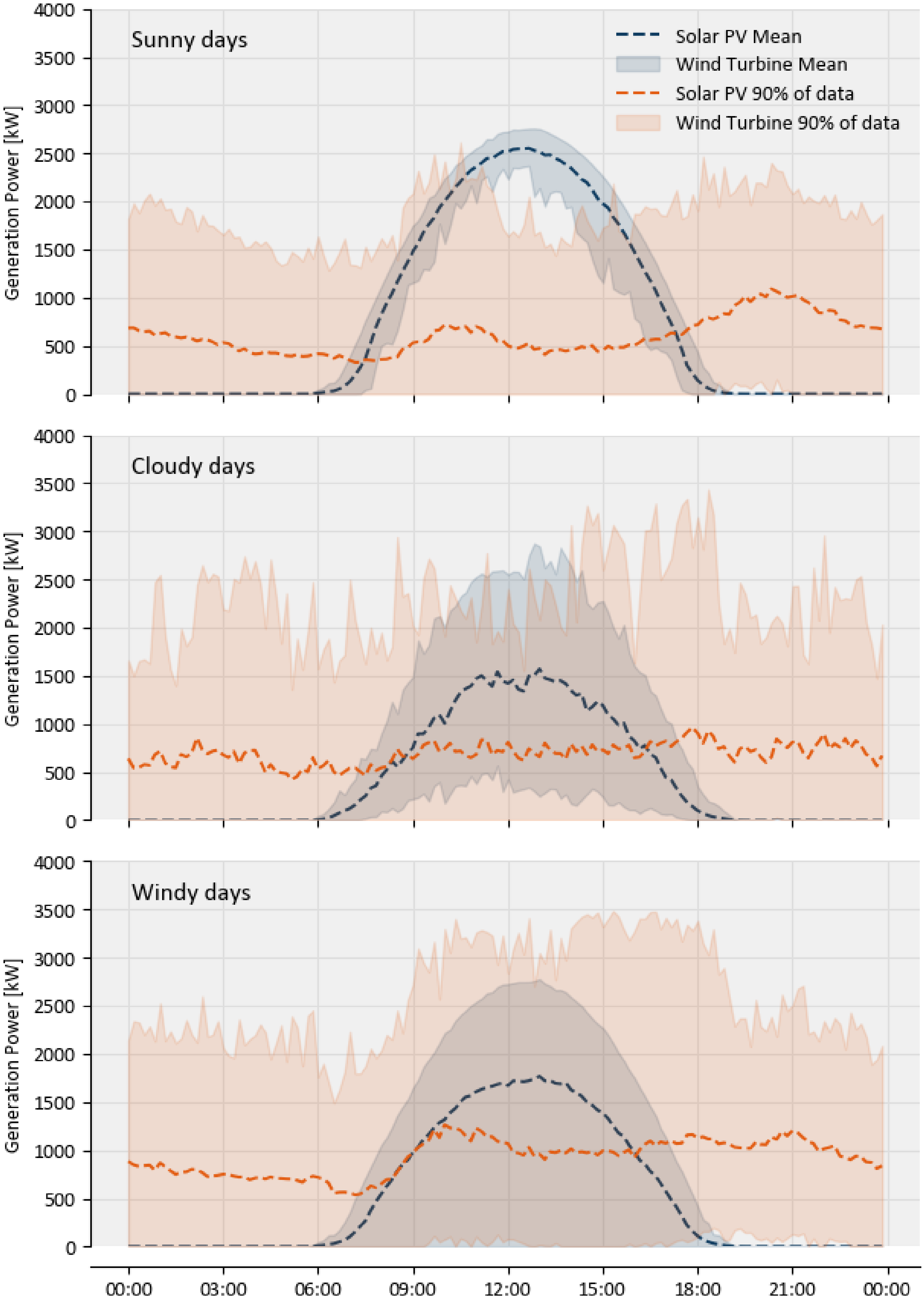


Figure 14. Diurnal average generation for wind tubine and fixed-tilt solar PV, on sunny, cloud, and windy days.

Economic Modelling

To assess and compare the cost of wind generation, an analysis was completed of the:

a) levelized cost of electricity (LCOE) from wind and solar PV, and

b) total present value cost of a range of system configurations that achieve a total of 50% renewable energy generation on the grid.

Cost assumptions

The assumptions listed in Table 6, below, were used to complete the economic modelling for the year of 2025. These assumptions have been drawn from the CSIRO GenCost 2021-22 [7] and the Cost and Technical Parameter 2022 Report by Aurecon [8]. Refer to Equation 1 in Appendix 2 for further understanding of the economic model equation.

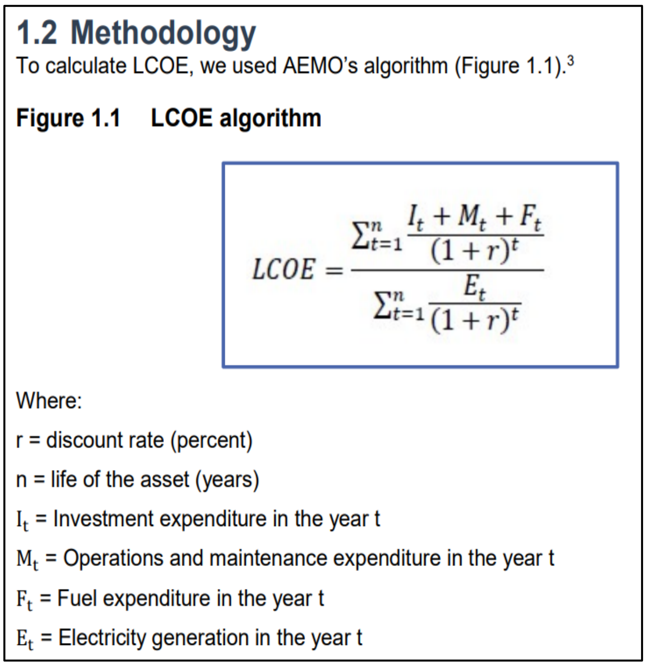
Table 6 Modelling Cost Assumptions

Generation Type	OPEX [$/kWh]	CAPEX [$/kWh]
Wind	$25	$2,281
Large-Scale PV	$17	$1,339
BESS (1 hour)	$4	$830
BESS (2 hour)	$5	$600
BESS (4 hour)	$8	$487
BESS (8 hour)	$14	$410

Note: For BESS capacity sizes other than those listed, the CAPEX value has been estimated as a linear interpolation of the listed values.

Levelised Cost of Electricity (LCOE)

The LCOE calculation used is shown Equation 1 LCOE Calculation. This is the same equation as used by the AER, AEMO and ARENA [9] .



1.2 Methodology

To calculate LCOE, we used AEMO's algorithm (Figure 1.1).[3]

Figure 1.1 LCOE algorithm

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

r = discount rate (percent)

n = life of the asset (years)

I_t = Investment expenditure in the year t

M_t = Operations and maintenance expenditure in the year t

F_t = Fuel expenditure in the year t

E_t = Electricity generation in the year t

Equation 1 LCOE Calculation

The LCOE for wind generation was compared to that of a large-scale solar PV array. To receive the LCOE for large-scale solar, a typical meteorological year (TMY) solar scenario has been used as the input weather file, and this scenario was constructed from publicly available long-term irradiance and ambient temperature measurements recorded at DKASC[3] [3]. To receive the LCOE for wind, wind generation results based on the simulation data from the as previously described 3.5 MW systems is used.

Results of the LCOE analysis are shown in Table 7 LCOE estimates for large-scale wind and solar generation., alongside the range representing the typical resource availability for the technology type across generators in Australia. The capacity factor values used to calculate the typical range have been drawn from CSIRO GenCost 2021-22. [7].

The LCOE for wind energy in Alice Springs was found to be significantly higher than the national range. Whereas the large scale PV LCOE in Alice Springs is within the national range.

Table 7 LCOE estimates for large-scale wind and solar generation.

Generation Type	Typical Range for Australia	Alice Springs
Wind	\$48.28 - \$56.92	\$130.35
Large-Scale PV	\$44.27 - \$64.69	\$59.30

Total cost of system in 50% renewable scenario

Based on the LCOE, the cost of wind generation in Alice Springs is significantly higher than other forms of generation when measured per lifetime energy. However, due to diurnal effect of solar and wind generation, it is worth still to consider its development potential as part of whole system. In saying this, further research and investigation must be undertaken before any wind power gets introduced – particularly a comparison of scenarios with Alice Spring’s current gas generation.

To perform this assessment, optimisation simulations were conducted that achieved 50% renewable energy contribution for the year 2030, in Alice Springs. The cost of these models where then calculated.

The simulation requirements for all scenarios is included in Table 8 Figures entered into simulation. Under these assumptions, the lowest cost system configuration achieving 50% renewable energy contribution includes 15 MW of wind turbine generation. The cost outcome for all scenarios modelled is included in Table 9.

Table 8 Figures entered into simulation

Simulation Requirement	Value
Base Load	6 MW [10]
Demand Increase	+ 0.6 % per year from now until simulation year
Distributed Generation	Provides 15% of total gross demand

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[3] PV losses are based on the International Energy Agency advice and include: [Soiling: 1.5%; Wiring: 2.0%; Connections: 0.5%]

BESS Rated Power	45 MW
Gas Generators [ON]	<= 3
Spinning Reserve	15 MW (from gas or BESS)

Table 9 Present value cost of 50% REF scenarios for Alice Springs in the year 2030 – (lowest cost scenario highlighted)

Wind Generation [MW] (Fixed)	Optimised 50% REF Scenario		
	Large Scale PVAC [MW]	BESS Capacity [MWh]	Present Value Cost [$m]
0	65	95	$187 m
5	55	90	$179 m
10	65	65	$186 m
15	**50**	**60**	**$171 m**
20	50	50	$175 m
25	35	65	$179 m

Figure *15* demonstrates the energy balance over a nominal-week (from model) in the 15 MW wind scenario.

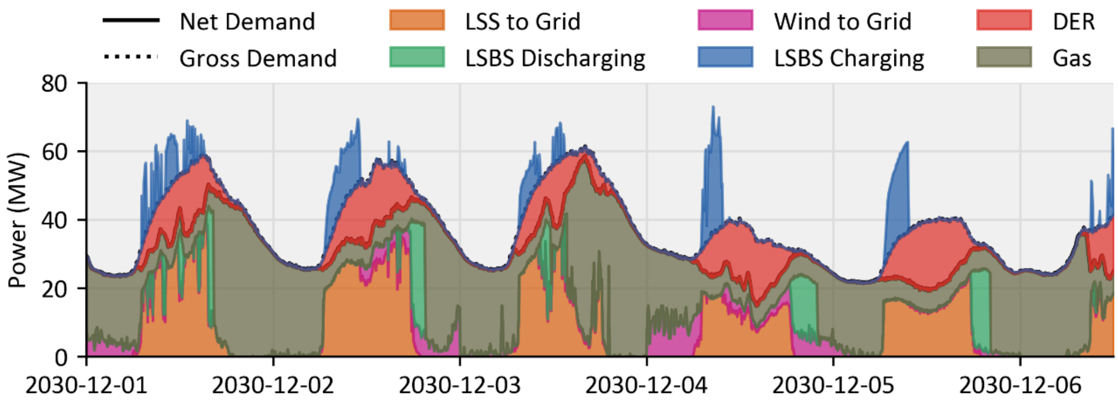

Figure 15. Simulated 50% renewable Alice Springs scenario with 15 MW of wind.

Conclusion

The Wind Resource Study has provided valuable insights into the potential of wind power as a complementary energy source to solar power in Alice Springs. Through the collection and analysis of wind resource data, the trial has shed light on the wind patterns and potential for harnessing wind energy in the Alice Springs region. The data collected has provided important information on wind speeds, wind direction, and other factors that may influence the viability of commercial wind power generation.

The Wind Resource Study has highlighted the potential synergy between wind and solar power generation in Alice Springs. By combining the intermittent but complementary nature of wind and solar resources, a more stable and reliable renewable energy supply can be achieved. This integrated approach could enhance the resilience and overall efficiency of the future grid in Alice Springs.

Overall, the Wind Resource Study has played a vital role in the Alice Springs Future Grid project by providing crucial baseline information on wind power opportunities. It has demonstrated the potential viability of wind to increase renewable energy penetration in Alice Springs, which will be further explored in the Roadmap to 2030.

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Appendix 1 – Variance Based MCP Methodology

Measure-correlate-predict methods models the relationship between wind data (speed and direction) measured at a target site, and concurrent data at a nearby reference site. The model is then used with long term data from the *reference* site which allows informed prediction of long-term wind speed and direction distributions at the *target* site [2]. This method adapted throughout this report is known as the "variance based MCP", which is described in detail in the referenced survey paper [2].

This methodology effectively allows for strong fluctuations, therefore is suitable when calculating with uncertainty[4] [11]. It is important to note that this methodology is suitable as Interannual Variability was correlated to the actual wind production.

The variance based MCP methodology is used in two instances in this report:

1. For development of the "corrected" Owen Springs SODAR dataset, using missing data imputation during periods of unavailability. In this case, the *target* site is the Owen Springs SODAR monitoring unit, and the *reference* site is the DKP SODAR monitoring unit.
2. For construction of a long-term historical dataset estimating the wind-speed at turbine height. In this case the *target* site is the "corrected" Owen Springs SODAR data, and the *reference* site is the Solcast satellite-derived data.

The variance-based MCP takes into consideration the variance of the target site windspeeds, to form a linear model. The variance of the predicted target site wind speeds for a linear model of the form $\hat{y} = mx + b$, is

$$\sigma^2(\hat{y}) = \sigma^2(mx + b) = m^2\sigma^2(x)$$

Thus, the linear model for which the predicted values are expected to have the same overall mean and variance as the observed values is:

$$\hat{y} = \left(u_y - \left(\frac{\sigma_y}{\sigma_x}\right)u_x\right) + (\sigma_y/\sigma_x)x$$

Where $u_x, u_{y,}\sigma_x$ and σ_y are the mean and standard deviations of the two concurrent data sets.

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[4] Uncertainty may include effects such as climate change. Therefore, when consulting future forecasts, it is important to consult how the location in focus is affected by future climate scenarios. Alice Springs is relatively unaffected for the foreseeable future, although more tropic areas must take this into consideration as wind turbines are not engineered to withstand cyclones.

Appendix 2 – LCOE Methodology

The LCOE is a screening tool for quantifying the relative competitiveness of electricity generating technologies and can be used to find the overall cost of the energy generated by a power plant. The LCOE incorporates both underlying resource strength (capacity factor) as well as all the costs incurred in the lifetime of the generating plant, including capital expenditure, operating expenditure, and fuel costs (if applicable). These costs are discounted to give the total present value cost, which is divided by the sum of all energy that will be generated, resulting in a cost per unit energy.

Equation 1 shows the formula used in all LCOE calculations.

$$
\begin{aligned}
LCOE &= \frac{C_T}{E_T} \\
&= \frac{\sum_{t=1}^{N} C_t \times (1+r)^{-t}}{\sum_{t=1}^{N} E_t \times (1+r)^{-t}}
\end{aligned}
$$

C_T	Total discounted cost of generating plant.
E_T	Total discounted energy generated by the plant over its lifetime.
t	Index of year (1, 2, …, N)
N	Lifetime of generating plant in years
C_t	Cost in year t (in real terms), including capital expenditure, operating expenditure, and fuel costs.
E_t	Energy generated in year t
r	Discount rate. Assumed to be 6%