


Australian Resources Development Limited

Submission regarding AEMO's Draft 2022 Integrated System Plan

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Introduction

From its website, one of AEMO's roles is to lead the design of Australia's future energy system. In fulfilling this role, "AEMO provides the detailed, independent planning, forecasting and modelling information and advice that drives effective and strategic decision-making, regulatory changes and investment." The 22DISP is part of this process.

The Invitation to engage with the 2022 Draft Integrated System Plan (**22DISP**) contains the following statement:

"Since 2018, the Integrated System Plan … has guided industry and government on the best investments to supply affordable and reliable electricity to Australian homes and businesses." (Page 3)

Further, the Executive summary commences with the following statement (edited for presentational purposes):

"Australia's National Electricity Market (NEM) is supporting … replacing legacy assets with low-cost renewables, adding batteries and other new forms of firming capacity, and reconfiguring the grid to support two-way energy flow to new power sources in new locations. It is doing so at world-leading pace, while continuing to provide reliable, secure and affordable electricity to consumers." (Page 8)

Thus, the 22DISP promotes significant investment across generation, storage and system service as well as transmission.

In this transition, the NEM must continuously meet the reliability and security requirements (**System Requirements**) set out in Table 3. (Page 19)

The major messages from these statements are:

1. The NEM currently supplies affordable and reliable electricity due to the guidance from the Integrated System Plan **(ISP**).
2. The replacement in the NEM of coal-fired generation with firmed renewables will continue to provide low-cost, highly reliable electricity in a system that continuously meets the System Requirements.
3. Australia's emissions reduction policies are "locked in" and this transformation of the NEM generation technology will deliver Australia's low emissions objective.
4. Thus, coal-fired generators are dismissed from the analysis as legacy assets that cannot compete with "low-cost" renewables.

In response to the Invitation, this **Submission** offers comments on these major messages.

How affordable reliable and secure is the current NEM?

Affordable?

Through major policy drivers, 33TWh of renewable electricity generation was forced into the NEM by 2020 from a 2001 base.

The Chart in Appendix 1 demonstrates graphically the massive increase in consumer electricity prices as a result of forcing the introduction of VRE into the NEM over recent years:

- This represents a significant transfer of wealth from power consumers (many of whom are in low-income brackets) to investors in renewable energy projects; i.e., the policies forcing the penetration of renewable energy are a regressive tax that differentially harms the low-income households and individuals.

Thus, the final 2022 ISP (**22FISP**) needs to explain the basis for the claim that that the NEM currently supplies "affordable" electricity.

Reliable and secure?

AEMO's latest Electricity Statement of Opportunities forecasts expected unserved energy (**USE**) to remain below the Interim Reliability Measure (**IRM**) of 99.9994% in all regions for the 2022-23 summer. However, expected USE is forecast to exceed the IRM in NSW and Victoria after 2027:

- Thus, the current NEM can be described as "reliable" in the short term but significant action is needed in the near term to maintain reliability.

The policy-driven changing of the NEM from a centralised thermal generation system to a system comprised of a diverse portfolio of behind-the-meter and grid-scale inverter-based energy resources means less inertia which presents challenges to maintain a secure power system and control system frequency following contingency events. In view of this, how secure is the current NEM? What is the NEM's capacity to maintain system frequency, voltage and strength within relevant standards?

Due to the forced penetration of renewable energy into the Australian electricity market, there are several indicators that the NEM has become less secure over the recent years including:

- The loss of the spinning reserve that was supplied by older, coal-fired generators; e.g., Hazelwood and Northern power stations.
- The reliance on interconnectors to supply the spinning reserve support across the NEM regions which exposes the system to the risk of major outages due to transmission outages; e.g., the South Australian black out in September 2016.
- The rapid increase in congestion costs and the growing use of market interventions to stabilise the market.

Thus, while the NEM can currently be described as supplying "reliable" electricity, the 22FISP needs to confirm that the current NEM system is also "secure".

How secure and reliable are the electricity systems in the scenarios?

The first operational requirement considered in developing the ISP is to ensure there "… is a sufficient overall portfolio of energy resources to continuously achieve the real-time balancing of supply and demand …" (Table 3, page 19). The major outcome of the 22DISP scenarios is the unprecedented penetration of variable renewable energy (**VRE**) supported by firming technologies **(Firming Capacity)**:

- The ISP modelling methodology optimises electricity dispatch for every hourly or half-hourly interval in order "…to reveal performance metrics for both generation and transmission." (AEMO 2021 ISP Methodology, Page 6). Presumably, the modelled outcomes demonstrate that the systems developed in the scenarios meet the System Requirements on a continuous basis.

Table 1	**2029-30**	**2039-40**	**2049-50**
VRE Ratio - VRE share of annual generation - Figure 16, page 41	79%	96%	97%
FS Ratio - electricity supplied from Firming Capacity to electricity supplied from VRE + Firming Capacity	12%	13%	12%

Some forecast ratios calculated from the most likely Step Change scenario (see Appendix 2) are set out in Table 1. These results indicate that:

- The VRE capacity factor decreases as the VRE share of total generation increases.
- Firming Capacity is only required to supply a little over 10% of the total electricity forecast to be supplied from VRE generation and Firming Capacity.

This implies a very high correlation between the VRE energy supplied and the load profile in each period such that the instantaneous VRE generation matches the load in the majority of periods, with the few periods of "over supply" of VRE sufficient to charge the storages.

- Figure 21 (page 48, reproduced in Appendix 2) depicts such an outcome based on a "sample" winter week. VRE supplies approximately 70% of the electricity with the remainder from Firming Capacity (including gas and hydro). Significantly, the maximum rate of energy storage (**Storage Load**) is approximately 30% of the total load.

In contrast, the CSIRO's Low Emissions Technology Roadmap (**CSIRO Roadmap**) released in June 2017 undertook a very serious analysis and modelling of the levels of battery capacity (i.e., Firming Capacity) required to be installed to ensure a reliable supply as the VRE share of delivered electricity in the system increases (**CSIRO Modelling**).

- The CSIRO Roadmap sought to ensure that modelled systems were "… robust under highly unlikely weather conditions." (CSIRO Roadmap, page 116). Thus, rather than using a "sample" week, the CSIRO Roadmap used a "worst three week" period "… using three repeated weeks in a row of the worse single weeks by state and by renewable resource (i.e. least wind and sun), actually observed…" (CSIRO Roadmap, page 116).

How secure and reliable are the electricity systems in the scenarios? (cont.)

Figure 37 of the CSIRO Roadmap (page 115, reproduced in Appendix 2) depicts the Firming Capacity required to support VRE through three consecutive high battery use days in NSW; i.e., three days of low wind and sun. By observation, VRE supplies significantly less electricity than in the 22DISP "sample" week. Most significantly, the maximum Storage Load is approximately 120% of the total load which means that much more Firming Capacity must be installed to ensure a reliable supply, relative to the 22DISP Figure 21 profile:

- While the NEM regions are regularly subject to wind and solar droughts (**Weather Droughts**), the 22DISP only refers on the last page to these phenomena as " … possibly resulting in extremely low energy availability." (Page 98); i.e., D22ISP fails to take account of Weather Droughts.

To date, Weather Droughts have had a minor impact on NEM supply reliability because coal-fired generators supply the majority of the load. The 22DISP's failure to take account of Weather Droughts in sizing the amount of Firming Capacity to achieve the real-time balancing of supply and demand in a system where VRE supplies almost 100% of the generation casts serious doubt on the robustness of the 22DISP.

In this regard, Appendix 2 also reproduces Figure 11 of the CSIRO Roadmap which depicts the relationship between the VRE Ratio and the ratio of Firming Capacity to VRE generation capacity installed in the NEM regions (**FC Ratio**) which increases exponentially as the VRE Ratio increases:

Table 2	**2029-30**	**2039-40**	**2049-50**
VRE Ratio - VRE share of annual generation - Figure 16, page 42	79%	96%	97%
22DISP FC Ratio - Firming Capacity to VRE installed generation capacity from the Step Change forecasts	30%	39%	34%
22DISP Firming Capacity (GW) for the Step Change forecasts	24	52	69
CSIRO FC Ratio - NEM weighted projections from the CSIRO Roadmap (Figure 11)	25%	100%	100%
Additional Firming Capacity (GW) required to achieve the CSIRO FC Ratio for the Step Change forecasts	0	82	137

Table 2 sets out the forecasts for the 22DISP FC Ratio based on the Step Change scenario forecasts and the CSIRO FC Ratio required for a reliable system based on Figure 11 of the CSIRO Modelling. There is clearly an enormous difference in determining the required Firming Capacity based on the 22DISP's "sample" week and the CSIRO's robust approach of using the "worst three week" period:

- The application of the more robust CSIRO modelling raises the forecast cost of firmed VRE generation enormously.

Thus, the final 22FISP needs to demonstrate in detail the robustness and credibility of its method of modelling the amount of Firming Capacity required to achieve the real-time balancing of supply and demand in a system where VRE supplies almost 100% of the generation:

- To do this, the 22FISP will need to demonstrate clearly in the " … compound extreme event case studies …" (Page 98) that the modelling faithfully takes account of the impact of the regular Weather Droughts experienced in the NEM regions.

How "low" is the cost of electricity in the scenarios?

The fundamental purpose of the 22DISP is to address "… the long-term interests of the consumers of electricity." (Page 12).

The 22DISP calls for "… significant investment across generation, storage, transmission and system services. A transformation of the National Electricity Market, to provide high reliability at low cost, while meeting the nation's objective to reduce emissions." (Page 3).

The 22DISP lists the net benefits as ranging from $3.4B to $70.2B from the Optimal Development Path (**ODP**) for each of the four scenarios:

- However, the net benefits listed in the 22DISP **only** apply to the transmission projects without which, "… the NEM would require more expensive generation capacity nearer to load centres … These technologies have higher capital costs than VRE, in addition to the fuel costs associated with gas generation." (Page 57).

Consequently, the 22DISP does not provide forecasts of the capital and operating cost of the massive amount of renewable generation and Firming Capacity required to supply the projected future NEM load while meeting the System Requirements.

The Step Change scenario requires the construction and connection of approximately $500B of new capacity by 2049-50 at current prices:

- Applying a 10% discount rate (typical of a major investor in generation capacity; e.g., Origin Energy) to amortise this sum over an average economic life of 20 years (given the preponderance of renewable and storage capacity) yields an annual payment of approximately $60B.
- This equates to approximately $150/MWh at current prices at the wholesale level (including the fixed operating costs) based on forecast 2049-50 total consumption (excluding efficiency gains).

This represents an enormous increase in the wholesale electricity cost and cannot be portrayed as providing "low-cost" electricity:

- The projected increase in electricity costs massively outweighs the relatively small net benefits estimated to accrue to consumers under the 22DISP Step Change scenario.

Moreover, Slide 5 concludes that applying the more robust CSIRO approach to forecast the requirements for Firming Capacity would raise the cost of firmed VRE generation enormously:

- If an additional approximate 140GW of Firming Capacity is added to the forecast Step Change scenario capacity in 2049-50 (see Slide 5), approximately $375B is added to the capital cost. When added to the 22DISP total cost, this equates to approximately $260/MWh at current prices at the wholesale level.

When extolling the net benefits of the ODPs, the 22FISP needs to be transparent with consumers by providing estimates of the forecast cost of the underlying construction programs and the impact on future wholesale electricity prices:

- As outlined above, this cost is enormous and will have to be paid either by consumers or taxpayers.

Australia's low emissions objective locked in

The fundamental purpose of the 22DISP is to address "… the long-term interests of the consumers of electricity." (Page 12).

- The 22DISP "interprets" the long-term interests to include the impact of Federal and State environmental policies, especially the Net Zero by 2050 "race".
- However, these policies are only applicable in the short term and will almost certainly change:
  - A good example is the US commitment to the Paris Agreement which has reversed twice over the last six years.
  - The current Federal Government's policy on Net Zero by 2050 was only introduced in October 2021.
  - The Labor opposition has a policy of 43% CO_2 reduction by 2030. Labor has also supported Net Zero by 2050. Which policy to model?
- It is particularly germane that a major part of AEMO's role is to provide "… the detailed, independent planning, forecasting and modelling information and advice that drives effective and strategic decision-making, regulatory changes and investment." (see Slide 2).
- In view of this uncertainty in a highly volatile political environment, AEMO should maintain its independence and use the ISP to investigate scenarios in which the Net Zero 2050 constraint is removed:
  - This will provide valuable information to politicians and the voters of the cost and emission consequences of such policies as Net Zero by 2050 and 43% CO_2 reduction by 2030.
  - The investigation of this scenario does not mean that AEMO supports the removal of Net Zero by 2050 just as the investigation of the Hydrogen Superpower scenario does not mean that AEMO is committed to that scenario.
- In this way, AEMO would play a valuable, independent role in informing the public debate.
- Unfortunately, as presently drafted, the 22DISP locks in the current policy objectives and fails to provide politicians and the voters with the cost impact of eliminating coal-fired power.

Thus, to maintain AEMO's independence, the 22FISP needs to analyse a scenario that removes Net Zero 2050 constraint and retains coal-fired generation (**Coal-fired scenario**).

Need for a Coal-fired scenario

As noted, a Coal-fired scenario would inform the debate about the cost and reliability consequences of transforming the NEM to total reliance on VRE.

The 22DISP defines the scenarios as "… plausible futures with varying rates of decarbonisation, electricity demand, and decentralisation." (Page 26)

This begs the question of why coal-fired plants are not being constructed and why coal-fired generators are announcing closure dates. These generators face three major risks that cannot be easily mitigated without policy changes:

Dispatch Risk - Under the NEM rules, coal-fired generators cannot be sure of dispatch even if they bid the same prices as the renewable generators because the latter are classified as semi-scheduled generators and are generally given priority for dispatch. This high dispatch risk makes it impossible to underwrite construction of new coal-fired plants as the investors can never be sure that their units will be dispatched, regardless of the level of bidding.

Price Risk - The Dispatch Risk makes it difficult to write long-term offtake contracts and finance new plants. The alternative is to sell into the pool. However, it is very difficult to predict pool prices in a market where the penetration of VRE is subsidised through Federal or State policies; i.e., merchant risk is very high and virtually impossible to value.

Carbon Tax Risk - The risk of a carbon impost and/or other environmental tax imposed by a future Federal or State governments.

The existence of these risks does not mean that a Coal-fired scenario should not be investigated as the risks can be mitigated by amending AEMO's dispatch regime and government policies as recommended by such bodies as the ACCC and the Energy Security Board:

- That is, a Coal-fired scenario is no more a policy-dependent future than the Progressive Change scenario which explicitly requires the retention of the subsidies under Australia's current Emissions Reduction Plan.

If the 2049-50 load were to be supplied by 10GW of life-extended existing coal capacity at 25% of the cost of replacement capacity, the retention of the Hydro and Peaking gas and liquids capacity required in the Step Change scenario and by 54GW of new black coal (advanced ultra supercritical PC) capacity would require the refurbishment, construction and connection of approximately $300B of new capacity by 2049-50 at current prices:

- ❑ Applying a 10% discount rate to amortise this sum over an average economic life of 25 years (given the part reliance on refurbished plant) yields an annual payment of approximately $30B.
- ❑ This equates to approximately $120/MWh at current prices at the wholesale level (including the fixed and variable operating and fuel costs) based on the forecast 2049-50 total consumption (excluding efficiency gains).

This represents an enormous saving to consumers relative to the projected prices in the Step Change scenario.

Thus, the 22FISP needs to include a a Coal-fired scenario to identify the size of the financial benefit to consumers of retaining coal-fired generation relative to the other scenarios.

Politicians and voters can then assess and value the countervailing environmental impact.

"Low-cost" renewables

Some gentailers and many politicians regularly promote the claim that firmed VRE is the lowest cost source of electricity generation. For example:

- The NSW Energy Minister Kean was quoted in September 2021 as stating that NSW coal-fired generators would be replaced with renewable generation by 2030 as firmed renewables are the lowest cost source of new generation capacity.
- "Australia is missing out on the jobs and cheaper energy that come with renewables." (Powering Australia, Australian Labor Party, December 2021).

The 22DISP also makes this claim: "… the transformation will deliver low-cost renewable electricity with reliability and security …" (Page 10)

- The reference to reliability and security means that the 22DISP claims that **firmed** VRE is "low cost".

The 22DISP does not substantiate this claim. What does "low-cost" mean? Is firmed VRE lower-cost than base-load coal or gas generation?

The impact of adding the cost of firming to the cost of the VRE generation is reflected in the estimated cost of electricity from a range of technologies based largely on AEMO data (See Appendix 3) at current prices set out in Table 3:

Table 3	**Black Coal**	**CCGT Gas**	**VRE (40% Utility scale solar, 60% wind)[1]**		
Operating condition	**Base Load**	**Base Load**	**Unfirmed**	**Firmed[2]**	**Firmed**
FC Ratio	NA	NA	NA	34%[3]	100%[4]
FY22$/MWh so	$76	$103	$75	$99	$145

1. The ratio of Utility scale solar generation to the sum of Utility scale solar and Wind generation in 2049-50 Step Change forecast from the Generation Outlooks.
2. Based on VRE capacity firmed by Large-scale Battery Storage (8 hours storage).
3. The 34% FC Ratio is the approximate average of the 22DISP FC ratios listed in Table 2.
4. The 100% FC ratio is derived from the CSIRO Modelling described in Slide 4.

The results do not support the 22DISP's claim that VRE is "low cost":

- The cost of unfirmed VRE is approximately equal to the cost of coal-fired generation operating in base-load mode.
- Once Firming Capacity is required, the relative cost of VRE rises substantially relative to the cost of coal-fired and CCGT gas-fired generation.

Thus, the 22FISP needs to substantiate the claim that firmed renewable electricity is "low cost".

Conclusion

The major messages from the 22DISP are:

1. The NEM currently supplies affordable and reliable electricity due to the guidance from the ISP.
2. The replacement in the NEM of coal-fired generation with firmed renewables will continue to provide low-cost, highly reliable electricity in a system that continuously meets the System Requirements..
3. Australia's emissions reduction policies are "locked in" and this transformation of the NEM generation technology will deliver Australia's low emissions objective.
4. Thus, coal-fired generators are dismissed from the analysis as a legacy asset that cannot compete with "low-cost" renewables.

The major results of this Submission are:

- The facts clearly show that the forced penetration of renewable energy into the Australian electricity market has led to massive price increases. The cost of this policy-induced disruption to the market is borne by electricity consumers and represents a significantly regressive tax that differentially harms the poor. Further, while the NEM can currently be described as supplying "reliable" electricity, the 22FISP needs to confirm that the current NEM system is also "secure".
- The 22DISP's failure to take account of Weather Droughts in sizing the amount of Firming Capacity casts serious doubts on the robustness of the 22DISP. Thus, the 22FISP needs to demonstrate in detail the robustness and credibility of its method of modelling the amount of Firming Capacity required to meet the System Requirements to achieve the real-time balancing of supply and demand in a system where VRE supplies almost 100% of the generation:
  - To do this, the 22FISP will need to demonstrate clearly that the modelling faithfully takes into account the impact of the regular Weather Droughts experienced in the NEM regions.
  - The failure to ensure that sufficient Firming Capacity is installed would significantly understate the cost of VRE and leave the future NEM exposed to severe and prolonged disruptions.
- An analysis based on AMEO's data outlined in this Submission for the Step Change scenario indicates a development of approximately $500B of new capacity by 2049-50 at current prices. This would result in a projected wholesale electricity price in 2049-50 of approximately $150/MWh. This represents an enormous increase in the wholesale electricity cost and massively outweighs the relatively small net benefits estimated to accrue to consumers under the 22DISP Step Change scenario.
  - Moreover, the application of the more robust CSIRO approach to determine the required Firming Capacity would raise the cost of firmed VRE generation enormously and would raise the projected wholesale electricity price in 2049-50 to approximately $260/MWh.

Conclusion (cont.)

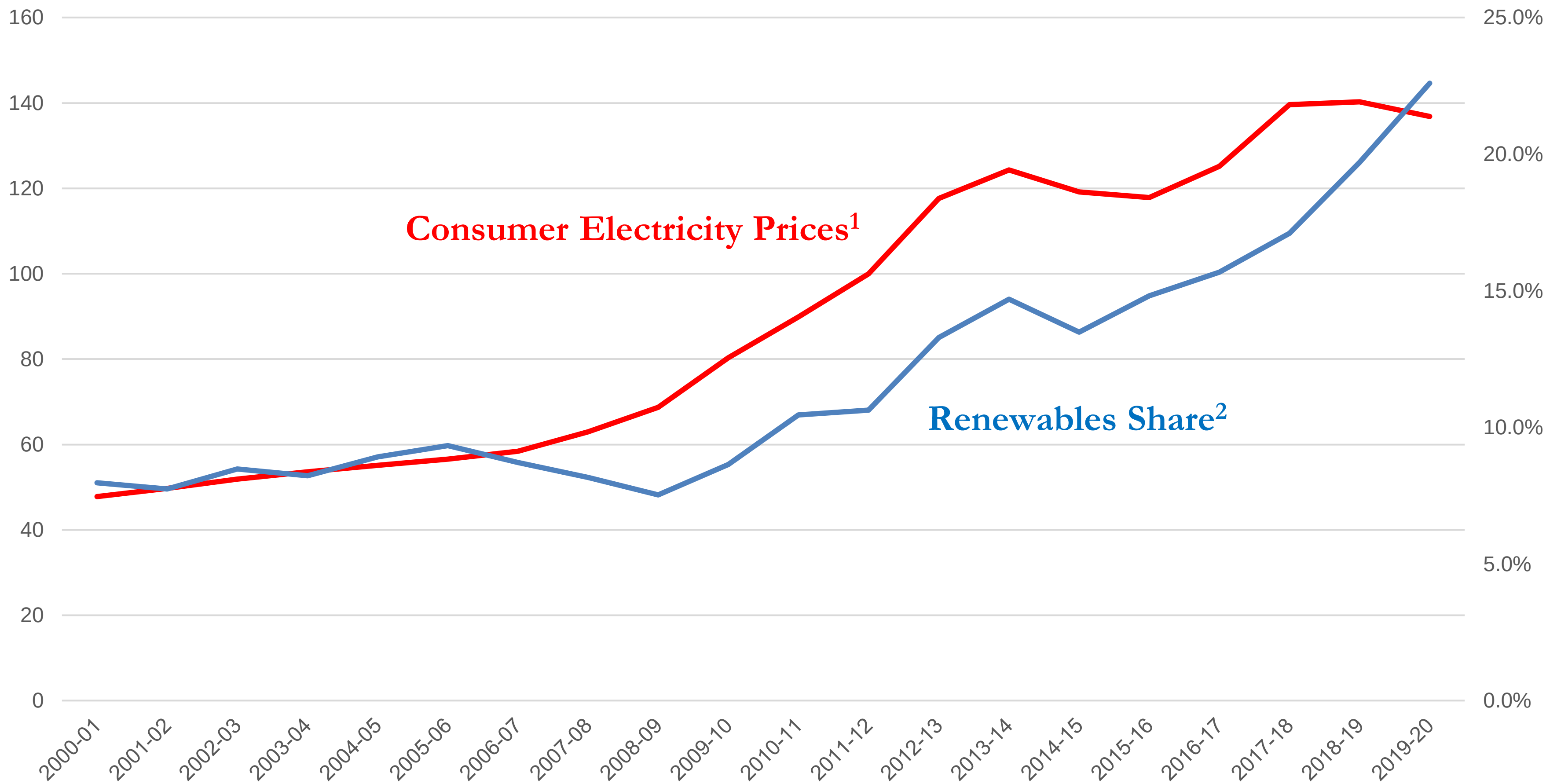
- An analysis presented in this Submission, based on AEMO's data, does not support the 22DISP's claim that VRE is "low cost":
  - The cost of unfirmed VRE is approximately equal to the cost of coal-fired generation operating in base-load mode.
  - Once Firming Capacity is required, the relative cost of VRE rises substantially relative to the cost of coal-fired and CCGT gas-fired generation.

  Thus, the 22FISP needs to substantiate its claim.
- Environmental policies can never be "locked in" in a highly volatile political environment. It is not AEMO's role to be the arbiter of future policies. Rather, AEMO should maintain its independence and use the ISP to investigate a Coal-fired scenario in which the Net Zero 2050 constraint is removed.

  Unfortunately, the 22DISP locks in the most recently formed party political objectives and so does not provide politicians and voters with an assessment of the cost of the elimination of coal-fired power:
  - The investigation of a Coal-fired scenario does not mean that AEMO supports the removal of Net Zero by 2050 just as the investigation of the Hydrogen Superpower scenario does not mean that AEMO is committed to that scenario.
- Consequently, the inclusion in the 22FISP of a Coal-fired scenario would inform the debate about the cost and reliability consequences of transforming the NEM to the total reliance on VRE.

  The current risks facing coal-fired generators arise from AEMO's dispatch regime and government policies which could be amended:
  - That is, a Coal-fired scenario is a no more policy dependent future than the Progressive Change scenario which explicitly requires the retention of the subsidies under Australia's Emissions Reduction Plan.
  - A plausible Coal-fired scenario outlined in this Submission based on AEMO's data would result in a wholesale electricity price of approximately $120/MWh at current prices compared with $150 – 260/MWh from the Step Change scenario depending on the amount of Firming Capacity to ensure a reliable system.
- Finally, AEMO has developed a reputation as an objective and skilled engineering-based organisation that provides independent advice. The fundamental purpose of the 22DISP is to address "… the long-term interests of the consumers of electricity." Thus, it is vital to the interests of consumers that AEMO retains its independence and credibility by ensuring that the 22FISP demonstrates a transparent and even-handed approach to the issues raised in this Submission, particularly with respect to analysis of the current and future costs and reliability of VRE relative to a Coal-fired scenario.

Appendix 1: Impact of Renewable Energy on Electricity Consumers



1. Australian Electricity Consumer Price Index, Australian Bureau of Statistics, series A2328141J, 2011-12 = 100.
2. Renewable Generation (including Hydro) as a percentage of total generation. Source: Table O1 Australian electricity generation, by fuel type, physical units, Australian Energy Statistics, Australian Department of Industry, Science, Energy and Resources

Appendix 2: 22DISP Firming capacity

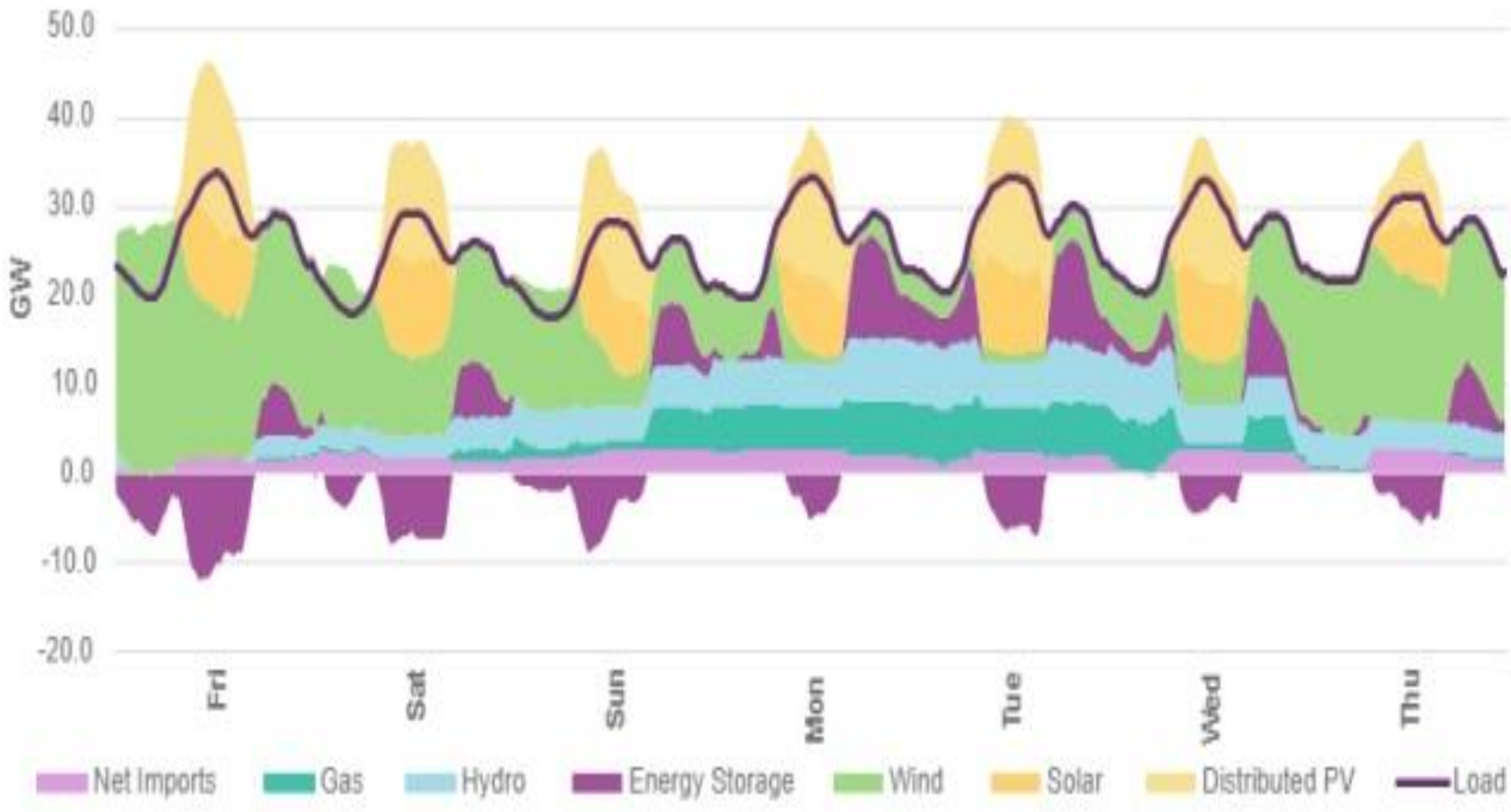
Inputs	**2029-30**	**2039-40**	**2049-50**
Installed Generation Capacity GW. Source: Draft 2022 ISP Chart Data.	**GW**	**GW**	**GW**
VRE Installed Generation Capacity	77.7	133.8	205.7
Total Installed Generation Capacity	121.5	195.2	281.7
Generation TWh (as generated). Source: The Generation Outlooks provided with the 22DISP.			
Non-VRE Generation as generated	68.5	25.4	25.6
VRE Generation as generated	184.5	332.2	458.7
Total Generation as generated	253.0	357.6	484.3
Firming Capacity GW. Source: Draft 2022 ISP Chart Data.			
Peaking gas and liquids	8.3	7.6	9.3
Utility Scale Storage	6.0	12.5	14.6
Coordinated DER storage	3.8	17.2	30.6
Distributed Storage	5.5	14.6	14.4
Total Firming Capacity	23.6	37.3	54.5
Source of supply TWh. Source: The Generation Outlooks provided with the 22DISP.			
VRE generation	170.1	290.3	404.4
Firming Capacity	22.7	41.9	54.3
VRE Ratio - VRE share of annual generation - Figure 16	79%	96%	97%
Calculations			
FS Ratio - electricity supplied from Firming Capacity to electricity supplied from VRE + Firming Capacity	12%	13%	12%
VRE Capacity Factor	25%	25%	22%
FC Ratio - Firming Capacity to VRE installed generation capacity	30%	39%	34%
Required FC Ratio. Source: CSIRO FC Ratio - NEM weighted projections from the CSIRO Roadmap (Figure 11)	30%	100%	100%
Required Firming Capacity based on CSIRO FC Ratio – GW	23.3	133.8	205.7
Additional Firming Capacity – GW	-0.2	82.0	136.7
Additional Firming Capacity - $B[1]	-0.7	223.4	372.7

Notes:

1. Based on the current construction and connection cost of Large-scale Battery Storage (8 hours storage) from the AEMO 2021 Inputs and assumptions workbook, December 2021, New Entrant Data Summary Sheet (**AEMO 21 Inputs**) at current prices.

Appendix 2: 22DISP Firming Capacity (cont.)

Figure 21 A week's dispatch outcomes across the NEM (excluding Queensland), *Step Change*, 2039



Appendix 2: 22DISP Firming Capacity (cont.)

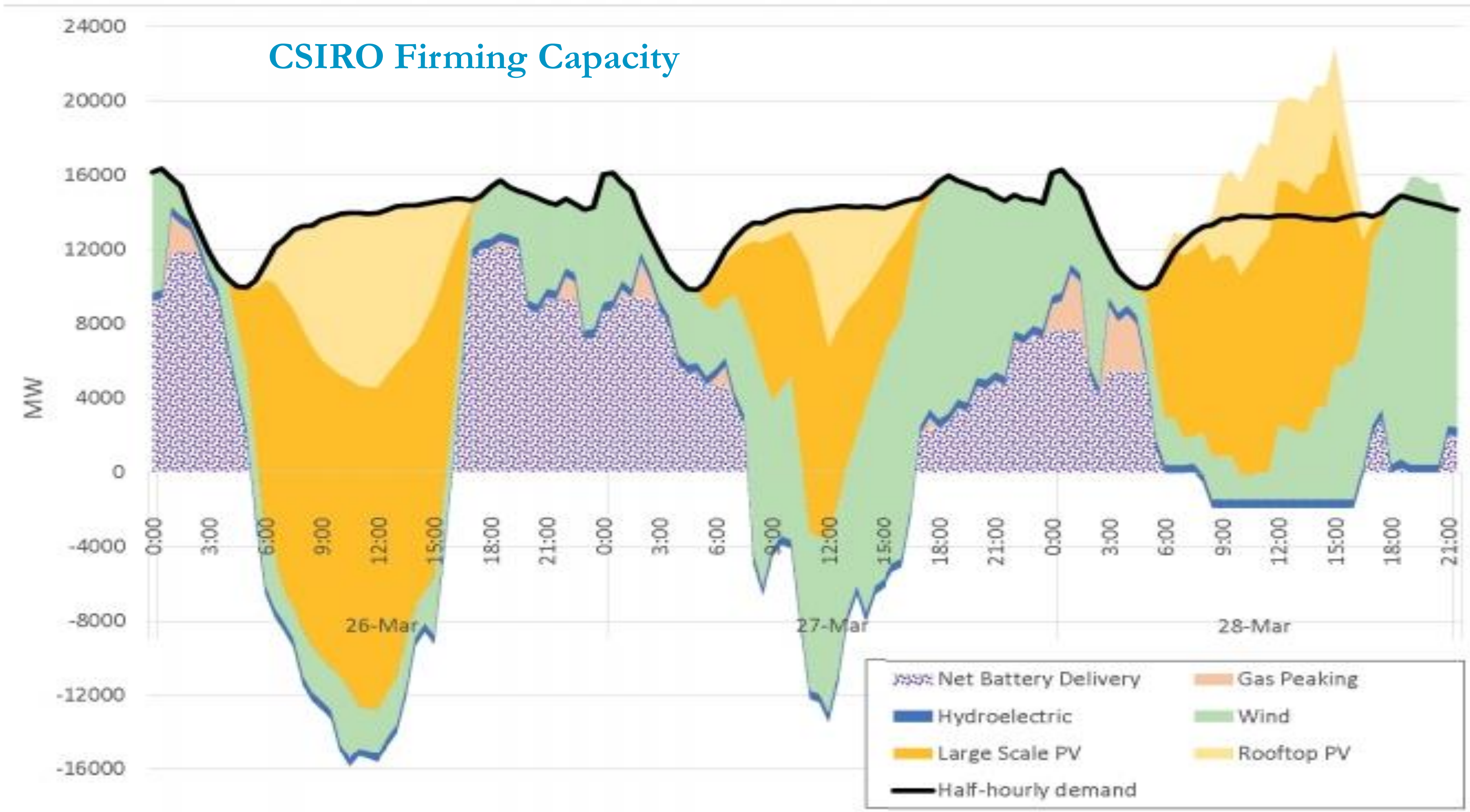


Figure 37. Example time series of electricity supply and demand in Pathway 2 showing role of battery storage; NSW, 2046, 3 example days

Appendix 2: 22DISP Firming Capacity (cont.)

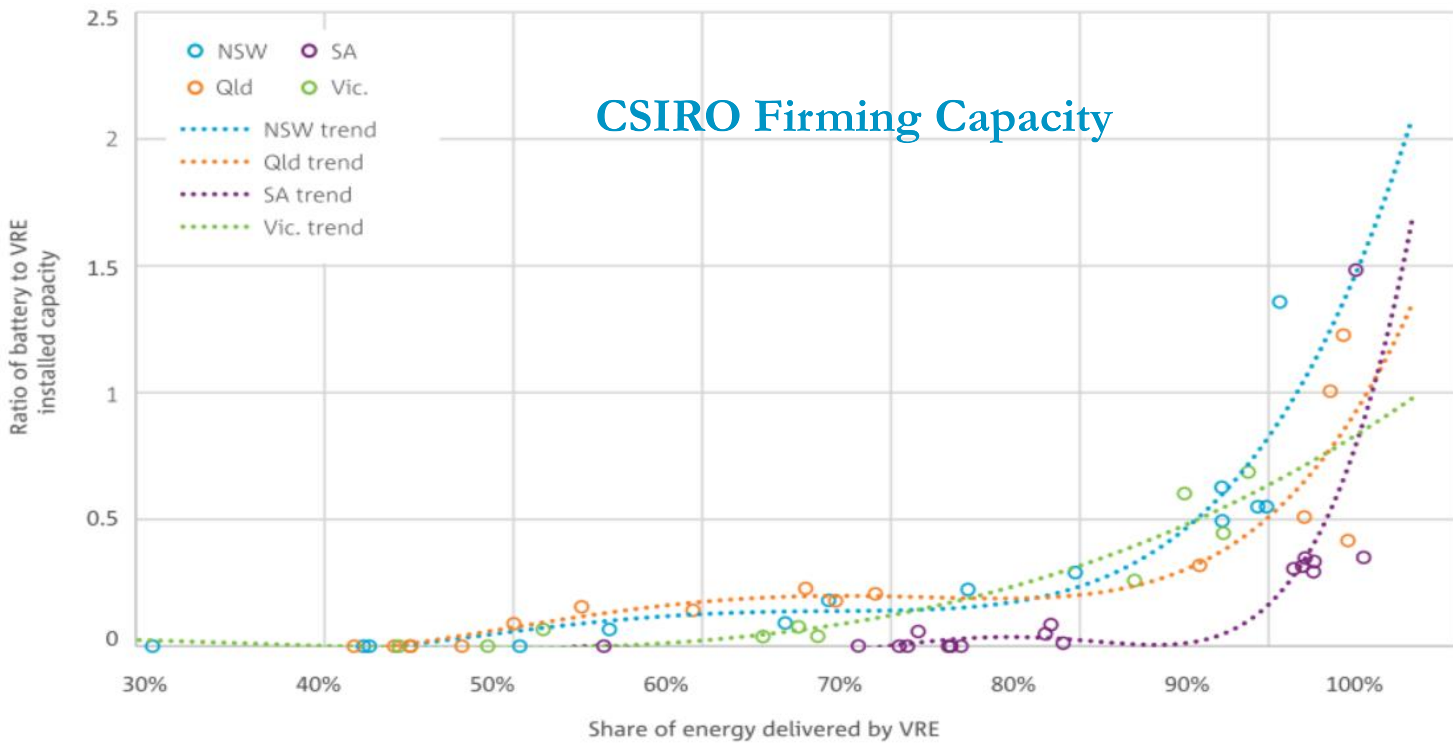


Figure 11. Ratio of battery and VRE generation capacity (GW) required to achieve energy balancing for modelled shares of energy (GWh) delivered by VRE

- The Figure demonstrates that as the VRE Ratio increases, the FC Ratio increases exponentially to ensure a reliable supply of electricity.

Appendix 3: Generation costs - Firmed VRE

FY22 dollars	Units	Black Coal	CCGT Gas	Wind	LS Solar PV	Firming[2]
Inputs[1]						
Economic Life	years	30	25	25	20	20
Construction and Connection Cost	$/kW	$4,697	$1,896	$2,270	$1,495	$2,726
Fixed O&M (FOM) cost	$/kW/yr	$55.15	$11.30	$27	$18.54	$28
Annual capacity factor[3]	%	95%	94%	31%	21%	27%[4]
Variable O&M (VOM) cost	$/MWh so	$4.37	$3.84	$0.00	$0.00	$0.00
Heat Rate	GJ/MWh so	8.82	7.25	NA	NA	NA
FY21 Fuel Cost	$/GJ	$2.70	$11.03	NA	NA	NA
Auxiliary Load	%	4.0%	2.50%	0.28%	0.20%	0.00%
Calculations						
Annual capital cost[5]	$/kW	$323.18	$141.35	$169.23	$125.09	$136.29
Annual FOM	$/kW	$55.15	$11.30	$27.27	$18.54	$28.02
Fixed Generation Cost	$/kW	$378.33	$152.65	$196.50	$143.63	$164.31
Annual generation at the capacity factor	kWh so	7,989	8,029	2,689	1,830	2,346
Fixed Generation Cost	$/MWh	$47.36	$19.01	$73.07	$78.50	$70.05
VOM	$/MWh	$4.37	$3.84	$0.00	$0.00	$0.00
Fuel Cost	$/MWh	$23.86	$79.93	$0.00	$0.00	$0.00
Total Generation Cost	**$/MWh**	**$75.58**	**$102.78**	**$73.07**	**$78.50**	**$70.05**

Notes: see next page.

Appendix 3: Generation costs - Firmed VRE (cont.)

Notes:

1 Source: AEMO 2021 Inputs and assumptions workbook, December 2021, New Entrant Data Summary Sheet (**AEMO 21 Inputs**), unless otherwise specified.

2 Firming Capacity: Battery Storage (8hrs storage), CNSW, NSW Low.

3 Capacity factors:

- Planned outage rate (**POR**) 2.9% (AEMO 21 Inputs) and a forced outage rate (**FOR**) 2.1% (assumption).
- CCGT Gas POR 3.5% (AEMO 21 Inputs) and a FOR 2.5% (assumption).
- The wind and solar capacity factors are the 2049-50 results for the Step Change scenario from the Draft 2022 ISP Chart Data and the Generation Outlooks provided with the 22DISP.

4 The relevant figure for Firming is the weighted average of the utility scale solar figure (40%) and the wind figure (60%). The weighting ratio is based on the 2049-50 generation forecast for the Step Change scenario from the Generation Outlooks provided with the 22DISP.

5 Annual payment (principal and interest) required to amortise the total Construction and Connection Cost over the economic life of the relevant technology applying a WACC of 5.5% based on the CBA Methodology. (Page 85)

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