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Supplementary Analysis to the

Electric Power Consulting

Submission on the

2022 Draft AEMO Integrated System Plan

26/9/2022

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About Dr Robert Barr AM and Electric Power Consulting Pty Ltd

Dr Robert Barr AM *is a consulting engineer, director of his company Electric Power Consulting Pty Ltd and a past National President of the Electric Energy Society of Australia. Robert has over 48 years experience in the field of power systems and electricity distribution, is a fellow of Engineers Australia and a member of Consult Australia. Robert is an Honorary Professorial Fellow at the University of Wollongong and was awarded the title of Australian National Professional Electrical Engineer of the year in 2012. Dr Barr became a Member of the Order of Australia in 2013 for services to the electricity industry.*

Since establishing Electric Power Consulting Pty Ltd in 1989, Robert has been providing specialist electrical engineering consulting services across Australia and overseas. Robert's main clients include electricity supply companies, high voltage electricity customers, federal, state & local governments, universities and other large energy users.

Dr Barr runs a post graduate course titled "Distribution Network Planning" at the University of Wollongong as part of a Masters in Power Engineering Degree.

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1 Reasons for Preparing this Report

1.1 This report has been prepared on short notice to highlight errors that have only recently been identified in the AEMO Draft 2022 Integrated System Plan (ISP) by Electric Power Consulting. This revised version of the report was prepared following added information provided by AEMO on Solar generation traces. The issues addressed in this report relate to:

Errors in wind trace data used in the ISP

Wind trace data errors have been identified that have the effect of boosting wind power output when wind levels are low across the NEM and decreasing wind power output when wind levels are high across the NEM. Correcting the wind trace data will very significantly impact the ISP and is likely to require a complete rewrite of the ISP if it is to meet the net zero target for 2050. The ISP will require vastly more wind, solar and storage resources than is required with the existing erroneous data to cater for the most extreme periods of wind drought and low solar radiance (dunkelflaute events).

Apparent Use of large Scale Concentrated Solar Thermal generation in the ISP

Variances in solar output between EPC and AEMO modelling highlighted a potential problem for EPC. The table of solar generation traces were found to contain concentrated solar thermal plants in the 2050 generation mix data. Concentrated solar thermal is a completely different type of technology to Solar PV in terms of cost, performance, storage capability and use as a proven/unproven technology.

After raising this issue with AEMO in our final version of this report, AEMO explained that although Concentrated Solar Thermal generation traces are provided in the Step Change Scenario data, they are not used. This explanation by AEMO increases the unsupplied energy in the EPC modelling.

EPC found the inclusion of solar generation traces that were not used in the ISP modelling very confusing. It is suggested that all unused wind and solar generation traces be removed from the provision of data to avoid such confusion in the future.

2 Introduction

2.1 This is a supplementary report to the Electric Power Consulting (EPC) submission to AEMO of 11 February 2022 on the Draft 2022 Integrated System Plan (ISP). The original EPC submission is currently available on the AEMO website and on the EPC website at https://www.epc.com.au/wp-content/uploads/EPC-Submission-on-the-2022-Draft-ISP-20220211-Final.pdf . A copy of this submission can be found at https://www.epc.com.au/wp-content/uploads/EPC_Supplementary_Response_to_ISP_Revision_1B_20220926.pdf .

2.2 All references in this report refer to the Step Change Scenario of the Draft ISP. The Draft ISP uses 10 reference years 2011 through to 2021 to define wind and solar characteristics. Details in this report refer only to the 2017/18 reference year. This single year has been selected by EPC because of ease of data availability. Analysis of one year is sufficient to identify how AEMO has processed the available data/information.

2.3 The key issue from the original EPC submission was the lack of generation and storage in projections looking forward to 2050. The EPC modelling shows unsupplied energy levels of 1.41%. The AEMO ISP team had chosen not to engage as requested in the EPC submission. They did however refer EPC to reference material that they used to build the Draft ISP. This material has been most useful in understanding why the AEMO and EPC modelling are in such great variance.

2.4 This report provides graphs and tables that help identify the key differences between the EPC and AEMO ISP modelling. They illustrate the very significant issues in the Draft ISP that need to be addressed in developing the final version of the ISP.

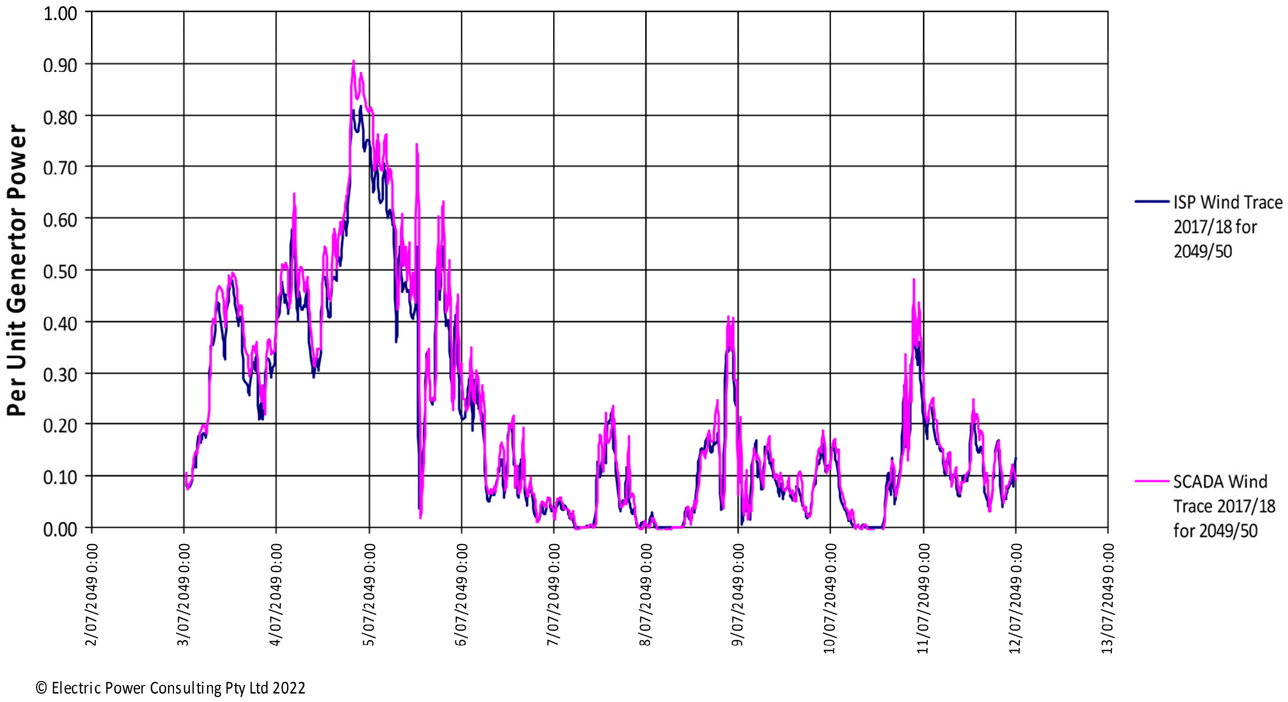
3 Wind Generation

3.1 The EPC modelling uses Supervisory Control and Data Acquisition (SCADA) generation data. This data is created by AEMO at 5 minute intervals and is readily available on the AEMO website. This data has been used by EPC as the basis for building wind and solar generation traces for the years 2017, 2018 and 2019.

3.2 In the Draft ISP, AEMO have created matching wind and solar trace profiles. Figure 1 shows a comparison of EPC SCADA data for the Ararat windfarm for the forecast period 3/7/2049 to 12/7/2049. To achieve this result, SCADA data beginning on 1/7/2017 was transposed to 3/7/2049. Close correlation can be seen between the ISP wind generation trace data and the SCADA data. This correlation confirms that the EPC analysis is using data mapping consistent to the Draft ISP.

3.3 Figure 2 shows generation traces for the three windfarms at Lake Bonnie over the period 3/7/2049 to 8/7/2049. Of significance is that there is good correlation of ISP wind trace data and SCADA data for Lake Bonnie Windfarm 1. By contrast, there are periods of large deviation between ISP Wind Trace data and SCADA data for both Lake Bonney 1 and Lake Bonney 2. The ISP wind trace for Lake Bonnie 2 has been increased by over 80% for some parts of 7/7/2049. Similar increases are evident at both Lake Bonnie 2 and Lake Bonnie 3 on 6/7/2049.

Figure 1 – Ararat windfarm Trace – Comparison of ISP Wind Trace and SCADA Data



3.4 Also of interest is at 1:00am on 5/7/2049, the ISP wind trace for Lake Bonnie 2 is about 10% less than the SCADA data.

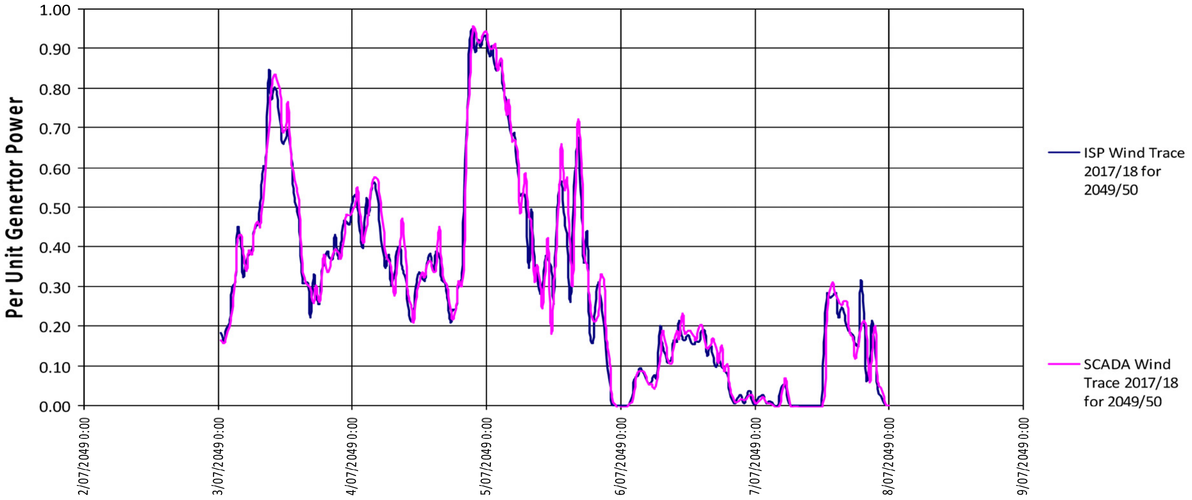
3.5 Further research showed that the deviations between SCADA data and ISP wind trace are widespread across many windfarms and across wide range of time frames. The conclusion reached is that the AEMO techniques used to build the ISP wind generation traces have used processes that have resulted in major distortions in windfarm output compared to that expected from the base SCADA data.

3.6 Figure 3 shows a generation duration curve for the Lake Bonnie Windfarm 2. Generation duration cures are a useful way of describing the proportion of time (days per year), generation can be expected to be above a specific level. For example, this graph shows that the Lake Bonnie Windfarm 2 had output above 0.2 per unit (20% of rating) for 180 days/year (i.e. 49% of the time).

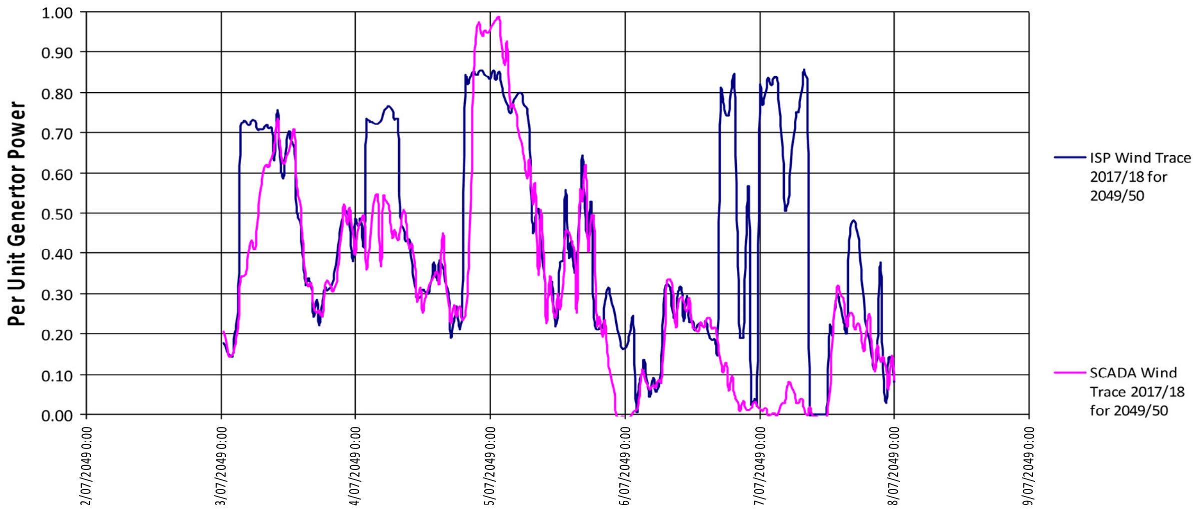
3.7 Despite the variations found in the time domain as detailed above, there is good correlation between the ISP wind trace data and the SCADA data. This suggests that the data processing undertaken by AEMO is creating the wind generation traces that have a balance of increases above and decreases below the reference SCADA data.

Figure 2 – Generation Comparison of Lake Bonnie Windfarms 1, 2 and 3

Lake Bonnie Windfarm 1



Lake Bonnie Windfarm 2



Lake Bonnie Windfarm 3

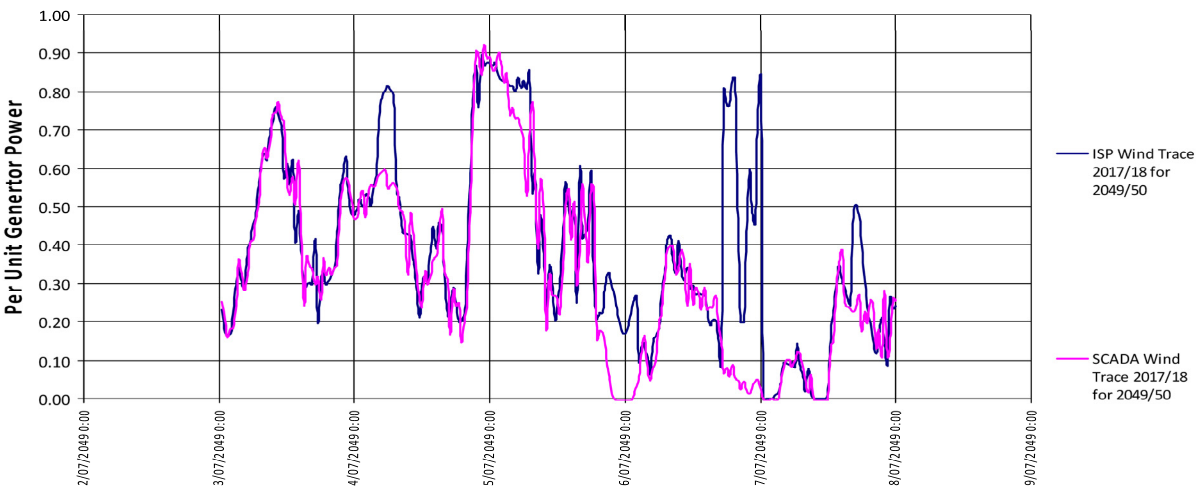
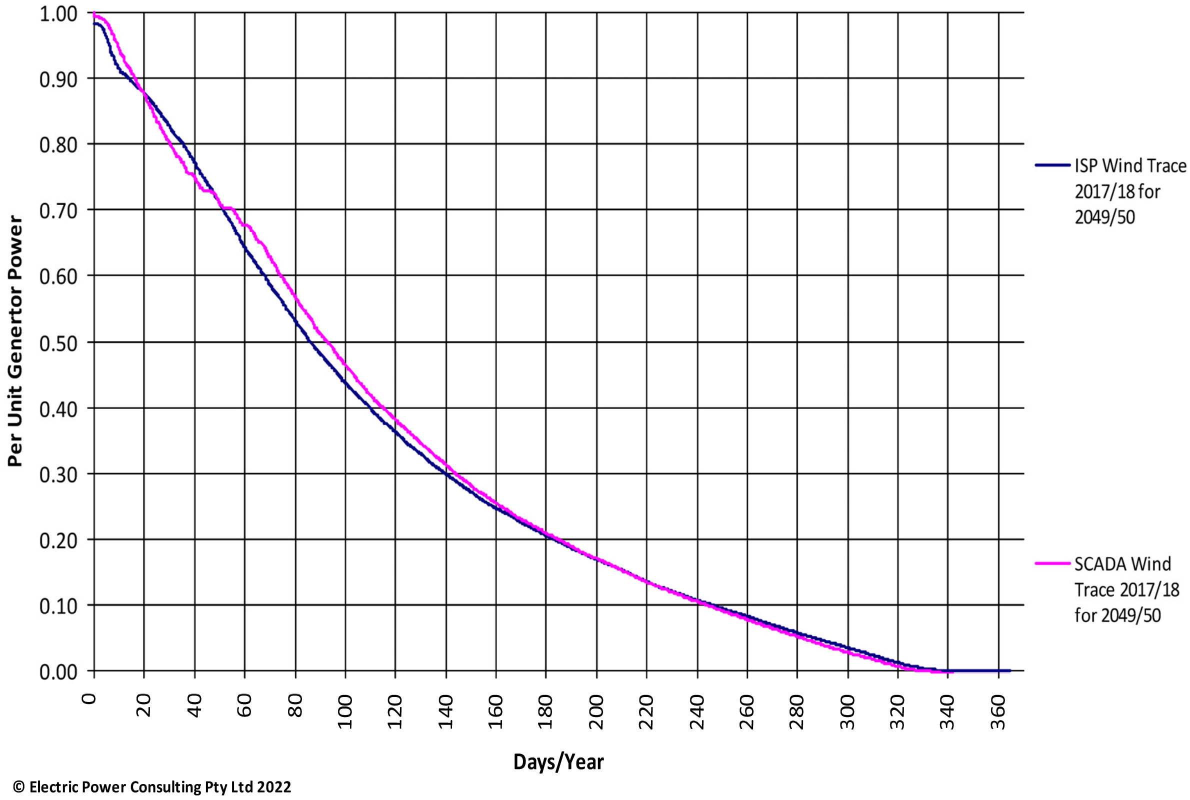


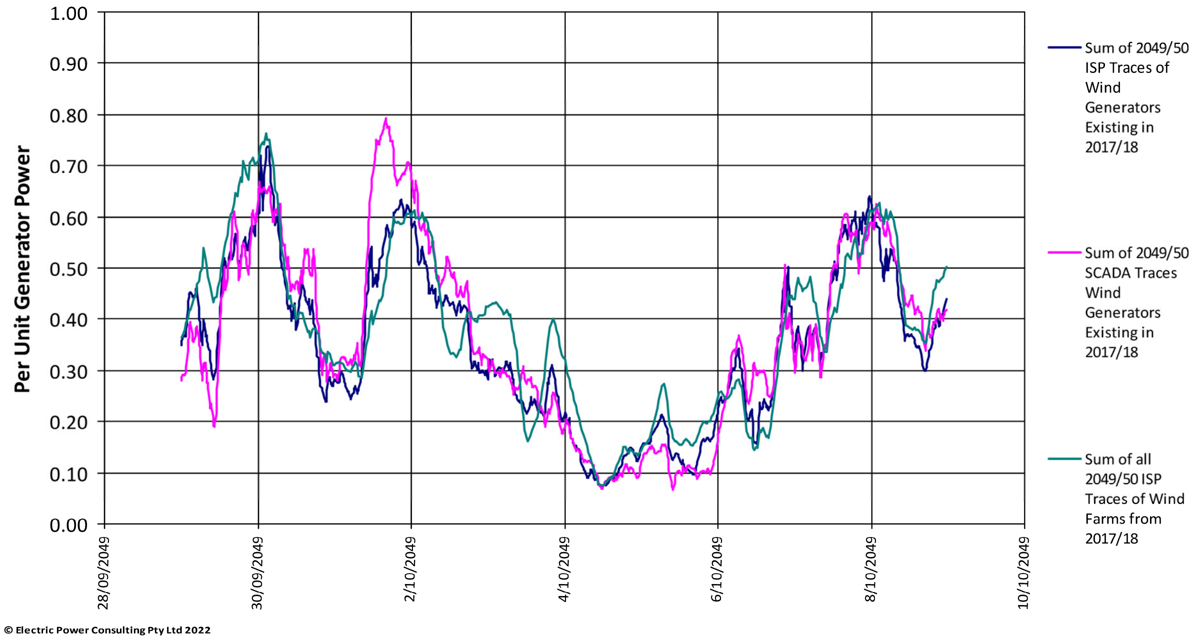
Figure 3 – Generation Duration Curve – Lake Bonnie Windfarm 2



3.8 Figure 4 shows three separate curves over time. The red curve represents the summation of SCADA data from the set of windfarms that existed in 2017/18. This included windfarms for the NEM regions NSW1, VIC1, SA1 and TAS1. No windfarms existed in QLD1 at that time. The blue curve represents the summation of AEMO ISP wind generation traces for the same set of windfarms. Close correlation between the red and blue curves was expected because they represent the same set of windfarms over the same time periods but this was not observed. Of significance is large variations between the summated AEMO ISP wind generation traces and the summated SCADA data during the evening of 30/9/2049. This is but one of many variations that were identified during the ISP 2049/50 year.

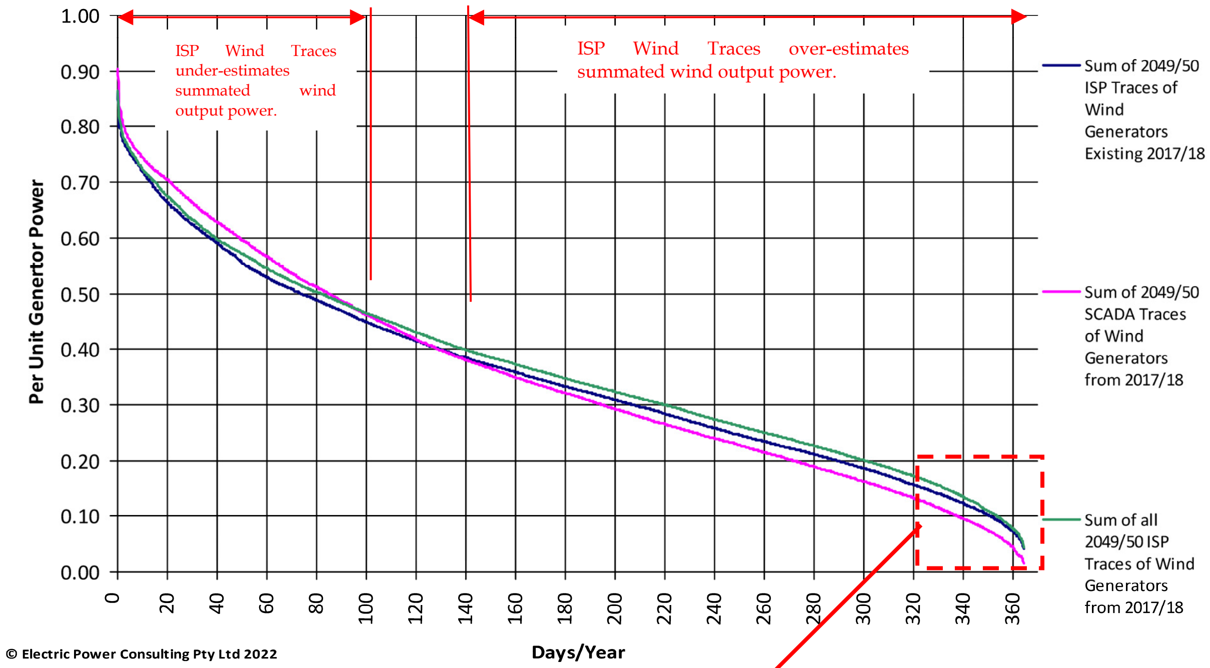
3.9 The green curve represents the summation of all ISP wind generation traces used in the ISP to build the 2049/50 characteristic. This includes all windfarms existing in 2017/18 plus all future windfarms that are planned under the ISP to be built through to 2050.

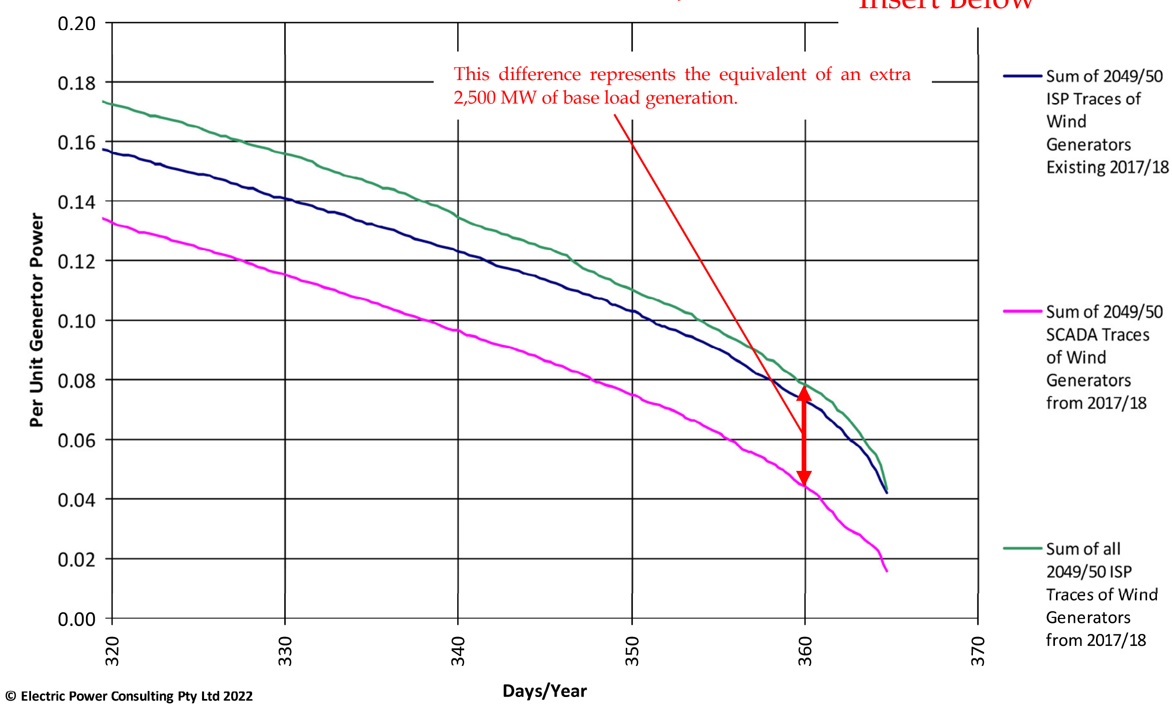
Figure 4 – Windfarm Generation Groups



3.10 Figure 5 shows data equivalent to that shown in Figure 4 presented as a generation duration curve. The duration curves show SCADA data from windfarms existing in 2017/18 (red curve) and the corresponding curve for the summation of the ISP wind generation traces (blue curve) for the same set of windfarms. The green curve shows that summation of all AEMO windfarms contributing to the 2050 ISP including those that are planned to be built in the future to supply the NEM in 2050. Figure 5 contains a detailed insert for the very important low wind output part of the curve. It is expected that the SCADA data from windfarms existing in 2017/18 (red curve) should align with the summation of the ISP wind generation traces (blue curve). This clearly is not the case.

Figure 5 – Summated Windfarms Generation Duration Curve





3.11 This graph contains some very significant characteristics. In summary the most significant observations are:

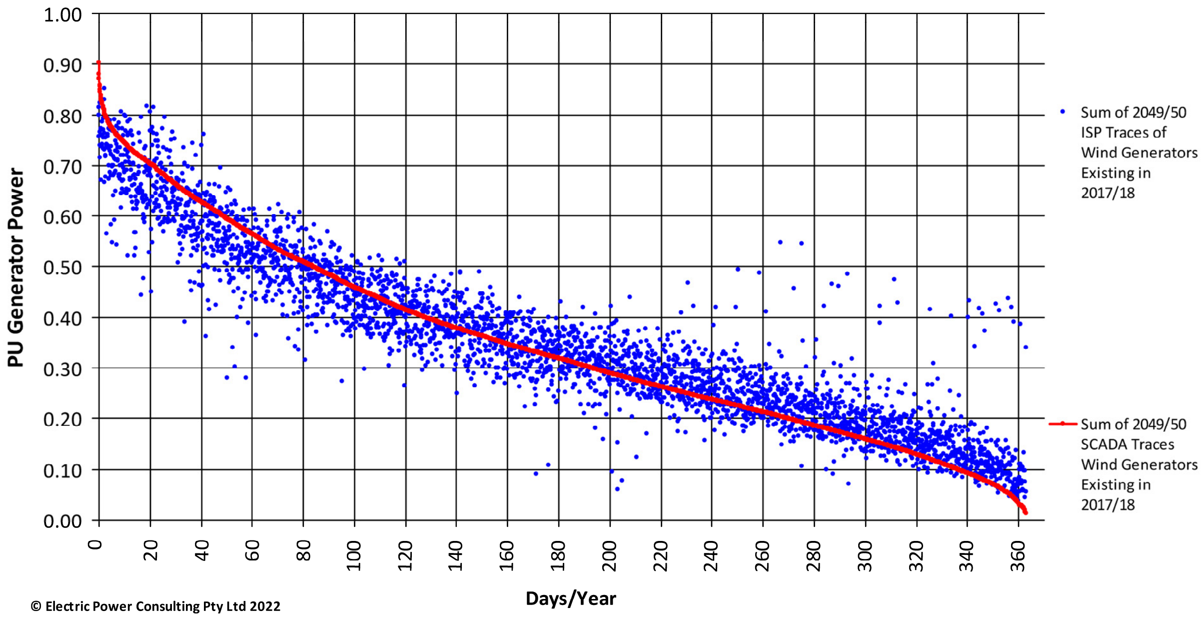
a) Under light wind conditions when wind output is very low across the entire NEM, the summated ISP wind generation traces (blue curve) sits above the summated SCADA data windfarm (red curve) by about 0.027 per unit (2.7%). The ISP summation of all windfarms, including those yet to be built, sits further above the SCADA data (red curve) by about 0.037 per unit (3.7%). EPC estimates that in the 2050 ISP Step Change Scenario, the differences identified represents an effective base load generation capacity increase from the full set windfarms of approximately 2,500MW. This is the equivalent of a very large power station of the size of the Eraring Power Station operating at full capacity 24/7 without ever breaking down.

b) For 225 days/year (62% of the time), the ISP over-estimates the summated outputs of windfarms across VIC1, NSW1, SA1 and TAS1. This occurs where the summated windfarm output is < 0.38 per unit output). This effect greatly impacts on the need for installed generator power (MWs) and storage output capacity (MWs) and storage capacity (MWhs). EPC has concluded that during below average wind conditions across VIC1, NSW1, SA1 and TAS1, the Draft ISP is utilising wind MW output that does not exist.

c) For 100 days/year (27% of the time), the ISP underestimates the summated outputs of windfarms across VIC1, NSW1, SA1 and TAS1. This occurs where the summated windfarm output is > 0.46 per unit output). This has little impact on the need for NEM generation and storage resources because the reduction in output of wind power is occurring at times where there is an abundance of wind generation.

Figure 6 illustrates similar information points as Figure 5 in a slightly different way. Each point in the red SCADA summation curves represents a point of time in 2049/50. The blue dots represent the summated ISP wind generation traces for the corresponding summated sites at exactly the same time. The blue dots tend to be above the red curve on the right hand side of the graph. In contrast, the blue dots tend to be below the red curve on the left hand side. This is consistent with summated ISP wind output being overestimated when output is low and underestimated when wind output is high.

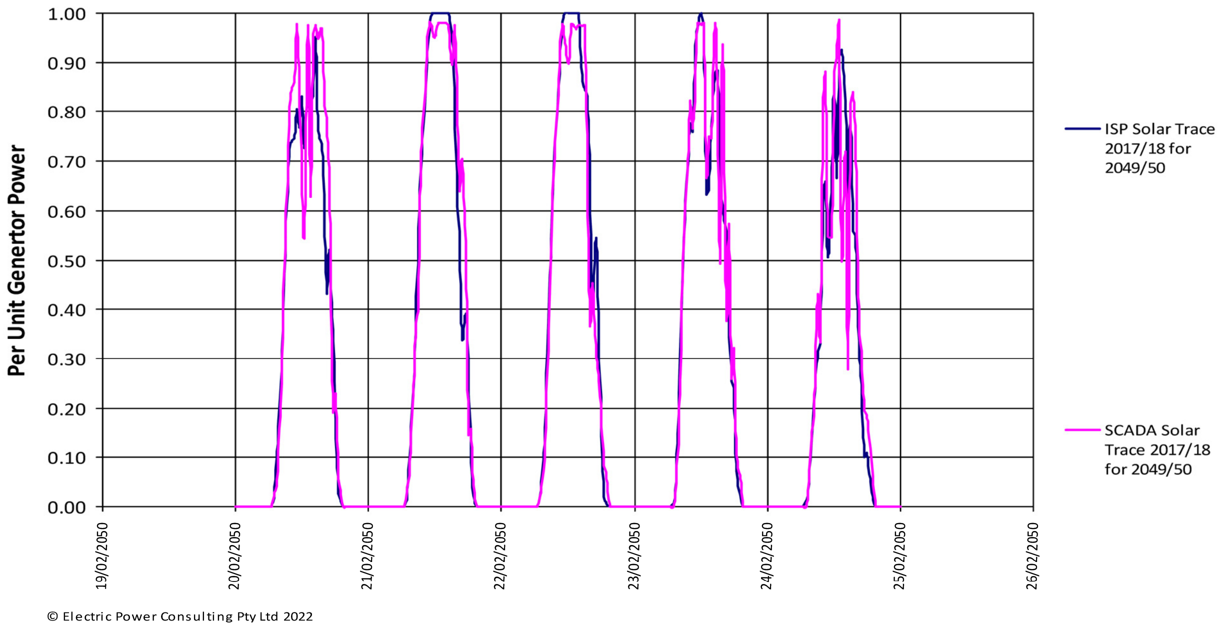
Figure 6 – Windfarms Generation Duration Curve with Time Synchronisation



4 Solar Generation

4.1 NEM solar farms have been analysed using the same techniques as the windfarm analysis detailed above. Figure 7 shows good correction between SCADA and ISP solar generation traces for the Broken Hill solar PV farm. This correlation confirms that the EPC analysis is achieving accurate data mapping between SCADA data and ISP Solar trace data consistent to the ISP.

Figure 7 – Broken Hill Solar Farm Trace – Comparison of ISP Solar Trace and SCADA Data



4.2 Figure 8 shows a generation duration curve for the Broken Hill PV Solar farm. The curves show good correction at output levels below 0.6 per unit output. The curves show that the solar farm is producing output for about 11.6 hours per day on average over the year 2049/50.

4.3 Figure 9 shows three separate generation duration curves. The red curve represents the summation of SCADA data from the set of solar farms that existed in 2017/18. This includes only solar farms for the NEM regions of NSW1. The blue curve represents the summation of AEMO ISP solar generation traces for same set of solar farms. Close correlation between the red and blue curves is expected and is achieved.

4.4 The green curve represents the summation of all ISP solar generation traces used in the ISP to build the 2049/50 characteristic. The unusual solar shape with output extending to an average of 20 hours per day (including at night time) was a most unexpected result.

4.5 Research into the provided data showed that unusual shape of the green curve was the direct result of the use of Concentrated Solar Thermal plants in the ISP Solar generation traces. Further investigation showed that the Draft ISP scenario for 2050 appeared to utilises 37 contracted solar thermal plants representing 22% of all solar plants across the NEM. A list of the thermal solar plants is detailed in Table 1.

4.6 AEMO advised in their communication to EPC that concentrated solar thermal plants were not used in any of the ISP scenarios. In the view of EPC, the provision solar generation trace data that are not used in the modelling is confusing and makes the ISP more difficult to independently model.

Figure 8 – Generation Duration Curve – Broken Hill Solar Farm

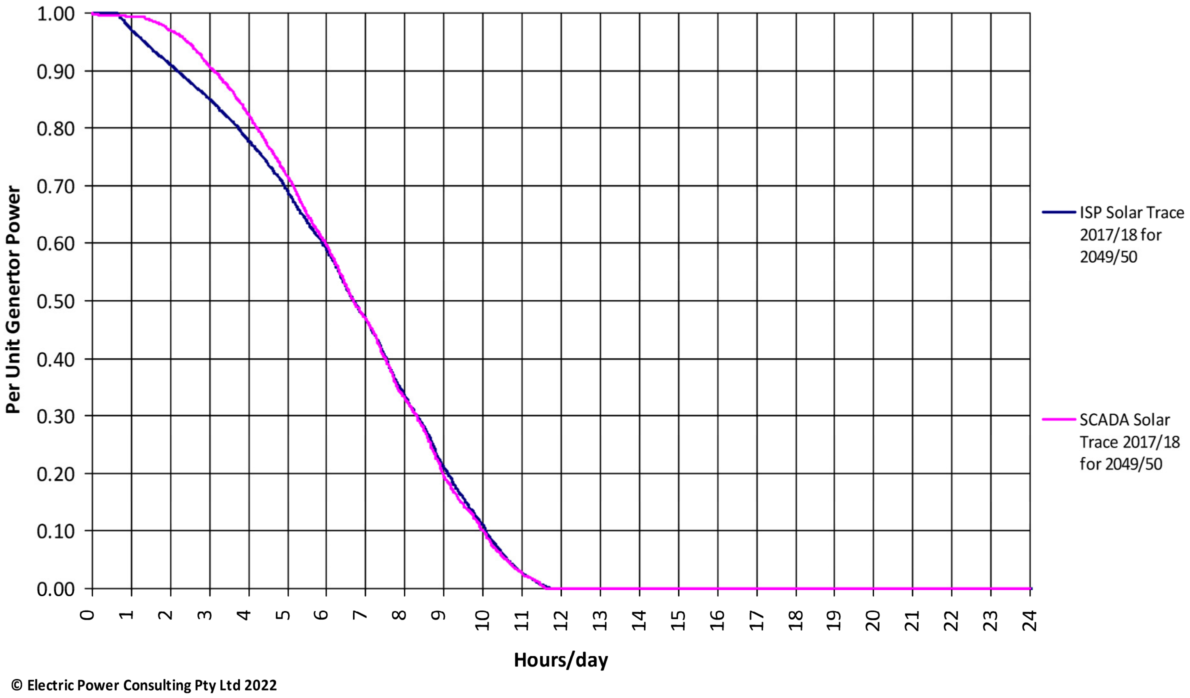


Figure 9 – Solar Farms Generation Duration Curve

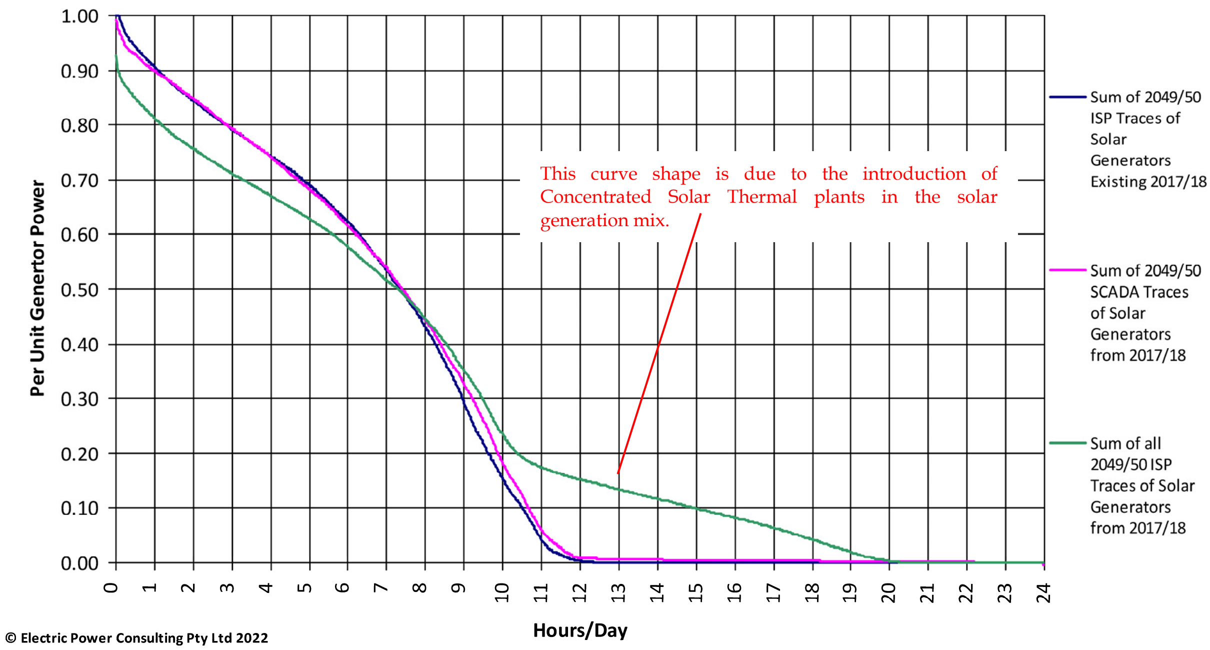


Table 1 – List of ISP Concentrated Solar Thermal Generator Plants

Item No.	Power Station Identifier	Solar Type
1	REZ_N0_NSW_Shadow_REZ_CST	CST
2	REZ_N1_North_West_NSW_CST	CST
3	REZ_N2_New_England_CST	CST
4	REZ_N3_Central-West_Orana_CST	CST
5	REZ_N4_Broken_Hill_CST	CST
6	REZ_N5_South_West_NSW_CST	CST
7	REZ_N6_Wagga_Wagga_CST	CST
8	REZ_N7_Tumut_CST	CST
9	REZ_N8_Cooma-Monaro_CST	CST
10	REZ_Q1_Far_North_QLD_CST	CST
11	REZ_Q2_North_Qld_Clean_Energy_Hub_CST	CST
12	REZ_Q3_Northern_Qld_CST	CST
13	REZ_Q4_Isaac_CST	CST
14	REZ_Q5_Barcaldine_CST	CST
15	REZ_Q6_Fitzroy_CST	CST
16	REZ_Q7_Wide_Bay_CST	CST
17	REZ_Q8_Darling_Downs_CST	CST
18	REZ_Q9_Banana_CST	CST
19	REZ_S1_South_East_SA_CST	CST
20	REZ_S2_Riverland_CST	CST
21	REZ_S3_Mid-North_SA_CST	CST
22	REZ_S4_Yorke_Peninsula_CST	CST
23	REZ_S5_Northern_SA_CST	CST
24	REZ_S6_Leigh_Creek_CST	CST
25	REZ_S7_Roxby_Downs_CST	CST
26	REZ_S8_Eastern_Eyre_Peninsula_CST	CST
27	REZ_S9_Western_Eyre_Peninsula_CST	CST
28	REZ_T1_North_East_Tasmania_CST	CST
29	REZ_T2_North_West_Tasmania_CST	CST
30	REZ_T3_Central_Highlands_CST	CST
31	REZ_V0_VIC_Shadow_REZ_CST	CST
32	REZ_V1_Ovens_Murray_CST	CST
33	REZ_V2_Murray_River_CST	CST
34	REZ_V3_Western_Victoria_CST	CST
35	REZ_V4_South_West_Victoria_CST	CST
36	REZ_V5_Gippsland_CST	CST
37	REZ_V6_Central_North_Vic_CST	CST

Note: 37 CST plants represents 22% of all solar plants

5 Impact Assessment of Wind Variances

5.1 One of the aims of this work has been to determine why the EPC modelling and the ISP modelling are in such variance. To assess the impacts of the wind issues identified in this report, the EPC model was run utilising wind generation traces provided by AEMO in the Draft ISP. The results of this work are supplied in Table 2.

Table 2 – Unsupplied Energy for a Range of Wind Assumptions Using the EPC Model

Model Scenario	EPC Modelled Unsupplied Energy		
	% of Total Energy	Average Load Shed Duration	
		hours/year	minutes/day
EPC/SCADA Wind and Solar generation traces from Wind Farms Existing in 2017/18 (This is the base case from the EPC ISP Submission)	0.99%	226.5	37.2
In the EPC Model use the 2049/50 ISP Trace of Wind Farms Existing in 2017/18	0.66%	145.0	23.8
In the EPC Model use the 2049/50 ISP Trace of all Existing and Future Wind Farms	0.33%	68.0	11.2

5.2 The results show that when the ISP generation traces for all 2050 windfarms were loaded into the EPC model, the level of unsupplied energy reduced from 0.99% with 37.2 minutes per day average load shedding to 0.33% with 11.2 minutes per day average load shedding. This is a very large reduction and goes a long way in explaining the differences between the EPC modelling and the ISP modelling. The corollary of this result is that if more accurate and representative wind generation traces data were used in the AEMO ISP modelling, very large increases in generation, storage and transmission resources would be required to satisfy customer load demands. This is consistent with the original EPC submission.

6 Conclusions and Recommendations

6.1 Prior to producing the future versions of the ISP it is imperative that AEMO carefully consider the material provided in the original EPC submission and in this supplementary report. To create a credible ISP from the Draft ISP, action is required to make improvements to ISP Wind generation trace data.

6.2 <u>ISP Wind generation traces</u>

6.2.1 Errors were identified in ISP wind generation traces for the 2017/18 year being used for the 2049/50 year. It is anticipated that this change alone will require large increases in wind, solar generation, storage and transmission resource to create a viable ISP that can progress toward net zero in 2050. Correction of these errors will fundamentally require the ISP to be completely reassessed.

6.2.2 To correct these errors it is recommended that :

ISP wind generation traces be reassessed so that they align and reflect historic wind conditions across the NEM as detailed in the SCADA data from their respective reference years. For example:

i. Where 2017/18 is the reference year, all wind generation traces of windfarms existing in 2017/2018 must reflect the historical SCADA wind output data for that year.

ii. Where modelling requires development of wind generation traces for windfarms that are planned to be built after the reference year, the wind generation traces must be consistent with the wind patterns that would have existed in that year.

6.3 Grid Solar PV and Grid Concentrated Solar Thermal

6.3.1 Many generation traces are provided for concentrated solar thermal plants in the data supporting the ISP. We are advised by AEMO that these generation traces are not used. We have found this situation very confusing when attempting to independently verify the ISP modelling.

6.3.2 To address this issue it is recommended that :

a) Only wind and solar generation traces used in the ISP modelling be provided in the ISP data. If concentrated solar thermal generation is used in any future ISP it should be clearly identified in the ISP report as a separate category of generation.

6.4 Other Issues

6.4.1 Limited time has prevented EPC from exploring other aspects of the ISP. Further exploration into the areas of LV customer solar PV generation and load profiles would be of great interest to EPC.

6.4.2 Despite the magnitude of the concerns identified in this report, further issues remain to be identified to bring the level of unsupplied load in the EPC modelling of the 2050 ISP down to zero.

7 Postscript to the 2022 ISP

7.1 AEMO finalised its 2022 ISP in June 2022. This October 2022 revised version of the EPC supplementary submission has been prepared after the finalisation date and hence AEMO will not able to implement the recommendations in the 2022 ISP. There will however be opportunities for AEMO to implement the recommendations in future ISPs.

7.2 In the 2022 ISP, costs for customer Low Voltage (LV) Solar PV, LV Batteries, LV and Medium Voltage distribution and transmission networks appear not to have been included in the ISP costings. We are told that the focus of the 2022 ISP was on transmission and grid connected generation, and the "other" costs are simply inputs and play no direct part in the formation of the ISP financial analysis. That is, they are out of scope. We are told that these "other" costs may be considered in the next ISP. Our view is that the "other" costs are likely to be larger than the transmission and generation costs that are currently being considered in the ISP.

7.3 It is becoming clear that AEMO need to move the emphasis from trying to assess the lowest cost transmission/generation system to a lowest cost of delivered electricity cost to customers. To get a solid understanding of where Australia is going with the implementation of the ISP, we do not believe that AEMO and the electricity industry can wait two years to get answers to these critical questions. These points were detailed in our EPC submission on the Draft 2022 ISP.

7.4 In October 2022, the NEM is facing an unprecedented crisis of high electricity prices and lack of confidence in the way forward. In the view of EPC, one of the key drivers of this crisis is the AEMO 2022 ISP and the previous ISPs. AEMO have built up expectations through their ISPs that in the view of EPC cannot be delivered. This report and the original EPC submission to the Draft 2022 have highlighted some of the key fundamental issues that could have been addressed in the 2022 ISP and that need to be addressed in future ISPs.