Submission to Inputs, Assumptions and Scenarios Consultation

By Independent Engineers, Scientists and Professionals, 13 August 2024

Introduction

The transition of the NEM to primarily wind and solar "renewables" is at a critical juncture.

Consumer prices for electricity are skyrocketing as more intermittent renewables are being forced into the grid without adequate, practical or economic means of "firming" being installed. Warnings by AEMO of "lack of reserve" are becoming more frequent.

There is widespread unrest in the community as realisation spreads concerning the huge impacts on environment and land use. In addition to the obvious problem of rapidly rising power rates, there is a growing concern over the capital costs of the transition and AEMO's (and the government's) apparent reluctance to provide full disclosure.

The Australian public is becoming anxious as political and media dialogue is increasingly expressing concern about how to secure future prosperity in an economy that is very likely to be facing both energy shortages and massive cost rises. Jobs and businesses are on the line.

Now is the time for serious re-examination, for AEMO to have the courage to speak truth to power.

The Imperative for Action

The ISP states that AEMO has taken the government's insertion of renewable energy targets in the National Electricity Rules as absolute constraints on what technology options it can consider in planning the future of the NEM. This amounts to replacing qualified power systems engineers with politicians and bureaucrats who have kowtowed to pressure from international and domestic pressure groups.

This must stop. AEMO, AER, AEMC and the government must now accept that the current plan is not the lowest cost nor the most reliable – that a new approach considering all technological options is now imperative.

Updated Assessments since Final release of the 2024 ISP

We have made extensive (unfunded) efforts as concerned citizens to make submissions to AEMO on the 2022 and 2024 draft ISP consultations. Our advice, supported by many others, regarding reliability and costs are now flashpoints that cannot be dodged or papered over.

Recently, we prepared two short papers on reliability and whole-of-system cost estimation. These are attached as Appendices to this input. They make the case that:

1. The ISP grid design will not deliver reliable power.
2. Wind and solar are not the lowest cost of electricity generation – they are most probably the most expensive on a whole-of-system basis.

We have found that our conclusions are confirmed by many highly qualified people.

Specific Recommendations

1. AEMO must rectify the lack of proper high reliability system design methodology, which is apparent in the ISP, by clearly defining in the ISP worst-case *design* scenarios and an adequate dispatchable reserve margin to guard against facility outages rather than just shortfalls in wind and solar outputs.

2. AEMO must realise there is a difference between design and analysis. Simulations are analytical tools, if used properly with accurate models and conditions, for assessing the consequences of grid designs based on conservative worst-case design requirements not average operating conditions.
3. Worst-case design must include the maximum demand, the minimum required dispatchable reserve margin, the minimum period over which back-up energy storages must be able to deliver a specified amount of back-up power and the maximum allowable time to recharge the storages in readiness for backing up additional wind and solar drought conditions.
4. AEMO must state and provide evidence that the daily demand profile, particularly during winter and summer months when demand is greatest, will never exceed a specified worst-case design profile overnight – not a typical profile from past history. This must include the predicted load due to recharging of storages. The use of a daily load profile, which has its origin in past grid operations well before anticipated demand for overnight EV charging, in a 2040 simulation simply has no credibility.
5. AEMO must provide a clear definition of dispatchable power as a function of duration of use of storages.
6. AEMO must provide open and transparent power budgets demonstrating reliability under worst-case conditions through both a 24-hour cycle and multiple days of "renewables drought". Simulations are not a substitute.
7. AEMO must provide results of any simulations with clearly stated worst-case conditions that demonstrate an intact reserve margin. Simulations are powerful analysis tools if run with proper inputs and assumptions but they do not replace power systems engineering methods for creating design concepts clearly relating to defined grid design requirements.
8. AEMO must provide open and transparent capital cost factors for generation and storage facilities in the ISP. If Gencost is the source, it must be openly stated.
9. AEMO must provide a comprehensive total capital cost estimate, including network costs, to the economy as a function of time out to year 2050 to provide an estimate that is understandable to the general public.
10. AEMO must provide the discount factor used and the result of any present value capital cost estimate, which is of interest primarily by financial experts.
11. AEMO must take into account in cost estimation, the replacement of lifetime-expired assets before 2050 in addition to expanded installations. For example, batteries installed before 2030 will probably need replacement twice over by 2050.
12. AEMO must clearly state the methodology used in cost estimation including data on the number of homes assumed to have solar power installations and batteries and how many EVs will be enrolled in VPP schemes to provide battery discharges at night. The outlook for social licence on EV support looks very doubtful.
13. AEMO must address the issue of whole-of-life whole-of-system emission estimation in future ISPs. Emissions are virtually the entire justification driving politicians to override qualified power systems engineers in mandating the transition to a renewables-heavy NEM. This data must therefore be publicly available for comparison with alternative proposals for future NEM designs.
14. AEMO must provide land use and maritime use estimates in future ISPs. The environmental and economic impacts of land and maritime use must be clearly stated.
15. AEMO must provide analysis and estimates of the probability of all assumptions in the ISP concerning social licence being obtained for CER, environmental impacts and DSP and EV participation.
16. AEMO must also note all risks to its plans including potential non-availability of solar panels, wind turbines and batteries from assumed supply chain sources.

Independent Engineers, Scientists and Professionals

This report has been prepared and supported by independent engineers, scientists and professionals who have many decades of relevant experience and requisite qualifications without any monetary conditions, employment or conflicting interests.

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Appendix 1

The AEMO 2024 ISP Will Not Deliver Reliable Power

AEMO's numbers just do not add up

A Report by Independent Engineers, Scientists and Professionals 11 August 2024

Introduction

Our 9 February 2024 submission to AEMO and CSIRO concerning the *draft* ISP identified serious potential reliability problems resulting from AEMO's electricity grid design. Our inputs were largely ignored.

The final version of the ISP, released on 26 June 2024, essentially reveals the same deeply flawed model of the NEM electricity grid.

Failure to Address Clearly Stated Reliability Issues

AEMO's ISP suffers from severe deficiencies in capacities of both energy storage and baseload back up power, starting in the next few years and lasting throughout the entire period to 2050. It shows no evidence of rigorous system design engineering required for high reliability systems based on worst case conditions and healthy reserve margins.

By 2030, the dispatchable reserve margin falls from historic levels in excess of plus 20% to **minus** 19% and in subsequent years it is substantially worse. It cannot deliver adequate power when NEM-wide grid demand is maximum, when overnight solar is zero and wind output is close to nothing.

The negative reserve margin provides no allowance for facility outages for maintenance and repairs and leads to blackouts when demand peaks. The grid design also suffers from insufficient power capacity to quickly recharge the energy storages to prepare for the next set of worst-case conditions.

AEMO's own historical NEM data demonstrates periods of very low renewable energy production lasting 3 or more consecutive days and dramatic falls occur multiple times in a month. Periods of several months, when wind and solar outputs are well below long term averages, are evident in both Australian and overseas data. May 2024 witnessed several major droughts.

The energy storage capacity in the ISP is too low by at least a factor of ten. Adding more batteries and additional renewable generation to recharge them is completely unaffordable.

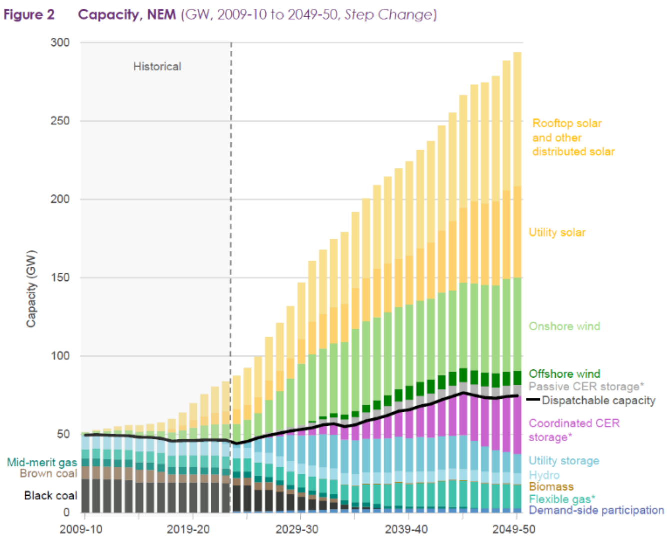
Deceptive Data Concerning Dispatchable Power

Figure 2 in the ISP is a graphical chart showing power from various generation sources and storages by year until 2050 (see next page).

It shows impressive growth to 2050 but almost all growth is in renewables which have very low capacity factors (25-32%). Similarly, energy storage outputs show remarkable growth but most of these provide power for just a few hours. Much of it is from coordinated home resources which are uncertain and cost almost twice that for utility scale batteries. The dispatchable black line climbs to above 75 GW by 2050 but in truth, it is meaningless because much of it cannot be used to back up the grid when solar and wind power are largely absent for periods of 16 hours overnight, multiple days and significantly below average for periods of months.

This deceptive portrayal is merely a summation of maximum power outputs from all sources. A truthful depiction would, as a minimum include warnings to the effect that renewables provide less than one third of maximum power on average and not all dispatchable power provides practical levels for grid back up.

Figure 2.4 in our submission (see below) provided an alternative version of this chart showing the true dispatchable power over various periods based on ISP data for energy storages (ISP Figure 20). By 2040, the dispatchable power of AEMO's ISP design falls to just 30 GW for backup durations of one week but at the same time it indicates that for 16 hours overnight, it is only 37 GW. However, a proper engineering design with a 20% dispatchable reserve margin will require over 62 GW by 2040.



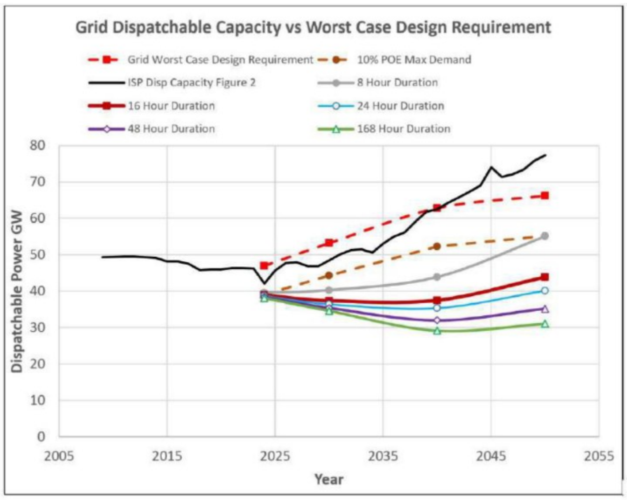


Figure 2.4 Dispatchable Power Capacity vs Grid Design as a Function of Duration

A Whole-of-System Power Budget Shows Failure of Reliable Power at Night

A whole-of-system power budget is fundamental to understanding the viability of the AEMO ISP and making a counterpoint to the CSIRO GenCost report, however, the ISP provides no system level power budget data. In fact, the ISP does not contain any data on maximum demand. Instead, it forecasts average annual energy production figures. This is no way to design a high reliability system.

Proper high reliability engineering design requires use of real worst-case conditions plus a margin for facility outages for maintenance and repairs. A whole-of-system power budget table (on the next page) is based entirely on AEMO's ISP data.

Our power budget uses maximum grid demand data from the August 2023 AEMO ESOO report because the ESOO update of March 2024 did not contain this data.

We show that by 2030, the dispatchable reserve margin falls to minus 19% on a single 16-hour overnight period when solar is zero and wind falls very close to zero. Any facility outages for maintenance or repairs will make this figure worse. There is simply not enough baseload power nor energy storage capacity.

To restore the dispatchable reserve margin to at least plus 20% would require an additional 17.4 GW of baseload or stored energy outputs in 2030, rising to 28.1 GW in 2040 and 2050.

In the event of multiple day wind and solar drought conditions, there is not sufficient surplus power during daytime to completely recharge expanded energy storages sufficient to handle another overnight period under worst case conditions.

Blackouts are inevitable. The AEMO ISP cannot deliver reliable power under worst case conditions. This is not a matter requiring fine tuning of the grid design. It is a massive failure.

2024 FINAL ISP Top-Down Whole-of-System Power Budgets

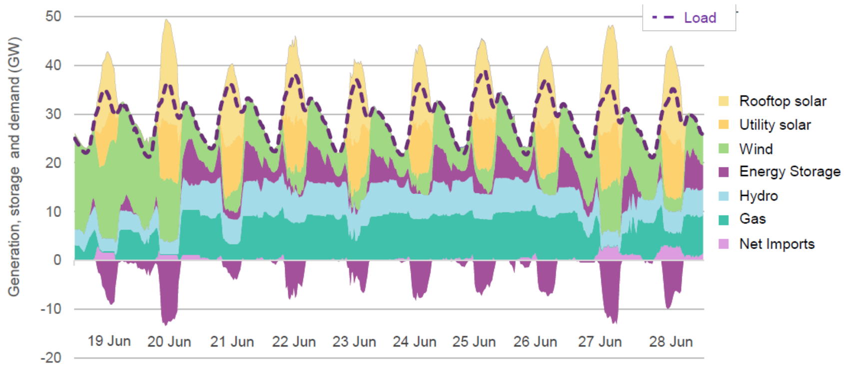
AEMO NEM Grid Design per 2024 FINAL ISP														
Worst Case & 20% Reserve Margin			**2024-25**			**2029-30**			**2039-40**			**2049-50**		
24 hr Top-level Whole-of-System Power Budget			**Capacity**	**Night**	**Daytime**	**Capacity**	**Night**	**Daytime**	**Capacity**	**Night**	**Daytime**	**Capacity**	**Night**	**Daytime**
Duration hours				16	8		16	8		16	8		16	8
NEM Power Demand				**GW**	**GW**		**GW**	**GW**		**GW**	**GW**		**GW**	**GW**
10% POE Max Demand (ESOO 2023)				39.1	39.1		44.3	44.3		52.3	52.3		55.2	55.2
Dispatchable Reserve Margin	20%			7.8	7.8		8.9	8.9		10.5	10.5		11.0	11.0
Total Power Design Requirement				**47.0**	**47.0**		**53.2**	**53.2**		**62.8**	**62.8**		**66.2**	**66.2**
Power Sources (Fig 2 2024 ISP)	**Capacity Factors**		**Capacity**	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**	
Baseload Power	**Night**	**Daytime**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Coal - Black & Brown	100%	100%	21.2	21.2	21.2	11.44	11.4	11.4	0	0.0	0.0	0.0	0.0	0.0
Gas - Mid Merit & Flex	100%	100%	12.54	12.5	12.5	11.62	11.6	11.6	15.89	15.9	15.9	15.0	15.0	15.0
Hydro	100%	100%	6.84	6.8	6.8	6.84	6.8	6.8	7.14	7.1	7.1	7.07	7.1	7.1
Biomass	100%	100%	0			0			0.45			0.45		
DSP	100%	100%	0.95			1.64			2.5			2.90		
Total Baseload Dispatchable			**40.6**	**40.6**	**40.6**	**29.9**	**29.9**	**29.9**	**23.0**	**23.0**	**23.0**	**22.1**	**22.1**	**22.1**
Energy Storage Fig 20 2024 ISP)			**GWh**			**GWh**			**GWh**			**GWh**		
Snowy 2.0 + Borumba			0.0			349.80			397.75			397.75		
Deep			6.27			6.27			42.10			77.81		
Medium, Shallow, Coord CER			12.27			55.27			102.30			170.42		
Total Storage Capacity			**18.5**			**411.3**			**542.2**			**646.0**		
			Capacity	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**	
Storage Max Power Capacity			**GW max**	**GW**	**GW**	**GW max**	**GW**	**GW**	**GW max**	**GW**	**GW**	**GW max**	**GW**	**GW**
Snowy 2.0 + Borumba			0.0	0.0	0.0	2.2	2.2	2.2	4.2	4.2	4.2	4.2	4.2	4.2
Deep (limited by max power output)			0.2	0.2	0.2	0.2	0.2	0.2	1.1	1.1	1.1	1.3	1.3	1.3
Medium, Shallow, Coord CER (avg output overnight)			3.9	0.8	0.0	14.0	3.5	0.0	31.5	6.4	0.0	44.7	10.7	0.0
Total Max Storage Power			**4.1**			**16.4**			**36.8**			**50.2**		
Avail. Storage Power Dispatchable				**1.0**	**0.2**		**5.9**	**2.4**		**11.7**	**5.3**		**16.2**	**5.5**
Total Dispatchable Power				**41.5**	**40.8**		**35.8**	**32.3**		**34.7**	**28.3**		**38.2**	**27.6**
Surplus/Deficit(-) wrt 10% POE Demand				**2.4**	**1.6**		**-8.5**	**-12.0**		**-17.6**	**-24.0**		**-17.0**	**-27.6**
Dispatchable Reserve Margin				6.2%	4.2%		-19.3%	-27.1%		-33.6%	-45.8%		-30.8%	-50.1%
VRE Renewables (Fig 2 2024 ISP)	**Capacity Factors**		**Capacity**	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**		**Capacity**	**Delivered**	
	Night	**Daytime**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**	**GW**
Wind: Onshore	0%	0%	13.0	0.0	0.0	39.26	0.0	0.0	51.87	0.0	0.0	59.53	0.0	0.0
Wind - Offshore	0%	0%	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	9.0	0.0	0.0
Solar Utility	0%	0%	9.5	0.0	0.0	15.58	0.0	0.0	31.17	0.0	0.0	58.26	0.0	0.0
Solar Distributed VPP	0%	0%	23.48	0.0	0.0	36.06	0.0	0.0	60.16	0.0	0.0	85.74	0.0	0.0
Non-dispatchable VRE			**46.0**	**0.0**	**0.0**	**90.9**	**0.0**	**0.0**	**152.2**	**0.0**	**0.0**	**212.5**	**0.0**	**0.0**
Total Dispatchable + VRE Power				**41.5**	**40.8**		**35.8**	**32.3**		**34.7**	**28.3**		**38.2**	**27.6**
Surplus/Deficit(-) wrt 10% POE Demand				**2.4**	**1.6**		**-8.5**	**-12.0**		**-17.6**	**-24.0**		**-17.0**	**-27.6**
	Efficiency				**GW**			**GW**			**GW**			**GW**
Req'd Daytime Recharge Power	**80%**				**2.4**			**14.6**			**29.2**			**40.4**
Avail. NEM Daytime Recharge					**1.4**			**-14.4**			**-29.3**			**-33.1**
Recharge Power Surplus/Deficit(-)					**-1.0**			**-29.0**			**-58.5**			**-73.5**

AEMO's Attempt to Demonstrate System Reliability is Misleading

In Section 6.5 "Reliability and security in a system dominated by renewables", the ISP acknowledges the challenge as renewables approach 100% of generation. But it claims: "*Consumers should be confident that the NEM's mix of technologies will keep electricity supply secure and reliable during normal operation, extreme peak demand and renewable droughts*."

In the ISP, Figure 24 (p72) attempts to illustrate operability through an eight-day renewable drought for the "NEM except Queensland". ISP Appendix 4 (Figure 15 p 26) reveals that this simulation test involved an "extended VRE drought event running from 21 June 2040 to 28 June 2040 (reflective of conditions observed historically in June 2019)."

Figure 24 Operability through eight-day renewable drought, NEM except Queensland



This one-off test looks impressive but is merely an illustration far short of what a proper statistical engineering analysis would require. A detailed examination of the data behind this test revealed the following:

1. It assumes imports of power from QLD yet represents a partial system.
2. It assumes maximum power continuously from all dispatchable resources. i.e. no facility outages.
3. It assumes not-so-extreme VRE drought conditions were for 6 days not 8 as indicated by the green wind data in the chart.
4. It assumes wind capacity factor was 10% in daytime; 13% overnight – not worst case.
5. It assumes solar capacity factor was 13-15% - not worst case.
6. Non-daytime grid demand in early evening was about 32 GW decreasing by 31% after to 22 GW; this profile is highly speculative in the face of increasing EV demand for overnight charging; no amount of social licence will be gained by draining EV batteries into the grid at night and forcing owners to recharge them during the day; worst case is a flat maximum demand.
7. The ISP admits that “reliability risk would be elevated, particularly if major generator or transmission outages occur” i.e. no facility outages were taken into account.

These are certainly NOT rigorous worst-case conditions. Instead of illustrating the reliability of the NEM grid design, this test indicates the extent to which the AEMO ISP misrepresents its viability. A close look at this chart shows no reserve margin at all – every night of the 8-day “drought” shows the very low load being exactly met by all dispatchable sources at 100% and 13% wind - no reserve margin at all unlike daytime when solar exceeds load. In fact, this fortuitous result looks somewhat contrived.

This highly dubious simulation test has more to do with marketing than proper system engineering.

Conclusions

Despite its impressive appearance, the ISP contains fundamental technical drawbacks. From an engineering perspective, the AEMO ISP is seriously flawed and fails to provide assurance that the NEM grid design has been developed in accordance with modern system engineering principles for high reliability systems.

We therefore conclude the AEMO ISP, which underpins the entire national economy, will not serve Australian consumers and businesses with reliable electrical power. It is clear this plan has been driven by changes to National Electricity Rules by non-technical politicians and bureaucrats to set artificial goals for renewables divorced from engineering realities.

It is critically important and urgent that an ongoing review process be implemented with advice and input by independent experts to oversee AEMO and CSIRO work on the future NEM.

It is beyond time for AEMO to state clearly its worst-case design criteria, worst-case demand and minimum dispatchable reserve margin capable of providing usable outputs for periods of many days not hours. AEMO must then provide proper systems engineering analysis showing grid performance under these conditions.

It is painfully obvious that the AEMO ISP is either deliberately misleading or fails due to incompetence. Neither is acceptable in leading a transition which will likely end in disaster for the entire economy. We have no knowledge of the qualifications of AEMO's staff but it seems plausible that AEMO's operational success over the years must be due to at least some highly qualified power systems engineers. The truth for this failure must be uncovered.

Independent Engineers, Scientists and Professionals

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Appendix 2

The Missing Whole-of-System Cost Model in the AEMO 2024 ISP

The Real Cost of the NEM Transition

A Report by Independent Engineers, Scientists and Professionals 31 July 2024

Summary

The government has not provided a true estimate of cost for AEMO's plan to transition the NEM to intermittent wind & solar, yet it claims adding reliable nuclear and gas power generation is too costly.

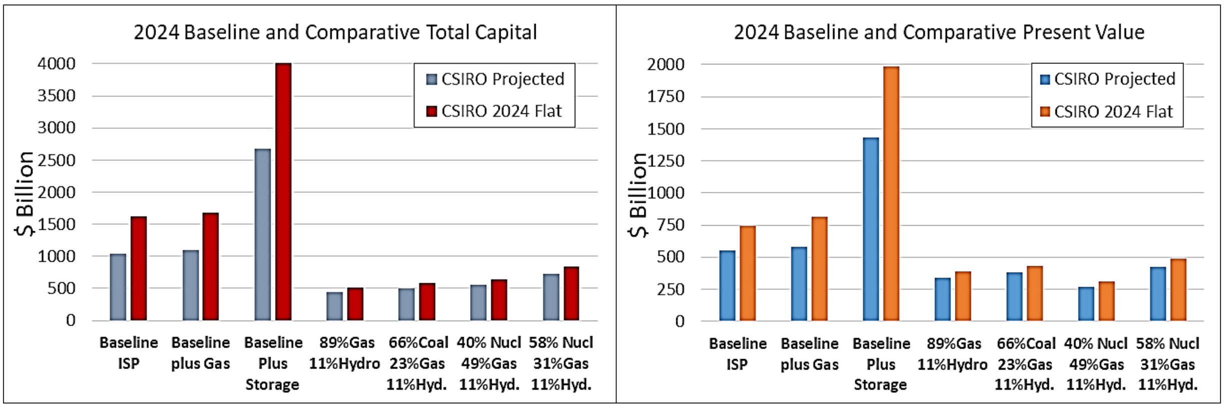
AEMO published its 2024 Integrated System Plan (ISP) in June. It contains only one paragraph[1] to indicate annualised capital costs as either $122 billion present value or $142 billion upfront present value, not including "commissioned, committed or anticipated projects, consumer energy resources, or distribution network upgrades". This unrealistic, poorly defined estimate needs much clarification.

The whole-of-system analysis in this report, draws on 2024 ISP capacities for generation and storages and CSIRO 2024 GenCost cost factors[2], and shows <u>total capital costs for the 2024 ISP over one trillion dollars for a system unable to deliver reliable power</u>[3]. This is about twice the capital costs of four alternative grid designs using gas, coal and nuclear. When fuel costs for gas and coal are considered, nuclear plus gas designs are likely to be the least costly of all options.

A More Comprehensive Capital Cost Analysis

The whole-of-system cost charts in Figure 1 below provide both total capital and present value for a more comprehensive model of the planned NEM grid transition, showing a present value more than four times higher than the 2024 ISP figures. Estimates include both CSIRO's somewhat optimistic declining future capital cost factors and its flat 2024 cost factors to reflect uncertainties in forecasting. The Baseline 2024 ISP estimates include all generation and storage costs including consumer energy resources, transmission lines, distribution network upgrades and other support costs to reflect the total costs to the economy.

Extending the Baseline ISP with additional gas or storage to overcome the major unreliability of the ISP's design incurs extra costs and makes clear that 'firmed renewables with batteries' is unaffordable.



[1] AEMO 2024 Integrated System Plan Page 74

[2] ISP Figures 2 and 20; GenCost Section 4.3;

[3] The 2024 AEMO ISP Will Not Deliver Reliable Power, Independent Engineers, Scientists and Professionals, 19 July 2024

Four alternative designs using gas, coal and nuclear provide comparisons. The results, based on AEMO and CSIRO data, show that the present transition plan is the most costly approach by a large margin.

Figure 1 AEMO 2024 ISP Baseline and Comparative Whole-of-System Capital Costs in 2024 dollars

Conclusions

1. Our analysis uses a proper high reliability systems engineering approach to assess a 24-hour cycle under worst-case conditions of maximum demand, wind and solar droughts and the need for a minimum 20% dispatchable reserve margin (DRM)[4] to guard against facility outages. A whole-of-system 'Baseline' power budget using 2024 ISP capacities shows the DRM at minus 19% by 2030 and falling much lower by 2040. Widespread and frequent blackouts are certain.
2. Adding battery storages and extra wind & solar to recharge them ('firmed renewables') to achieve 20% DRM overnight results in completely unaffordable total capital costs of several trillion dollars and provides storage for just one 16-hour overnight period. And it still leaves daytime DRM massively negative. Battery storage capacity for one week requires \$5-7 trillion. Replacements every decade would cost upwards of \$3.5 trillion. This is simply not a viable path.
3. Alternatively, adding gas to existing hydro to essentially duplicate the grid when wind and solar are in drought requires a not-insignificant additional capital cost of \$30-60 billion. It would provide continuous backup capability, day and night, but its low utilisation rates would make its economics unattractive for investors.
4. The four alternative grid designs, 89% gas plus hydro, 66% coal plus gas & hydro, 40% nuclear plus gas & hydro, and 58% nuclear plus gas & hydro, provide reliable 24/7 power with less than about half the capital costs. The nuclear options, with lifetimes up to 80 years lasting far beyond 2050 compared with wind and solar, minimise costs for gas and probably reduce emissions to less than the Baseline ISP, once whole-of-life emissions for mining, processing and manufacturing of almost 900 times more material is taken into account. All four alternatives impose a tiny environmental footprint compared to the 1.6 million hectares for Baseline ISP wind & solar.
5. It is clear that contrary to continual claims that wind & solar are the cheapest form of electricity generation, it is in fact the most expensive when proper whole-of-system estimates are made. The present plan for transition of the NEM is disastrous in terms of reliability, cost to the economy and in particular to the environment, without being a path to the lowest emissions.
6. The alternative cost models assume wind & solar installations taper off after 2030. At additional cost, a small level of wind & solar (15-20%) can be maintained in the long term grid design.

Recommendations

1. A thorough investigation by independent authorities and immediate implementation of effective accountability mechanisms must be implemented to counter the complete failure of public energy policy regarding reliability and energy costs based on misleading information from public institutions.
2. The AEMO ISP and CSIRO GenCost documents must be subjected to higher genuine standards for truthfulness, completeness and professional engineering processes in place of slavishly following flawed existing policies.
3. Embedding wind & solar targets into the National Electricity Rules must be halted to end the replacement of power systems engineers by politicians and government bureaucrats selecting technological design solutions without proper engineering qualifications.

[4] DRM is the sum of baseload power over maximum demand. In 2019 the DRM was plus 20% (AER)

4. Independent expertise for frequent technical and financial review must be employed in new accountability processes at multiple levels and points in time with a mandate to examine and openly examine a wide range of technological approaches.
5. The AEMO 2024 ISP must be discarded and an immediate start be made on a new energy NEM plan considering all power system technologies.

Independent Engineers, Scientists and Professionals

This report has been prepared and supported by independent engineers, scientists and professionals who have many decades of relevant experience and requisite qualifications without any monetary conditions, employment or conflicting interests.

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Attachment A Estimation Methodology

A. The AEMO 2024 ISP provides the data (Figures 2 and 20) regarding total NEM capacities of all generation (GW) and energy storages (GWh) in 2024-25, 2029-30, 2039-40 and 2049-30.

B. The CSIRO 2024 GenCost report (Section 4.3) provides projected capital cost factor data (in 2024 dollars) for various energy technologies. This data excludes of all subsidies, offsets and tax breaks, which nevertheless have to be paid by all consumers in one form or another.

C. Since the projected cost factors are largely declining and are based on forecasts which contains substantial uncertainties, a second estimate using flat CSIRO 2024 cost factors provides higher cost estimates reflecting potential upsides.

D. A power budget for each grid design model is based on a 24-hour cycle broken into 8 hours centred on midday when solar is available and 16 hours overnight when solar is essentially zero. The DRM is the surplus/deficit of the sum of baseload power over peak demand in each of the 8 and 16 hour periods. Stored energy is used only during overnight periods to contribute to dispatchable power; recharging takes place in daytime when solar is expected to be available but is also subject to weather conditions causing low outputs.

E. Except for the Baseline 2024 ISP model using only the capacities specified in the ISP, the capacity data for other models is adjusted to achieve a DRM in each period and year of at least plus 20% to ensure reliability in the face of facility outages.

F. The capital costs of Snowy 2.0 and Borumba pumped hydro facilities are taken from current government announcements. Costs of passive storages behind the meter are included because they lower demand while making no direct input to the grid.

G. The capital costs prior to 2024-25 are estimated using the 2024-25 ISP capacities and CSIRO 2024 cost factors.

H. The capital costs for each of three periods, 2024-30, 2030-40 and 2040-50 are estimated as the sum of the various generation capacities installed in each period plus the replacement for past installations that have exceeded lifetimes valued by the cost assumption for the mid-point of each period.

I. The modelled lifetimes are 10 years for batteries, 20 years for wind and solar, 30 years for gas, 50 years for coal and 80 years for pumped hydro and nuclear.

J. Costs for existing hydro facilities were not included in any models due to lack of data. Costs for existing coal plants were not included since they are near end-of-life and being retired.

K. The present value estimate is derived by applying a 7% per annum pre-tax, real discount rate applied to capital expressed in 2024 dollars in three periods: 2024-30, 2031-40 and 2041-50 at mid points.

L. The demand side participation (DSP) capacity derived by the 2024 ISP is not used since it is clearly not a source of power but rather a reduction in demand brought about by time-of-use tariffs and central controls to impose rationing on consumers. i.e. this misguided policy attempts to make customers serve a deficient grid design rather than the grid delivering power to consumers as and when required.

M. NEM peak demand is defined by AEMO's 2023 ESOO report for 10% Probability of Exceedance (POE) loads based on detailed forecasting. Note: peak demand will exceed this value about 36 days per year, reinforcing the need for a healthy DRM.

N. The AEMO ISP's use of daily demand profiles to demonstrate grid performance is rejected for use in high reliability system design, which requires worst case conditions. The advent of EV recharging overnight will flatten future demand profiles (according to the 2022 ISP and supported by surveys which show most EV owners prefer/require overnight charging). Incentives (punishing tariffs) to recharge during daytime when solar power is often in surplus is highly problematic and unlikely to gain social licence. Worst case system design must use a flat peak demand. The 10% POE peak demand definition is further support for a conservative approach to worst case conditions.

O. Other costs applied to all models include transmission lines, low voltage distribution networks, grid stabilisation facilities, land acquisition for transmission lines (land costs are included in Gencost cost factors for generators), and an allowance for disposal, recycling and remediation.

P. While the accuracy of this whole-of-system cost estimation methodology is not precise, neither are all future model projections, which inevitably contain considerable uncertainty. However, we apply the same methodology to all seven case models, thus making relative accuracy among them better than absolute accuracy.

Attachment B Cost Model Notes

Baseline 20024 ISP Model Case

The Baseline ISP 2024 grid design contains severe deficiencies in both baseload power and energy storage capacity causing the DRM by 2030 to be minus 10% instead the desired plus 20% – a shortage of 30% in dispatchable power. For 2040 and 2050, the shortages exceed 60%.

Such a design could only be based on hopes that weather conditions will always enable ‘some power’ to be produced in ‘some parts’ of the grid to be delivered to the rest of the NEM by an extensive network of transmission lines. However, AEMO’s historical power supply data[5] tells a different story of frequent periods, often on windless nights, when NEM available solar and wind power capacity factors fall close to zero. Some drought periods can last for more than three days and repeated episodes can often occur with only short intervals in between. Prolonged months-long spells can cause average renewable capacity factors well below expectations.

The AEMO 2024 ISP is a deeply flawed grid design which cannot deliver reliable power – blackouts are inevitable.

The cost of transmission network upgrades is based on the 2024 ISP plan to install 10,000 km of new transmission lines. Costs are estimated to be $1.3 to 2.0 million per km and subject to escalation. Significantly less transmission line costs are required for the four alternative cases.

The 2024 ISP “…assumes upgrades and other investments needed to enable distribution networks….will occur through other mechanisms…”. This study makes an estimate for distribution network upgrade costs of about 5-10 thousand dollars per house based on expert opinion[6]. Much of this cost becomes unnecessary for the four alternative cases.

Stabilisation facilities such as synchronous condensers (costing $10-20 million each) will increasingly be required as baseload plants with rotating machinery are retired in favour of systems using electronic inverters. However, as with the transmission and distribution network costs, much of this is unnecessary for the four alternative cases.

[5] Independent Engineers , Scientists & Professionals, Submission to AEMO CSIRO Draft 2024 ISP GenCost 9Feb2024, P18-20

[6] Electric Power Consulting Submission on the 2024 Draft AEMO Integrated System Plan

Land acquisition costs for transmission lines are estimated from $200K-230K per km and are a subject of considerable debate in project approval hearings, where social licence is in short supply.

There is little information on projected costs for disposal, recycling and land remediation as a result of very substantial materials from expired wind turbines, solar panels and batteries. A nominal figure of $1-2 billion per year in future is used as large volumes of required replacements build up in the Baseline ISP case.

Baseline Plus Additional Gas Generation Case

The 2024 ISP phases out coal generation by 2037 and replaces CCGT (merit) gas plants with OCGT (flex) gas plants (designed to some day burn hydrogen, if or when available). To restore a plus 20% DRM, this Case adds much additional gas generation, starting in 2030, to almost quadruple the planned level by 2050. The daytime period is most critical since the minimal 2024 ISP storages will be depleted overnight and are primarily intended to handle short peak demands and transients.

Maximum gas generation, hydro and biomass baseload provide a 20% reserve margin indefinitely during daytimes which rises well above 20% combined with storages at night. At night, gas generation would probably be lowered to reduce emissions but also at the cost of reducing the capacity factors of gas plants and their economic efficiency.

One implication of this case is the need to assure domestic gas supplies and deliver infrastructure are sufficient.

Costs for transmission lines and other elements remain as for the baseline case.

Table 1 provides a summary of key power system demand and DRM.

	2029-30		**2039-40**		**2049-50**	
	Night	**Day**	**Night**	**Day**	**Night**	**Day**
	GW	**GW**	**GW**	**GW**	**GW**	**GW**
Peak Demand	44.3	44.3	52.3	52.3	55.2	55.2
Baseload Power	53.2	53.2	62.5	62.5	66.5	66.5
Storage Power	5.9		10.8		16.2	
Dispatchable Reserve Margin %	33.3	20.0	40.1	19.5	49.7	20.5

Table 1 Baseline Plus Gas Generation Case

Baseline Plus Additional Storage and Wind & Solar Case

This Case leaves gas generation the same as in the Baseline Case and retires coal generation in the 2030s. A massive addition of extra utility battery storage of almost six times the level in the 2024 ISP by 2050, is required to achieve a DRM above 20% to protect against a worst case wind & solar drought on windless nights. And this also requires a corresponding massive increase in wind & solar to recharge them.

Even this large storage capacity would only cover a single night under worst case conditions.

The capital cost is estimated at $2.6-3.9 trillion. Since the marginal cost of adding batteries is $485 billion per day, a grid system with a seven day battery storage capacity would have a total capital cost of $5-7 trillion, even without adding more renewable recharge capability. The 10 year life of batteries also incurs massive ongoing replacement costs on the order of $3.5 trillion per decade.

Moreover, two further interrelated problems need addressing. The DRM during daytime – absent storage outputs – is disastrously below minus 50% so that there is no means to recharge the large battery capacity in the event of a wind & solar drought.

The reality is a reliance on a minimum level of at least 10% capacity factor for all wind and solar generation. This is not a real solution for DRM since wind & solar are not dispatchable.

In view of these estimates, this Case, widely touted as "firmed wind & solar with big batteries", is simply neither technically viable nor economically affordable.

An 89% Gas Powered Grid Case

This Case follows on from the Baseline plus added gas Case. Capital cost is minimised by keeping the same gas generation, which together with hydro can indefinitely provide the plus 20% DRM both night and day. By halting further rollout of both wind & solar and battery storage after 2030, major capital cost savings are obtained as a trade-off against a lower reduction of operating emissions.

However, it should be noted that gas generation has about half the emissions of the present coal-based grid. The Case also avoids the substantial emissions involved in mining, processing and manufacturing of all of the materials required for wind turbines, solar panels and batteries and their frequent replacements. The amount of such materials has been estimated at about 700-900 times the materials needed for a typical baseload power plant. Therefore, the net increase in emissions of this Case may not be substantial.

Further, the very small environmental footprint of this alternative is negligible compared to wind and solar farms and is therefore another factor for consideration.

Another significant benefit is that gas and hydro facilities will run at higher capacity factors providing more attractive returns for investors, thus providing greater market stability and improving national productivity.

A detailed analysis is needed of the trade-off (Trade Off Analysis) in this Case between the lower capital costs and the postulated emissions reductions offset by the increased Renewable Materials Costs and other environmental benefits.

A 66/23% Coal/Gas Grid Case

This Case is a continuation of using coal generation and its expansion. Instead of retiring existing coal plants, they are replaced and expanded to double the present capacity by 2050. As for the previous Case, wind & solar and storage rollouts are halted after 2030.

While limited emission reductions are evident in this Case, potential exists for using advanced coal plant technology to improve efficiency. Carbon capture is not part of this model. However, benefits include the avoidance of renewable facility costs, a negligible environmental footprint and reduction of substantial emissions from mining, processing and manufacture of wind & solar.

As for the 89% Gas Powered grid Case, another significant benefit is that coal, gas and hydro facilities will run at higher capacity factors providing more attractive returns for investors, thus providing greater market stability and improving national productivity.

Again, a Trade-off Analysis is required for the Case.

A 40/49% Nuclear/Gas Grid Case

For this alternative, the GenCost 2024 cost assumption for large scale nuclear power plants is used. Ongoing product development of SMR systems is proceeding briskly at multiple companies including Rolls Royce (the manufacturer of the planned AUKUS submarine reactors). SMRs offer a vision of production line manufacturing efficiencies for standard products, which will be approved by multiple countries as are commercial jetliners, thus simplifying and shortening the approval process. It will be several years before SMR products are sufficiently mature to be able to assess their true cost factors. This has not prevented many countries from already placing orders for SMRs.

Nuclear fission power plant technologies have a 70 year history of increasing safety, maturity, minimal environmental impact and zero operating emissions, which provides an attractive option.

This Case posits a blend of gas (for fast reaction to load variations and grid transients) and nuclear power generation. The 2024 GenCost 2024 capital cost assumption for large scale nuclear plants can be favourably compared with other generation technologies when adjusted for estimated lifetimes as indicated in Table 2.

From this comparison, a nuclear power plant is effectively much more competitive than the GenCost 2024 results would indicate.

	Nuclear	**Gas**	**Solar**	**Onshore Wind**	**Offshore Wind**
Lifetime Years	80	30	20	20	20
GenCost 2024 Cost Assumption $B/GW	8.5	1.3	1.4	3.0	6.7
Lifetime Adjusted Nuclear Cost Assumption $B/GW	8.5	3.2	2.1	2.1	2.1

Table 2 Equivalent Nuclear Capital Cost Factor Adjusted for Lifetime

In this Case, rollout of wind & solar and storages are halted after 2030 because nuclear and gas baseload generation can run continuously, thus avoiding further capital costs. As its capital cost is much higher than gas plants, nuclear plant should be run continuously at high utilisation rates to achieve the lowest unit cost since the fuel cost per KWh is much cheaper than gas. The gas component provides an ability to quickly ramp up and down to compensate for variable load demands.

Since nuclear plant installation is unlikely to commence before mid-2030s, it is vital that new gas generation facilities be launched as soon as possible supported by expansion of domestic gas production infrastructure on the east coast. Gas is a critical component of all viable future electricity grid options. There should be no equivocation, unless it is preferred to maintain coal generation indefinitely. Gas will be the bridge to and ongoing support to reliable nuclear generation.

If it is desired to maintain some level of wind & solar in the grid, the substantial gas generation in this Case provides plenty of scope for backing up wind & solar. However, this will lower the capacity factors of the gas plants thus increasing their unit costs and the wind & solar will incur additional capital costs and increased emissions from mining, processing and manufacture of wind & solar.

Again, a Trade-off Analysis is needed for this Case.

A 58/31% Nuclear/Gas Grid Case

This Case increases nuclear power generation while reducing gas and maintaining hydro outputs. The increased capital cost relative to the previous case of 40% nuclear needs to be traded off against the potential for emissions reductions.