# Response to
# Draft AEMO 2022 Integrated System Plan

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Submitted by
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# 1 Introduction

As a group of independent engineers and scientists, we thank you for the opportunity to critique AEMO's draft 2022 Integrated System Plan (ISP). The observations and criticisms herein are given in good faith with intent to inform and improve the national approach to managing the NEM. We sincerely support the government's goal for a reliable grid that delivers low cost energy to customers while helping the environment.

# 2 Executive Summary

(a) After examining the draft 2022 ISP, we conclude that it does not provide evidence or justification that would confirm the proposed approach to transforming the NEM, nor will it meet the stated goals (p18-20) for reliability, cost of energy and net-zero emissions as set forth by government.

(b) Furthermore, the ISP is not likely to secure community support and does not take into account the uncertainties of global policies and supply chains (p18). Not everyone will appreciate these criticisms. They may, however, give pause to reflect on serious issues.

(c) The ISP is lengthy and complex in detail but suffers from major shortcomings:

i. The ISP prescribes a "once-in-a-century" grid transformation (p8) by 2050 requiring 204 GW of renewable energy (RE) generation capacity, made up of two thirds (137 GW) of solar utility and residential, and one third (69 GW) of wind. Baseload generation from hydro and gas totals 16 GW maximum (p10, 33-36, Appendix 2, Table 1 p8).

ii. Energy storage of 620 GWh is comprised of 330 GWh at Snowy 2 and 290 GWh in utility and residential storage (Figure 22 p50). Snowy 2 provides a 7 day output of 2 GW while the rest can provide short term maximum power of up to 58 GW lasting 5 hours.

iii. The ISP predicts a total annual NEM output of 330 TWh in 2050 (p9) to meet demand – an average annual demand of 38 GW (p10, 33-36, Appendix 2 Table 1 p8). An average planning demand, allowing for seasonal variations and a reasonable margin, would be 45 GW. Peak demand, using the same factor as the current grid, is likely to be 64 GW.

iv. Night falls on the entire NEM grid at about the same time – every day. There will be no solar power for interconnectors to share for about 14-16 hours a day on average (longer in winter, shorter in summer). Energy storage provisions must be made for nights and multiple sequential days of little sunshine and wind. It must also be sufficient to quickly recharge storage systems.

v. The ISP plans an extensive set of interconnector projects ($29 billion) to enable surpluses in some regions to supply power to those that are in deficit – this does not add to total power generation but is simply redistribution but with added transmission losses (2-5%).

vi. A simple addition of all NEM sources, excluding wind and assuming interconnectors enable energy to be shifted to wherever needed, shows a maximum output of 36 GW, from hydro, gas, Snowy 2 and utility/residential storages for a 16 hour period of no solar.

vii. To meet peak demand of 64 GW, wind must operate at 40% capacity factor, well above an expected average capacity factor of 22% (after transmission losses). If the capacity factor falls to a plausible level of 13%, the NEM suffers a deficit of 21 GW (33%) below peak demand or about 2 GW (4%) below planned average demand.

viii. Wind data from the last 10 years across SE Australia shows multiple events every year of wind capacity factor below 10% and lasting at least 18 hours. Some last as long as 74 hours and capacity factors can drop to as little as a few percent.

ix. This simple accounting using AEMO's ISP parameters under plausible conditions shows unequivocally that the 2050 ISP design has insufficient margins. It is obvious, even before statistical analysis of wind and solar data, the ISP design is incapable of supplying reliable power to a standard of 99.998% reliability, set out by the ISP (Table 3, p19).

x. Furthermore, if solar capacity factor also falls to 13%, there is insufficient power during the succeeding 8 hour period to completely recharge utility/residential storages causing an increased NEM deficit of over 4 GW (about 10% below planned average) during the next 16 hour period and insufficient power to recharge Snowy 2.

xi. The above conditions are not severe nor uncommon – they are entirely plausible. The 99.998% system reliability requirement cannot be achieved.

xii. Recent experience in jurisdictions such as the UK/Europe has demonstrated the unreliability of wind and solar generation over months for a region almost as large as Australia.

xiii. The ISP places reliance on interconnectors to transfer surplus energy from some regions to those that experience shortages on the basis that "…Dunkelflaute-type events (wind and solar droughts) *tend* to be localized, with lesser risk of a NEM-wide event." (Appendix 4 p13 italics added).

xiv. This 'hopeful' assumption depends on all regions over-building their required capacity but the above example shows that there is simply not enough power being generated across the NEM for the interconnectors to be effective.

xv. Despite claims to the contrary (p18), the ISP is not a "rigorous whole-of-system plan" but one with many omissions. There is no System Levelised Cost of Energy (SLCOE) analysis that compares the plan with 'genuine alternatives' to demonstrate that costs are lowest or affordable. Cost information in the ISP is focused primarily on grid interconnector projects.

xvi. System power modelling (2.4 p31) refers to CSIRO's GenCost 2020-21 report which does not provide system levelised for alternative grid solution. Instead it compares estimated costs per MWh for various generating technologies. Without justification, it reduces support costs for wind and solar from its previous report (p60) in an attempt to show wind and solar as the least expensive options in Figure 5-4.

xvii. The ISP provides no whole-of-life analysis of emissions, including mining, manufacture, land, installation, operation and end-of life waste disposal/recycling for all components (taking into account the low lifetimes of RE systems compared to conventional baseload power plants) and a comparison with alternative solutions to demonstrate that emissions will be net-zero by 2050.

(d) The ISP not only fails to meet the goals set by government, it also poses substantial risks for the environment:

i. The ISP states "The land needed for variable RE (VRE), storage and transmission projects to realise these goals is unprecedented." (p15). No information is provided about how this land area will be acquired and at what cost other than to mention the importance of Renewable Energy Zones (REZ) in remote locations. It seeks social licence for the use of such land, without defining what that means.

ii. The scale of infrastructure required for wind and solar demands vast amounts of materials – concrete, steel, aluminum, copper, carbon fiber, graphite, nickel, cobalt, lithium and rare earths – a demand well in excess of current supply and hundreds of times more than baseload generators. Costs for some of these materials are already rising. Lifetimes for wind turbines, solar panels and batteries are much less than for reliable conventional power plants, more than doubling the impact on the environment.

iii. The end-of-life waste disposal/recycling problems for solar panels, wind turbines and batteries have also not been addressed. They demand new technologies that have not been developed and for which the economics are unknown.

iv. On a per installation basis, wind farms pose a well-known high risk to wildlife, particularly to bird populations, including endangered species. They also destroy landscapes which affects real estate and community values.

(e) The ISP does not address national security policies, which have been strengthened in recent years to avoid over-dependence on foreign supply of critical infrastructure.

i. Most wind and solar systems are primarily (>90%) imported from China which has purposely acted to acquire ownership and control of the majority of key materials involved in RE systems, EVs (electric vehicles) and related products.

ii. Coal, gas and nuclear baseload generators provide a safe path for domestic self-sufficiency.

(f) Productivity is a fundamental tenet of economic analysis to determine best outcomes. The ISP describes a system with low productivity, well under 20%, due to inherent RE intermittency and worsened by unavoidable losses due to energy storage and transmission of electricity over long-distance interconnectors. Compared with reliable conventional baseload generators, which operate at 65-70% utilisation rates and can surge to 24/7 full dispatchable power on demand, it is difficult to envision how the planned system in the ISP will provide lower costs and better reliability.

(g) The ISP makes a prediction that 65% of residences in 2050 will have installed solar PV systems, "with most systems complemented by battery energy storage" (p10). No evidence is provided to back up this prediction. These Distributed Energy Resources (DER) systems accounts for 34% of the total grid power capacity and almost 40% of non-Snowy 2.0 storage capacity (p50). Batteries for the envisioned residential capacity will cost an estimated $132 billion every 10 years, making this assumption problematic.

(h) The previous 2020 ISP and the May 2020 Minimum Technical Standards specification explicitly detail plans to implement a DER management system via the Internet to take control of home solar, battery and EV systems – and include the ability to control residential loads such as heaters and air conditioners and to extract stored energy to cover grid shortages.

(i) The 2022 ISP provides only a vague mention of the need to manage DER (p46, 92). The 'voluntary' curtailment of loads by demand-side participation (DSP) in the 2020 ISP (p37) appears to be replaced by AEMO seeking 'social licence' to implement DSP. What does this mean? A working group of AEMO, network service providers and Energy Networks Australia is said to be addressing this issue (p92), but without apparent consumer input.

(j) Will social licence be obtained through legislation or regulation for mandatory management of DER? Without it being mandatory, will the planned approach be viable? Is it possible that consumers will embrace and accept this command and control system? Is it not evident that the need for load shedding is an admission of a failed grid design? Community support is unlikely.

(k) The conclusion of this critique is inescapable. New evidence emerges daily that RE is incapable of being used on a large scale to implement a reliable electrical grid system. Experience in Australia, US, UK and Europe underlines the reality that RE intermittency cannot be economically offset by any available or planned technology to produce a reliable and cost effective electricity grid.

(l) The proposition that the draft 2022 ISP represents the best future path for transforming the NEM into a reliable, low cost and a net-zero emissions by 2050 grid has not been justified.

# 3 Recommendations

Rather than proceed down the planned path, the following recommendations are provided:

(a) AEMO must return to an examination of genuine alternative solutions which are more certain to provide reliable power at reasonable cost based on a sovereign supply capability to ensure national security. These alternatives can include HELE coal, gas and nuclear, all of which can lead to emission reductions without resort to massive scale of materials, vast land use, restricted operational lifetimes and severe environmental impacts. These alternatives must be allowed to operate at their normal high rates of utilisation to deliver optimum efficiency and lowest costs. RE may be part of the mix but the level that can be tolerated without destabilizing the grid has probably already been reached.

(b) AEMO must set up an oversight and accountability function involving regular review, assessment and auditing of its full range of technical studies and research using external independent experts having no connection to industrial or governmental entities with monetary conflicts of interest or links to ideological activism and political organisations.

(c) The NEM must be returned to a properly functioning market, as recommended by the ESB in the last year, free of distortions by subsidies, preferencing, cross-linking and political orders. This can only be accomplished if all companies wishing to supply the NEM are required to contract for supply of 24/7 reliable power using whatever mix of generation and storage technologies it considers viable This will quickly allow the market to ascertain the true cost of supplying reliable energy to consumers.

# 4 Discussion

(a) The purpose of the ISP (p18-20) is predicated on publicly stated policies of governments (state and commonwealth) for a future electricity grid which produces *reliable power* at *low cost to consumers* and with a 2050 target for *net-zero emissions*.

(b) It is not within AEMO's remit to challenge these goals despite there being considerable, independent scientific evidence refuting catastrophic climate warnings. [See *Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters* by Dr. Stephen E. Koonin for a good recent summary of the science.]

(c) However, the ISP fails to demonstrate its planned solution (e.g. Step Change) will meet any of the goals set out by government policy – *reliability, low cost and net-zero emissions*.

## 4.1 System Levelised Life-cycle Costs and Emissions

(a) When life-cycle costs and emissions are considered, it is necessary to examine them with a System Levelised Cost of Energy (SLCOE) approach which includes:

i. Not just operating costs and emissions but whole-of-life processes including mining, manufacture, land, installation, maintenance and end-of-life disposal/recycling,

ii. All components of the grid including wind turbines, solar panels, baseload power generators, energy storage facilities, stabilisation systems, transmission lines, interconnectors and management control systems, and

iii. Duplication of wind and solar generation capacities (compared with conventional baseload generators) and depth of energy storage to achieve the required level of system reliability (99.998% p19 Table 3) under conditions that represent a very high percentage of statistical weather variations.

(b) Only with SLCOE, can modelling be applied to make a valid comparison of a variety of 'genuine alternative' plans for a mix of grid technologies.

(c) AEMO may have made such studies in the past but the ISP does not reference them, does not present the results of such studies nor provide any justification for its renewable energy-dominant approach. Section 2.4 (p31) discusses cost modelling with particular reference to the CSIRO June 2021 *GenCost 2020-21 Report*.

(d) The GenCost Report 2020-2021 provides useful forecast data for capital costs of various technologies used for electricity generation. It uses the STABLE program to make LCOE estimates but notes (p54) that "…it is not a substitute for….electricity system modelling". In particular, it addresses both stand-alone and integrated LCOE for wind and solar in 2030. It does not provide system level modelling.

(e) In the previous CSIRO report, integrated VRE costs included energy storage at $19 to $106/MWh (2 to 6 hours of storage) but did not include transmission lines and synchronous condensers (nor probably land, interconnectors, standby baseload fossil fuel plants, energy management systems and disposal/recycling since these are not mentioned).

(f) In its current report, CSIRO states that costs to support renewables have been lowered to $6 to $19/MWh based on a less conservative approach, which assumes some RE will always be available in the NEM (p60). This appears to reflect the system design philosophy of the ISP to provide extensive interconnectors throughout the NEM to move energy from where it is available to where it is needed. The report did not state whether these new support costs, about 80% lower, include the costs of the land, interconnectors, synchronous condensers, energy management systems and disposal/recycling. Nor did it state whether the limited lifetime of batteries was taken into account.

(g) The reason for this substantial lowering of VRE support costs is dubious, given the assessments in Sections 4.4 and 4.5 below. If these costs had been kept at the same level, Figure 5-4 of the CSIRO report, which provides a comparison of LCOE for various energy sources, would look like Figure 1 below which is marked up to show that CSIRO's previous integrated wind and solar LCOEs are not the least expensive approach to electricity generation but are on a par with gas and the lower range of nuclear. Given the lack of detail and rigour in the CSIRO report, it is necessary for a rigorous and independent review be done.

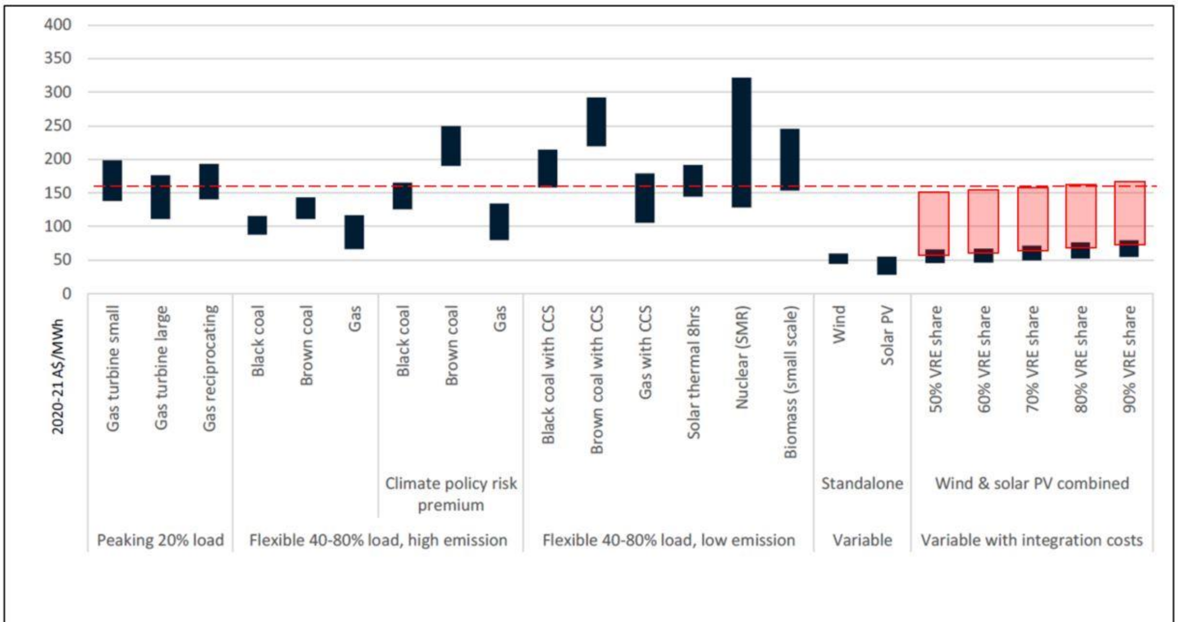

Figure 5-5 Calculated LCOE by technology and category for 2030

Figure 1 CSIRO GenCost 2020-21 Report with markups using its previous report

(h) Other organisations have made SLCOE studies in this direction but it is AEMO's responsibility to openly assess them to determine completeness and methodological adequacy.

(i) One such SLCOE study by Electric Power Consulting Pty Ltd in 2018 compared six cases of NEM technology mixes involving RE, coal, gas, hydro and nuclear. It produced variations of 6:1 on cost/MWh and 16:1 on emissions/MWh.

(j) This type of SLCOE modelling shows there are major differences in outcomes among genuine alternative solutions and that realistic energy storage capacities lead to higher costs for a RE intensive solution. These alternatives must be realistically assessed. The ISP does not provide such information.

## 4.2 Environmental Impact

(a) Not only is the presented solution to cut emissions not credible but the environmental implications are dire. The ISP fails to report the full environmental impact of its focus on renewable energy generation:

   i. The ISP admits (Page 15) "The land needed for major VRE, storage and transmission projects to realise these goals is unprecedented." The solution appears to be to secure 'social licence' for vast land use without explaining how this will be accomplished or its environmental impact. For the Step Change scenario, land use amounts to over 1.7 million hectares (greater than 7 times the area of the ACT); for the Hydrogen Superpower scenario, it amounts to over 7.2 million hectares (about 80% of the area of Tasmania); this land use is many hundreds of times larger than the area needed for reliable baseload generators.

   ii. The scale of the ISP RE solution involves the building of vast infrastructure, also requiring hundreds of times more materials and energy than other conventional approaches. The world-wide supply of these materials – concrete, steel, aluminum, copper, carbon fiber, graphite, nickel, cobalt, lithium and rare earths – falls far short of many of these requirements and costs for many of them are rising sharply due to excess demand. The ISP fails to address the pollution and emissions caused by mining, manufacture, installation and eventual disposal/recycling of these materials. The planned system is most definitely not net-zero. A full accounting and comparison with genuine alternatives needs to be made.

iii. Also not addressed are the substantial technical/cost challenges involved in end-of-life waste disposal on a massive scale for wind turbines, solar panels and batteries with lifetimes less than half that for conventional power plants. The methods for recycling batteries and solar panels are being researched but require large amounts of energy, which compounds the life-cycle emissions and cost problems.

iv. The ISP does not address the substantial environmental harm to wildlife, particularly bird populations including endangered species, from large scale wind and solar farms. Numerous studies have pointed to these problems.

## 4.3 National Security

(a) There are profound implications for national security in the ISP solution. In recent years, Australia imported over 90% of wind turbines and solar panels from China. Indeed, China has captured 80% of the world market for RE systems and has acted decisively to acquire ownership and control over the majority of materials required for RE and associated products such as batteries. China is the largest manufacturer of EVs.

(b) In light of tensions caused by China's trade actions against Australia and its aggressive actions across regional SE Asia and Australia, government policy has decisively swung onto the defensive. The pandemic emergency has demonstrated the folly of over-reliance on China as a supplier and China's extensive cyber aggression has made it necessary to exclude Chinese products from Australia's telecommunication networks.

(c) The NEM is just as critical to national sovereignty and the economy as the telecoms network; some would say more so. The idea that Australia's national grid should be built almost exclusively around products made in China is something that needs active discussion within the highest levels of government. AEMO needs to seek urgent government guidance and incorporate that into the 2022 ISP.

(d) The 2020 ISP and the May 2020 DER Minimum Technical Standards specification, explicitly identified the need for an internet-based network management system reaching into all network facilities including residential. The vulnerability to cyber-attack was directly addressed but the 2022 ISP is silent on this subject.

## 4.4 Variability, Intermittency and Productivity

(a) The primary drawback of the ISP's RE-dominant approach is its inherent variability and intermittency. The ISP first prescribes energy storage to compensate. But the extremely high cost of storage makes it uneconomic to provide backup beyond a few hours when in reality days and weeks are required. As a second recourse, the ISP prescribes a $29 Billion program of building transmission lines – interconnectors – to transmit 'surplus' energy from one region to another. However, uncertainties of weather have forced the inclusion of gas turbine generators to provide a third layer of backup.

(b) Economics focuses on productivity as the driving force behind labour and machinery in producing best outcomes. The laws of physics also place constraints on any scheme involving energy. There are no magical solutions that produce more than 100% efficiency, otherwise perpetual motion machines would be a reality. Every step in generating, converting, storing and transmission of energy involves losses, which make all processes less than 100% efficient.

(c) Plant utilisation rates and ability to provide power at maximum rated output (called the capacity factor) have a big impact on productivity. Baseload generators are capable of operating indefinitely at 65-70% average utilisation rates (leaving room to handle peak demands and maintenance shutdowns). Wind and solar 'average' capacity factors are 20-30%, dependent entirely on the weather and incapable of surging on demand. When energy storage facilities are added, the inherent losses in transmitting power to them, converting it to another form for storage, transforming it back into electricity and then distributing it back to the grid imposes another layer of inefficiency, which can be up to 40-50%. Transmission losses from remotely located Renewable Energy Zones (REZ) and interconnectors can subtract 3-6% from delivered energy. The entire system, therefore produces a net productivity as low as 8-18%.

(d) Compared to baseload generators, RE-based grid design suffers from a large economic disadvantage. Therefore, it is not surprising that the ISP calls for installation of 283 GW (p35-36, Appendix 2 Table 1 p8) of RE, storage and backup power capacity, far in excess of a baseload grid design for meeting peak demand.

(e) The ISP forecasts annual energy demand will rise (p9) from a current 180 TWh to 330 TWh by 2050, an 83% rise accounting for a mass adoption of EVs. That works out to an annual 'average' demand in 2020 of 21 MW and 38 MW in 2050. The Australian Energy Regulator (AER) reports peak demand in 2019-20 of 35MW, a factor of 1.7 above the average. Applying that to AEMO's forecast of 38 GW in 2050 indicates a peak demand of 64 MW. Given the variability of seasonal demand and uncertainties, it is prudent to plan for average 2050 demand to be about 20% higher at 45 GW for and a surge capability to meet peak demand.

(f) The bottom line is that the planned all-up power capacity in 2050 is more than four times higher than the peak demand, a factor which weighs heavily against renewable energy when being compared against reliable dispatchable power generators. A proper SLCOE comparative analysis will reflect this difference and suggests in principle that capital costs, installation, operation, maintenance and disposal/recycling costs for RE may be unfavourable.

(g) In addition to the over-build of RE generation capability, the costs of land, energy storage facilities, voltage stabilisation equipment, transmission lines, interconnectors and energy management systems have to be factored into the productivity of the whole system. Common sense, even before detailed analysis begins, raises doubts.

## 4.5 Energy Storage

(a) The ISP acknowledges the need for storage but falls short on providing comprehensive evidence that demonstrates what is required – how much and for how long. To achieve a system reliability of 99.998% (an outage of just 10 minutes per year) (Table 3 p19), it is critical that RE variability and intermittency be rigorously analysed for proof of grid design adequacy. No such analysis or proof is presented or referenced by the ISP.

(b) The ISP states that AEMO has "…*explored* Dunkelflaute-type events" when wind and solar power are very low "…based on historical conditions from 2010-2011 to 2019-2020" (italics added). It concludes that "…considering the geographic and technological diversity forecast in the Draft ISP, AEMO does find severe Dunkelflaute-type events tend to be localised, with lesser risk of a NEM-wide event." It goes on to claim that "diversity of resources" (storage) and "transmission…will improve the operability of the grid during these conditions." (Appendix 4 p13).

(c) No quantitative risk analysis is provided or discussed. Are we to rely on claims that these problems will "tend" not to impact reliability?

(d) It is not reassuring when no information is provided on any kind of analysis of statistical weather data to back up these conclusions. Instead, it appears to be entirely ‘exploratory’. The ISP presents a “sample week in July 2039” (Figure 21; Figure 10 in Appendix 4) when the NEM “might” suffer a three day, low wind period but with typical solar outputs. This material is clearly hypothetical; illustrative rather than a definitive basis for design of a reliable grid system.

(e) Yet historical data on RE outputs across all of Australia is produced by AEMO itself. A number of other websites download it into alternative formats. What would be instructive is to filter all aggregate wind and solar capacity factor data over at least five years and examine the statistics of how many periods occur – at the NEM top level – when the capacity factor is lower than the average set in the grid design model and for periods exceeding a set duration.

(f) For example, a quick review of SE Australia wind data from 2011 to 2020 provides the following Table 1 for the number of occasions each year that capacity factors were lower than 10% of maximum output and which exceeded 18 hours. An arbitrary threshold for average wind output might be 22%, hence 10% is a drought of 55% (reduction) during that period.

(g) This example using AEMO historical data shows that there are frequent periods of substantial wind drought each year lasting between 18 hours and up to 74 hours. AEMO has the data and needs to assess it in the manner required to assess overall reliability of the NEM for a given set of grid design parameters. The analysis needs to go well beyond the simple example in Table 1.

**Periods of Wind Capacity Factor Below 10%**

| Year | Number | Minimum Period hrs | Maximum Period hrs |
|---|---|---|---|
| 2011 | 6 | 18 | 74 |
| 2012 | 19 | 20 | 67 |
| 2013 | 9 | 19 | 54 |
| 2014 | 14 | 20 | 46 |
| 2015 | 16 | 18 | 39 |
| 2016 | 6 | 18 | 61 |
| 2017 | 18 | 18 | 72 |
| 2018 | 6 | 18 | 57 |
| 2019 | 4 | 18 | 40 |
| 2020 | 4 | 18 | 33 |

Table 1 SE Australia Wind Capacity Factor Data

(h) Recent experience of the UK/Europe clearly demonstrates that weather patterns over large areas in 2021 resulted in substantially lower than expected RE wind (up to 38% lower for onshore wind) being available for periods of several months. AEMO’s conclusion (Subsection (b) above) must therefore be considered unsupported by evidence and unrealistic.

(i) Most experts appear to consider 14 days of storage as a minimum to support VRE; some indicate 30 days. Snowy 2.0 provides 7 days at full 2 GW output power; 14 days at half output power.

(j) The primary issue is whether the depth of energy storage is sufficient given that interconnectors are proposed to be the primary method of backing up VRE, on the assumption there will always be sufficient RE somewhere in the NEM to meet all NEM power demands.

(k) This can be accomplished with a detailed model of the entire proposed system run with properly designed weather data to represent with high certainty all of the weather extremes expected in the NEM. This is a major task and needs to be urgently undertaken before a commitment is made by government to this design approach.

(l) It is instructive, as a start, to examine a simple average power/energy budget model of the entire 2050 NEM based on the ISP design parameters and the following plausible conditions:

  i. All interconnectors are in place allowing power to travel seamlessly to where it is needed.

  ii. Wind and solar experience multiple days of drought by a factor of 40% reduction of average outputs.

iii. Solar and wind energy have an expected capacity factor of 25% and suffer a 3% loss due to transmission.

iv. Wind occurs uniformly all day while solar is concentrated in an 8 hour period.

v. Gas and hydro power have transmission losses of 2%.

vi. Utility storage includes all DER and grid batteries plus pumped hydro beyond Snowy 2.

vii. Snowy 2 separately provides 2 GW of power to the grid post-transmission.

viii. The average grid demand for planning is 45 GW. Peak demand is forecast at 64 GW.

ix. One-way efficiency of charging and outputting of stored energy is 90% for utility storage and 80% for Snowy 2.

x. Utility storage starts fully charged at 290 GWh, Snowy 2 at 330 GWh, for a total of 620 GWh (Figure 22 p50).

(m) Table 2 shows the power budget data for sources and loads using ISP values. The columns show two days, each broken into 16 hour and 8 hour periods. During 16 hour periods solar is zero; its entire daily average is generated in the 8 hour period. The complete absence of solar, which is two thirds of RE, places the grid into deficit during 16 hours, which is compensated by continuous full hydro and gas outputs and outputs from utility storages and Snowy 2.

(n) Utility storage is completely drained in the first 16 hour period, leaving a small grid output deficit of 1.7 GW, about 4%. During the next eight hour period solar comes back on, gas and hydro are maintained at full output and surplus energy recharges utility storages. Note this model is dependent on running gas and hydro at 100% utilisation indefinitely. Despite this, there is insufficient surplus to fully charge utility storages and hence Snowy 2 has no charge supply available but is only partially discharged.

(o) The second 16 hour period again draws the partially charged utility storages down to zero but can output less power to the grid resulting in a deficit of 4.2 GW, or 10%. In this example, the cycle continues indefinitely and Snowy 2 is depleted in about 9 days.

| Power - GW | | | | | | |
|---|---|---|---|---|---|---|
| Solar/Wind Drought | | 40.0% | | | | |
| Average RE Outputs = | | 60.0% | | Hours | | |
| | ISP | Average Capacity | 16 | 8 | 16 | 8 |
| Sources | Capacity | % | Output | Output | Output | Output |
| Solar | 67.9 | 13% | | 26.9 | | 26.9 |
| DER | 68.6 | 13% | | 27.2 | | 27.2 |
| Wind | 69.2 | 13% | 9.1 | 9.1 | 9.1 | 9.1 |
| Gas | 9.3 | 98% | 9.1 | 9.1 | 9.1 | 9.1 |
| Hydro | 7.1 | 98% | 7.0 | 7.0 | 7.0 | 7.0 |
| Utility Storage | 30.4 | 100% | 16.3 | -33.9 | 13.8 | -33.9 |
| Snowy 2 | 2.0 | 100% | 2.0 | | 2.0 | |
| Total | 254.5 | | 43.5 | 45.4 | 41.0 | 45.4 |
| Load | 45 | 100% | 45 | 45 | 45 | 45 |
| Surplus/Deficit | | | -1.5 | 0.4 | -4.0 | 0.4 |
| Energy Storage - GWh | | | | | | |
| | Capacity | Efficiency | | | | |
| Utility Storage | 290 | 90% | 0 | 244 | 0 | 244 |
| Snowy 2 | 330 | 80% | 290 | 290 | 290 | 290 |
| Total | 620 | | 290 | 534 | 290 | 534 |

Table 1 2050 NEM Power/Energy Average Budget for 40% Dunkelfalute

(p) This budgetary accounting exercise may be simple but it illustrates that, independent of interconnectors and under a plausible 40% reduction in RE generation (to 13.2% capacity factor), the amount of energy storage is manifestly too small to maintain average grid outputs – right from the first day. Furthermore, there is no surge capacity whatsoever to handle peak demands which are 19 GW higher. The hydro and gas generation runs continuously to meet average demand with no space capacity for surges in demand.

(q) The result demonstrates a failure of design, not by a small amount but by a massive amount. The size of energy storage is too low and by a large margin.

## 4.6 Battery Storage

(a) The depth and duration of storage is critical to the credibility of the ISP. The ISP (Figure 22 p50) shows the total storage envisioned for 2050 to be 620 GWh, over half of which (330 GWh) is Snowy 2.0. The ISP states (P10) that the NEM will require this storage to provide 45 GW of power, which equates to just 14 hours of supply. But when Snowy 2.0 is operating at full output, the remaining storage capacity of 290 GWh can supply 43 GW power for less than 7 hours.

(b) The ISP makes predictions (without evidence) that 65% of residential consumers will have PV systems (p10) "*with most systems complemented by battery energy storage*." (italics added) How many consumers will be persuaded to purchase expensive battery storage (without government providing large subsidies) is not explained. CSIRO's GenCost report indicates residential batteries cost over $1200/KWh, about 4 times higher than grid scale batteries (p48).

(c) DER (residential) storages account for about 110 GWh or 38% of non-Snowy 2.0 capacity in Figure 22 (p50). The potential cost of this to consumers totals over $132 billion and requires replacement every 10 years. For the 65% of households installing solar, the battery cost amounts to about $2400 per year assuming an average occupancy rate of 3 per household. What is the impact on the ISP if the assumed uptake of home battery installations does not occur?

(d) Utility-scale batteries are mentioned numerous times in the ISP but always lumped in with something else. For example (p10), "…utility-scale pumped hydro and batteries [will provide] 15 GW" (power) without mentioning the duration of that capacity. The cost and feasibility of batteries to provide baseload back-up deserves to be explicitly addressed since the media provides numerous claims concerning plans for utility-scale batteries.

(e) The reality is that the high cost of batteries make them uneconomic for serving in any role except for very short term smoothing of sudden variations in RE supply and peak load relief for a few hours. Batteries are intended for smoothing peak wholesale costs – not for providing baseload back up for system reliability.

(f) Future battery costs in 2035 are estimated at US$200/KWh (in 2018 dollars not allowing for inflation) by the US Renewable Energy Laboratory (USREL) in 2019 and are consistent with CSIRO's GenCost report. This is in stark contrast to the ISP (Figure 4, p23) suggesting lithium-ion battery costs at $100 per MWh – about 2800 times less – as a priority of Australian research. Perhaps there is a typo in this figure; should it read $100/KWh?

(g) The USREL estimate puts the cost of a 1 GW grid-scale battery lasting 4 hours at US$800 Million, or about a billion in 2018 Australian dollars. If the non-DER storage, excluding Snowy 2, was implemented using only batteries, it would amount to $54 billion, again requiring replacement every 10-15 years.

(h) Another issue that needs to be taken into account in system modelling is that battery capacity declines slowly with age. The same is true of solar panels. Media reported Elon Musk estimates a reduction to 70% capacity over the lifetime of the battery.

(i) Batteries are not a viable solution to baseload back-up of RE and the ISP needs to be explicit on this matter. The total costs for consumers, direct and through electricity rates need to be stated.

## 4.7 Pumped Hydro

(a) Pumped hydro is another storage solution which the ISP does not adequately address. Snowy 2.0 produces a peak output of 2 GW and has a capital cost trending towards three times that of an equivalent gas-fired power plant. In Figure 22 (p50), storage capacities are forecast by year in terms of both power output and energy storage. By 2050, Snowy 2.0 still represents over half of total energy storage.

(b) Despite the fact that pumped hydro costs are approximately one tenth the cost of batteries (based on Snowy 2 costs), the ISP makes no mention in Parts C and D of additional pumped hydro projects in the future, although it states that "Deeper pumped hydro storages will be vital…" (p10).

(c) Environmental activists are strongly opposed to almost any dam building.

## 4.8 Hydrogen

(a) Clean hydrogen is a big part of the Emission Reduction Plan to store energy with a goal to develop renewable hydrogen electrolysis by 2035. Although this technology is in early stage R&D, it is mooted to play a key role, particularly in the Hydrogen Superpower scenario (p26). However, it faces major challenges:

i. Achieving adequate end-to-end efficiency needed to make it an economic solution is difficult. Boosting electrolysis efficiency is a major subject of research.

ii. The low density of hydrogen makes it difficult and expensive to store as a gas requiring very high pressures; leakages are a serious problem and hydrogen is explosive in air over a wide range of mixtures.

iii. The cryogenic temperature required for liquefaction is extremely low and expensive.

iv. Hydrogen embrittlement of many metals poses serious materials problems for storage, handling, transportation and use.

v. The ISP notes that some domestic hydrogen production will be used to support transport and blending with pipeline gas without mentioning its possible application to grid-scale energy storage. Its costs and viability are unknowns at this time.

## 4.9 Interconnectors

(a) Interconnectors are the largest component in the ISP solution for overcoming intermittency of RE generation. The ISP lists many specific projects. However, the viability of interconnectors playing a major role is undermined by the following:

i. As indicated by recent UK/Europe experience with substantial falls in RE outputs over a wide area and for prolonged periods in 2021, the ISP's conclusion from its "exploratory look" at weather data (Appendix 4, p13) that severe RE drought events are more localized is doubtful. Much more rigorous risk analysis needs to be done. Risk quantification is imperative since the requirements for the grid as set out in Table 3 (p19) call for 99.998% reliability of supply meeting demand. NOTE: this equates to an outage of just 10 minutes per year.

ii. If reliance is placed on regions to generate not just sufficient energy for its own demands but surplus energy for use by other regions in shortfall, this implies a very substantial overbuild of generation capacity in all regions. This will have major capital cost impacts and large land use. Assuming that adjacent regions are likely to have surplus energy to share is a fundamental shortcoming in a grid design that is almost completely reliant on weather.

iii. Interconnectors are high capital cost projects. The proposed projects amount to $29 Billion dollars. These costs are not required if a solution is adopted using reliable baseload generators. CSIRO's GenCost 2020-21 report suggests these costs have not been included in a total cost accounting for the average LCOE cost of RE.

iv. Electricity transmission on interconnectors also causes inevitable energy losses due to line resistance. This cause inefficiencies which are proportional to distance. The ISP is silent on this issue.

### 4.10 Demand-side Participation

(a) The ISP mentions demand-side participation only once (p46) in vague terms whereas the 2020 ISP specifically described it (Section C3.3 p57) as the need for AEMO to trigger load reductions and access behind-the-meter battery and EV charging demands. It also specifically identified the cyber security risks of the control network (Section C1.2 p42). This approach is popularly referred to as a "smart grid" network.

(b) AEMO's May 2020 Minimum Technical Standards (p16) explicitly identifies Distributed Energy Resources as solar panels, home batteries and electric vehicle batteries, and controllable loads such as "air conditioners, electric storage hot water systems, pool pumps and electric vehicle supply equipment."

(c) The ISP (p46) states "The willingness of consumers to lower their consumption during high price periods (referred to as demand-side participation, or DSP) will also have an important role to maintain reliability and avoid involuntary load shedding."

(d) Does "high price periods" suggest the deliberate use of consumer pricing to 'encourage' people to use energy mainly when *it suits the grid rather than when they need it* – a widely disliked feature and essentially a sign of grid design failure? Or does it simply refer to periods when the grid design fails to supply sufficient power to meet forecast demands?

(e) This lack of clarity makes it difficult to determine if DSP, as expressed in the 2020 ISP, enabling AEMO to intrusively control via the internet certain loads within a residence such as heaters and air conditioners and EV chargers, has been dropped deliberately or just not mentioned at this time. A recent article (28 Nov 2021) by the Chair of the Australian Energy Market Commission, Anna Collyer, mentions DSP twice.

(f) The ISP further states (p47) that "Flexible demand response will be used to flatten the shape of operational demand, helping to reduce the need for new firming capacity [42]".

"[42] The scale of demand response potential assumed in later years in some scenarios, market reforms such as those reported on in Section 4.3, may be necessary, *as well as acceptance from consumers*." (italics added)

(g) Section 4.3 (p54) refers to approval of the Energy Security Board's (ESB) post-2025 reform recommendations and AEMO's plan (May 2020 Minimum Technical Standards) for better integration of DER (home solar and batteries). It also states AEMO is working with industry to develop a NEM Regulatory and IT Implementation Roadmap.

(h) The above indicates that the ISP continues with plans to implement a command and control system at the residential level. It further states in regards to DER (p92) the need to secure Social Licence for DER; "…there comes a point beyond which some active management is needed to maintain the reliability and security of the whole system……Full DER integration requires a step change in engagement across the industry to ensure all consumers, retailers, networks and other market participants orchestrate these resources to optimise net benefits and maintain security and reliability."

(i) Managing DER is a necessity because already there are frequent days when home solar, which is hardwired to the grid, overwhelms the ability of solar and wind farms to deliver energy during periods of low demand and causes complaints from the RE industry.

(j) Will active management disadvantage home DER by blocking their access? Will home owners be compensated with capacity standby fees?

(k) The 2020 ISP talked about voluntary acceptance of DSP; the 2022 ISP talks about obtaining "social licence". What does this actually mean? There is a working group of service providers, Energy Networks Australia and AEMO to consider this matter. Where is the consumer on this working group?

(l) It seems unlikely that Australians will agree voluntarily to accepting a command and control system (using AI algorithms) which blocks their solar panel feed-in to the grid, blocks their access to power for heaters and air conditioners when they need it most and draws power from their home back-up battery and possibly their EV. Clearly, DSP is required to rectify an energy shortage caused by a grid designed to be vulnerable to weather.

(m) Does 'social licence' mean mandatory acceptance of this reality?

(n) What is the impact on the ISP if such a social licence is not forthcoming, noting that Figure 22 (p50) indicates that DER constitutes 80% of storage power capability and about 20% of energy storage capacity?

(o) It should be noted that plans for rotating disconnects of home heating and air-conditioning is based on a technical fallacy. The energy consumed by these thermostatically-controlled devices is set not by their maximum power consumption but by the amount of heat that flows through walls and windows of the building. Turning them off does not stop heat flow; turning them on again after a short period (such as an hour), causes the thermostat to continuously draw energy at maximum power from the grid to restore room temperature *using almost exactly the same energy as the energy saved.* This not only negates the whole concept but worsens it by posing increased power demands upon restoration.

# 5 Alternative Technology Solutions

(a) As stated at the beginning of this submission, the ISP makes no attempt to justify the choice of 100% renewables as the goal of a claimed "once-in-a-century" transformation of the grid (p8) nor does it make cost and reliability comparisons with genuine alternative design approaches. As discussed above, the amount of planned energy storage contemplated is insufficient compared to what is needed to back up intermittent wind and solar. The effect of all the interconnector projects is of little use if the total energy available in all regions is insufficient to meet all NEM demands. Recent experience in other countries suggests RE is not a reliable or cost effective answer. There is a swing underway back to energy realism.

(b) The reality is that conventional baseload power plants will be required in perpetuity to ensure a grid reliability of 99.998%.

(c) Existing coal plants are deemed unacceptable for their emissions; high efficiency low emission (HELE) coal plants may not reduce emissions sufficiently to satisfy environmental demands. Low footprint gas-fired power plants offer major reductions in emissions and are responsible for enabling some countries, such as the United States, to move forward on emission reductions ahead of others.

(d) Nuclear power generation is the ultimate zero emissions back up for wind and solar. However, it completely negates the need for wind and solar generations using massive amounts of land and materials, duplication of power capacity many times over, expensive energy storage systems, costly interconnectors, grid stabilization measures and an intrusive (and cyber-vulnerable) smart grid. This would appear to be a sensible, low footprint solution at potentially a much lower cost but is strongly opposed by the renewable energy industry and environmentalists.

## 5.1 Gas Generation

(a) The ISP (Figure 1 p9) envisions a small amount of gas turbine generation restricted to peaking of demand. In reality, as Section 4.5 shows, it is an essential part of baseload back-up of RE when wind and solar drops. The current role for short-term gas peaking and smoothing restricts it to a lower utilization rate than if it could compete with non-subsidised RE on a proper allocation of support cost basis taking into account it does not require, storage, stabilisation or interconnectors. The current result is that such facilities are rendered uneconomic and can only stay in business if substantial "capacity" subsidies are paid.

(b) While operating emissions reduction are less, when system levelised true cost and emissions impacts of the mining, manufacture, installation and disposal of RE and all of the back-up and storage systems are taken into account, a more proper comparison of emissions would be informative. In addition the lifecycle of gas generation plants is over twice as long as RE, the environmental impact on land use is far less and such facilities remove dependence on imports from China.

## 5.2 Nuclear Power

(a) The commercial race for development of small modular reactors (SMR) capable of assembly line manufacture at much lower cost has started in many countries. Based on a deep technical background of submarine propulsion, which has demonstrated high reliability and safety over many decades, their technical feasibility is highly likely; the main challenge will be to demonstrate their economics.

(b) Within a decade SMR will probably be available and provide all of the benefits of high reliability, low cost and zero emissions without the large environmental impact of RE, excessive overbuild of capacity, energy storage facilities and expensive interconnectors. This pathway, if successful, will almost certainly displace the rush to renewables in those countries that have already experienced RE shortages. Europe and the UK have taken steps to promote these developments as they struggle with power shortages and rising costs.

(c) It is recognised that the federal government will have to remove legal restrictions on nuclear development to enable this option to be considered. In light of the AUKUS agreement and the growing public acceptance of the safety of nuclear generation, it is a path that needs to be explored and factored into the ISP, which is silent on the nuclear option.

# 6 Conclusions

1. The draft 2022 AEMO ISP does not provide either evidence or justification to show that its planned NEM design approach will meet government goals for low cost, reliability and net-zero emissions.

2. No System Levelised Cost of Energy studies are referenced or presented to show the costs and emissions of a renewable energy-dominant approach is the best way forward. The referenced CSIRO GenCost 2020-21 report is deficient in not including whole-of-system and whole-of-life

costs for wind and solar generation or any of the alternatives – their conclusions are therefore unsubstantiated. Other independent SLCOE studies suggest a different comparison.

3 The environmental impacts on land use are acknowledged without any attempt to estimate costs or mitigation other than obtaining social licence, which may in fact be regulatory in nature rather than community acceptance.

4 The pollution and emissions costs of mining, manufacture, installation, and eventual disposal/recycling from building a vast array of wind and solar generators and associated energy storage, stabilization, interconnectors, energy management systems and back-up generators has not been addressed. The substantial harm to wildlife is ignored.

5 National security issues regarding the almost exclusive reliance on China as the dominant supply chain for RE systems from China are not addressed and the issue of cyber-vulnerability of the proposed active management of DER residential systems has not been mentioned.

6 The primary drawbacks of extreme variability and intermittency of RE generation result in very low levels of system productivity, possibly in the range of 8-18% compared with reliable baseload alternatives at 65-70%, suggesting poor economics.

7 Energy storage is the primary means to resolve variability and intermittency but costs for both batteries and pumped hydro are extremely high. The ISP prescribes inadequate levels of energy storage even for modest wind and solar shortfalls as demonstrated by a simple accounting of the balance of power sources and demand, and energy storage for 2050 using the ISP design parameters under plausible weather conditions.

8 The heavy reliance of the ISP on interconnectors on the assumption that there will always be surplus energy in some parts of the NEM when some regions experience wind and solar droughts is misplaced. The reality is that solar, 2/3 of the RE generation mix, is completely zero for periods of 16 hours every day and simultaneously everywhere in the NEM. Wind is highly variable at all times of day. AEMO's publicly-available data demonstrates for example, that wind outputs fall to less than 10% of capacity for at least 18 hours (sometimes as long as 72 hours - days) many times per year. Outputs can also fall to low single digits. This combination of wind and solar cannot guarantee an adequate supply of energy to the NEM no matter how many interconnectors are built. Energy storage is therefore critical.

9 The NEM system reliability requirement of 99.998% (10 minutes of outage per year) cannot be met with the ISP approach. The ISP makes no attempt to assess NEM reliability with a detailed system modelling approach.

10 The ISP is reliant on an assumption that 65% of households will install rooftop PV panels and 'most' will install battery back-up. Given CSIRO's cost estimate for small scale batteries, this implies a cost to consumers in those households of $132 billion, which amounts to approximately $2400 per year assuming a 10 year battery lifetime. This assumption (barring a massive government subsidy program) is therefore unlikely to be valid.

11 The ISP does not address the impact on grid performance from degradation in solar panel outputs with time nor of battery capacity versus time.

12 Pumped hydro capital costs are about three times as expensive as conventional gas generation. Environmentalists are determinedly against building dams and the number of suitable sites in Australia for large-scale pumped hydro is limited. The ISP, while stating it is a vital technology, makes no mention of it in the projects for consideration.

13 The primary thrust of the ISP is to advance a $29 billion program of building interconnectors. Cost estimates for all other aspects of the ISP system are not addressed, either on a capital cost or SLCOE basis.

14 The ISP provides no detail on its planned DSP smart grid approach to actively manage DER resources. It is unlikely that the social licence it seeks for its implementation will be forthcoming. An intrusive command and control system which will block access of home solar panels to the grid, block supply of power to home heaters, air conditioners and EV chargers, just when they are needed, and drain power from home batteries and EVs appears very unlikely to gain any support from consumers and the public.

15 The necessity to consider DSP is an admission of failure to design a reliable grid system.

16 Gas-fired generation is a viable opportunity for Australia to secure a reliable NEM based on domestic fuel supplies and substantial reduction of emissions. When compared on a proper SLCOE basis with RE, it will likely produce a better outcome for reliability, cost and emissions.

17 Nuclear generation is the ultimate low emissions path forward but faces regulatory/legal hurdles and SMR technology will not be ready for another ten years. It is based on a solid foundation of technical and safety in its prior use for submarine propulsion over the last 60 years.

18 Recent experience in California, Texas and the UK/Europe have been a wake-up call. The unreliability and cost impacts of intermittent and highly variable wind and solar is forcing a recalibration of plans. Renewable energy shortfalls of 30% have persisted for several months in 2021. Nuclear and gas are now recognized by the EU as green technologies.

19 The ISP requires a new approach involving rigorous studies of all genuine alternatives, using a system levelised cost and emissions approach and a rigorous analysis of system reliability.

20 Failure to re-examine previous assumptions underpinning the planned way forward and to perform detailed engineering design based on comprehensive will have serious consequences to the economy, the government and consumers.