An Open Letter Concerning AEMO's 2022 Integrated System Plan

To: Mr Daniel Westerman, CEO AEMO

CC: David Fredericks PSM, Secretary DIEER
Anna Collyer, Chair of AEMC and ESB
Mr Ben Barr, CEO AEMC
Ms Claire Savage, Chair AER
Kathie Standen, Interim CEO AER
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Ms Kathryn Fagg AO, Chair CSIRO
Dr Larry Marshall, CEO CSIRO
Dr Cathy Foley, Chief Scientist

22 August 2022

Dear Mr Westerman

Your preface to the 2022 ISP states "…the ISP offers the most robust 'whole-of-system plan' available for supplying affordable and reliable electricity to homes and businesses…" However the assessment we submitted last February showed quite the opposite. AEMO's 2022 ISP Consultation Summary Report released in June acknowledged a few of our assessed points but completely avoided its main thrust – that the draft ISP could not meet any of its three goals: reliability, affordable cost and emissions.

As independent engineers and scientists, we now send you an updated assessment focused on the reliability implications posed by the final 2022 ISP for the NEM grid. Reliability is surely the most important of the three goals for consumers, the economy and our national security. The attached assessment, based on a whole-of-system top-level power budget, compares total power from all sources with maximum grid demand plus a reasonable reserve margin long used by the grid to guard against facility outages. *This analysis uses AEMO's ISP numbers throughout and is based on 100% interconnectivity*.

This updated assessment shows that the 2022 ISP does not have adequate energy storage depth and baseload back-up power generation to meet a reasonable system reliability design criteria under any weather conditions in years 2030, 2040 and 2050. If the ISP numbers do not add up to meet this design criteria, there is simply no way it will meet your stated reliability figure of 99.998% (10 minutes system outage per year) with a more detailed system design analysis. The ISP's primary reliance on interconnectors to shore up system reliability instead of highly expensive energy storage is irrelevant – this top-level power budget inherently is based on 100% interconnectivity….and it does not work.

Our previous criticisms of the draft ISP remain intact with the publication of the final 2022 ISP. The ISP contains hundreds of pages filled with impressive charts, graphs, tables and technical jargon, so formidable it deters most non-technical readers from venturing past the Executive Summary, while conveying an impression of competency. However, to the eyes of experienced and independent engineers and scientists it comprehensively fails to convince.

The ISP's primary shortcoming is a glaring lack of systems engineering methodology and proper analysis for its basis. In terms of reliability, it provides no power budgets at any level and detailed data on forecast demand is omitted from the ISP – it is found in another part of AEMO's website. The ISP goes to great lengths to present "illustrations" of system power predicted to be generated at various arbitrary dates under various weather conditions, which are not adequately or specifically defined. This does not constitute professional whole-of-system engineering analysis, it is merely a poor means to reassure or divert non-technical readers. This meaningless chatter is no substitute for rigorous analysis to establish system reliability.

Our attached reliability assessment is a first step in examining the performance of the NEM grid as a whole. The results are significant power deficits (and in some cases massive deficits), which guarantee frequent blackouts. It is little wonder that the ISP is now incorporating Demand Side Participation as a *system of rationing* to help deal with predictable power shortages. When this finally sinks in to the public at large, confidence in AEMO, the regulatory agencies, government departments and ministers will evaporate.

A similar whole-of-life, whole-of-system design approach to costs and emissions almost certainly will produce similar results showing massive increases in consumer costs and far larger emissions than the zero emissions constantly advertised by the renewable energy lobby. We will be addressing these issues in the coming weeks and reporting on them.

Mr Westerman, it is not necessary to reply to this letter by sending a polite response restating your confidence in the ISP. If you wish for some of your expert staff to honestly engage with the serious issues we have raised, we would welcome the opportunity to conduct a dialogue.

While it is not AEMO's responsibility to set climate emissions policy, it is incumbent upon AEMO, as the sole agency with design authority over the NEM, to deliver realistic plans. AEMO is expected to do so using engineering skills and knowledge, not possessed by most decision makers in government, to avoid misinformation and misleading guidance. AEMO's mission is to serve not just narrow interests but the whole nation.

It is our aim to serve the people of Australia with honesty, truthfulness and clarity.

Yours sincerely,

Dr James Taylor

Dr James Taylor PhD
Independent Engineers and Scientists

NEM Reliability – Top Level Power Capacity vs Demand

Assessment of the AEMO 2022 Integrated System Plan

Independent Engineers and Scientists

20 August 2022

Executive Summary

AEMO's 2022 ISP Electricity Grid Design Cannot Provide Reliable Power

Using a top-level, whole-of-system analysis for years 2030, 2040 and 2050, this assessment by independent engineers and scientists shows that the Australian Energy Market Operator's Integrated System Plan fails to provide sufficient power for system reliability whether wind and solar conditions are average, lower or higher.

Introduction

A top-level NEM power budget *inherently assumes 100% interconnectivity of the grid for transferring power from any place to any where it is required.* To ensure reliability, which is described in Table 3 (p19) of the ISP as 99.998%, a critical design criteria is for total maximum generation capability to exceed maximum demand plus a 20% reserve margin to protect against equipment failures and outages due to facility maintenance. The previous NEM has always met this criteria.

Based entirely on data in AEMO's 2022 ISP for the planned capacities of all power generation sources and energy storage systems (Figure 1 p9 and Figure 23 p54), a power budget is calculated for a 24 hour cycle comprised of 8 daytime hours when solar and wind energy are generated and 16 other hours when solar is not available. The 16 hour period is further broken into 4 hours of peak demand and 12 remaining hours of off-peak.

The total capacity available under various wind and solar power generating conditions is then compared against AEMO's forecast maximum demand plus the 20% reserve design criteria.

Primary Findings

Using AEMO's ISP and recharging of energy storages, *simple arithmetic* reveals the following:

1. Under **average renewable energy conditions** across the grid (power outputs vs. maximum power – the capacity factor – 25% for solar and wind in daytime, 20% wind at other times), daytime power meets the reliability criteria while during the remaining 16 hours the grid fails to deliver sufficient power to be reliable. For much of the 16 hours in 2030, 2040 and 2050, the deficit in power falls below minus 20% meaning ***frequent blackouts are inevitable***.

2. When **reduced wind and sun** occurs across the NEM (drought conditions with capacity factors of 10% solar and wind in daytime and 7% wind at other times), catastrophic deficits occur almost continuously – often below minus 20% meaning ***major grid collapse***, despite all dispatchable sources, gas and hydro, running continuously at 100% capacity.

3. When a **surplus of wind and sun** occurs across the NEM (capacity factors of 40% solar and wind in daytime and 35% wind at night), the daytime grid capacity is in surplus by huge margins. The result will be a ***collapse of spot power prices and large amounts of unsold power*** even when all dispatchable power is shut down. This will cause **substantial economic losses to both**

renewable energy and baseload generators. **Yet the grid is still unable to get through the 16 hour non-solar period without *significant deficits thus risking frequent blackouts***.

These dire results are a direct result of attempting to design an electrical grid with a vast majority of intermittent, highly variable, weather-dependent wind and solar generation with completely inadequate means for firming from dispatchable baseload power and energy storage systems. ***This analysis is based on unlimited 100% interconnector capabilities and AEMO's ISP data***.

No responsible authority would proceed with such a non-viable plan. Furthermore, the implications for the economy and for national security by relying on China, which dominates the market for wind and solar equipment and materials, are extremely negative. See Attachment 1 for the tables and details regarding the power budget analysis for the three conditions.

Some answers to frequently asked questions

1. **Why is the reliability number so high?** Public utilities such as water, power and telecommunications have long used this level of reliability as the criteria for delivering critical public services. 99.998% means service must not fail for more than 10 minutes per year! Partial failures may affect local areas for longer but over the year, total system shortfall must be less than 10 minutes of grid system output. Yes, the reliability requirement is very strict – this is what consumers demand.
2. **Why is a 20% reserve margin necessary for reliability?** This is a grid design criteria to guard against power generation and transmission facilities being out of action for periodic maintenance and for repairs due to equipment failures. The NEM has always met or exceeded this criteria but the recent experience in June shows that when multiple unexpected facility repairs are needed *and solar and wind generation is at a low ebb*, the grid is at risk of blackouts. Europe has experienced months-long periods of below average solar and wind conditions. AEMO's public data shows the same thing with days-long periods of extremely low VRE.
3. **Why is solar only available for 8 hours?** Solar panels are ideally mounted to face north, where the sun is highest in the sky at noon, to produce maximum power. Most are firmly mounted for maximum strength against winds and lowest cost. In early morning, the easterly sun is rising at a low angle above the horizon, providing little or no illumination of the panels. The same situation exists when the sun sets in the west. The effective period during which solar power is generated is about 4 hours on each side of noontime although seasonal variation occurs. Clouds also cause significant variation throughout the day and large weather systems can affect almost the entire NEM at the same time.
4. **Surely wind and solar will produce more power during the 16 hour period somewhere in the grid?** This is a major assumption of the ISP. However, the entire NEM grid experiences night at about the same time – every day. Hence total NEM solar generation goes to zero. Yet the AEMO grid design is for solar generation to be two thirds of all renewable power! Wind generated power varies at all times of the day and night. When atmospheric pressure gradients are low, wind decreases and at night it often tends to fall close to zero in the absence of solar-induced thermal activity.
5. **Isn't a surplus of wind and solar power during daytime a good thing**? If it is captured and stored for use in the non-solar 16 hour period it would be helpful but the cost of energy storage is far beyond economical. However, wind and solar is not in surplus every daytime – AEMO

records data on all of its power generation outputs every few minutes of every day. The data shows that wind and solar generation frequently falls to almost zero over large areas sometimes for days, for example NSW and Victoria, which together account for 60% of NEM demand. In this situation, all other regions not only must have high capacity interconnectors, they must also massively overbuild wind and solar generators beyond their own needs in order to serve other regions. Over-capacity means a very low return on investment for wind and solar farms.

6. **Why doesn't AEMO's grid design use more energy storage?** AEMO's design has probably avoided sufficient energy storage to meet reliability goals due to its enormous expense. To match Snowy 2.0's 7 day storage capacity, battery storage to back up the grid in 2050 (in excess of Snowy 2.0 and dispatchable power) would require at least 7980 GWh instead of the 319 GWh in the ISP. Cost estimates for this scale of battery back-up would be in the $5-7 trillion range, made worse by the rapidly rising cost of lithium, cobalt and other battery materials - clearly an unaffordable cost which recurs every 10 years. Instead, the ISP focuses on interconnectors as the solution. However, interconnectors produce no additional power and the ISP design is clearly short of power generation. More wind and solar generation, as has been publicly advocated by many, does not add significant power at night when wind and solar conditions are close to zero.
7. **Do interconnectors lose some of the power being transmitted?** Yes, the longer the distance of transmission, the greater the losses due to resistance in the wires. Each interconnector will have its own characteristics but losses can be as much as 8-15%. Our power budget analysis optimistically makes no allowance for interconnector losses. Transmission losses of 0-3% in the power budget are for local distribution. Solar and wind farms in remote Renewable Energy Zones have higher losses than local baseload generators.
8. **Why doesn't AEMO's plan use nuclear energy to firm up renewables?** This idea, which has been suggested by several prominent people, is rejected by climate activists and the renewables industry alike. Activists oppose all nuclear power on safety grounds but the renewable energy industry rejects it because it would be far more sensible and less expensive to run the "zero-emission" nuclear power plants 24/7 and entirely eliminate the massive costs of wind and solar farms, energy storage systems, interconnectors and voltage stabilization facilities. Nuclear power is expensive in terms of traditional large-scale custom-designed plants. Small modular reactors for nuclear power plants are under active development in many countries and offer the promise of high safety, production line cost efficiencies with standard designs, flexibility in siting and expandability to meet changing requirements. By 2030 SMRs will be available and costs will probably be well known.
9. **What happens when more people buy EVs and want to charge them up at night**? The AEMO forecast for future electricity demand is partly based on increasing EV demand and recent studies have revealed that 95% of EV owners wish to recharge overnight. The analysis shows the non-daytime period of 16 hours when solar is not available is the period in which the planned grid is most likely to fail to meet demand. The prevailing reality that peak grid demand occurs in early evening and early morning will likely be replaced by peak demand lasting through most of the night.

A closer look at AEMO's 2022 ISP

1. Over the period 2030 to 2050, coal is eliminated, gas is reduced by 22% and hydro remains constant (no more dams). Therefore, *reliable baseload generation decreases by 41%.*

2. Snowy 2.0 provides a relatively low 2.1 GW of power compared to total design requirements of 50-66 GW in total. Its 7 day storage capacity will be useful over extended periods of wind and solar drought but many power system engineers think energy storage should be sized for at least twice that. To reliably firm up renewables in AEMO's grid design would require the equivalent of 20-30 Snowy 2.0 pumped hydro schemes, costing hundreds of billions of dollars. *Does Australia have the sites and environmental mandates to proceed with pumped hydro on this scale?*

3. Coordinated DER and Distributed DER are home storage batteries but only "coordinated" batteries are available to supply the grid directly. Distributed batteries are behind-the-meter and benefit the grid only by reducing possible grid demands from the particular residence. Strangely, the ISP forecasts 'coordinated' batteries to grow strongly by 800% while 'Distributed storages' stop growing completely by 2040 – *is this because regulations by 2040 will make "coordinated" home batteries mandatory?*

4. Home storage batteries cost about 5 times more per unit capacity than large utility batteries ($1500/KWh compared to about $300 per KWh) and provide 2-3 hours at maximum output. The total capital cost of the ISP's coordinated and distributed batteries is estimated at $135 billion and the lifetime of these batteries is about 10-12 years. By 2050, many homeowners will have bought two of them. Despite this high cost, AEMO's ISP is critically dependent on *consumers willingly paying for home batteries*, because they account for 70% more than utility storages in 2030 rising to 175% by 2050. *How realistic is this assumption?*

5. Distributed PV in the ISP is home solar panel installations. They grow by 85% from 2030 to 2050 when they will be nine times more than today's capacity. They will exceed one third of the total renewable energy capacity in the grid. That represents about 7-9 million homes and businesses. Without this assumed massive uptake in heavily-subsidized home solar, the ISP plan fails to generate even the clearly insufficient power in its plan. In the face of rapidly rising costs for polysilicon (much of it produced in China by Uighur slave labour) and other materials to manufacture solar panels, *will this assumption hold up or will residents be forced to install solar panels?*

6. "Coordinated" means that homes are connected to AEMO's control centre (or a network service provider) via the Internet. New technical standards adopted in 2021 require all new home installations to be internet-capable. This will allow AEMO, using artificial intelligence software, *to disconnect residential solar panels from supplying the grid during the day when massive surpluses threaten to destabilize grid voltage*.

   It also will enable AEMO, under the Demand Side Participation (DSP) scheme to turn off major home loads – heaters and air conditioners, hot water heaters and EV chargers when energy shortages exist – a frequent occurrence under this ISP plan. It will also allow AEMO to discharge a home battery, including an EV battery, into the grid to help compensate for power shortages. *How acceptable will DSP be for home owners or will it become mandatory?*

Conclusions

This assessment reveals that **AEMO's 2022 ISP is a non-viable approach** for powering Australia's future economy. Not only will its in-built unreliability cause **frequent and major energy shortages**, it will make Australia **completely dependent on China**, which dominates the market for wind and solar equipment and materials, for our most critical infrastructure.

Under plausible, wide-ranging conditions for solar and wind generation covering both lower and higher-than-average conditions, the ISP fails to deliver adequate power to consumers and for recharging storages over a 24 hour cycle *despite an assumption of 100% connectivity*. **Blackouts will be a frequent occurrence once coal power plants are closed**.

Current and proposed battery storages are for very short term smoothing of fluctuations in renewable energy outputs – they **are tiny compared to what is required to firm renewable energy** over periods of days and they would be enormously expensive. Snowy 2.0 storage capacity is 7 days but its power output is only 2 GW when peak and average grid demands easily exceed 30 GW.

Failure to meet even this simple analysis of top-level total power capacity versus forecast demands **makes this plan unsuitable for consideration as national policy**.

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Attachment 1 AEMO 2022 ISP Top-Level Power Budget and Demand Tables

The tables on the next three pages provide the 2022 ISP top-level NEM power budgets compared to the design criteria for reliability, which requires maximum grid output to be greater than the maximum forecast demand plus a 20% reserve to account for outages due to maintenance and repairs.

These tables assume that the grid has 100% interconnection. The explanation notes for various items in the tables is as follows:

Notes

1. Source power outputs from 2022 ISP Figure 1 for 2029-30, 2039-40 & 2049-50
2. Storage capacities from2022 ISP Figure 23
3. AEMO Maximum Power Demand Forecast
4. Transmission losses are low for regional power supplies but higher for remote Renewable Energy Zones; losses for use of interconnectors are not included.
5. Distributed DER Storage (residential systems behind the meter) is not available to the grid but potentially reduce demands from their own installation.
6. Recharge efficiency accounts for transmission of power to storage sites, converting electricity to and then back from an alternative form.
7. It is assumed that all interconnector projects are implemented allowing all power generated anywhere to be delivered anywhere.
8. The 20% Reserve requirement guards the grid against transmission line failures and both scheduled and non-scheduled facility repairs and maintenance.
9. The power budget is for a 24 hour cycle broken into 8 hrs when solar is available and 16 hrs comprising 4 hours of peak demand and 12 hours of off-peak.
10. The power delivered to the grid is subject to a capacity factor - the percentage of maximum capacity that is dispatchable (baseload and storage) or available (wind/solar).
11. The capacity factor of baseload is adjusted downwards if a surplus of supply exists.
12. Preference is given to stored renewable energy over baseload.
13. The Energy Start and End lines record the stored energy levels before and after energy is delivered to the grid remaining in storage
14. Stored energy is allocated first to the 4 hour peak period; the remainder spread out over the 12 hour period.
15. The capacity factors for variable and intermittent renewable energy can be adjusted to reflect average grid conditions for wind and solar generation.
16. 25% is a nominal average daily capacity factor for wind and solar; daily solar output is focused to 8 hrs per day at 3 x the daily rate, average wind falls slightly at night.
17. Recharge power is calculated to restore full storage levels within the 8 hour window for solar energy generation.
18. A deficit exceeding -20% indicates blackouts are a certainty; blackouts may occur at any point of deficit if some generation facilities or transmission lines are inoperative.
19. A surplus indicates unsold energy; thus reducing the profitability of energy generators.

AEMO Forecast Maximum Demand Data

https://forecasting.aemo.com.au/Electricity/MaximumDemand/Operational

Step Change Scenario

Maximum Summer Demand	**Operational (Sent Out)**		
	2030	**2040**	**2050**
Region	**GW**	**GW**	**GW**
NSW	14.6	16.9	18.9
VIC	10.5	12.4	14.2
QLD	11.3	13.1	15.0
SA	3.5	4.1	4.8
TAS	1.5	1.5	1.6
Total Max Op sent out	**41.3**	**47.9**	**54.5**

Table 1 Average Wind and Solar Conditions

AEMO 2022 ISP Top-Level Power Budget

Step Change Scenario with Complete Interconnection [7]

Renewable Energy: Average Conditions

Daily Capacity Factor: Solar 25%

Wind 25% Daytime; 20% Night

AEMO Sources of Power

							Maximum Grid Power Inputs over 24 Hours Period - GW								
						Period [9]	2030			2040			2050		
						hrs	16		8	16		8	16		8
							Peak [14]	Remainder	Daytime	Peak [14]	Remainder	Daytime	Peak [14]	Remainder	Daytime
						hrs	4	12	8	4	12	8	4	12	8
Maximum Dispatchable Power [1]							**Operating Capacity Factor CF % [10, 11]**								
		2030	**2040**	**2050**	**Transmission**		**100%**	**100%**	**55%**	**100%**	**100%**	**65%**	**45%**	**100%**	**0%**
Dispatchable Sources		GW	GW	GW	**Losses [4]**		**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Coal		9.0	0.9	0.0	1.0%		8.9	8.9	4.9	0.8	0.8	0.5	0.0	0.0	0.0
Gas		12.3	9.1	9.6	1.0%		12.2	12.2	6.7	9.0	9.0	5.8	4.3	9.5	0.0
Hydro		7.2	7.1	7.1	1.0%		7.1	7.1	3.9	7.1	7.1	4.6	3.1	7.0	0.0
Subtotal Dispatchable		**28.6**	**17.0**	**16.7**			**28.3**	**28.3**	**15.6**	**16.9**	**16.9**	**11.0**	**7.4**	**16.5**	**0.0**
Maximum Storage Power Output and Energy Capacity [1]					**Transmission**		**Maximum Available Power for Non-Daytime Periods [12]**								
Dispatchable Storage [2]		**2030**	**2040**	**2050**	**Losses [4]**		**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Snowy 2.0 Power	GW	2.1	2.1	2.1	3.0%		2.0	2.0		2.0	2.0		2.0	2.0	
Energy Start [13]	GWh	349	349	349											
End Peak Period	GWh	341	341	341											
End Remainder	GWh	316	316	316											
Utility Storage Power	GW	3.9	10.8	13.7	3.0%		3.7	1.3		10.5	8.1		13.3	10.3	
Energy Start [13]	GWh	31	144	182											
End Peak Period	GWh	16	101	127											
End Remainder	GWh	0	0	0											
DER Coordinated Power	GW	3.8	17.2	30.6	1.0%		2.0	0.0		11.6	0.0		26.7	0.0	
Energy Start [13]	GWh	8	47	108											
End Peak Period	GWh	0	0	0											
End Remainder	GWh	0	0	0											
(Behind the Meter) Impact on Grid [5]					Effectiveness										
Distributed DER Power	GW	5.5	14.6	14.4	50.0%		1.8	0.0		3.8	0.0		3.6	0.0	
Energy Start [13]	GWh	14	30	29											
End Peak Period	GWh	0	0	0											
End Remainder	GWh	0	0	0											
Subtotal Storage Power GW		**9.8**	**30.1**	**46.4**			**9.5**	**3.3**		**27.9**	**10.2**		**45.7**	**12.3**	
Total Dispatch. Power	**GW**	**38.3**	**47.1**	**63.1**			**37.8**	**31.5**	**15.6**	**44.7**	**27.0**	**11.0**	**53.1**	**28.8**	**0.0**
						8E+06									
Variable/Intermittent Renewables Maximum Power [1]					**Transmission**		**Daily Capacity Factor % and Available Power GW [15, 16]**								
VRE Sources					**Losses [4]**				**25%**			**25%**			**25%**
Utility Solar	GW	13.6	34.7	69.6	3%	GW			9.9			25.2			50.6
									25%			**25%**			**25%**
Distributed PV	GW	37.2	55.0	68.6	0%	GW			27.9			41.2			51.4
							20%	**20%**	**25%**	**20%**	**20%**	**25%**	**20%**	**20%**	**25%**
Wind	GW	36.5	49.5	69.7	3%	GW	7.1	7.1	8.9	9.6	9.6	12.0	13.5	13.5	16.9
Total VRE GW		**87.3**	**139.1**	**207.9**			**7.1**	**7.1**	**46.7**	**9.6**	**9.6**	**78.5**	**13.5**	**13.5**	**119.0**
Total Supply Capacity - Dispatchable plus VRE GW						GW	**44.9**	**38.6**	**62.2**	**54.3**	**36.6**	**89.4**	**66.6**	**42.3**	**119.0**
Required Recharge Energy					**Recharge**		**Required Recharge Power GW [17]**								
Storage Recharge		**Required Energy GWh**			**Efficiency [6]**				**GW**			**GW**			**GW**
Snowy 2.0	GWh	44.2	44.2	44.2	75%				5.5			5.5			5.5
Utility Storage	GWh	36.5	169.4	214.1	85%				4.6			21.2			26.8
DER Coordinated	GWh	9.4	55.3	127.1	85%				1.2			6.9			15.9
Total Required Recharge Power GW									**11.3**			**33.6**			**48.2**
Total Available Customer Grid Power GW							**44.9**	**38.6**	**50.9**	**54.3**	**36.6**	**55.8**	**66.6**	**42.3**	**70.8**
Grid Power Demand and Reliability Reserve															
AEMO Maximum Power Demand Forecast GW [3]							41.3	41.3	41.3	47.9	47.9	47.9	54.5	54.5	54.5
20% Reliability Reserve GW [8]							8.3	8.3	8.3	9.6	9.6	9.6	10.9	10.9	10.9
Total Grid Power Requirement							**49.6**	**49.6**	**49.6**	**57.5**	**57.5**	**57.5**	**65.5**	**65.5**	**65.5**
Surplus [19]/Deficit [18] (Avail. Power - Grid Power Demand + Reserve) GW							-4.8	-11.0	1.3	-3.2	-20.9	-1.7	1.2	-23.1	5.4
							-9.6%	-22.1%	2.7%	-5.5%	-36.4%	-3.0%	1.8%	-35.3%	8.2%

Table 2 Below Average Conditions

AEMO 2022 ISP Top-Level Power Budget

Step Change Scenario with Complete Interconnection[7]

Renewable Energy: Moderate Drought Conditions

Daily Capacity Factor: Solar 10%

Wind 10% Daytime; 7% Night

AEMO 2022 ISP Sources of Power

							Maximum Grid Power Inputs over 24 Hours Period - GW								
						Period[9]	2030			2040			2050		
						hrs	16		8	16		8	16		8
							Peak[14]	Remainder	Daytime	Peak[14]	Remainder	Daytime	Peak[14]	Remainder	Daytime
						hrs	4	12	8	4	12	8	4	12	8
Maximum Dispatchable Power[1]							**Operating Capacity Factor CF %**[10, 11]								
		2030	**2040**	**2050**	**Transmission**		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Dispatchable Sources		GW	GW	GW	**Losses**[4]		**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Coal		9.0	0.9	0.0	1.0%		8.9	8.9	8.9	0.8	0.8	0.8	0.0	0.0	0.0
Gas		12.3	9.1	9.6	1.0%		12.2	12.2	12.2	9.0	9.0	9.0	9.5	9.5	9.5
Hydro		7.2	7.1	7.1	1.0%		7.1	7.1	7.1	7.1	7.1	7.1	7.0	7.0	7.0
Subtotal Dispatchable		**28.6**	**17.0**	**16.7**			**28.3**	**28.3**	**28.3**	**16.9**	**16.9**	**16.9**	**16.5**	**16.5**	**16.5**
Maximum Storage Power Output and Energy Capacity[1]					**Transmission**		**Maximum Available Power for Non-Daytime Periods**[12]								
Dispatchable Storage[2]		**2030**	**2040**	**2050**	**Losses**[4]		**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Snowy 2.0 Power	GW	2.1	2.1	2.1	3.0%		2.0	2.0		2.0	2.0		2.0	2.0	
Energy Start[13]	GWh	349	349	349											
End Peak Period	GWh	341	341	341											
End Remainder	GWh	316	316	316											
Utility Storage Power	GW	3.9	10.8	13.7	3.0%		3.7	1.3		10.5	8.1		13.3	10.3	
Energy Start[13]	GWh	31	144	182											
End Peak Period	GWh	16	101	127											
End Remainder	GWh	0	0	0											
DER Coordinated Power	GW	3.8	17.2	30.6	1.0%		2.0	0.0		11.6	0.0		26.7	0.0	
Energy Start[13]	GWh	8	47	108											
End Peak Period	GWh	0	0	0											
End Remainder	GWh	0	0	0											
(Behind the Meter) Impact on Grid[5]					Effectiveness										
Distributed DER Power	GW	5.5	14.6	14.4	50.0%		1.8	0.0		3.8	0.0		3.6	0.0	
Energy Start[13]	GWh	14	30	29											
End Peak Period	GWh	0	0	0											
End Remainder	GWh	0	0	0											
Subtotal Storage Power GW		**9.8**	**30.1**	**46.4**			**9.5**	**3.3**		**27.9**	**10.2**		**45.7**	**12.3**	
Total Dispatch. Power	**GW**	**38.3**	**47.1**	**63.1**			**37.8**	**31.5**	**28.3**	**44.7**	**27.0**	**16.9**	**62.2**	**28.8**	**16.5**
Variable/Intermittent Renewables Maximum Power[1]					**Transmission**		**Daily Capacity Factor % and Available Power GW**[15, 16]								
VRE Sources					**Losses**[4]				10%			10%			10%
Utility Solar	GW	13.6	34.7	69.6	3%	GW			3.9			10.1			20.3
									10%			10%			10%
Distributed PV	GW	37.2	55.0	68.6	0%	GW			11.2			16.5			20.6
							7%	7%	10%	7%	7%	10%	7%	7%	10%
Wind	GW	36.5	49.5	69.7	3%	GW	2.5	2.5	3.5	3.4	3.4	4.8	4.7	4.7	6.8
Total VRE GW		**87.3**	**139.1**	**207.9**			**2.5**	**2.5**	**18.7**	**3.4**	**3.4**	**31.4**	**4.7**	**4.7**	**47.6**
Total Supply Capacity - Dispatchable plus VRE GW						GW	**40.3**	**34.0**	**46.9**	**48.1**	**30.4**	**48.2**	**66.9**	**33.6**	**64.1**
Required Recharge Energy					**Recharge**		**Required Recharge Power GW**[17]								
Storage Recharge		**Required Energy GWh**			**Efficiency**[6]				**GW**			**GW**			**GW**
Snowy 2.0	GWh	44.2	44.2	44.2	75%				5.5			5.5			5.5
Utility Storage	GWh	36.5	169.4	214.1	85%				4.6			21.2			26.8
DER Coordinated	GWh	9.4	55.3	127.1	85%				1.2			6.9			15.9
Total Required Recharge Power GW									**11.3**			**33.6**			**48.2**
Total Available Customer Grid Power GW							**40.3**	**34.0**	**35.7**	**48.1**	**30.4**	**14.6**	**66.9**	**33.6**	**16.0**
Grid Power Demand and Reliability Reserve															
AEMO Maximum Power Demand Forecast GW[3]							41.3	41.3	41.3	47.9	47.9	47.9	54.5	54.5	54.5
20% Reliability Reserve GW[8]							8.3	8.3	8.3	9.6	9.6	9.6	10.9	10.9	10.9
Total Grid Power Requirement							**49.6**	**49.6**	**49.6**	**57.5**	**57.5**	**57.5**	**65.5**	**65.5**	**65.5**
Surplus[19]/Deficit[18] (Avail. Power - Grid Power Demand + Reserve) GW							-9.4	-15.6	-13.9	-9.4	-27.2	-42.9	1.5	-31.9	-49.5
							-18.9%	-31.4%	-28.1%	-16.4%	-47.2%	-74.6%	2.2%	-48.7%	-75.6%

Table 3 Above Average Wind and Solar Conditions

AEMO 2022 ISP Top-Level Power Budget

Step Change Scenario with Complete Interconnection [7]

Renewable Energy: Surplus Conditions

Daily Capacity Factor: Solar 40%

Wind 40% Daytime; 35% Night

AEMO 2022 ISP Sources of Power

Maximum Grid Power Inputs over 24 Hours Period - GW

Period [9]	2030			2040			2050		
hrs	16		8	16		8	16		8
	Peak [14]	Remainder	Daytime	Peak [14]	Remainder	Daytime	Peak [14]	Remainder	Daytime
hrs	4	12	8	4	12	8	4	12	8

Maximum Dispatchable Power [1]	2030	2040	2050	Transmission	Operating Capacity Factor CF % [10, 11]								
					100%	100%	0%	100%	100%	0%	0%	100%	0%
Dispatchable Sources	GW	GW	GW	Losses [4]	GW	GW	GW	GW	GW	GW	GW	GW	GW
Coal	9.0	0.9	0.0	1.0%	8.9	8.9	0.0	0.8	0.8	0.0	0.0	0.0	0.0
Gas	12.3	9.1	9.6	1.0%	12.2	12.2	0.0	9.0	9.0	0.0	0.0	9.5	0.0
Hydro	7.2	7.1	7.1	1.0%	7.1	7.1	0.0	7.1	7.1	0.0	0.0	7.0	0.0
Subtotal Dispatchable	**28.6**	**17.0**	**16.7**		**28.3**	**28.3**	**0.0**	**16.9**	**16.9**	**0.0**	**0.0**	**16.5**	**0.0**

Maximum Storage Power Output and Energy Capacity [1]					Transmission	Maximum Available Power for Non-Daytime Periods [12]								
Dispatchable Storage [2]		2030	2040	2050	Losses [4]	GW	GW	GW	GW	GW	GW	GW	GW	GW
Snowy 2.0 Power	GW	2.1	2.1	2.1	3.0%	2.0	2.0		2.0	2.0		2.0	2.0	
Energy Start [13]	GWh	349	349	349										
End Peak Period	GWh	341	341	341										
End Remainder	GWh	316	316	316										
Utility Storage Power	GW	3.9	10.8	13.7	3.0%	3.7	1.3		10.5	8.1		13.3	10.3	
Energy Start [13]	GWh	31	144	182										
End Peak Period	GWh	16	101	127										
End Remainder	GWh	0	0	0										
DER Coordinated Power	GW	3.8	17.2	30.6	1.0%	2.0	0.0		11.6	0.0		26.7	0.0	
Energy Start [13]	GWh	8	47	108										
End Peak Period	GWh	0	0	0										
End Remainder	GWh	0	0	0										
(Behind the Meter) Impact on Grid [5]					Effectiveness									
Distributed DER Power	GW	5.5	14.6	14.4	50.0%	1.8	0.0		3.8	0.0		3.6	0.0	
Energy Start [13]	GWh	14	30	29										
End Peak Period	GWh	0	0	0										
End Remainder	GWh	0	0	0										
Subtotal Storage Power GW		**9.8**	**30.1**	**46.4**		**9.5**	**3.3**		**27.9**	**10.2**		**45.7**	**12.3**	
Total Dispatch. Power	**GW**	**38.3**	**47.1**	**63.1**		**37.8**	**31.5**	**0.0**	**44.7**	**27.0**	**0.0**	**45.7**	**28.8**	**0.0**

Variable/Intermittent Renewables Maximum Power [1]					Transmission		Daily Capacity Factor % and Available Power GW [15, 16]								
VRE Sources					Losses [4]				40%			40%			40%
Utility Solar	GW	13.6	34.7	69.6	3%	GW			15.8			40.4			81.0
									40%			40%			40%
Distributed PV	GW	37.2	55.0	68.6	0%	GW			44.7			66.0			82.3
							35%	35%	40%	35%	35%	40%	35%	35%	40%
Wind	GW	36.5	49.5	69.7	3%	GW	12.4	12.4	14.2	16.8	16.8	19.2	23.7	23.7	27.0
Total VRE	**GW**	**87.3**	**139.1**	**207.9**			**12.4**	**12.4**	**74.6**	**16.8**	**16.8**	**125.5**	**23.7**	**23.7**	**190.4**
Total Supply Capacity - Dispatchable plus VRE	**GW**					GW	**50.2**	**44.0**	**74.6**	**61.5**	**43.8**	**125.5**	**69.3**	**52.5**	**190.4**

Required Recharge Energy					Recharge	Required Recharge Power GW [17]								
Storage Recharge		Required Energy GWh			Efficiency [6]			GW			GW			GW
Snowy 2.0	GWh	44.2	44.2	44.2	75%			5.5			5.5			5.5
Utility Storage	GWh	36.5	169.4	214.1	85%			4.6			21.2			26.8
DER Coordinated	GWh	9.4	55.3	127.1	85%			1.2			6.9			15.9
Total Required Recharge Power GW								**11.3**			**33.6**			**48.2**

Total Available Customer Grid Power GW	**50.2**	**44.0**	**63.4**	**61.5**	**43.8**	**91.9**	**69.3**	**52.5**	**142.2**
Grid Power Demand and Reliability Reserve									
AEMO Maximum Power Demand Forecast GW [3]	41.3	41.3	41.3	47.9	47.9	47.9	54.5	54.5	54.5
20% Reliability Reserve GW [8]	8.3	8.3	8.3	9.6	9.6	9.6	10.9	10.9	10.9
Total Grid Power Requirement	**49.6**	**49.6**	**49.6**	**57.5**	**57.5**	**57.5**	**65.5**	**65.5**	**65.5**
Surplus [19]/Deficit [18] (Avail. Power - Grid Power Demand + Reserve) GW	**0.6**	**-5.7**	**13.8**	**4.0**	**-13.7**	**34.4**	**3.9**	**-13.0**	**76.7**
	1.1%	**-11.4%**	**27.7%**	**7.0%**	**-23.8%**	**59.8%**	**5.9%**	**-19.8%**	**117.2%**