NO LONGER LOST IN TRANSMISSION

August 2023 | Bruce Mountain, Simon Bartlett and Darren Edwards

Expanding transmission need not be at the expense of land-holders, renewables investors, communities, consumers and the environment.

VICTORIA UNIVERSITY

Victoria Energy Policy Centre

The **Victoria Energy Policy Centre** (VEPC) is a research centre focussing on policy challenges in energy in Australia, with a particular focus on Victoria. The VEPC's core research discipline is economics, but we encourage collaboration between experts from different academic traditions. We combine academically rigorous research and analysis, with a practical understanding of government processes.

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EXECUTIVE SUMMARY

Variable renewable electricity generation (rooftop solar, wind and solar farms) has grown more quickly in Victoria than in any other jurisdiction of Australia over the last decade. From just 2.7% of demand supplied by the transmission system in the first half of 2012, it has reached 43% in the first half of 2023. This is remarkable progress. However, the transmission system required to connect the new generation to the centres has hardly changed.

The Australian Energy Market Operator (AEMO's) modelling for the VNI-West Project Assessment Conclusion Report (PACR) shows that AEMO expects that for the next four years the wind farms in Western Victoria will waste up to 40% per year of the electricity that they are able to produce because the transmission system is not able to accommodate their production. The picture is no better with solar farms in the Murray River REZ expected to waste up to 40% per year of their production potential over the next eight years. By national and global standards of variable renewable generation curtailment, these are extremely poor outcomes. This suggests a major failure of transmission planning and transmission development.

There can be no doubt that to reduce such waste and to more than triple the production of electricity from large scale solar and wind, as is needed to meet the Victorian Government's target that 95% of Victoria's electricity is sourced from renewable energy generated in Victoria by 2035, significant transmission expansion is needed. Co-located storage will help to reduce curtailment and improve the utilisation of transmission but will not obviate the need for significant expansion of the transmission system. A credible transmission expansion plan that is accepted by affected communities, taxpayers, consumers, and renewables investors is now a critical factor not just in the transition to renewable electricity but also in keeping the lights on.

AEMO is responsible for planning the expansion of Victoria's transmission system, a role that it does not have in other jurisdictions. Together with Transgrid - the New South Wales (NSW) transmission monopoly - AEMO has proposed VNI-West, a new 500 kV double circuit transmission line that starts on the north west outskirts of Melbourne and ends at Wagga Wagga in the south west of NSW, via Bulgana, Kerang and Dinawan. The

Dinawan to Wagga Wagga section is shared with Project EnergyConnect (PEC) and is also yet to be constructed. If it is eventually built, VNI-West will be by far the most expensive transmission line developed in Australia.

AEMO and Transgrid say that VNI-West and a much smaller augmentation of transmission in South Western REZ (by 2034) and an even smaller augmentation in Central Northern REZ (by 2046) is all that is needed to almost completely decarbonise electricity supply in Victoria.

AEMO first proposed VNI-West in its inaugural 2018 Integrated System Plan ("2018 ISP"). The 2018 ISP mentioned "interconnector" or its equivalent 145 times. In addition to VNI-West, the 2018 ISP also recommended major new interconnectors between Tasmania and Victoria, between South Australia and NSW and between NSW and Queensland.

This interconnector super-highway philosophy did not however originate in the 2018 ISP. The blueprint for the development of 500kV interconnector super-highways was initially sketched out as the "NemLink" proposal in AEMO's inaugural Transmission Network Development Plan in 2010.

In the case of VNI-West, this part of NemLink took a leap forward when Snowy Hydro proposed Snowy 2.0, thus leading to AEMO's suggestion of what it then called "SnowyLink South" which it justified on the basis that it would connect Snowy 2.0 to Victoria. SnowyLink South was subsequently renamed VNI-West, presumably when it became clear to AEMO that its modelling found that the construction of VNI-West would not have a material impact on Snowy 2.0's operation.

In the 2018 ISP, AEMO said that it expected that the first leg of VNI-West, a 500 kV transmission line between Melbourne and North Ballarat, would be commissioned in 2023. The environmental impact assessment of this proposed project has yet to be completed.

AEMO's assessment and our critique of AEMO's assessment

AEMO contends that the benefits of VNI-West substantially exceed its costs. It concludes that the main benefit of VNI-West for Victoria is being able to substitute new pumped hydro in Victoria for batteries in NSW. Across the NEM, AEMO says the main benefits of VNI-West are the deferral or "avoidance" of the amount of renewable generation needed to meet demand.

In our Submission to the VNI-West Consultation Report, we pointed to AEMO's assumptions indicating that renewable generation costs were comparable across the NEM, and so questioned how such expensive interconnection could be justified. AEMO rejected such analysis which it derided as "simplistic" and insisted that its modelling (with its consultants EY) took account of all relevant factors and credibly forecast outcomes for every hour until 2050.

In fact, such modelling does not have intelligence of its own. It is no more than a conventional optimisation calculation that relies on many input assumptions and a simplistic characterisation of the market and electrical system. We have identified many concerns about the assumptions and methodology which AEMO has used (set out in our Submission[1]), none of which AEMO has adequately addressed.

To get a "first-principles" assessment of the value of increased interconnection between NSW and Victoria we compared the value that would arise if the cheapest wind or solar in NSW displaced the most expensive wind or solar in Victoria (and vice versa) using CSIRO's latest assumptions of costs (AEMO will use these in its forthcoming ISP) and AEMO's latest assessment of all other relevant parameters. We found that the value per MW is less than a quarter of the cost of VNI-West per MW.

With reference to data on the correlation of wind/solar resources in some REZs in NSW with others in VIC, AEMO also suggests that interconnection is valuable in being able to diversify variable renewable generation. The value of diversification of variable renewable resources is difficult to estimate and it is not yet well understood. But AEMO's

[1] https://www.vepc.org.au/_files/ugd/92a2aa_18d15bdcf9034cc68684754e0c14d526.pdf

data suggests no greater diversification of variable renewable generation between NSW and VIC than it finds within REZs in VIC, or within REZs in NSW.

AEMO has had powerful incentives over a long period of time to produce compelling evidence on the value that interconnection might have in diversifying variable renewable supply risk. That it has failed to produce such evidence despite such powerful incentives to produce it, is telling.

Leaving to one side our critique of the merits of interconnection, our analysis of the results of AEMO's modelling analysis of VNI-West finds that it is not successful in meaningfully addressing the pressing problem of renewables curtailment in Victoria. AEMO's results show a slight reduction in renewable curtailment in those REZs affected by VNI-West in the decade after VNI-West is commissioned. But this is followed by a return to the pre-VNI-West levels of curtailment a decade after commissioning.

AEMO admits that such curtailment will discourage the renewable generation expansion that its model predicts but then says that the (now defunct) "Post 2025 Project" by the (now defunct) Energy Security Board will reform the market (i.e. change the arrangements so as to compensate curtailed generation for their unsellable production) so that its renewable generation expansion predictions come true.

AEMO also defends its projected curtailment on the basis that it has determined the "efficient" outcome. This is not correct: AEMO has failed to account for generation curtailment (i.e. that curtailed generators will require higher prices than uncurtailed generators in order to compensate their curtailment) in its modelling of the relative economics of variable renewable generation and transmission.

Moving onto the impact on prices as a result of its proposals, AEMO says that VNI-West will only raise transmission charges by 25% in Victoria. But AEMO uses 2021 prices, a cost of capital that does not reflect the re-pricing of risk that AEMO is adopting in its forthcoming ISP, ignores interest during construction and understates capital costs and greatly understates operating costs. AEMO, in collaboration with other transmission network service providers, has a track record of under-estimating, often by a very wide

margin, the costs of transmission projects including those that it proposes[2]. Correcting for these underestimates and errors will mean that VNI-West alone (excluding the additions that are essential for it to integrated with the Victorian grid) can be expected to double transmission charges in Victoria. But developing the VNI-West project will require (in addition to the cost of VNI-West alone) a further $3.2 billion[3] to be spent on Victoria's 220 kV transmission networks (in the Murray River and Western Victoria REZs) just so that VNI-West's 500 kV lines are able to integrate with Victoria's 220 kV transmission system. This means that VNI-West can actually be expected to increase transmission charges by at least 127%.

How can this apparent failure in planning be explained?

Various factors may have played a role. Perhaps a perfectly understandable desire to bed down a plan – and recognising the prodigious effort needed to obtain acceptance for a plan - has resulted in rigidity and impeded responsiveness to new information. We have previously suggested that since NEMLink was proposed in 2010, wind generation costs are now a third and solar a tenth of what they were then. Recent academic research in the United States finds the same trends there[4]. In addition, it is now evident that the capital, social and environmental costs of transmission have been greatly under-estimated. Furthermore, AEMO's work suggests that the temporal diversity of variable renewable generation is no bigger between neighbouring regions of the NEM than it is within regions, contrary to what has long been suggested to be the case. A failure to respond to this new information has resulted in transmission plans that have become superseded by events and new knowledge.

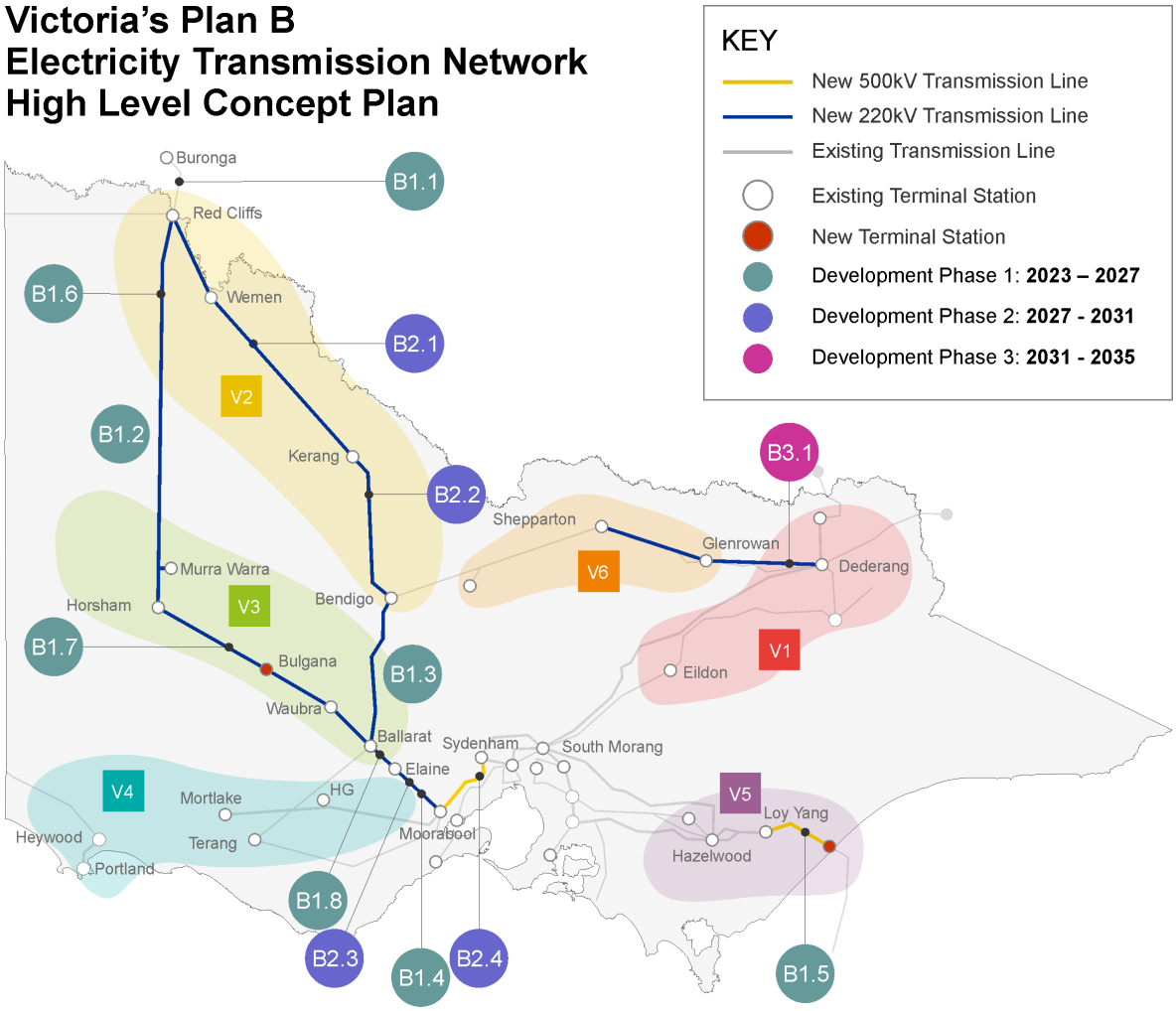
[2] For example: In 2018 AEMO estimated that HumeLink (then called SnowyLink North) would cost between $575m and $1,725m (and would be completed by 2025). TransGrid has now admitted it will cost more than $5 billion (excluding interest during construction and project management costs) and construction of it is yet to begin. For Project Energy Connect from South Australia, AEMO estimated it would cost $1bn in 2016 (and be completed by 2021), but in 2021 the Australian Energy Regulator allowed $2.3bn. We understand that the latest estimate is $3.5bn although neither Electranet, Transgrid or AEMO have said so publicly yet. For the whole VNI-West, AEMO estimated $2.7bn in 2018 (of which about half in Victoria), but in the PACR it said the Victoria element would be $3.3bn. For the first leg of VNI-West to North Ballarat, in its 2019 PACR, AEMO said it would cost $479m, but by November 2022 it said $789m. We estimate the Victorian half of VNI West to now be $4.9bn (2023$) (see Appendix D).

[3] To be clear this about the same as what AEMO has suggested VNI-West alone will cost.

[4] See for example "Transmission Impossible? Prospects for Decarbonizing the US Grid". Lucas W. Davis, Catherine Hausman, and Nancy L. Rose NBER Working Paper No. 31377 June 2023.

Plan B

Considering the importance of an effective plan and our conclusion that AEMO's plan is not adequate, we have developed an alternative, "Plan B", to be implemented in three phases, illustrated in the chart below.



Ref	REZ	Phase 1 Projects
B1.1	V2	Open-circuit Buronga – Red Cliffs 220 kV line
B1.2	V2-V3	Increase maximum conductor temperature on some 220 kV lines
B1.3	V2-V3	On-line dynamic rating Red Cliffs-Ballarat-Moorabool-Sydenham
B1.4	V3	Elaine to Moorabool
B1.5	V5	Gippsland REZ – 500 kV Loy Yang to near Basslink Transition Point
B1.6	V2	V2 220 kV network upgrade: Red Cliffs to Murra-Warra
B1.7	V3	V3 220 kV network upgrade: Murra-Warra to Ballarat
B1.8	V3-V4	V3-V4 220 kV network upgrade Ballarat – Moorabool (line 1)
		Phase 2 Projects
B2.1	V2	V2 220 kV network upgrade: Red Cliffs to Kerang
B2.2	V2-V3	V2-V3 220 kV network upgrade Kerang-Bendigo-Ballarat lines
B2.3	V3-V4	V3-V4 220 kV network upgrade Ballarat-Moorabool (line 2)
B2.4	V4	V4 500 kV S/C Sydenham to Moorabool
		Phase 3 Projects
B3.1	V6-V1	V6-V1 220 kV line Shepparton-Glenrowan-Dedarang

Plan B is designed to deliver sufficient transmission infrastructure to deliver Victoria's Renewable Energy Target (VRET) of 65% (of Victorian electricity generation) to be supplied by renewable sources in Victoria by 2030, and 95% by 2035. In addition, Plan B is designed to meet three subsidiary objectives:

- less than 13% curtailment, and marginal loss factors exceeding 0.93 in the Murray River and Western Victoria REZs (i.e. even lower curtailment and smaller marginal losses in the other REZs);
- no Single Points of Failure (SPoF) on new transmission lines that are likely to be defined as Systems of National Significance under the Security Legislation Amendment (Critical Infrastructure Protection) Act 2022 (SLACIP Act); and
- minimising the amount of new land required for transmission by making use of existing transmission networks and easements wherever possible.

Unlike AEMO's primary objective for VNI-West being to strengthen interconnection with NSW, for the reasons set out earlier there is no reason to believe that this is valuable and so we have not pursued interconnection as a design objective. If Victoria and NSW wish to pursue stronger interconnection for other reasons this is of course a matter for the respective governments. If so, this should be stated and explained and the design objectives of such interconnection clearly stated so that suitable options may be proposed.

To fairly compare Plan B to AEMO's plan, we could not limit the analysis to VNI-West and the 1,500 MW augmentation that AEMO anticipates in South Western Victoria. Rather we had to include two major projects to augment the 220 kV networks in the Western Victorian and Murray River REZs without which VNI-West will not be able to offer any increase in hosting capacity in Victoria. We also included a necessary augmentation in Gippsland and between Shepparton and Dederang without which AEMO's renewable hosting capacity increases are obviously impossible to achieve. Together this constitutes what we call AEMO's "Extended VNI-West" project, which can be compared with Plan B. The key points of the comparison are as follows:

- Plan B offers a total variable renewable hosting capacity of 16.8 GW in order to ensure curtailment below 13% in all REZs and to provide greater flexibility and equity between REZs. By comparison, Extended VNI-West offers total hosting

capacity of 14.8 GW and average curtailment across all Victoria's REZs of 20% from 2032 (when VNI-West is assumed to be commissioned) to 2050. Plan B has more hosting capacity in the Murray River, Western Victoria, Central North and Gippsland REZs. It will offer comparable hosting capacity to Extended VNI-West in the Ovens Murray and South West REZs.

- Plan B's total line length is 1,451 km. With the exception of AusNet's proposed G-REZ projects in Gippsland, all Plan B projects use existing or spare easements, thus greatly reducing impacts on landholders. By comparison only 2 of Extended VNI-West's 7 projects (386 km out of total length of 1,659 km) use existing easements.
- Most of Plan B's projects are 220 kV with 41 metre towers, with a small length of single circuit 500 kV towers up to 48 meters high. By comparison 466 km of Extended VNI-West's projects are double-circuit 500 kV, with 70 to 80 metre high towers. Since visual impacts rise as the square of height, shorter towers have substantially smaller visual impact.
- Plan B is projected to cost $6 billion whereas Extended VNI-West is expected to cost $11 billion (about three times the value of Victoria's existing transmission network).
- Extended VNI-West has more than 1,000 "single points of failure" on transmission lines that are likely to be defined as a System of National Significance under the Security Legislation Amendment (Critical Infrastructure Protection) Act 2022 (SLACIP Act). Plan B eliminates the risk of cascading collapse of the Victorian grid by avoiding double circuit 500 kV single tower lines and by making the most of Victoria's deeply meshed, dual redundant and resilient 220 kV network.
- Extended VNI-West has much greater risks of project delivery delays and cost blow-outs associated with supply chain constraints, skilled labour shortages, insufficient competent contractors, social licence challenges, inadequate competition, and conflicts with other Victorian critical infrastructure provision. This is because it requires the establishment of a new 500 kV network in central-north-western Victoria whereas Plan B utilises less complex, standard 220 kV plant and construction services. VNI-West requires several massive 500 kV substations with expensive and scarce power transformers, line reactors and 500 kV switchgear together with large amounts of sophisticated, higher risk power electronics equipment including power flow controllers, series compensation and FACT's devices.

- Our "multi-criteria assessment" (gives Plan B a score of 23 and Extended VNI-West 79 (the lower the score the better). The biggest differences between Plan B and Extended VNI-West are in the areas of socio-economic & environmental, visual and culture & heritage. At the route of this difference is that Extended VNI-West consumes so much more land than Plan B.
- Extended VNI-West is likely to increase annual electricity bills in Victoria by $1.1bn more than Plan B. To put this into context that is about 170% the level of transmission charges in Victoria this year.

The comparison between Extended VNI-West and Plan B is summarised below.

	Extended VNI-West	**Plan B**
Total length new lines	1,659 km	1,451 km
Requires new easements. Located on existing easements. Require minor (~10) widening	1,270 km 386 km	130 km 281 km 1,040 km
Area of new easements	733 ha	169 ha
Multi-Criteria Analysis (the lower the better) 1. Cost 2. Socio-economic & Environmental 3. Visual 4. Cultural & Heritage Total	 15 32 20 12 79	 10 7 3 4 23
Capital cost (2023 dollars)	$11 billion	$6 billion
Renewables hosting capacity by 2035 (MW)	14,830	16,675
Curtailment (REZs affected by VNI-West)	20% to 40%	13%
Marginal loss factors (REZs affected by VNI-West)	0.80	0.93
Single Points of Failure	~ 1000	0
Increase in annual electricity bills relative to Plan B	$1,124 million	0

Recommendations

We present the following recommendations for consideration by the Victorian Government, the Australian Government, and the Energy and Climate Change Ministerial Council.

1. Recommendations for consideration by the Government of Victoria

a) The confusion created by the multiplicity of transmission planning bodies in Victoria should be resolved as a matter of urgency by appointing VicGrid as the Victorian Jurisdictional Transmission Planner under the National Electricity Rules

or equivalent role under the National Electricity (Victoria) Act 2005, in place of AEMO.

b) VicGrid should be asked to publicly advise, using its Victorian Transmission Investment Framework (VTIF), on the relative merits of Plan B compared to AEMO's VNI-West in meeting the Victorian Government's target that 95% of Victoria's electricity is sourced from renewable energy generated in Victoria by 2035.

c) VicGrid should be asked to advise, as a matter of urgency, on the merits of implementing projects B1.4, B1.7 and B1.8 in advance of any decision to develop VNI-West to Bulgana at 500 kV.

d) VicGrid should be asked to advise, as a matter of urgency, on the specific merits of implementing projects B.1.6, B2.2, B2.3, and B2.4 of Plan B in advance of any decision to develop VNI-West from Bulgana to Kerang.

2. **Recommendations for consideration by the Australian Government:**

The Clean Energy Finance Corporation has been asked to issue loans funded by the Rewiring the Nation funding pool. Considering the concerns raised in this report about AEMO's assessment of the costs and benefits of the proposed transmission augmentations, the Productivity Commission should be asked to advise on the principles and criteria to be followed by the CEFC in its decisions on loans funded by the Rewiring the Nation funding.

3. **Recommendations for consideration by the Energy and Climate Change Ministerial Council:**

While this report has focussed specifically on VNI-West, the failure of transmission expansion planning it suggests, is systemic and should be seen in the broader context of the Regulatory Investment Test, the Actionable Integrated System Plan regulatory arrangements, the Take-Out-One-at-a-Time methodology for the AER assessment of Contingent Project Applications and the relative roles of AEMO versus state-based transmission network service providers.

We recommend an inquiry into these arrangements led by eminent persons who have no current or prior relationships to Australia's existing regulatory institutions or major electricity producers. The terms of reference of this inquiry should seek advice on changes to the arrangements for transmission planning and transmission access that will ensure that national and state-based emission reduction targets are met at the lowest possible cost to electricity consumers and taxpayers, landholders, affected communities and the environment.

1 Introduction

The Australian Energy Market Operator's (AEMO) Victorian planning division - AEMO Victorian Planning (AVP) - in partnership with the New South Wales (NSW) transmission monopoly (Transgrid) recently finalised its assessment of a major new interconnection "VNI-West" between Victoria and NSW. The line is proposed to run from Sydenham on the outskirts of Melbourne in a north-westerly direction for about 190 km to near Bulgana in Western Victoria and then in a north-easterly direction for 220 km to pass into NSW near Swan Hill and thence for about 220 km to Dinawan to connect with a new interconnector "Project EnergyConnect" (PEC) being built between Adelaide and Sydney. It then shares the 170km long 500 kV section of PEC to the new Gugga substation near Wagga Wagga. The total length is around 800 km.

VNI-West will involve about 1,600 steel towers, placed about 400 meters[5] from the other, each with 24 insulators holding 24 conductors which, if placed end to end, would go between Melbourne and Sydney 22 times. This transmission line, if it is ultimately built, will be the most expensive and longest single line ever developed in Australia. Most of VNI-West is to be built on land that does not currently host a transmission line or is not on a pre-existing easement.

The rest of this introduction explains why this report has been written, provides history and context to the VNI-West proposals, and explains the layout of this report.

5 https://www.transmissionvictoria.com.au/assets/PDF/fast-facts-farming-and-electricity-transmission-v07.pdf

1.1 Why has this report been written?

AEMO says that by the end of this year, Victoria will have a little over 5,000 MW of large-scale wind and solar generator. AEMO's analysis in the VNI-West PACR also suggests that it expects that this year 29% of Victoria's wind generation and 25% of its large-scale solar generation in the Western Victoria and Murray River REZs respectively, will be curtailed i.e. not able to produce electricity because the transmission system is not able to accommodate it. This "wasted" electricity will be replaced mainly by highly polluting generation from Victoria's coal-fired generators.

Renewable generators in Victoria had not anticipated this curtailment and many of their owners are sustaining large financial losses. Unless this is rectified, renewable generators will be deterred from investing in Victoria.

This is especially important because the Victorian Government's target is that 95% of the electricity consumed in Victoria is to be produced by renewable generation in Victoria, by 2035. Achieving this target will require the capacity of wind and solar generation in Victoria to roughly triple from the current level. To attract the circa $20bn needed to fund the new generation, a very rapid and large expansion of transmission capacity in Victoria will be needed to ensure that existing and new generators are able to reliably access the market.

AEMO is responsible for planning the transmission system in Victoria. Other than its VNI-West interconnector, AEMO says that little other transmission is needed to meet Victoria's targets over the next 25 years.

The Victoria Energy Policy Centre, in collaboration with Simon Bartlett and Darren Edwards has studied AEMO's proposals and has engaged in AEMO's consultations on it.

Our previous work and commentary can be found here[6], here[7], here[8] and here[9]. Our analysis leads us to the conclusion that there has been an important failure of transmission planning. Specifically, AEMO's plan will place a large burden on affected land-holders, the environment, existing and future renewable generators and consumers. It will also greatly increase Victoria's exposure to the risk of catastrophic power system failure, will cost far more than AEMO says and exposes Victoria to technology, labour supply and investment constraints. Large subsidies for new entrant renewable generators will be needed to compensate renewable generators for the enduring curtailment that AEMO's plan exposes them to. For these reasons, and the sheer cost of AEMO's plan, electricity will cost far more than it needs to ensure that the Government's renewable energy targets are met. This report draws on and extends our previous work to provide the reasoning and evidence to support these conclusions.

The ills we expect are avoidable and we propose a transmission expansion plan that avoids them. The essence of our "Plan B" is to upgrade Victoria's existing 220 kV networks, using existing towers and easements as far as possible to expand the hosting capacity of renewable generation around Victoria.

This report presents that plan, and recommendations for consideration by the Victorian Government, Australian Government and the Energy and Climate Change Ministerial Council.

1.2 History and context

The first official mention of VNI-West (then known as Snowylink South) was in AEMO's inaugural Integrated System Plan in 2018 ("2018 ISP"). In the 2018 ISP, AEMO first set out the details for its vision for the development of strengthened interconnection from Tasmania to Queensland. The words "interconnector", "interconnection" and "interconnected" were used 145 times in the 2018 ISP and it is that document that first

[6] https://www.vepc.org.au/_files/ugd/92a2aa_18d15bdcf9034cc68684754e0c14d526.pdf
[7] https://reneweconomy.com.au/put-up-a-parking-lot-why-these-new-transmission-projects-will-fail-wind-and-solar/
[8] https://reneweconomy.com.au/new-links-could-turn-victoria-into-energy-importer-solar-and-storage-would-be-cheaper/
[9] https://reneweconomy.com.au/the-investment-test-for-electricity-transmission-has-become-a-sham/

presented and argued in detail for what it then called VNI-West. The grand vision for 500 kV AC interconnection was first sketched out in the "NEMLink" proposal in AEMO's inaugural Transmission Network Development Plan in 2010[10], with an interconnector planned to run from Melbourne to Bendigo and then due north east to Sydney.

In the 2018 ISP, VNI-West was called "Snowy Link South" and AEMO said it would allow Victoria to access the benefit of the forthcoming Snowy 2.0 pumped hydro power station in NSW. VNI-West has had two legs, the first called (at first) the Western Victoria Transmission Network Project (WVTNP) that started in Sydenham on Melbourne's outskirts and was initially planned as a dual-circuit 500 kV line to a new terminal station north of Ballarat then continuing as a 220 kV dual-circuit line to Bulgana. The Environmental Effects Statement for the WVTNP is yet to be completed, and the WVTNP has since changed name and has now a very different configuration from the initial proposal and is now 500 kV dual circuit for its full length.

The regulatory assessment of the WVTNP was completed in 2019. AEMO said that the main benefit of the WVTNP would be greater generation from Victoria's (cheap) brown coal generators that would be delivered through the WVTNP along with the second leg of SnowyLink South (from Ballarat to Bendigo to Kerang and then to NSW) displacing generation from more expensive black coal generation in NSW and Queensland, until 2075.

A much cheaper option for the expansion of transmission to western Victoria (from Sydenham via Moorabool to Bulgana) that did not pre-suppose interconnection with NSW was rejected by AEMO on the basis that its preferred option (connecting to the second leg of SnowyLink South) would have higher net benefits. This calculation depended on excluding most of the cost of a new terminal station north of Ballarat from the preferred option, on the basis that that cost would be included in the second leg of SnowyLink South (from Ballarat to Bendigo to Kerang and then to NSW).

[10] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ntndp/2010/2010-ntndp.pdf?la=en&hash=96894D728DF1C9CC24BCDECBD618DF0E

AVP/Transgrid's draft assessment of VNI-West was released in July 2022. This time it was recognised that Victoria's coal generators would not run to 2075, but nonetheless AEMO's modelling assumed greater coal generation if VNI-West was built than if it was not built, and this was a large source of its claimed benefit.

AEMO also excluded most of the cost of the North Ballarat terminal station on the basis that the WVTNP (now renamed the Western Renewables Link - WRL) would proceed and so the terminal station would be built anyway therefore there was no need to include it in the cost of VNI-West (by this time the second leg of SnowyLink South from North Ballarat to Kerang had been renamed "VNI-West"). In this way, about $300m of expenditure had been assumed away from both WRL and what was then called VNI-West.

In February 2023, AVP/Transgrid issued a new "Consultation Report" (effectively a new draft assessment) to assess new options for VNI-West that would now be 500 kV for its entire length from Sydenham to Dinawan. At this point "VNI-West" now described the single project between Dinawan in NSW to Sydenham in Melbourne with possible routes via Kerang to Bulgana to Ballarat to Sydenham or via Bendigo to Ballart to Sydenham.

This Consultation Report, at last, honestly recognised that WRL (which had many possible forms) and what was originally called "SnowyLink" (which also had many possible forms) were simply the two sequential legs of what was always envisaged as a new interconnector from Melbourne to Sydney. The Consultation Report did not assess the costs and benefits of the whole line as it only included the incremental costs of increasing the voltage of WRL from 220 kV to 500 kV.

VNI-West has been progressively pushed further and further west starting from the shortest, most direct route alongside the existing 330 kV VNI, then a central route via Shepparton, then even further west via Kerang, and now via south-west NSW. This has increased its length by as much as 500 km and has also increased the electrical impedance of VNI-West reducing its utilisation and its effectiveness compared with the existing VNI.

There are currently legal challenges (in the Supreme Court) to AEMO's regulatory assessment of the WVTNP and separately also to two sets of Orders issued by the Victorian Minister for Energy and Resources, relating to the development of VNI-West.

Objections have also been made to the Australian Energy Regulator that AEMO's assessment of VNI-West does not comply with the National Electricity Rules.

1.3 Plan B

Our Plan B is designed to deliver sufficient transmission infrastructure to deliver Victoria's Renewable Energy Target (VRET) for 65% (of Victorian electricity consumption) to be supplied by renewable generation in Victoria by 2030 and 95% by 2035. Under VRET's 95% target, Victoria's will need to completely replace its coal-fired generation with renewables, with the only remaining fossil-fuelled generation being gas turbines operating infrequently.

Our primary Plan B design objective is accompanied by five subsidiary objectives:

a) Deliver less than 13% curtailment, and marginal loss factors exceeding 0.95 95 for V2 and V3 REZs and even lower for other.
b) Avoid Single Points of Failure (SPoF) on new transmission lines that are likely to be defined as Systems of National Significance under the Security Legislation Amendment (Critical Infrastructure Protection) Act 2022.
c) Minimise the amount of new land required for transmission by making use of existing transmission networks and easements wherever possible.
d) Minimising public opposition (which has been a material source of delay for transmission projects).
e) Diversifying large scale supply around the State.

The last of these five subsidiary objectives means that although it may well be cheaper to concentrate renewable supply in Gippsland so as to take advantage of the Latrobe Valley to Melbourne transmission capacity, we have instead allowed for substantial transmission augmentation around Victoria. We have done this in anticipation that this may fit better with Government's policy, and the expectations of many in the community.

Considering the enormous uncertainty about Victoria's future electricity demand and the prodigious rate of technology change, attempting to plan beyond 2035 invites grave

mistakes. For this reason, and the Victorian Government's very substantial 2035 renewable electricity target, we plan to 2035.

1.4 Layout

Section 2 establishes the renewable hosting requirement that the Victorian transmission system needs to have in order to meet the Victorian Government's renewable energy targets. Section 3 and Appendix D examine Plan B. Section 4 and Appendix E presents AEMO's plan. Section 5 is comparative critique of Plan B and AEMO's plan. Section 6 draws attention to concerns about the governance of transmission. The final section presents recommendations. Appendices A, B and C respond to contentious issues that we raised in our Consultation Report that AEMO responded to and that merit a written public response.

2 Renewable generation hosting capacity needed to meet the Victorian Renewable Energy Target (VRET)

This section presents and explains our calculation of the renewable generation hosting capacity needed to meet the VRET.

2.1 Renewable electricity production target

Plan B uses the Victoria end use electricity demand projections in AEMO's 2022 *ISP's* Step Change Scenario, for the purposes of developing a like-for-like comparison. We nonetheless suggest that the forecast demand growth in Victoria in the ISP is likely to be exaggerated, noting it assumes that over the period to 2050, demand in Victoria will grow by 120% compared to 76% in NSW.

We also suggest that AEMO has been too optimistic in the assumed rate of growth of distributed (behind the meter) solar (rising by a factor of almost three between now and 2031). It may be that this served a (strategic) purpose in AEMO's analysis (i.e. to understate the extent of large scale renewable expansion needed to meet decarbonisation objectives).

We are more conservative than AEMO in our rooftop solar expansion forecasts. The effect of this is to increase the large-scale renewable generation hosting requirement, and hence necessary transmission capacity expansion.

It is necessary to be clear about the Victorian Government's renewable energy target in order to work out the hosting requirement. The Renewable Energy Jobs Investment Act (Victoria) 2017 Act defines renewable energy targets as the percentage of electricity generated in Victoria by renewable energy sources. This is different to the Queensland definition that calculates the percentage in terms of state-wide electricity consumption (not generation).

The objects of the Victorian Act include:

a. to support the development of projects and initiatives to encourage investment, employment, and technology development in Victoria in relation to renewable electricity generation.
b. to promote the transition of Victoria to a clean energy economy.
c. to contribute to the security of electricity supply in Victoria.

To the extent that Victoria imports electricity from neighbouring states and if it can be demonstrated that this electricity is produced from renewable sources (a big "if"), then it may not be necessary to greatly expand renewable generation in Victoria (the renewable generation percentage in Victoria would increase if coal or gas is closed in Victoria even if renewable electricity production does not expand in Victoria). Amending the Act to calculate the renewable generation requirement as a percentage of total Victorian electricity consumption would eliminate this confusion. In this report we calculate the required amounts of Victorian renewables needed to comply with the objects of the Act.

Table 1 presents AEMO's load forecast for Victoria in its 2022 Integrated System Plan. This forecast does not include:

- electricity consumed in transmission network losses and distribution network losses.
- round-trip losses in front-of-meter energy storage devices.
- additional electricity consumed by residential and business customers but provided by behind-the-meter roof-top solar PV after allowing for spillage and losses.

To cater for these omissions, we use AEMO's forecasts of transmission and distribution losses contained in the 2022 ISP and the rooftop PV generation, and generation/charging energies for VPPs and distributed batteries in Victoria, extracted from the spreadsheets from the PACR for Option 5A. The final row relates the total electricity consumption to the VRET to calculate the required production from renewable electricity in Victoria.

Table 1. Required renewable electricity meet the VRET target targets in 2023, 2025, 2030 and 2035 (GWh)

Categories	2023/24	2024/25	2029/30	2034/35
Business	24,729	24,578	23,286	22,100
Residential	9,392	8,903	6,019	5,014
Electrification	5,500	6,563	8,686	13,678
Electric Vehicle charging	41	78	1,983	5,856
Hydrogen production (by AEMO)	nil	nil	nil	nil
Transmission losses	738	738	774	920
Distribution losses	1,638	1,650	1,752	2,170
Losses in grid connected energy storage	31	29	30	129
Losses in VPP's energy storage	7	17	125	213
Losses in distributed batteries	27	45	102	269
Total electricity consumption	42,103	42,601	42,625	50,439
Renewables target	37%[1]	40%	65%	95%
Required renewable energy	15,578	17,040	27,706	47,832

Note 1. Based on 2020 target of 25% and the 2025 target of 40%, the interpolated target for 2023 would be 37%.

2.2 Shortfall in renewable generation capacity in AEMO's VNI-West PACR

Having established the renewable electricity generation requirement to meet the VRET requirements, it is now possible to incorporate AEMO's forecasts for large scale renewable generation and our projection of rooftop PV generation, to work out the shortfall that needs to be made up in order to the VRET requirements. This is shown in Table 2, which includes the large scale renewable energy generation for Victoria from the VNI-West PACR spreadsheets for Option 5A in the Step Change Scenario (rows 1, 2, 3) and our projection of rooftop PV generation (row 4).

From these numbers it is possible to work out the large-scale renewable electricity generation gap relative to the VRET (row 9). This shows that by 2034/35 there will be a

shortfall of 5,141 GWh (2,130 MW)[11]. In other words, to be VRET compliant, 2,130 MW (5,141 GWh) more large-scale renewable generation must be hosted in Victoria by 2035, than AEMO has forecast in its VNI-West PACR.

Table 2. Large scale renewable energy generation shortfall (GWh)

Row	Source	2023/24	2024/25	2029/30	2034/35
1	Hydro	2,748	3,336	3,418	3,405
2	Wind (after curtailment)	10,177	12,813	20,737	29,132
3	Large-scale PV (after curtailment)	2,205	1,888	1,850	5,154
4	Rooftop PV (after curtailment)	3,872	4,128	5,100	5,460
5	Total Victorian renewables (after curtailment)	19,002	22,165	31,105	42,691
6	VRET target	37%	40%	65%	95%
7	Required renewable generation	15,578	17,040	27,706	47,832
8	Total electricity consumed in Victoria (see Table 1)	42,103	42,601	42,625	50,439
9	Shortfall in renewable generation compliance (GWh) (negative is shortfall)	0	0	0	5,141
10	Shortfall in renewable capacity (MW)	0	0	0	2,130

2.3 Required Victorian renewables hosting capacity

The required hosting capacity for Plan B to ensure that Victoria meets the VRET includes the shortfall of 2,130 MW by 2035, as well as the combined amounts of wind-power and large-scale PV in AEMO's PACR for VNI-West Option 5A. This is set out in
Table 3 below. The last row shows that by 2029/30, the Victorian transmission system must be capable of hosting 9,223 MW of renewable generation. By 2034/5 this expands to 14,903 MW.

[11] The shortfalls in renewable energy have been converted into MW's by assuming each MW delivers 2,413 MWh p.a. to Melbourne. This assumes a 50 : 50 mix of wind-power to PV, 36.8% annual capacity factor (a.c.f). for wind, at Western Vic REZ and 27% a.c.f. for PV at Murray River REZ, only 10% spillage and l.5% transmission losses.

Table 3. Required minimum VRE hosting capacity for Plan B to comply with VRET.

	2023/24	**2029/30**	**2034/35**
Option 5A: wind	4,122 MW	8,141 MW	9,881 MW
Option 5A: large scale PV	1,082 MW	1,082 MW	2,892 MW
Option 5A: Total VRE	5,204 MW	9,223 MW	12,773 MW
Shortfall (row 10 of Table 2)	0	0	2,130 MW
Plan B required minimum hosting capacity	5,204 MW	9,223 MW	14,903 MW

To meet the design objective Plan B must therefore deliver minimum renewable generation hosting capacities of 9,223 MW for 2030 and 14,903 MW by 2035 including the additional 2,130 MW by 2035, not delivered by AEMO's plan.

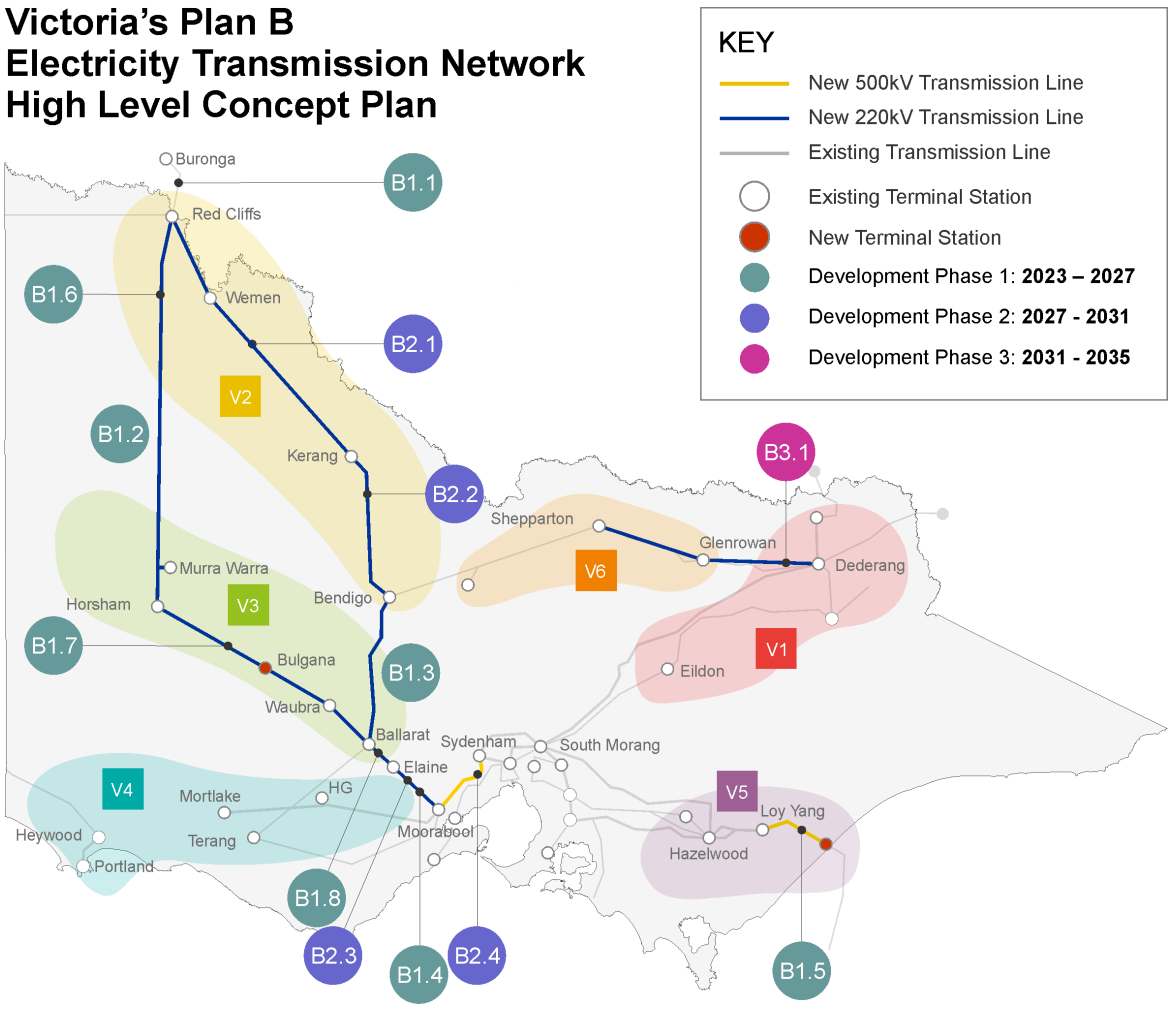
3 Plan B

This section sets out our "Plan B" for Victorian transmission augmentations to be commissioned by 2035 to meet the design objectives.

Plan B is separated into three phases:

1. Phase One (1) covers the period from 2023 to mid-2027 (to coincide with AEMO's optimistic date for when the first leg of VNI-West (WRL) would be fully operational);
2. Phase Two (2) covers the period mid-2027 to mid-2031 (to coincide with AEMO's optimistic date for when the second leg of VNI-West would be operational); and
3. Phase Three (3) covers the period mid-2031 to mid-2035, the date by which the 95% VRET is due to be met.

Figure 1. Plan B



A summary specification of Plan B is shown in Table below.

Table 4. Summary of Plan B costs and specification

	Project	Details of project scope of works	Cost ($million, 2023) including IDC	Cost ($million, 2022) excluding Interest During Construction (IDC)	Easement	Length (km)
1.1	Open-circuit Buronga – Red Cliffs 220 kV line	Daytime - open Buronga - Red Cliffs circuit to avoid overloading V2 & V3 lines			n/a	-
1.2	Increase maximum conductor temperature on some 220 kV lines	Field measurements of conductor clearances by AusNet Services			n/a	-
1.3	On-line dynamic rating Red Cliffs-Ballarat-Moorabool-Sydenham	Weather monitors and telecommunications - installed on some easements.			n/a	-
1.4	Elaine to Moorabool	Elaine - Moorabool, 220 kV D/C, twin Peach conductors, could extend to Ballarat	204	175	spare easement	43
1.5	Gippsland REZ - 500kV Loy Yang to near Basslink transition point	Loy Yang - Giffard, two 500 kV S/C lines, Giffard 500 kV/220 kV substation	842	691	AusNet Services initiated project	130
1.6	V2 220kV network upgrade: Red Cliffs to Murra-Warra	Red Cliffs - Murra Warra, 220 kV D/C, twin Peach conductors	1,003	823	existing easement, ~10 m shift	263
1.7	V3 220 kV network upgrade: Murra-Warra to Ballarat	Murra-Warra - Ballarat, 220 kV D/C, twin Peach conductors	873	716	existing easement, ~10 m shift	229
1.8	V3-V4 220 kV network upgrade Ballarat –	Ballarat - Moorabool (1), 220 kV D/C, twin Peach conductors, 500 kV/220 kV trans	289	248	existing easement, ~10 m shift	64

	Project	Details of project scope of works	Cost ($million, 2023) including IDC	Cost ($million, 2022) excluding Interest During Construction (IDC)	Easement	Length (km)
	Moorabool (line 1)					
2.1	V2 220 kV network upgrade: Red Cliffs to Kerang	Red Cliffs - Kerang, 220 kV D/C, twin Peach conductor	878	720	existing easement, ~10 m shift	230
2.2	V2-V3 220 kV network upgrade Kerang-Bendigo-Ballarat lines	Kerang-Bendigo-Ballarat, 220 kV D/C, Pearl conductors	725	595	existing easement, ~10 m shift	190
2.3	V3-V4 220 kV network upgrade Ballarat-Moorabool (line 2)	Ballarat - Moorabool (2), 220 kV D/C, twin Peach conductors, 500/220 kV transformer	289	248	existing easement, ~10 m shift	64
2.4	V4 500 kV S/C Sydenham to Moorabool	Sydenham - Moorabool, 500kV S/C, quad conductor	316	271	spare easement	63
3.1	V6-V1 220 kV line Shepparton-Glenrowan-Dedarang	Shepparton - Glenrowan - Ballaratt, 220 kV, Peach conductor	542	465	spare easement	175
	TOTAL		**5,962**	**4,952**		**1,451**

3.1 Developments not involving new lines

We suggest the following three actions to rapidly increase hosting capacity without large capital outlays:

- Existing curtailment can be quickly and significantly reduced by Victoria's transmission network owner and operator (AusNet Services) increasing the maximum allowable conductor temperature to 90 degrees. Doing this for each of the three 220 kV lines servicing REZs V2 and V3 could increase the transmission

limits by some 240 MW (i.e. 3 x 20% x 400 MW), even during Phase 1. This alone would provide much-needed additional line capacity during contingencies that currently cause much of the spills at V2 and V3. This is however a stop-gap initiative, and these lines must all be replaced by much higher capacity 220 kV lines.[12]

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- Dynamic rating equipment on the Ballarat - Moorabool & Sydenham - Moorabool & Red Cliffs to Murra – Warra easements and possibly other V2 and V3 easements would allow higher capacity limits. Installing on-line weather stations and adopting real-time ratings taking into account real-time ambient temperatures and wind speed for these existing lines would deliver an even larger increase in thermal ratings for most times of the year when it's cooler and when wind is cooling the conductors (but much less so in daytime in summer), further reducing renewable energy spills once this equipment is installed and calibrated.

- Open-circuit Buronga – Red Cliffs 220 kV line in the daytime to prevent overloading V2 and V3 networks. This will not require additional capital investment and can be implemented in the Transgrid and AusNet Services control rooms. It is necessary to prevent over-loading of the 220 kV networks in V2 and V3. Otherwise, PEC would have to be constrained to levels well below its 800 MW rating. This will prevent loop flows and deep network issues in the 220 kV Victorian network. It should mostly be required during the daytime when the solar farms in South-West NSW REZ are generating. Whether this action will be required in Phases 2 and 3 is yet to be established.

[12] Nearly all Victorian transmission lines have Aluminium Conductor Steel Reinforced (ACSR) conductors with a steel core that reduces the sag of the conductor enabling them to operate safely at higher conductor temperatures than the 75 degrees it was designed for, and still have compliant conductor-to-ground clearance. Even with conductor temperatures up to 90 degrees, there should not be other conductor issues, such as bird-caging risks caused by differential expansion of the steel and aluminium strands. The Panther conductor used on most Victorian 220 kV lines has a 17% higher strength-to-weight ratio and an 8% lower coefficient of thermal expansion than other Victorian ACSR conductors. Increasing the conductor temperature from 75 degrees to 90 degrees would increase their maximum transmission limit by 20% and reduce their ground clearance by less than 0.5 meters. If low ground clearances are identified for some spans, they may be rectified by replacing the insulation arrangements on the adjacent transmission towers**.** It may also be necessary to uprate some terminal equipment and reset protection settings**.**

3.2 Comment on VicGrid's Victorian Renewables Energy Zones Development Plan Directions Paper

Before outlining the transmission projects forming Plan B, we comment on VicGrid's Victorian Renewables Energy Zones Development Plan Directions Paper (VREZDPDP), February 2021. VREZDPDP has two stages, the first containing those projects that are targeted to be implemented by 2025, with larger longer-duration projects in Stage 2.

Stage 1 projects are mostly synchronous condensers required to maintain adequate system strength and synchronous inertia. An issue arises where conventional inverters (used to connect wind farms and solar farms to the network) produce very high frequency harmonics that can resonate across the power system with other inverters, causing sub-synchronous (< 50 cycles/second) undamped power oscillations that can threaten power system security. Rotational inertia synchronous generators are traditional mechanisms for reducing transient changes in frequency and are important for maintaining power system stability. However, new technologies such as grid-forming inverters connected to battery energy storage, appear to be much better solutions. Ideally this technology would be integrated with the inverters at the renewable generators, to emulate the traditional performance of synchronous generators.

We suggest this program of synchronous generators should be reviewed including of the need, scope, and timing to take into consideration:

a. The substantial strengthening of the 220 kV networks in V2 and V3 REZs in Phase 1 of Plan B.
b. V4 (South West) REZ is supported by its substantial 500 kV line and the proposed turn-in of the Moorabool-Mortlake 500 kV circuit to Haunted Gully. This is likely to eliminate the need for the proposed Haunted Gully synchronous condenser for many years.
c. Trials with grid-forming inverters with batteries are now approved in Victoria. This is a vastly superior technical solution to old-world synchronous condensers.

Batteries will provide on-going real-power injection whereas synchronous condensers can only do that for seconds, as the rotating machine slows[13].

Stage 1 also includes upgrading the WRL line, since superseded by AEMO's proposals, and turning in the Haunted Gully to Tarrone 500 kV at Mortlake. The turn-in is unlikely to provide an additional 2,500 MW of renewables hosting capacity, as has been claimed.

Stage 2 of the Interim REZ Development Plan identifies a range of options. Our observations of these projects are:

a. Our earlier comments on synchronous condenser and battery bank projects apply.
b. The 220 kV augmentations should be of much greater capacity, using double circuit, and much higher rated conductors.
c. The 500 kV augmentations are mostly not required.
d. In the case of the V5 REZ 500 kV extension in Gippsland, the initial development should be two single circuit 500 kV lines, not a double circuit line for power system security reasons. Beyond that double-circuit 500 kV lines could be suitable.

[13] See for example:
https://www.vepc.org.au/_files/ugd/92a2aa_2e5921d911de44c9b991ef0a97e00beb.pdf

3.3 Plan B Hosting capacity

Plan B's transmission projects to be built in Victoria for each phase between now and 2035 are listed in Table 5 below, along with the additional Victorian renewables hosting capacity they will support in each REZ. Appendix D describes the projects in detail.

Table 5. Plan B additional renewable generation hosting capacity (MW)

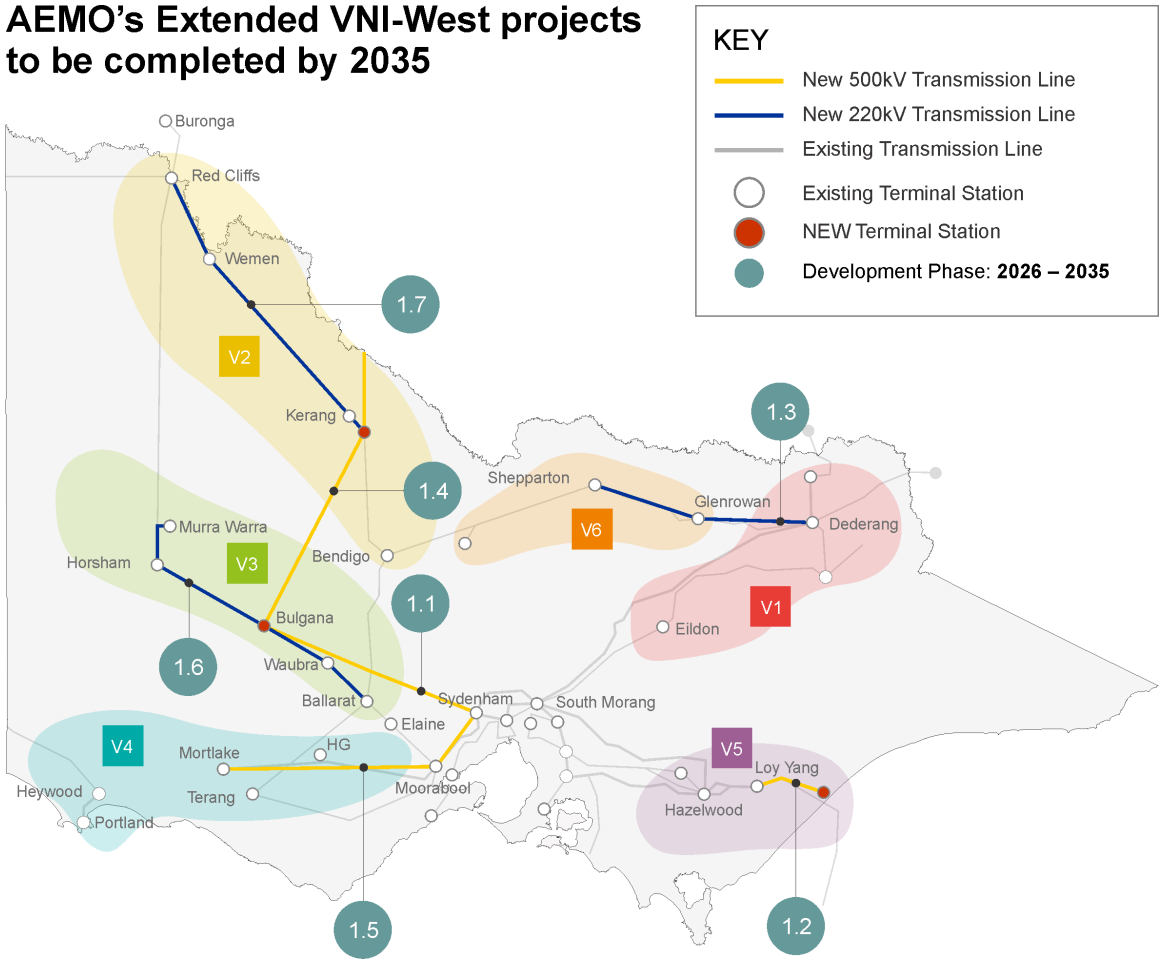
		V1 Ovens Murray	V2 Murray River	V3 Western Victoria	V4 South West Victoria	V5 Gippsland	V6 Central North	TOTAL
1.1	Open-circuit Buronga – Red Cliffs 220 kV line							
1.2	Increase maximum conductor temperature on some 220 kV lines		160	160				320
1.3	On-line dynamic rating Red Cliffs - Ballarat-Moorabool-Sydenham							
1.4	V3-220 kV Elaine to Moorabool			1,914				
1.5	Gippsland REZ - 500 kV Loy Yang to near Basslink transition point					3,000		3,000
1.6	V2 220kV network upgrade: Red Cliffs to Murra-Warra		957					957
1.7	V3 220 kV network upgrade: Murra-Warra to Ballarat							-
1.8	V3-V4 220 kV network upgrade Ballarat – Moorabool (line 1)							
	Total Phase 1 additional hosting capacity (completed by mid-2027)	**-**	**957**	**1,914**	**-**	**3,000**	**-**	**5,871**
2.1	Minor works at Loy Yang and Hazelwood 500 kV substations							
2.2	V2 220 kV network upgrade:		1,514					1,514

		V1 Ovens Murray	V2 Murray River	V3 Western Victoria	V4 South West Victoria	V5 Gippsland	V6 Central North	TOTAL
	Red Cliffs to Kerang							
2.3	V2-V3 220 kV network upgrade Kerang-Bendigo-Ballarat lines							
2.4	V3-V4 220 kV network upgrade Ballarat-Moorabool (line 2)							-
2.5	V4 500 kV S/C Sydenham to Moorabool				3,000			
	Total Phase 2 additional hosting capacity (completed by mid-2031)	**-**	**1,514**	**-**	**3,000**	**-**	**-**	**4,514**
3.1	V6-V1 220 kV line Shepparton-Glenrowan-Dedarang						1,100	1,100
	Total Phase 3 additional hosting capacity (completed by mid-2035)	**-**	**-**	**-**	**-**	**-**	**1,100**	**1,100**
	Total Plan B additional hosting capacity by mid-2035	**-**	**2,471**	**1,914**	**3,000**	**3,000**	**1,100**	**11,485**

4 Extended VNI-West

The previous section described our proposed Plan B. What is AEMO's plan to which our plan can be compared? This section describes what we have called the "Extended VNI-West" Plan. A summary of its projects is shown in Figure 2 below.

Figure 2. Extended VNI-West plan



The Extended VNI-West Plan takes AEMO's VNI-West recommendation then adds the 220 kV augmentations needed in Victoria to ensure that VNI-West can actually be useful to Victoria (explained in 4.2), adds an augmentation in the South West to add the 1,500 MW that AEMO claims as part of its VNI-West plans and adds augmentations in the Central North REZ and Gippsland REZ without which AEMO's claimed increase in hosting capacity can't be achieved. A summary of the Extended VNI-West projects is

shown in Table 6 below. Appendix E presents the detailed costing and specification of the projects included in Extended VNI-West

Table 6. Extended VNI-West project summary

	Project	Details of project scope of works	Cost ($million, 2023) including IDC	Cost ($million, 2022) excluding Interest During Construction (IDC)	Easement	Length (km)
1.1	VNI-West 500 kV Sydenham to Bulgana (WRL)	Sydenham to Bulgana option 5A D/C 500kV towers, quad conductors	1,861	1,525	new, parallel existing line part-way	190
1.2	500 kV D/C Loy Yang to Basslink Transition	Loy Yang to new Giffard substation, 500kV D/C line, quad conductors	1,040	853	new green field easement	65
1.3	220kV S/C Shepparton to Dedarang via Glenrowan	Shepparton - Glenrowan - Dederang, 220 kV S/C, twin Lemon conductors	370	317	spare easement	175
1.4	VNI-West Option 5A 500 kV Bulgana to NSW border	Bulgana - New Kerang - near Swan Hill, option 5A, 500 kV D/C, quad conductors	3,057	2,506	new green field easement	236
1.5	500 kV S/C Sydenham to Mortlake	Sydenham - Moorabool - Haunted Gully - Mortlake, 500 kV S/C, quad conductor	1,425	1,102	spare easement to Moorabool	214
1.6	220 kV network for V3 (Western Vic REZ)	Murra Warra to Horsham to Ballarat, 220 kV D/C, twin Lemon conductors	907	744	new green field easement	229
1.7	220 kV network for V2 (Murray River REZ) - 2 D/C lines	Two lines Red Cliffs - Wemen - New Kerang or equivalent, 220 kV D/C, twin Lemon conductors	2,312	1,788	new green field easement	550
	TOTAL		**10,972**	**8,835**		**1,659**

4.1 How much renewable hosting will VNI-West deliver?

AEMO says that VNI-West can host 4,140 MW by the time it is complete. To be clear 900 MW of the 4,140 MW is in South-West NSW, and the remaining 3,240 MW is in Victoria.[14] AEMO has also included an unspecified transmission augmentation in South Western Victoria to be commissioned in 2034 which it says will add 1,500 MW of hosting.

Adding these amounts together (600 MW + 1,500 MW + 3,240 MW) gives 5,340 MW of additional hosting capacity by 2035. This falls far short of the circa 11.3 GW of additional renewables hosting capacity needed to achieve the circa 15 GW of renewable generation that is needed to meet the Government's 95% renewable energy generation by 2035 target.

Noting the step change in renewables entry in various Victorian REZs in AEMO's VNI-West modelling results, we had assumed that several transmission augmentations were hidden from view (or that AEMO was not aware that its modelling had included those augmentations). We raised this in our submission. However, in response AEMO has been emphatic that it had not hidden any transmission lines, and AEMO said that we had confused renewable generation entry with the necessary expansion of transmission capacity. AEMO's representatives said this also at a public meeting in Wedderburn.

The implication of renewable entry that far exceeds transmission expansion, is that renewable generation is curtailed. In other words, according to AEMO's plan much of the new generation is not actually accommodated on the grid. Evidence of this can be seen in the curtailment (the proportion of renewable generation that is available but not produced because the grid can't accommodate it). We have also previously noted[15] that with AEMO's plan, Victoria is expected to be importing 26% of its electricity by 2040. Table 7 below presents our analysis of the curtailment of renewable generation in the two Victorian REZs (Western Victoria and Murray River) that VNI-West traverses.

[14] As an aside we note that VNI-West's n-1 contingency thermal rating is likely to be no more than 3,000 MW and AEMO's own analysis shows that only 2,245 MW of new Victorian renewable generation can be attributed to VNI-West.

[15] https://reneweconomy.com.au/new-links-could-turn-victoria-into-energy-importer-solar-and-storage-would-be-cheaper/

Table 7. Average renewable generation curtailment in Murray River REZ and Western Victoria REZ, based on AEMO's Option 5A modelling results.

Curtailment			
	Average 2023-2030	**Average 2031-2040**	**Average 2041-2050**
Murray River (solar)	36%	25%	35%
Western Victoria (solar)	25%	19%	24%
Western Victoria (wind)	33%	19%	22%

This table shows the average curtailment of solar is unchanged to 2050. So, Victoria's main solar REZ (Murray River) can expect less curtailment over the period 2031 to 2040 but it rises again in the decade to 2050, to the level in the current decade. Despite such enormous curtailment, AEMO still expect that solar capacity in the Murray River zone will increase six-fold from the current 600 MW. Similarly, in Western Victoria, solar spills reduce a little in the decade after VNI-West is complete, but then increase again to levels they were at before VNI-West is built.

Essentially therefore, AEMO anticipates that VNI-West will not meaningfully reduce the curtailment of renewables. Is it inconceivable that, if renewable developers trust AEMO's projections of curtailment, they will invest as AEMO says? If so, they will knowingly be investing in anticipation of huge financial losses. We noted earlier that AEMO recognises that its claims (of generation expansion) are inconsistent with the market design as it currently exists.

4.2 Additional 220 kV expansion needed to deliver VNI-West's hosting expansion

Large 220 kV reinforcements to V2 (Murray River REZ) and V3 (Western Victoria REZ) will be essential if VNI-West is to deliver its claimed additional hosting capacity. Specifically, WRL will <u>not</u> increase the hosting capacity of V3 unless the 220 kV line to the West and east of the Bulgana 500 kV/220 kV substation is upgraded.

The western 350 km of that single 400 MW line between Red Cliffs and Bulgana already has 534 MW of renewables connected, so it can't possibly host any more renewables plus the 121 MW Carwarp solar farm now being commissioned. The eastern 104 km from Bulgana to Ballarat already has 512 MW of connected wind farms, so it too can't host any more renewables, even if it is forced to back-feed into Bulgana by open-circuiting the Waubra-Ballarat section (as apparently suggested in the 2023 IASR). If more renewables do connect in V2 and V3 without these upgrades and on the expectation that VNI-West alone will expand hosting capacity, the curtailment will actually increase even higher than the current 40% given the existing 220 kV line can't be safely or legally operated above its rating.

Addressing this in order to obtain some value out of WRL will require increasing the scope of VNI-West to include, at the least, a new 229km double circuit 220 kV transmission line between Murra-Warra, Bulgana and Ballarat to provide an additional 800 MW of hosting capacity to the West, and 800 MW to the east of Bulgana (i.e., to deliver the +1,460 MW + 200 MW promised by the PACR for V3 REZ).

With regard to AEMO's claim of the additional renewables hosting in the Murray River REZ that will be delivered by VNI-West, VNI-West will not increase the hosting capacity of the Murray River REZ as it does not upgrade the ~275km of 220 kV line that runs from Red Cliffs to the New Kerang 500 kV/220 kV substation. This single 400 MW line already has 353 MW of solar farms connected and will also carry NSW and South Australian solar power down to Melbourne via the vastly upgraded Buronga to Red Cliffs line (part of stage 1 Project EnergyConnect to be energised next year).

If more renewables connect to V2 REZ, thinking that VNI-West will expand hosting capacity, the spillages will actually increase higher than now as the existing 220 kV line can't be safely or legally operated above its rating. Addressing this in order to deliver the promised +1,580 MW hosting capacity of VNI-West will require the equivalent of two new double circuit 220 kV lines of 800 MW each, from Red Cliffs to New Kerang.

4.3 220 kV expansion in Central North Victoria contained in AEMO's projections

Despite AEMO's insistence that there is no transmission augmentation in the Central North Victoria (V6) REZ, its VNI-West PACR results show that in 2030, 363 MW of wind farms are installed taking the total renewables capacity in V6 REZ from 402 MW to 766 MW. In 2031 the PV energy generation drops 10% indicating increased spills, yet the following year (2032) the PV generation bounces back indicating that the V6 REZ transmission has been augmented. According to AEMO's ISP Data and Assumptions[16], the augmentation is a single circuit 220 kV line between Shepparton and Dederang via Glenrowan and so we have included that in the Extended VNI-West Plan.

4.4 Transmission expansion in South West Victoria

AEMO's VNI-West PACR results showed an additional 2,000 MW of renewables hosting in South Western Victoria in 2033 plus another 500 MW in 2037. AEMO do not say how this is to be achieved but they do acknowledge that there is a transmission augmentation to South West Victoria REZ. The ISP data and assumptions workbook has two options for augmenting the transmission hosting capacity of South West Victoria REZ being Option 1: Sydenham to Mortlake 500 kV or Option 2: 500 kV from Mortlake to North Ballarat. We have assumed Option 1 since North Ballarat substation is no longer proposed.

4.5 Transmission expansion in Gippsland

Transmissions expansion will be required in Gippsland, connecting to the Loy Yang terminal station in order to host the 2,000 MW wind farm expansion AEMO has assumed for Gippsland. Therefore, we have included the 500 kV Gippsland REZ project in the AEMO Draft Transmission Options Report for the Extended VNI-West Plan. But again,

[16] https://aemo.com.au/en/consultations/current-and-closed-consultations/2023-inputs-assumptions-and-scenarios-consultation

we have given AEMO the benefit of the doubt by recording this additional hosting at 3,000 MW – the amount that we (and AusNet) consider to be the additional hosting capacity.

4.6 Hosting capacity

The projects described in this section establish the Extended VNI-West Plan, to 2035, summarised in Table 8 below.

Table 8. Summary of Extended VNI-West projects to be completed by 2035.

Project	Necessary completion date
VNI-West 500 kV D/C Sydenham to Bulgana (WRL)	mid 2027
500 kV D/C line from Loy Yang to near Basslink transition station + 500kV/220kV substation	mid 2029
220 kV S/C line Shepparton to Dedarang via Glenrowan	mid 2030
VNI-West Option 5A 500kV D/C & New Kerang 500kV/220kV substation	mid 2031
500 kV S/C Sydenham to Moorabool to Mortlake	mid 2033
220 kV D/C lines Murra-Warra to Bulgana; and Bulgana to Ballarat	end 2026 (pre WRL)
220 kV D/C lines Red Cliffs to Wemen to New Kerang;	end 2030 (pre VNI-West)

We estimate the REZ-specific hosting capacity as shown in Table 9 below:

Table 9. Extended VNI-West additional renewable generation hosting capacity (MW) in each REZ by 2035

Extended VNI-West Plan	V1 Ovens Murray	V2 Murray River	V3 Western Victoria	V4 South West Victoria	V5 Gippsland	V6 Central North	TOTAL
VNI-West 500 kV Sydenham to Bulgana (WRL)			1,460				1,460
500 kV D/C Loy Yang to Basslink Transition					3,000		3,000
220 kV S/C Shepparton to Dedarang via Glenrowan						400	400
VNI West option 5A 500kV Bulgana to NSW border		1,580	200				1,780
500 kV S/C Sydenham to Mortlake				3,000			3,000
220 kV network for V3 (Western Vic REZ) - for WRL							-
220 kV network for V2 (Murray River REZ) - for VNI-West							-
Total additional Hosting capacity by 2035		**1,580**	**1,660**	**3,000**	**3,000**	**400**	**9,640**

4.7 Cost

We have costed the Extended VNI-West Plan using the latest cost estimates in AEMO's Draft 2023 Transmission Expansion Options Report[17], restated in 2023 dollars. This incorporates AEMO's and its consultant's (Mott MacDonald) expertise on transmission project scoping and cost estimation. In the case of WRL and VNI-West Option 5A, the estimated cost is based on the PACR's for both projects, and the updated WRL cost estimates, and includes the adjustments identified in the Mountain/Bartlett Submission to the VNI-West Consultation Report (explained in Appendix B).

Table 10 summarises the capital outlay for each project. Additional details are set out in Appendix B and Appendix E.

Table 10. Summary of the capital outlay of the Extended VNI-West program including Interest During Construction

	Project	**Cost ($million, 2023)**
1.1	VNI-West 500kV Sydenham to Bulgana (WRL)	1,861
1.2	500 kV D/C Loy Yang to Basslink Transition	1,040
1.3	220 kV S/C Shepparton to Dedarang via Glenrowan	370
1.4	VNI West option 5A 500kV Bulgana to NSW border	3,057
1.5	500 kV S/C Sydenham to Mortlake	1,425
1.6	220 kV network for V3 (Western Vic REZ)	907
1.7	220 kV network for V2 (Murray River REZ) - 2 D/C lines	2,312
	TOTAL	**10,972**

[17] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-2023-transmission-expansion-options-report.pdf?la=en

5 Comparative critique of Extended VNI-West and Plan B

This section critically examines VNI-West and Extended VNI-West (defined in Section 4) and in relevant areas compares it with Plan B (defined in Section 3).

5.1 VNI-West can't be justified on regional renewable generation cost differences.

VNI-West, from the Sydenham terminal station to the border with NSW, is approximately 410 kilometres long. AEMO says it is able to host 3,240 MW of new renewable generation in Victoria. Its "n-1" contingency rating is likely to be no more than 3,000 MW and AEMO's own analysis shows that only 2,245 MW of new Victorian renewable generation can be attributed to VNI-West. As set out in Appendix B, VNI-West alone is likely to cost at least $4.9bn (2023$) and will require $148m (2023$) each year to operate and maintain. This section sets out the analysis to substantiate the conclusion that the cost of VNI-West far exceeds the highest possible estimate of the differences in renewable generation costs in NSW and Victoria and so VNI-West can't be justified on account of production cost differences.

Conventional infrastructure economics provides the framework for the calculation here: a bridge is worth building if the value from the trade of goods over the bridge exceeds the cost of the bridge. So, we start by establishing the cost of the bridge: what would VNI-West need to charge to exporters from NSW to Victoria or vice versa, to cover its costs? This is straight-forward to calculate. The capital outlay of VNI-West is $3,968 per MW per km. The capitalised present value (discounted at 7%) of the operating cost is $1,643 per MW per km, giving a total of $5, 611 per MW per km or $2.3 million per MW. Expressed as an annual charge (discounted at 7%) over 50 years this would be $0.17 million per MW per year.

Is this less than the savings that can be achieved by using the cheapest possible wind generation in NSW to substitute for the most expensive wind generation in Victoria? Let's

imagine, for argument's sake, that NSW's most productive (and hence cheapest) wind generation was available at the point where VNI-West terminates in NSW. In its ISP, AEMO says that the capacity factor of the best wind generation in NSW (in the Cooma-Monara and Tumut REZs) is 43%. By comparison, AEMO says that the least productive (and hence most expensive) wind generation in Victoria has a capacity factor of 30% (it is located in the Murray River REZ). Would the savings obtained by displacing the least productive wind generation in the Murray River REZ by the most productive wind generation in Monara/Tumut be enough to justify paying $0.18million per MW per year for VNI-West?

This is also straight-forward to calculate. Using CSIRO's 2023 GenCost Report[18] (this is the latest official source of generation costs and will be used by AEMO in its forthcoming ISP) gives a capital cost of wind generation of $1.969 million per MW. Adding operating costs of $28/kW/year, discounting at a cost of capital of 7% over a 25-year life, gives an annual cost of NSW's most productive wind generation of $0.237 million per MW per year.

Doing same analysis but for the least productive wind generation in Victoria (Murray REZ, 30% capacity factor) and subtracting it from the most productive NSW wind gives a difference of $0.047 million per MW per year. This is the saving if the most productive (and hence cheapest) wind generation in NSW displaces the least productive (and hence most expensive) wind generation in Victoria.

This difference ($0.047 million per MW per year) is just 28% of the income that would be needed if VNI-West was to cover its costs (i.e. $0.047 million divided by $0.18 million). Clearly the saving available by using the cheapest wind in NSW to displace the most expensive wind in Victoria (assuming for argument's sake that this was possible[19]) is much too small to justify the cost of VNI-West. Though we do report the sums here, this conclusion also holds if we assume the cheapest wind generation in VIC displaced the most expensive wind generation in NSW.

[18] https://www.csiro.au/en/research/technology-space/energy/energy-data-modelling/gencost

[19] This assumes that there is as much possible supply in the cheapest REZ in VIC that is needed to meet all of the demand for wind in NSW and Victoria

What about solar generation, can differences in the cost of solar generation in NSW and Victoria justify VNI-West? A calculation constructed in the same way for solar[20] reveals a difference of $0.021million per MW per year. This is just 12% of the annual charge per MW for VNI-West. Evidently the case for VNI-West on the basis of solar cost differences between NSW and VIC is even weaker than it is for wind cost differences.

These conclusions will not be surprising to economists or engineers. It is well documented that wind/solar costs have declined greatly in absolute terms and more so relative to transmission costs over the last decade. We have previously suggested that solar costs are now tenth of their levels in 2010 and wind a third. Recent academic research suggests similar in the United States[21].

The inevitable conclusion is that the relative costs of wind and solar generation in NSW relative to Victoria do not justify the expense of VNI-West. However, this conclusion should not be taken as a categorical conclusion against all possible interconnections. There may be cases where interconnection can be expanded at a cost that is less than the savings from the dispatch of cheaper generation and/or the value from diversification of supply risk. Such value may arise through innovations in storage (such as the Victoria Big Battery or through better contingency management or control technologies that allows greater use of existing infrastructure). But we can confidently conclude that there is no chance that VNI-West can be justified on the basis of generation cost differences in NSW and VIC.

5.2 VNI-West will not diversify supply risks

Might VNI-West be valuable in the diversification of supply by providing access to wind/solar generation in Victoria when it is not available in NSW or vice versa?

[20] Specifically, build costs of $984/kW per CSIRO, capacity factor of 30% (Broken Hill) in NSW and 20% (Gippsland) in VIC

[21] See for example "Transmission Impossible? Prospects for Decarbonizing the US Grid". Lucas W. Davis, Catherine Hausman, and Nancy L. Rose NBER Working Paper No. 31377 June 2023.

The potential for diversification through interconnection may be established by measuring the coincidence of production in neighbouring states. AEMO rejected our claim that the correlation of renewable generation in neighbouring NEM regions meant that geographic supply diversification could not justify VNI-West. The basis of this rejection was that it "*appears to be based on a high-level view of coincidence and not on detailed analysis of similar calibre as that implemented in the VNI-West RIT-T*"[22].

AEMO then presented its analysis of correlation. In this analysis AEMO did not specify what period of time it used to measure its reported correlations between wind/solar/demand in some REZs with wind/solar/demand in other REZ zones. Neither is the data whose correlations is measured clear (for wind/solar AEMO describes its data as "a sample of the key renewable resource profiles") and there is no definition – not even an obscure one - of what demand is measured.

AEMO has also misunderstood the meaning of correlation. For example, it notes that the correlation in wind between Western Victoria and South West New South Wales REZs is 0.61. "*but (this) still means that there are a substantial number of periods when the wind is blowing in one REZ but not in another*". This is not the correct understanding of correlation. Correlation measures the extent to which variables change together at a constant rate.

Finally, AEMO is not actually measuring wind generation, it is measuring wind speed (we presume this is what it means by "resource profiles"). Contemporary wind turbines can reach their maximum output at relatively low wind speeds. So, measuring correlation outside of this wind speed range is irrelevant to the measurement of wind generation.

Finally, it is also not clear what claims AEMO is making in relation to these data. The broad tenor of their narrative seems to point to a claim that "generation diversity" justifies VNI-West, although they do not say this explicitly.

Notwithstanding all of these concerns, the data that AEMO presents can't support a claim that "generation diversity" justifies VNI-West. Specifically, we draw attention to AEMO's claim that the correlation of the wind resource in Gippsland and Western Victoria is 0.51,

[22] AEMO, 2023. "VNI-West Project Assessment Conclusions Report Volume 2: Additional Consultation Report Submissions". Page 67.

and between Gippsland and South West NSW is 0.37. Statistically, such correlation difference in "wind resource" is likely to be insignificant (AEMO did not mention the p-values of its correlation estimates).

Furthermore, AEMO suggests that VNI-West will be fully congested for at least half the time just a decade after it is built (at these times wind generation in South West NSW will be constrained from displacing production in Victoria).

Finally, AEMO's ISP assumptions workbook shows that the wind generation capacity factors are much lower in South West NSW than in any part of Victoria. Not only is there likely no statistically significant difference in diversity measured regionally, but the underlying resource that AEMO reports as offering that diversity is actually a greatly inferior resource. How then can it be credible to claim that generation diversity in wind can in any way justify VNI-West?

Perhaps sensing that their correlation analysis has not been successful, AEMO then presents a chart with "time of day profiles of wind and demand" which shows hourly average available generation in four Victorian REZs, two NSW REZs (not including South West NSW) and one Queensland REZ. Without any reference to information in this chart, AEMO says that "the variability at the hourly level is still sufficient to provide resource diversity". This is, evidently, an unsubstantiated claim.

5.3 AEMO has developed an expansion plan that is not financially viable for renewables developers

In its VNI-West PACR, AEMO says that wind and solar generation in Victoria will expand from 5 GW in 2023/24, to 14 GW in 2034/35 to 27.8 GW in 2049/50. But their own analysis shows that only 2.25 GW of new Victorian renewable generation can be attributed to VNI-West. AEMO also included an unspecified 1.5 GW augmentation in South Western Victoria to be commissioned in 2034 which it says will add 1.5 GW of renewables hosting, and an augmentation in Central North Victoria that it says will add 0.6 GW in 2047. How then is the additional 11.3 GW of hosting capacity needed to achieve the total 21.6 GW of additional hosting capacity by 2050 to be delivered?

In our Consultation Report Submission, we suggested that AEMO had hidden several transmission augmentations (or at the least that it was not aware that their modelling had included those augmentations). However, in its response to our submission, AEMO insisted that we had confused renewable generation entry and the expansion of transmission capacity, and they confirmed that it was not necessary to expand the Victorian transmission system other than to build VNI-West and a 500 kV augmentation in South Western Victoria (in 2034) and a much smaller 220 kV augmentation in North Central Victoria (in 2047).

Since the new renewable entry far exceeds the capacity expansion of the transmission system, by implication AEMO concludes that much less renewables hosting capacity is needed, relative to the amount of new renewable capacity they expect. This begs the question: what then happens to the new renewable generation that is not able to export to the grid because the grid is constrained? Must it necessarily mean greater curtailment?

Part of the gap is explained by higher imports of electricity into Victoria from NSW. We previously found[23] that with AEMO's plan, in 2040 expected that Victoria would be importing 26% of its electricity from its neighbours.

Another (large) part of the gap is explained by curtailment (in other words, renewable generation capacity expands but is not able to produce all of its production because the transmission network is constrained. Our analysis of AEMO's modelling results in Table 11 shows that VNI-West will reduce expected curtailment a bit in the decade after it is commissioned (relative to the decade before it was built) and then curtailment will increase again to around the levels it was before VNI-West was built in some REZs, increase more than before in other REZs, or decrease a little in others. The table shows the average annual curtailment of wind and solar farms in those REZ's whose production is affected by VNI-West. These four solar REZ's account for the vast bulk of new solar generation in Victoria. The average curtailment a decade after VNI-West is commissioned is worse than it is in the period between now and when VNI-West is commissioned. For wind generators, the picture is only a little better than for solar farms.

[23] https://reneweconomy.com.au/new-links-could-turn-victoria-into-energy-importer-solar-and-storage-would-be-cheaper/

Table 11. Analysis of AEMO average-annual REZ-level curtailment in Victoria in REZ's affected by VNI-West

	Average 2023-2030	**Average 2031-2040**	**Average 2041-2050**
Ovens Murray (solar)	24%	18%	14%
Murray River (solar)	36%	25%	35%
Central North (solar)	6%	14%	34%
Western Victoria (solar)	25%	19%	24%
Western Victoria (wind)	33%	19%	22%

Curtailment affects the viability of renewable generation. Since renewable generation has negligible operating costs, almost all of its revenue becomes operating profit needed to finance its loans and compensate its owners for the risks they have taken. To compensate for the curtailment, higher prices will need to be paid for the uncurtailed production, in order for the renewable generators to be able to recover their costs on the energy that they will actually be able to produce and sell.

This price increase (relative to the price assuming no curtailment) must also adjust for the revenue foregone to compensate transmission losses (through the application of marginal loss factors). The formula for the price required to cover for spills and marginal loss factors is: Price increase (%) = (Price assuming no spills/(1-spill percentage))/marginal loss factor. Table 12 below uses the 2023 marginal loss factors and the curtailment shown in Table 11 to work out the price increase that new entrant wind/solar generators will need, in order to compensate them for their and their marginal loss factor adjustments.

The price increases in Table 12 are so large that it is inconceivable that renewable generators would invest if they actually believed AEMO's modelling. To do so would be to knowingly invest in deeply unprofitable projects.

For the avoidance of doubt, the picture in NSW is no better than in Victoria. In the South West NSW REZ and the Wagga REZ, where AEMO says solar generation will expand 4-fold and 3-fold respectively over the period to 2050, curtailment in South West NSW does not improve after the development of VNI-West and in the Wagga REZ, as with the Central North REZ in Victoria, it gets very much worse.

Table 12. Prices increases needed to compensate for curtailment and marginal loss factors in Victorian REZ's affected by VNI-West

	Average 2023-2030	**Average 2031-2040**	**Average 2041-2050**
Ovens Murray (solar)	37%	26%	20%
Murray River (solar)	64%	40%	62%
Central North (solar)	6%	17%	59%
Western Victoria REZ (wind)	61%	27%	32%
Central North (wind)	18%	10%	23%

AEMO recognises that VNI-West results in generation expansion that is not financially viable. Specifically, AEMO says that its modelling has delivered results that are "*not necessarily the outcomes that would emerge from the current regulatory structure*"[24]. But AEMO then says that "*NEM reform activities, such as the Post 2025 project, are being looked at separately by the market bodies to ensure the regulatory and market arrangements are fit to best address the needs of power consumers, today and into the future*"[25].

Both the "Post 2025 project" and the organisation – the Energy Security Board – that pursued it, are now defunct. Nevertheless, perhaps the adjustment AEMO envisages will arise through some other process, by recovering renewable generator curtailment compensation from taxpayers or electricity consumers, or through unprofitable investment by the State Electricity Commission. Policy makers will then need to explain to consumers just why it is that they say that the transition to renewable electricity will reduce electricity prices.

Perhaps policy makers will refuse such compensation and renewable generators consequently refuse to invest. This might explain in part the observation of very little renewable generation reaching financial close at present. If this is the case, then the Government of Victoria (and/or electricity customers) will almost certainly need to subsidise continued production from Victoria's brown coal generators beyond their expected closure dates.

[24] AEMO, 2023. "VNI-West Project Assessment Conclusions Report Volume 2: Additional Consultation Report Submissions". Page 69.
[25] *Ibid*

Finally, AEMO's claim that as a result of its sophisticated VNI-West modelling it has calculated the "efficient" level of renewable generation curtailment merits scrutiny. By "efficient" AEMO says it means it has calculated the level of spills that "*lower costs to consumers overall*" … since … "*moving wind or solar capacity build to other locations with the objective of reducing spill would increase overall system cost*."[26] But AEMO has not calculated the "efficient" level of renewable generation. This is because in their modelling they do not price renewable generation at the level needed to actually finance that generation, i.e. by taking account of its curtailment. Rather they assume it is not curtailed and neither is it charged for marginal losses. AEMO therefore do not correctly calculate the efficient combination of generation, storage, and demand to meet customers' needs.

To see what this means in practice, consider this: AEMO says that onshore wind generation in Gippsland is only slightly less productive than it is in Western Victoria (2 percentage points difference for "average" wind). But AEMO also says the average curtailment (from now to 2049/50) in the Gippsland REZ will be 2%, but in the Western Victoria REZ it will be 24% (so 22 percentage points difference). Since wind farms can be built in both REZs for the same price (according to AEMO) if AEMO had properly accounted for curtailment, its model would have located additional wind generation in Gippsland, not Western Victoria. Yet it does not: despite wind farms in the Western Victoria REZ requiring break-even prices after accounting for curtailment and losses to be 28% higher in Western Victoria, by 2035 AEMO locates 150% more wind generation in Western Victoria than in Gippsland.

5.4 AEMO's plan will result in large, needless increases in electricity bills relative to Plan B

We costed the Extended AEMO plan (see Section 4) at $11 billion inclusive of interest during construction. Depreciated over 45 years at 7% and assuming 3% (of the initial outlay) for annual operating costs establishes a revenue requirement of $1,126 million, on top of the existing $647 million that is currently recovered from Victorian electricity

[26] Ibid, page 60.

consumers for the provision of transmission. By comparison, Plan B will establish an additional revenue requirement of $611 million.

In addition, if we assume average variable renewable curtailment in the Extended VNI-West program that is (conservatively) 20% higher than in Plan B, this translates into additional subsidies to be recovered from consumers (or taxpayers) in 2035 of 20%* 47,832 GWh[27]* $45[28]/MWh = $425 million in 2035.

In summary therefore, Extended VNI-West can be expected to raise annual electricity bills by $940 million ($1,126m + $425m - $611m) more than Plan B, by 2036.

5.5 AEMO's plan presents much greater risk of delivery delays and cost blow-outs

The Extended VNI-West plan has much greater risks of project delivery delays and cost blow-outs associated with supply chain constraints, skilled labour shortages, insufficient competent contractors, lack of competition and conflicts with other Victorian critical infrastructure provision. This is because it requires the establishment of a new 500 kV network in central-north-western Victoria whereas Plan B utilises less complex, standard 220 kV plant and construction services.

VNI-West requires several massive 500 kV substations with long-lead-time, highly sought after power transformers, line reactors and 500 kV switchgear together with large amounts of sophisticated, higher risk power electronics equipment including power flow controllers, series compensation and FACT's devices. It requires 35% more conductor (28,000 kms compared with 20,700 km), 23% more concrete (314,000 tonnes vs 256,000 tonnes). Since Plan B mostly utilises existing easements, work can be started almost immediately whereas the VNI-West amended plan is almost entirely sited on "yet-to-be-acquired" new easements almost certain to involve long delays and additional costs.

[27] See last row of Table 3.
[28] This is the weighted average uncurtailed cost of producing electricity from the mix of variable renewable resources in 2035.

5.6 AEMO's plan will result in a much more vulnerable transmission system

The Extended VNI-West Plan greatly increases the risk of state-wide black-outs and extended electricity outages in Victoria. Specifically, VNI-West will introduce ~1,000 single-points-of-failure as it relies on a 500 kV dual-circuit transmission line with single towers supporting both 500 kV transmission circuits. This means that a single event of severe lightning, destructive wind gusts, bushfires, extreme flooding, and sabotage would take-out the entire line, causing an instantaneous cascading tripping of any parallel 220 kV lines and the existing VNI and Heyward interconnections, plunging southern Victoria including Melbourne and the Portland smelter into an absolute blackout.

AEMO has acknowledged that WRL will create this severe risk of cascading power system collapse in their recommendation 10 of the AEMO "Power System Frequency Risk Review"[29] of 26 July 2022. AEMO's responses to our claim of these serious power system security risks, i.e. that VNI-West would survive such an event is not correct. AEMO has evidently discounted the fact that 18 transmission towers have collapsed as a result of extreme down-drafts in the last 14 years and suggests this risk can be ignored because these previous collapses did not lead to black outs.

By comparison Plan B, continues with Victoria's resilient grid design using redundant lines located on different easements, and single circuit 500 kV lines, thus avoiding single-points-of-failure greatly reducing the risk of cascading power system collapse, extreme weather, or other force majeure events. A system design that used a single corridor would have been less costly. Instead, the system was designed to provide resilience against hazards using geographic diversity and an appropriate amount of redundancy. This is what Plan B also achieves.

[29] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/psfrr/2022-final-report---power-system-frequency-risk-review.pdf?la=en

5.7 Multi-Criteria Analysis of Extended VNI-West and Plan B finds Plan B far superior

The Victorian Government's February 2023 NEVA Order 102 requires a Multi-Criteria Analysis (MCA) to be undertaken considering environment, cultural heritage, land use and engineering aspects, in addition to net economic benefits to rank transmission development options according to their performance against each criterion. The VNI-West PACR presents an MCA that was developed by AEMO and their consultant, AECOM. It was used in the Consultation Report and PACR to further assess the options and help determine which option is most likely to facilitate timely delivery, consistent with the functions conferred by the February 2023 NEVA Order 102.

The AEMO framework has six objectives (economic, social, cultural heritage, land use and engineering) scored from 1 (most favourable) to 5 (least favourable). Each criterion was then measured, and a weighting score ranked the options.

We do not consider that the MCA conducted by AEMO/AECOM is credible. Economic benefits (i.e. the net benefit estimate in the PACR) receives 70% of the weighting, 10% is applied to socio-economic and 5% to all other objectives. With a 70% weighting, all other objectives are, essentially, inconsequential. How can this be considered to be a plausible "multi-criteria" analysis? We also note AEMO has misapplied its own analysis. While the rating system allocates 1 as the highest and 5 as the lowest AEMO has applied the rating in the reverse for its economic benefits measure[30].

We have developed an MCA that we suggest appropriately focusses on the important socio-economic, environmental, visual, and cultural concerns to be weighed in the planning and siting of transmission lines in Victoria. Our MCA identifies the following considerations:

[30] As it turns out, this is somewhat besides the point anyway since AEMO does not evaluate competing options – it only has one "option".

- **Consumer impact:** This indicator is based on capital cost per kilometre. Projects are all weighted relative to VNI-West (Bulgana to Kerang) which gets a score of 30. The aggregate score is the weighted average of individual projects (weighting by kilometres).

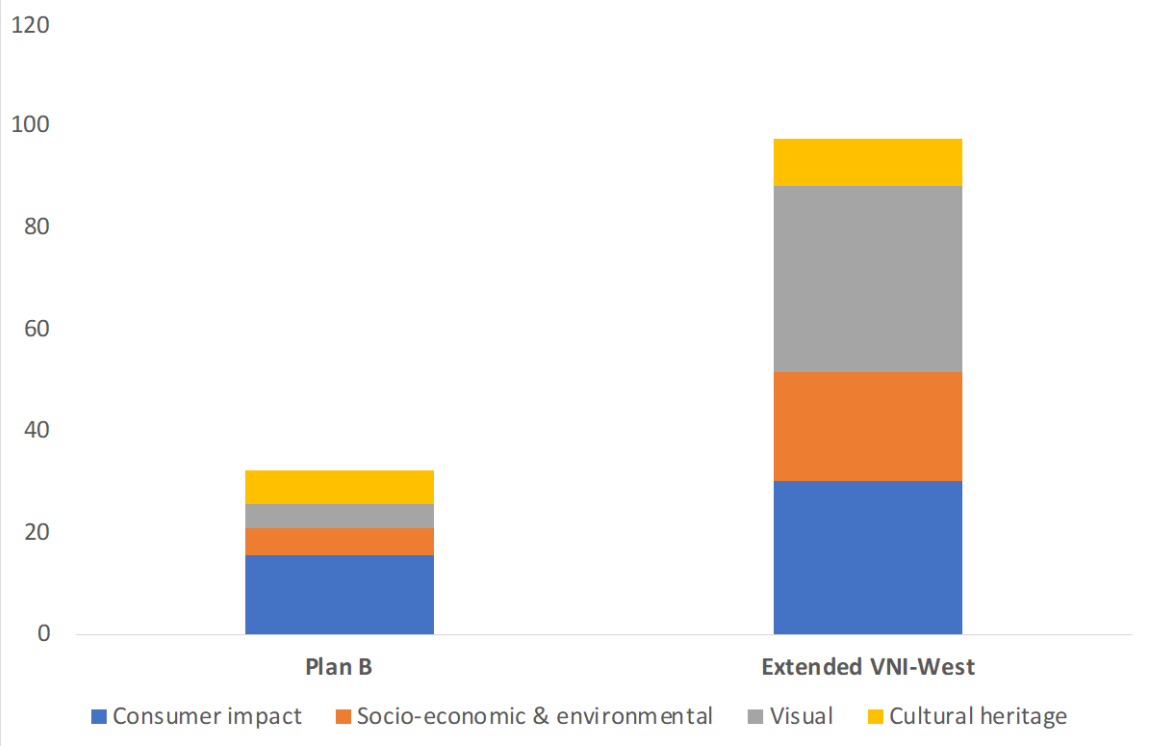
- **Socio-economic & environmental impact:** transmissions lines that require new easements (or expanded) easements impose costs on landowners and cause environmental damage (on flora, fauna and ecosystems) caused by the clearing, construction and maintenance of new transmission lines. This is measured by the area of new/expanded easements required to host new or expanded transmission lines all weighted relative to VNI-West (Bulgana to Kerang) which gets a score of 30. The aggregate score is the weighted average of individual projects (weighting by hectares of new or expanded easement).

- **Visual impacts:** Transmission towers, insulators and conductors are unsightly. This measure scores the square of the height of the towers (visibility rises as the square of height) multiplied by the number of wires strung between them, and adjusted for whether they are built alongside existing transmission lines or if they are sited on new land all weighted relative to VNI-West (Bulgana to Kerang) which gets a score of 30. The aggregate score is the weighted average of individual projects (weighting by hectares of new or expanded easement).

- **Cultural Heritage impacts:** Cultural heritage is difficult to assess without the trust and input of the elders, being the custodians of the stories and knowledge of their Country. For this reason, these impacts can't be adequately assessed via desktop analysis for any project from a proxy-based measure used here. However, for program-level assessment, we are confident the approach we have used is realistic. We consider whether the transmission line is on existing easements, alongside or in new Country. This equally weighs cultural heritage impacts above-ground (e.g. scar trees, archaeological sites, stone tools) with below-surface impacts due to the excavation of tower footings and access tracks. Individual projects are assessed relative to VNI-West (Bulgana to Kerang) which gets a score of 10. The aggregate score is the weighted average of individual projects (weighting by hectares of new or expanded easement).

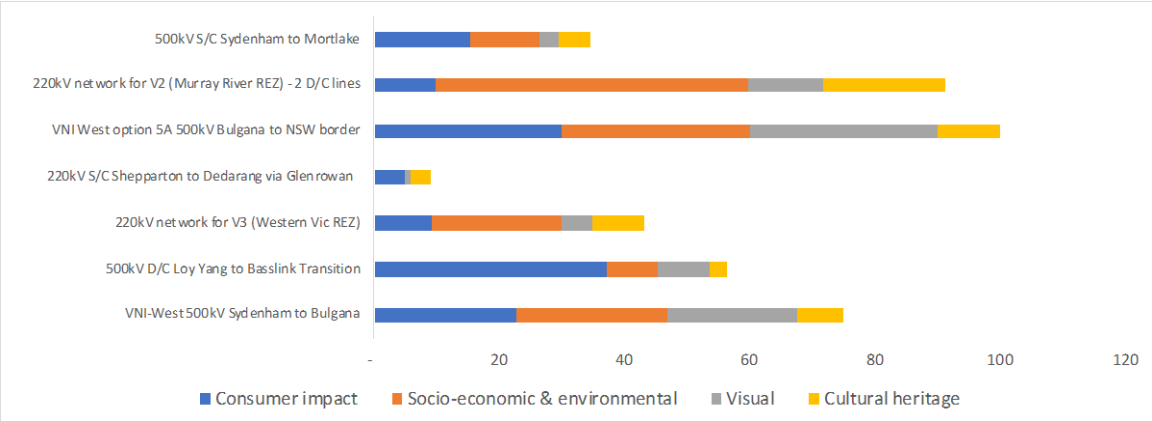
Figure 3 below compares the MCA score for the Extended VNI-West versus Plan B. It shows that the Extended VNI-West is significantly worse on all five measures.

Figure 3. Aggregate MCA score for Plan B v Extended VNI-West



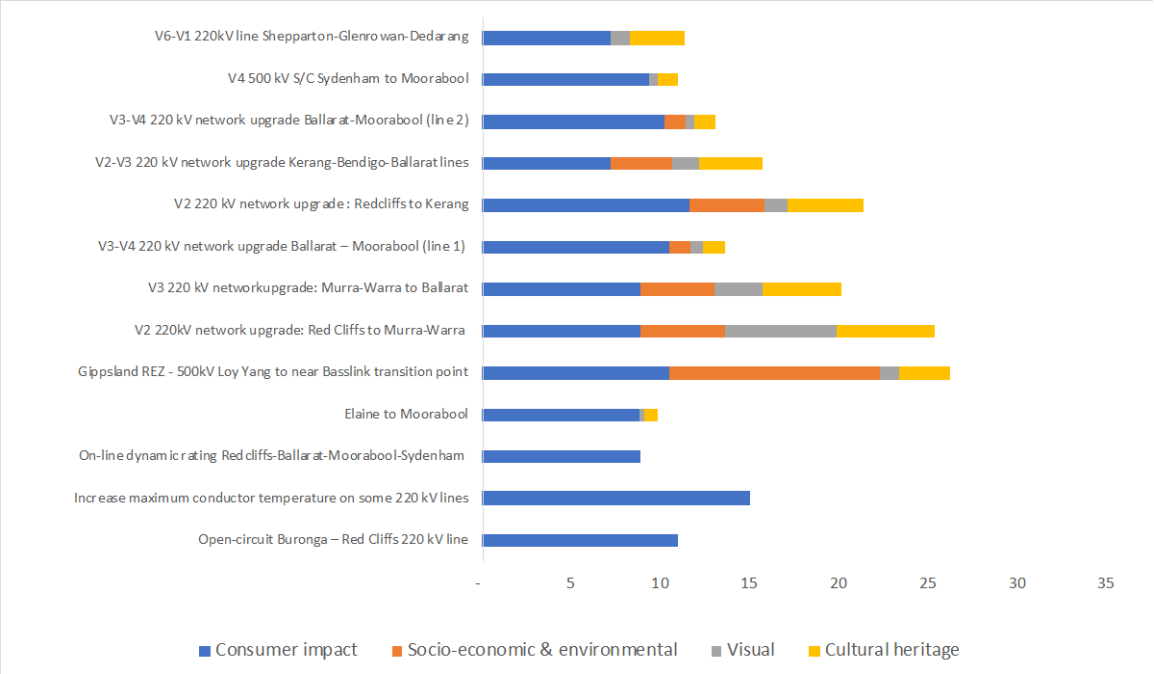
The project-by-project analysis of the Extended VNI-West projects, in Figure 4 below, shows that most of the detriment associated with AEMO's projects is the VNI-West project.

Figure 4. Project-by-project MCA for Extended VNI-West



The project-by-project MCA analysis of the Plan B programs is shown in Figure 4. It shows that almost all of the Plan B projects have similar or smaller impacts than almost all of the Extended VNI-West projects.

Figure 5. Project-by-project MCA for Plan B



5.8 Summary comparison of Extended VNI-West and Plan B

The main points of comparison between Extended VNI-West and Plan B are summarised in Table 13 below.

Table 13. Summary comparison of Extended VNI-West and Plan B

	Extended VNI-West	**Plan B**
Total length new lines	**1,659 km**	**1,451 km**
Requires new easements. Located on existing easements. Require minor (~10) widening	1,270 km 386 km	130 km 281 km 1,040 km
Area of new easements	**733 ha**	**169 ha**
Multi-Criteria Analysis (the lower the better) 1. Cost 2. Socio-economic & Environmental 3. Visual 4. Cultural & Heritage Total	 15 32 20 12 79	 10 7 3 4 23
Capital cost (2023 dollars)	**$11 billion**	**$6 billion**
Renewables hosting capacity by 2035 (MW)	**14,830**	**16,675**
Curtailment (REZs affected by VNI-West)	**20% to 40%**	**13%**
Marginal loss factors (REZs affected by VNI-West)	**0.80**	**0.93**
Single Points of Failure	**~ 1000**	**0**
Increase in annual electricity bills relative to Plan B.	**$1,124 million**	**0**

6 Governance of transmission planning in Victoria: some questions

When the electricity industry in Victoria was privatised in the 1990s, the Government of the day separated the planning of transmission, from transmission asset development and ownership. VENCorp, a statutory corporation established in 1997, was made responsible for planning the transmission system and for administrating competitive procurement of major transmission augmentations. A little over a decade later, VENCorp was wound up and its transmission planning role for Victoria taken over by the then newly created AEMO. This has put Victoria in a unique position, compared to the other NEM States, where an authority that does not report to the Government or Parliament, is responsible for transmission planning in Victoria.

It is beyond the scope of this paper to analyse and critique the arrangements for the separation of transmission expansion planning and transmission asset ownership. However, the evidence on the development of VNI-West suggests these arrangements are not working well. For example, in seeking expressions of interest[31] in 2019 to develop what was then known as the Western Victoria Transmission Network Project, AEMO precluded respondents from contacting any landowner (or party with interest in land), tenant or occupier of land, without AEMO's consent. How then could respondents develop proposals that took account of landowner's concerns? AEMO did not itself engage with landowners either.

In 2020 the Victorian Government began to take back transmission planning authority by establishing VicGrid, currently a division within the Department of Energy Environment and Climate Action. VicGrid describes its role as "co-ordinating the overarching planning and development of Victorian renewable energy zones". We understand that the Government intends to establish VicGrid as a statutory authority, in 2024.

[31]https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/Call-for-Expressions-of-Interest-Western-Victoria-Transmission-Network-Project.pdf

VicGrid, as discussed, has begun to establish its own views of transmission expansion in Victoria. It has established its own approach to the selection of transmission projects (the Victorian Transmission Investment Framework) and has established a list of "Stage One" and "Stage Two" projects that it intends to pursue[32]. VicGrid has said that it does not intend to apply its VTIF to VNI-West, and so effectively its co-ordination of the "overarching planning and development of Victorian renewable energy zones" stops short of VNI-West.

This may not be problematic if VNI-West was an inconsequential augmentation. But AEMO has insisted in response to our Submission and subsequently at a forum in Wedderburn in May, that the generation outcomes that it forecasts in its VNI-West assessment (i.e. almost complete decarbonisation of electricity supply in Victoria by 2050) does not envisage any other transmission expansion in Victoria other than VNI-West, an (unspecified) 1,500 MW augmentation in South Western Victoria (in 2034) and a smaller (unspecified) 600 MW augmentation in Northern Victoria in 2046. This is despite the fact that AEMO identifies many billions of dollars' worth of augmentations in its Transmission Expansion Options Report[33].

Furthermore, none of VicGrid's Stage One or Stage Two projects were included in AEMO's assessment of the costs and benefits of VNI-West. Why then, if AEMO's plan is believed by the Government, should VicGrid exist? Moreso why would the Government go to the bother of legislating it as a statutory authority if, according to AEMO, it essentially has nothing to do? And why has VicGrid in its short life already reached such a different view to AEMO on necessary transmission expansion in Victoria, and on how transmission expansion is to be assessed (VTIF bears no relation to the Regulatory Investment Test that AEMO applies)?

Recent developments have added yet more confusion. For example, in Gippsland, VicGrid has taken responsibility for "transmission co-ordination and engagement" for all transmission expansion and AusNet has been precluded from engagement with local communities with respect to its proposed unregulated G-REZ transmission project. Yet

[32] www.energy.vic.gov.au/renewable-energy/renewable-energy-zones

[33] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-2023-transmission-expansion-options-report.pdf?la=en

AEMO, possibly extending its authority beyond what is conferred on it under the National Electricity Law, has recently established Transmission Company Victoria Pty Ltd[34] to "*discuss the VNI-West transmission project with landholders, Traditional Owners and the community*" and "*to make sure that commitments made in the early stages are captured and honoured across the life of the project*". This begs the questions: why did AEMO need to create a new company in order to "discuss" VNI-West with landholders, Traditional Owners and the community; and what commitments made to whom, require the formation of a new company in order to ensure that they are honoured?

Evidently the roles and responsibilities for transmission planning in Victoria, and the governance thereof, is confused. Clarification at such a critical time in the development of Victoria's transmission system is particularly important.

[34] https://www.transmissionvictoria.com.au/#:~:text=What%20is%20TCV,the%20project%20moves%20towards%20construction.

7 Recommendations

We present the following recommendations for consideration by the Government of Victoria, the Australian Government and Energy and Climate Change Ministerial Council.

1. Recommendations for consideration by the Government of Victoria

a) The confusion created by the multiplicity of transmission planning bodies in Victoria should be resolved as a matter of urgency by appointing VicGrid as the Victorian Jurisdictional Transmission Planner under the National Electricity Rules or equivalent role under the National Electricity (Victoria) Act 2005, in place of AEMO.

b) VicGrid should be asked to publicly report, using its Victoria Transmission Investment Framework, on the relative merits of Plan B compared to AEMO's VNI-West in meeting the Victorian Government's target that 95% of electricity generated in Victoria is from renewable generation.

c) VicGrid should be asked to advise, as a matter of urgency, on the merits of implementing projects B1.4, B1.7 and B1.8 in advance of any decision to develop VNI-West to Bulgana at 500 kV.

d) VicGrid should be asked to advise, as a matter of urgency, on the specific merits of the implementing projects B.1.6, B2.2, B2.3, and B2.4 of Plan B in advance of any decision to develop VNI-West from Bulgana to Kerang.

2. **Recommendations for consideration by the Australian Government:** The Clean Energy Finance Corporation has been tasked with issuing loans funded by the Rewiring the Nation funding. Considering the concerns raised in this report about AEMO's assessment of the costs and benefits of the transmission augmentations that it proposes, the Productivity Commission should be asked to advise on the principles and criteria to be followed by the CEFC in its decisions on loans funded by the Rewiring the Nation funding.

3. **Recommendations for consideration by the Energy and Climate Change Ministerial Council:** While this report has focussed specifically on VNI-West,

the serious failure of transmission expansion planning it finds, is systemic and should be seen in the broader context of the Regulatory Investment Test, the Actionable Integrated System Plan regulatory arrangements, the Take-Out-One-at-a-Time methodology for the AER assessment of Contingent Project Applications and the relative roles of AEMO versus state-based transmission network service providers. We recommend an inquiry into these arrangements led by eminent persons who have no current or prior relationships to Australia's existing regulatory institutions or major electricity producers. The terms of reference of this inquiry should seek advice on changes to the arrangements for transmission planning and transmission access that will ensure that national and state-based emission reduction targets are met at the lowest possible cost to electricity consumers and taxpayers, landholders, affected communities and the environment.

Appendix A: Do the benefits of VNI-West arise through avoided storage or avoided/deferred renewable generation?

Notwithstanding our conclusion above that AEMO's calculation of benefits is not credible, it is important to understand AEMO's claim about where the benefits from VNI-West arise, and to respond to AEMO's criticism of our analysis of this.

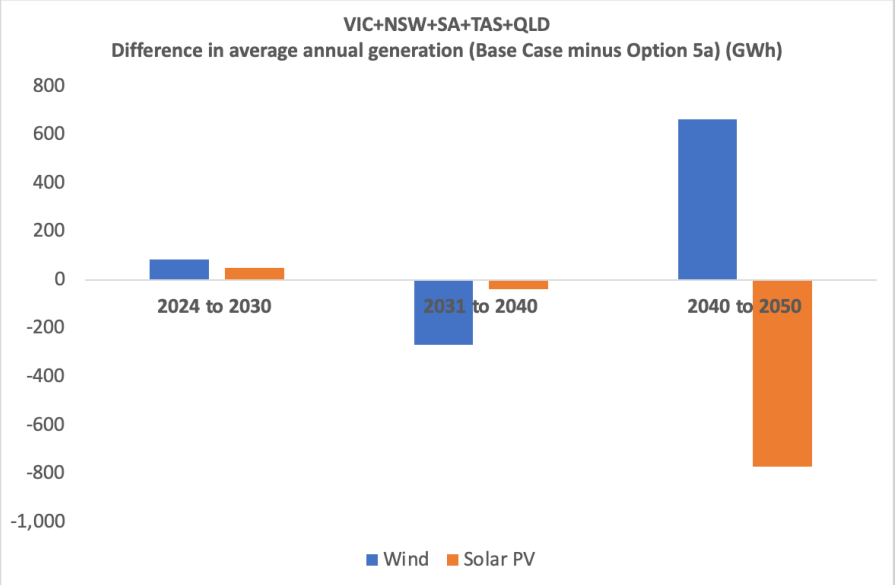
In its Consultation Report, AEMO said that "A*voided/deferred generation and storage costs (the darkest sections of each bar in Figure 5) are primarily driven by deferred/avoided investment of solar and wind, large-scale storage (mostly pumped hydro energy storage) and gas that is otherwise needed in Victoria to maintain reliability once brown coal retires*" (CR, page 38). In our Submission we analysed AEMO's spreadsheets and concluded that "*VNI-West reduces expenditure on pumped hydro in Victoria (by about $160m per year) and replaces it with more expenditure in NSW (about $35m) per year in NSW. We can see from this that this net difference makes up most of the "Avoided generation/storage costs which as noted repeatedly in this submission is 75% of AVP's estimate of the total benefit of VNI-West"* (Submission page 21).

We stand by this conclusion. Using AEMO's calculation of the annual value of the capacity differences between Option 5/5a and the Base Case in Victoria and valuing these differences at the annual cost of generation/storage based on the capital cost assumptions in the ISP reveals that 66% of the total capital cost benefit that AEMO calculates for Victoria is based on the claim that VNI-West results in the substitution of 24-hour storage in Victoria by batteries in NSW.

In our Consultation Report submission, we also pointed out that: "*AVP claims small benefits arising from the differences in the production of renewable energy between the Base Case and its five options. This is credible. It reflects the fact that variable renewable energy is inexpensive and consequently differences in the location of renewable electricity attributable to the construction of VNI-West are small. The important conclusion from this is that it can't be claimed that VNI-West creates any meaningful level of benefit by facilitating the development of renewable electricity in locations where there are better renewable resources*." (Submission p. 53)

The first part of this quote (the first two questions) is borne out by the evidence of the differences in the production from variable renewable generation (wind and solar)

comparing the Base Case with Option 5/5a. This comparison is presented graphically below in which a positive value shows higher production in the Base Case relative to Option 5/5a and negative values the converse. We see from this chart - for all five regions of the NEM - that the main effect of VNI-West is relatively greater production by solar in substitution of production from wind.



We accept criticism (although this is not AEMO's critique) that the third sentence of our quote does not follow from the first two sentences. AEMO's contention is that the third sentence, irrespective of the first two i.e. that "*it can't be claimed that VNI-West creates any meaningful level of benefit by facilitating the development of renewable electricity in locations where there are better renewable resources*" is wrong.

It is true that AEMO claims that VNI-West creates a meaningful level of benefit by facilitating the development of renewable electricity in locations where there are better renewable resources. But, for the reasons explained in the previous section, we conclude that AEMO is wrong. The basis of this conclusion as set out above, and in our Submission, is that AEMO has failed to determine a financially viable generation schedule. AEMO counts the benefits of avoiding or deferring renewable generation in some regions and advancing it in others, but this is not plausible since it assumes generation entry that would not occur since those generators - based on AEMO's spills and marginal losses - would simply not invest as AEMO assumes they will, on the basis of the large financial losses they would incur.

Appendix B: VNI-West will more than double transmission charges, not increase them by 25% as AEMO says

In our Consultation Report we said that "*Recovering the capital outlay in VNI-West will increase transmission charges in Victoria by at least 70%. The ongoing operation and maintenance charge will increase transmission charges by a further 25%. In round numbers, VNI-West will therefore double transmission charges in Victoria*".

AEMO rejected this and instead said that the impact of VNI-West will be to increase transmission charges by 25%. Specifically, AEMO said that VNI-West Option 5A is estimated to cost $3.5 billion, with approximately $1.8 billion capex to be spent in Victoria. Using a 5.5% discount rate and assuming a 40-year contract term, this is equivalent to approximately $112 million per year. Expressed as a ratio of AEMO's estimate of transmission charges in 2023/24, this is $112m/$650.2m = 17.2%. AEMO did not quantify opex, but presumably it assumes that this will add another 8%, so that in total they get to their 25%.

AEMO has made several errors of calculation:

1. It has used a discount rate (5.5%) that is 150 basis points lower than the discount rate it says it will be using for its 2024 ISP. Since VNI-West will be built from 2024 onwards (if indeed it is built at all) it is not appropriate to use a historic rate that fails to reflect the repricing of risk in financial markets, which AEMO correctly recognises in its ISP. The correct rate is 7%.
2. It makes no provision for interest during construction. We calculate (see below) that this adds 21% to the value of the asset that will enter the regulated asset value and hence be recovered in regulated charges.

   It uses costs estimated in 2020/2021$, instead of 2023/24 dollars, ignoring the substantial impact of inflation between 2020/2021 and 2023/24.

In addition, AEMO persists with capital costs that are under-estimated and operating costs that are badly under-estimated.

We use AEMO's 40-year amortisation period, the 7% discount rate it will use in the forthcoming ISP, 3% opex and correctly account for interest during construction, our assessment of capital costs and escalation to 2023/24 dollars as shown in Table 14 below. This results in annual capital charges of $366 million per year and operating charges $121m per year, giving a total of $487m. Expressed as a ratio of 2023/24 transmission revenues, this is a 75% increase.

In addition, it is necessary to add the cost of 220 kV augmentations in Victoria that are needed to ensure wind and solar farms in the Murray River and Western Victoria REZ are able to access the 500 kV VNI-West. This is explained in Section 4.2. The additional outlay for items 1.6 and 1.7 in the Extended VNI-West Plan (see Table 10) is $3,219 million.

Amortising this over 45 years at 7% and adding 3% average annual opex gives an annual revenue requirement of $333 million. Expressing this plus the annual revenue requirement for VNI-West (shown above) and expressing this total as a percentage of current transmission charges, means that prices will need to increase by 127%, not 25% as AEMO says.

We should stress that we think this is a likely lower bound estimate of price impacts. This is because we have been conservative (optimistic) in our estimate of capital and operating costs. In addition, we have made no allowance for what will almost certainly be a large increase in indirect costs. These are costs such as head-office costs (the finance and human resources departments, the chief executive's office and so on). Such a huge project will almost certainly lead to a large increase in indirect costs.

Table 14. Our estimate of VNI-West costs

VNI West Option 5A	2023	2024	2025	2026	2027	2028	2029	2030	2031	TOTAL
VIC early works	$ 33	$ 29	$ 6	$ 5	$ -	$ -	$ -	$ -	$ -	$ 73
VIC 500kV substation works	$ -	$ -	$ -	$ -	$ 4	$ 116	$ 392	$ 165	$ 8	$ 685
VIC 500kV line works	$ -	$ -	$ -	$ -	$ 9	$ 260	$ 648	$ 343	$ 18	$ 1,277
VIC power flow control and repeater site	$ -	$ -	$ -	$ -	$ 2	$ 54	$ 181	$ 76	$ 4	$ 316
VIC property/land access/easements	$ -	$ -	$ 77	$ 64	$ -	$ -	$ -	$ -	$ -	$ 141
VIC biodiversity offset costs	$ -	$ -	$ -	$ 8	$ 5	$ -	$ -	$ -	$ -	$ 14
Total VNI West	$ 33	$ 29	$ 83	$ 77	$ 20	$ 430	$ 1,220	$ 585	$ 30	$ 2,506
WRL Option C2										
VIC WRL Option C2 incremental - substation works	$ 4	$ 62	$ 210	$ 88	$ 4	$ -	$ -	$ -	$ -	$ 368
VIC WRL Option C2 incremental - lines works	$ 10	$ 207	$ 528	$ 280	$ 10	$ -				$ 1,035
VIC WRL Option C2 incremental - power flow control and repeater site	$ -	$ -	$ -	$ -	$ -	$ -				$ -
VIC WRL Option C2 incremental - land/access/easements	$ 61	$ 51	$ -	$ -	$ -	$ -				$ 112
VIC WRL Option C2 incremental - biodiversity offset costs	$ 4	$ 7	$ -	$ -	$ -	$ -				$ 11
Total WRL	$ 79	$ 327	$ 738	$ 368	$ 14	$ -	$ -	$ -	$ -	$ 1,525
Total WRL-VNI	$ 112	$ 357	$ 820	$ 445	$ 34	$ 430	$ 1,220	$ 585	$ 30	$ 4,032
Interest during construction at 7% p.a. real WRL	$ 32	$ 102	$ 166	$ 53	$ 1					$ 354
Interest during construction at 7% p.a. real VNI						$ 134	$ 275	$ 85	$ 2	$ 495
Total including interest during construction	$ 144	$ 458	$ 986	$ 498	$ 35	$ 563	$ 1,495	$ 669	$ 32	$ 4,880

Appendix C: AEMO has unreasonably constrained the development of renewables in Gippsland

In our Consultation Report Submission, we said the following:

"*The 2022 ISP Data and Assumptions spreadsheet (refer to tag "Build Limits") specifies a limit on the transmission capacity of the Gippsland REZ available for renewables as 500 MW of high-quality wind power, 1,500 MW of medium wind, and 500 MW for PV with a combined transmission limit of 2,000 MW.*

These transmission limits are derived by AEMO with no consideration of the existing 9,450 MW of transmission capacity available for use by all generators in the Gippsland REZ as well as Basslink, Marinus Link and offshore wind. If Gippsland renewables exceed any of these artificial transmission limits there is a transmission charge imposed of $570,000/MW of exceedance, despite there being 9,450 MW of free transmission capacity that every generator and Basslink/Marinus Link is entitled to use. Yet only the Gippsland renewables are constrained by artificial, much lower transmission limits above which huge imaginary transmission charges makes it uneconomic to exceed.

AEMO's specification of the area of land in the Gippsland REZ that is available for renewables also constraints renewables expansion in Gippsland. This land area is defined (by AEMO) to be only 4,947 km2 of which AEMO says only 5% is available for wind power and 1% is available for PV. The area shrinks to just 247 km2 for wind power and 49 km2 for PV.

Since wind power needs 24 ha/MW, only 1,030 MW of wind power is possible before an artificial land use penalty of $250,000/MW or $10,416/ha applies for any additional wind power up to AEMO's hard limit of 2,000 MW. Since PV needs 2ha/MW, the maximum capacity of PV is 2,474 MW before it too is penalised $250,000/MW. The tiny land area limits the development of PV to 2,474 MW and wind power to 1030 MW beyond which a $250,000/MW land penalty applies.

In addition, AEMO applies a 2,000MW transmission limit for renewable generation only in the Gippsland REZ, beyond which a transmission cost of $570,000/MW applies. This charge may even commence at 500 MW for PV. This is despite the 2005 VENCorp report having established that the Latrobe Valley has existing transmission capacity of 9,450 MW and is able to be extended to

more than 17,000 MW cheaply and quickly by minor substation works and new 500 kV lines built on existing easements as discussed above.

During a consultation that we attended AEMO and EY claimed, without evidence, that there was a stability constraint on Latrobe Valley to Melbourne transfer. Our investigations have not uncovered a stability limitation that would explain the low transmission capacities only applicable to renewables located in the Gippsland REZ in the ISP and in the Consultation Report. AEMO also explained that the tiny land use area is necessary because of social license issues in the Gippsland REZ, however the Gippsland REZ covers a very large area.

The combined hosting and transmission penalty charges of $905,000/MW exceeds the capital cost of PV and is 48% of the cost of wind power. In this way, AEMO constrains the development of wind and solar in the Gippsland REZ to the artificial transmission limits and land areas it controls through the input data to the ISP used in the Consultation Report.

With such build limits, transfer limits and penalties it is now clear why the Gippsland REZ is not developed for renewables in the ISP and the Consultation Report despite having the strongest transmission network in the southern hemisphere, plenty of land, and good wind and solar resources."

In response, AEMO said that we had:

1. Failed to understand that the transmission limit was not fixed at 2000 MW, but that it increased to 6,800 MW as coal generation closed.
2. That transmission was not the constraining factor but rather that land use penalties were the constraining factor.

We respond to each of these claims and then critique AEMO's response.

1. On the first criticism, we recognise that the transmission limit (beyond which penalties apply) increases from 2,000 MW in 2024/25 up to 6,800 MW by 2032/33. We did not suggest that the 2,000 MW limit applied to the end of the modelling period, albeit that we did not explicitly point out that the limit increased.
2. We reject the second criticism. AEMO can't know that its transmission penalty was not a binding constraint simply because new wind and solar is less than the transmission limit and penalty for exceedance. It may have been that the

transmission penalty was binding and stopped the entry of wind and solar below the transmission limit.

AEMO has not responded to our fundamental critique. In particular:

1. AEMO continues to provide no justification for the land use constraints they apply for the development of wind and solar. These are simply arbitrary AEMO assertions.
2. AEMO continues to ignore the evidence from VENCorp that the transfer limit from the Latrobe Valley to Melbourne is 9450 MW in summer and this can be increased to 11,200 MW (summer rating) for $22m (2005 prices) and then to 17,620 MW.
3. AEMO transmission limits (2,000 rising to 6,800) not only fail to reflect the existing Latrobe Valley to Melbourne transmission capacity but also make a fundamental error in relating the capacity to the closure of coal generation. Coal generators do not have firm access rights and hence a claim to transmission capacity under the National Electricity Rules. The transfer capacity of the Latrobe Valley to Melbourne transmission path is independent of the existence of coal generators. By failing to recognise this requirement in the Rules, AEMO is jeopardising the entry of renewable generation in Gippsland by providing preferential access of the coal generators to Latrobe Valley transmission.
4. AEMO has continued to fail, as noted, to provide any substantiation for its hard wind and solar build limits.
5. AEMO justifies its transmission penalty on the basis that it is lower than the penalty that applies in other REZ zones. This is not credible: there is no justification for any penalty on transmission above the 9,450 MW. Above that, the penalties should reflect VENCorp's costing, not the cost of transmission capacity expansion from the Latrobe Valley to Bairnsdale.

The conclusion in our Submission remains: AEMO has hobbled renewable generation in Gippsland for no good reason.

Appendix D: Specification and costing of Plan B

The estimated capital cost of each project has been derived from relevant project in the AEMO's Draft Transmission Cost Estimates Report, amended where appropriate for changes in the scope of the project relative to the scope of the project from that Report. Details are provided below for each Network Project in Plan B.

	Project	**Details of project scope of works**	**Cost ($million, 2023) including IDC**	**Cost ($million, 2022) excluding Interest During Construction (IDC)**	**Easement**	**Length (km)**
1.1	Open-circuit Buronga – Red Cliffs 220 kV line	Daytime - open Buronga - Red Cliffs circuit to avoid overloading V2 & V3 lines			n/a	-
1.2	Increase maximum conductor temperature on some 220 kV lines	Field measurements of conductor clearances by AusNet Services			n/a	-
1.3	On-line dynamic rating Red Cliffs-Ballarat-Moorabool-Sydenham	Weather monitors and telecommunications - installed on some easements.			n/a	-
1.4	Elaine to Moorabool	Elaine - Moorabool, 220 kV D/C, twin Peach conductors, could extend to Ballarat	204	175	spare easement	43
1.5	Gippsland REZ - 500kV Loy Yang to near Basslink transition point	Loy Yang - Giffard, two 500 kV S/C lines, Giffard 500 kV/220 kV substation	842	691	AusNet Services initiated project	130
1.6	V2 220kV network upgrade: Red Cliffs to Murra-Warra	Red Cliffs - Murra Warra, 220 kV D/C, twin Peach conductors	1,003	823	existing easement, ~10 m shift	263

	Project	Details of project scope of works	Cost ($million, 2023) including IDC	Cost ($million, 2022) excluding Interest During Construction (IDC)	Easement	Length (km)
1.7	V3 220 kV network upgrade: Murra-Warra to Ballarat	Murra-Warra - Ballarat, 220 kV D/C, twin Peach conductors	873	716	existing easement, ~10 m shift	229
1.8	V3-V4 220 kV network upgrade Ballarat – Moorabool (line 1)	Ballarat - Moorabool (1), 220 kV D/C, twin Peach conductors, 500 kV/220 kV trans	289	248	existing easement, ~10 m shift	64
2.1	V2 220 kV network upgrade: Red Cliffs to Kerang	Red Cliffs - Kerang, 220 kV D/C, twin Peach conductor	878	720	existing easement, ~10 m shift	230
2.2	V2-V3 220 kV network upgrade Kerang-Bendigo-Ballarat lines	Kerang-Bendigo-Ballarat, 220 kV D/C, Pearl conductors	725	595	existing easement, ~10 m shift	190
2.3	V3-V4 220 kV network upgrade Ballarat-Moorabool (line 2)	Ballarat - Moorabool (2), 220 kV D/C, twin Peach conductors, 500/220 kV transformer	289	248	existing easement, ~10 m shift	64
2.4	V4 500 kV S/C Sydenham to Moorabool	Sydenham - Moorabool, 500kV S/C, quad conductor	316	271	spare easement	63
3.1	V6-V1 220 kV line Shepparton-Glenrowan-Dedarang	Shepparton - Glenrowan - Ballaratt, 220 kV, Peach conductor	542	465	spare easement	175
	TOTAL		**5,962**	**4,952**		**1,451**

Cost of B1.1 Open-circuit Buronga – Red Cliffs 220 kV line in the daytime to prevent overloading V2 and V3 networks.

This would require no additional capital investment and could be implemented in the TransGrid and AusNet control rooms. It is necessary to prevent over-loading of the 220kV networks in V2 and V3 otherwise Project EnergyConnect would have to be constrained to levels well below its 800MW rating. This will prevent loop flows and deep network issues in the 220 kV Victorian network. It should mostly be required during the daytime when the solar farms in south-west NSW REZ are generating. Whether this action will be required in Phases 2 and 3 is yet to be established.

Standard cost estimates for rebuilding existing 220 kV lines with 220 kV D/C lines on existing easement.

Projects B1.6, B1.7, B1.8, B2.1, B2.3 all involve the rebuilding of an existing 220 kV S/C line with a 220 kV D/C line, in its existing easement using twin Peach conductors, followed by the demolition of the existing line and the restoration of the ~10 m of easement width for relinquishment of the easement no longer required to the landowner. These 5 projects have been estimated by determining the average $m/km for that type of project and then applying that rate to the length of each line. This standard rate has been based on the project REZ V6 Option 1, in the AEMO Draft Transmission Options Costing Report being a heavy-duty double circuit 220kV network between Shepparton and Dederang via Glenrowan. There are differences between that project and five Plan B projects, that necessitated the following adjustments to the REZ V6 option 1 cost estimation process:

- As these 5 Plan B lines are being built largely on an existing easement requiring only 10 m additional easement width, the allowance for easement costs and biodiversity costs was adjusted to 10 m instead of 50 m.
- The green fields 12% allowance was not required for this brown field site.
- The 6% cultural-heritage allowance applies to civil and structural works and reduced to 1% for electrical works as only the tower earthing may need monitoring.
- Given the line design is standard and the site well known, the allowance for unforeseen scope and technology risks was reduced from 28% to 14%.

- As one of the two additional 220kV circuits would re-use the substation equipment, the number of numbers of new switching bays was halved.
- Likewise, there will not be any requirement for new substation control buildings to house just one or two additional switching bays at substations.
- The plant and electrical cost components were increased for the larger conductor (Peach compared with Paw-Paw) using the scaling model used in the AEMO Transmission Cost Estimating Report, by comparing the scaling factors used in that model for increasing the conductor size from Lemon to Paw-Paw.

The adjusted estimated cost of REZ V6 Option 1 project is $464.5 million for 175km of D/C twin Paw-Paw conductor or $2.63 million per km. An allowance for tower demolition and site refurbishment of $125,000/km was added based on $50,000 per tower and an additional $400,000/km was added for the larger Peach conductor. The resultant average cost of $3.1 million per km was applied to the length of each project. A lower rate of $2.8 million per km was used for project B1.4, as it is being built on a spare easement with no need to acquire more easement or to demolish an existing transmission line.

Network Element Number	Network Element	Total Network Element Cost ($million)
1	Substation: Glenrowan 220 kV	6.26
2	220 kV Line: Shepparton-Glenrowan-Dederang	410.84
3	Substation: Shepparton 220 kV	4.67
4	220 kV Line: Shepparton-Glenrowan	2.53
5	Substation: Dederang 220 kV	4.78
	Total Network Element Cost	**429.08**
	Indirect Costs	
	Project Development	11.66
	Works Delivery	14.41
	Land and Environment	2.74
	Stakeholder and Community Engagement	3.60
	Procurement Costs	1.72
	Insurance	1.37
	Total Indirect Costs	**35.51**
	Total Expected Project Cost	**464.58**

Cost of B1.4 V3 220 kV Elaine to Moorabool.

There is a vacant 220 kV easement between Elaine and Moorabool (43 km long). The easement extends the extra 20 km to Ballarat however, there has been some encroachment on the easement at the Ballarat end which may necessitate undergrounding the final sections though the outskirts of Ballarat. Project B1.4 has been costed in two ways. Firstly, by applying the $2.8 million per km rate to the 43 km from Elaine to Moorabool gives a figure of $133 million. Secondly the AEMO Draft Transmission Options Report has an Elaine to Moorabool 220 kV line, that after adjustments (as assumed a green-fields easement is required) give a figure of $171 million.

Whilst achieving the goals of Plan B does not require the Elaine to Ballarat section before 2035, it would be prudent to construct the overhead line on the spare easement as far as is practical towards Ballarat during Phase 1, and to install the cable connection at a future stage.

It would not be necessary to establish a new Bendigo substation as only one feeder per double circuit line needs to be taken into Bendigo (as it currently does) with the other 220 kV feeder passing by. The satellite photos on Ballarat substation indicates that there should be sufficient space to turn another four 220 kV circuits into the existing substation, with final arrangements being resolved in the layout.

Cost of B1.5 V5 - twin S/C 500kV Loy Yang to Basslink Transition Point.

As proposed by AusNet Services for their non-regulated GREZ project, and also proposed by AEMO as one of the transmission options in their Draft Transmission Options Costing Report, this is an ~ 65km extension of the Latrobe Valley 500 kV network from Loy Yang 500 kV substation to a new 500 kV /220 kV substation in the vicinity of the Basslink Transition station.

The Plan B scope of works includes two new single circuit 500 kV lines rather than a double circuit 500 kV line, for power system security reasons, similar to those that resulted in the Latrobe Valley network and most of Victoria's 500 kV grid comprising single circuit

500 kV lines. Whilst this requires an additional $130 million to $140 million investment, it is a relatively short transmission line and could host over 3,000 MW of renewables.

The new substation is proposed to be a fully switched 500 kV breaker and half switchyards with provision for three single phase 1,000 MVA 275/220 kV transformers. Given the short 65 km line length, line reactors are not required. No new substation building would be required at Loy Yang substation and modular containers would be more cost effective for the Giffard terminal substation. There is considered to be no requirement for a $196 million synchronous condenser in Melbourne for this project.

The estimated costs of this project have been determined from project SEVic1 Option 1 in the AEMO Draft Project Cost Report, adjusted as above and summarised below. The $198 million Melbourne synchronous compensator that was included for this project in the Extended VNI-West project is not required for Plan B. This is because it was included by AEMO in the project to help manage the high voltages that are already occurring on the 500 kV network around Melbourne, and which will become much higher by the addition of WRL and VNI-West 500 kV lines pushing up the 500 kV voltages even higher when loaded below their Surge-Impedance-Loading (SIL). Plan B replaces these additional 500 kV lines with 220 kV lines, with much lower SIL's, and which can be more readily switched of, without serious power system security implications as a means of controlling high voltages when the Victorian grid is lightly loaded.

G-REZ Component	**Basis of estimate – AEMO estimate for REZ V5 – Option 1 less syn comp**	**$million at 2022 prices**
500kV transmission lines	2 x 65km @ $m2.7/km	351
Easement	65km, 100m wide @ $m0.9/km	59
Giffard substation works	Giffard 500 kV/220 kV with 2 transformers	140
Hazelwood works	AEMO adjusted for bays & building	50
Biodiversity offsets	From AEMO estimate adjusted for 100m	21
Sub-Total		**624**
contingency	10%	62
Total		**686**

This has been cross-checked by adjusting the AEMO cost estimate as follows.

		($million)
AEMO Cost Estimate		**853**
	Exclude indirect costs	(65)
	Less reactors & associated switching	(64)
	Less synchronous condenser	(196)
	More efficient control buildings	(20)
Adjusted cost		**508**
	Extra cost of lines & easements	135
	Indirect costs	53
Total cost		**696**

Taking the average, $691m is used.

Cost of B1.6 V2 220 kV network upgrade: Red Cliffs to Murra-Warra.

The $3.1 million per km was applied to the 266 km line length to obtain $824 million for the estimated cost of this project.

Cost of B1.7 V3 220 kV network upgrade: Murra-Warra to Ballarat.

The $3.1 million per km was applied to the 229 km line length to obtain $711 million for the estimated cost of this project.

Cost of B1.8 V3-V4 220 kV network upgrade Ballarat – Moorabool (line 1).

The 63 km Ballarat to Moorabool line would cost $195 million and a further $53 million has been included for a 500 kV / 220 kV transformer at Moorabool. Total cost $248 million. It should not be necessary to establish a new Bendigo substation as only one feeder per double circuit line needs to be taken into Bendigo (as it currently does) with the other 220 kV feeder passing by. The satellite photos on Ballarat substation indicates that there should be sufficient space to turn another four 220 kV circuits into the existing substation, with final arrangements being resolved in the layout.

Cost of B2.1 V2 220 kV network upgrade: Red Cliffs to Kerang.

This 230km line is estimated to cost $716 million.

Cost of B2.2 V2-V3 220 kV network upgrade Kerang-Bendigo-Ballarat lines.

This 190 km of 220 kV lines and substation connections will cost $595m at $3.1 million per km.

Cost of B2.3 V3-V4 220 kV network upgrade Ballarat-Moorabool (line 2).
This is identical to Project B1.8 and is estimated to cost $248 million.

Cost of B2.4 V4 500 kV S/C Sydenham – Moorabool.

This 63 km of single circuit 500 kV line has been costed from the relevant components and costing factors used in deriving the $864 million estimate for the 151 km Moorabool to Mortlake project and taking into account there is a vacant 500 kV easement between Sydenham and Moorabool. The resultant cost is estimated to be $271 million averaging $4.3 million per km compared with $5,5 million per km for Mortlake to Moorabool. The difference of $1.2 million per km is partly due (i.e. $0.8 million/km) to the cost of acquiring the easement and the other $0.4 million/km is due to risk factors for the more green-field route.

Cost of B3.1 V6-V1 220 kV line Shepparton-Glenrowan-Dederang.

Network Element Number	Network Element	Total Network Element Cost ($million)
1	Substation: Glenrowan 220 kV	6.26
2	220 kV Line: Shepparton-Glenrowan-Dederang	410.84
3	Substation: Shepparton 220 kV	4.67
4	220 kV Line: Shepparton-Glenrowan	2.53
5	Substation: Dederang 220 kV	4.78
	Total Network Element Cost	**429.08**
	Indirect Costs	
	Project Development	11.66
	Works Delivery	14.41
	Land and Environment	2.74
	Stakeholder and Community Engagement	3.60
	Procurement Costs	1.72
	Insurance	1.37
	Total Indirect Costs	**35.51**
	Total Expected Project Cost	**464.58**

Appendix E: Specification and costing of Extended VNI-West

The Victorian transmission projects in the Extended VNI-West Plan are listed in Table15. The rest of this appendix provides details on the costing of these projects.

Table 15. Summary of Extended VNI-West projects and their specifications

	Project	Details of project scope of works	Cost ($million, 2023) including IDC	Cost ($million, 2022) excluding Interest During Construction (IDC)	Easement	Length (km)
1.1	VNI-West 500 kV Sydenham to Bulgana (WRL)	Sydenham to Bulgana option 5A D/C 500kV towers, quad conductors	1,861	1,525	new, parallel existing line part-way	190
1.2	500 kV D/C Loy Yang to Basslink Transition	Loy Yang to new Giffard substation, 500kV D/C line, quad conductors	1,040	853	new green field easement	65
1.3	220kV S/C Shepparton to Dedarang via Glenrowan	Shepparton - Glenrowan - Dederang, 220 kV S/C, twin Lemon conductors	370	317	spare easement	175
1.4	VNI-West Option 5A 500 kV Bulgana to NSW border	Bulgana - New Kerang - near Swan Hill, option 5A, 500 kV D/C, quad conductors	3,057	2,506	new green field easement	236
1.5	500 kV S/C Sydenham to Mortlake	Sydenham - Moorabool - Haunted Gully - Mortlake, 500 kV S/C, quad conductor	1,425	1,102	spare easement to Moorabool	214
1.6	220 kV network for V3 (Western Vic REZ)	Murra Warra to Horsham to Ballarat, 220 kV D/C, twin Lemon conductors	907	744	new green field easement	229
1.7	220 kV network for V2 (Murray River REZ) - 2 D/C lines	Two lines Red Cliffs - Wemen - New Kerang or equivalent, 220 kV D/C, twin Lemon conductors	2,312	1,788	new green field easement	550
	TOTAL		**10,972**	**8,835**		**1,659**

The estimated costs of these projects are based on AEMO's latest cost estimates in their Draft Transmission Options Report (which is at mid-2022 price levels) and incorporates AEMO's and their consultant, Mott MacDonald's, knowledge, experience and expertise on transmission project scoping and cost estimation.

Projects 1.1 (WRL) and 1.4 VNI-West are not costed in AEMO's Draft Transmission Options Report. The cost of those projects has been estimated based on the VNI-West PACR and the updated WRL Cost/Benefit Analysis Report and includes the adjustments documented in the Mountain/Bartlett submission to the VNI-West Consultation Report (see Appendix B).

As only Victorian costs are required in this comparison, the estimated cost of VNI-West does not include NSW costs including the additional $135 million for the extra ~30km of transmission line and easements in NSW now required for Option 5A (refer to Transgrid's corridor selection report that states that Option 1 is 222 kms long compared with the 203 km stated in the PACR). As this is the length of the centreline of the study corridor, it has been increased by 5% to 233 km to allow for further route refinements as the EIS and consultation with impacted landowners proceeds.

The details of the cost estimate for each project are presented in the rest of this section that follow.

Cost of projects 1.1 and 1.4: VNI-West Option 5A.

1.1 and 1.4 have each been estimated as stand-alone projects, not using confusing incremental cost estimating methods, based on the VNI-West PACR, with adjustments contained in the Mountain/Bartlett submission and escalated 20% from mid-2020 prices to mid-2022 prices in accordance with the 20% increase noted in AEMO's Draft 2023 Transmission Expansion Options Report[35].

[35] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-2023-transmission-expansion-options-report.pdf?la=en

According to Transgrid's CEO at the NSW Government Inquiry into Undergrounding on 17th July 2033, transmission project costs have increased by 50% in the last two years[36]. The average cost of the 360 km long Humelink is now $13.9 million per km which is 73% higher than WRL's $8.0 million per km ($1,525 million per 190 km), and 30% higher that VNI-West (in Victoria) $10.7 million/km ($2,506 million per 235 km).

Cost of project 1.2: 500 kV D/C project from Loy Yang 500 kV substation to Basslink Transition Point.

The VNI-West PACR assumes 500 MW of wind-power in Gippsland REZ by 2024 and a further 1,500 MW of wind-power by 2029. This will require extending the 500 kV Latrobe Valley network from the Loy Yang 500 kV substation for around 65 kms to a location near the Basslink Transition Point, where there are excellent wind and solar resources.
The 2024 delivery date is not possible. The earliest possible date of end 2027 is assumed to be feasible as that is the date proposed by AusNet Services for their non-regulated G-REZ project.

AEMO has estimated the capital cost of this project in their draft Transmission options report, project SEVIC1 Option 1 at $853 million in June 2022 prices. That is around $250 million more than the indicative $600 million cost proposed by AusNet Services for its unregulated equivalent, which is similar to the Plan B project for Gippsland in Phase 1.
The AEMO cost estimate is summarised below, and further details are included in sheets B and C of SEVIC1 Option 1, Victorian REZ transmission in the Cost Estimates[37] report folder.

[36] Specifically, he said that Humelink is now expected to cost $5bn, compared to the $3.3bn estimated just two years ago.

[37] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-cost-estimate-reports.zip?la=en

Table 16. Cost of 500 kV D/C project from Loy Yang 500 kV substation to Basslink Transition Point

	Total Expected Costs ($million)
Baseline Cost	454.43
Adjusted Baseline Cost	533.31
Known Risk Allowance	71.31
Unknown Risk Allowance	182.89
Total Network Element Cost	**787.50**
Indirect Costs:	
Project Development	21.42
Works Delivery	26.46
Land and Environment	5.04
Stakeholder and Community Engagement	6.62
Procurement Costs	3.15
Insurance	2.52
Total Indirect Cost	**65.21**
Total Expected Project Cost	**852.71**

Cost of project 1.6: 220 kV network for V3 (Western Vic REZ).

WRL will not increase the renewables hosting capacity of Western Victoria V3 REZ as it does not upgrade the 220 kV line to the west and east of its new Bulgana 500 kV / 220 kV substation. The existing 220 kV network comprises a single 220 kV single-circuit transmission line with twin Panther ACSR conductors, already frequently constrained to its full thermal capacity of ~400 MW. Renewables from Red Cliffs to Murra-Warra flow through V3 REZ and constraints will be exacerbated by loop flows from Project EnergyConnect (PEC) as soon as it is energised.

WRL will provide little additional hosting capacity to V3 REZ and may increase the already high renewable energy spills when combined with PEC loop flows. This will increase the curtailment of renewable generation to the north-west of Bulgana as far as Red Cliffs**.**

The western section is part of a 350 km, single 400 MW transmission running from Red **C**liffs to Bulgana that already has 534 MW of renewables connected, so it cannot possibly host any more renewables**,** noting the 121 MW Carwarp solar farm just coming on-line. The eastern 104 km from Bulgana to Ballarat already has 512 MW of connected wind farms, so it too cannot host any more renewables. If more renewables do connect, thinking

WRL will help, the renewable curtailment will increase even more than now, since the existing 220 kV line cannot be safely or legally operated above its rating.

Addressing this serious issue and obtaining some value out of WRL will require building ~229km of new 220 kV transmission line between Murra-Warra, Bulgana and Ballarat to provide an additional 800 MW of hosting capacity to the west and 800MW to the east of Bulgana (i.e., to deliver the promised +1,460 MW + 200 MW of V3 hosting capacity promised by the PACR for V3 REZ.

Project REZ V2 Option 1 in AEMO's Draft 2023 Transmission Expansion Options Report is very similar in scope and cost per km, being 275 kms of new 220 kV double circuit line from Red Cliffs to New Kerang, with twin lemon ACSR conductors, a rating of 892 MVA, an estimated total cost of $894 million averaging $3.25 million/km. Since the transmission line component is 88% of that project's total cost, it is reasonable to use the $3.25 million/km rate to estimate the costs for the V2 and V3 220 kV projects by multiplying the $3.25 million/km rate by the appropriate network length.

Such an augmentation should alleviate congestion of the existing 220 kV network by tripling its thermal capacity, however this would need to be confirmed by power system AC contingency studies. AEMO's estimated cost of REZ V2 Option 1 is summarised below. For the purpose of estimating the cost of the V3 220 kV works, the 229 kms of new 220 kV line between Murra-Warra and Ballarat has been priced at $3.25 million per km to give a total estimated project cost of $744 million.

Network Element Number	Network element	Total Network Element costs ($million)
1	OHL 1: New Kerang - Wemen 220kV - Red Cliffs	730.82
2	OHL4: New Red Cliffs - Wemen 220kV Line Diversion	2.00
3	SS1: Red Cliffs 220kV	29.67
4	SS2: Wemen 220kV	16.68
5	SS3: new Kerang 220kV	37.31
6	OHL Tie: Red-Wem-Ker	9.49
7	Underground cable exit for Red Cliffs	0.00
	Total Network Element Cost	825.98
	Indirect Costs	
	Project Development	22.47

	Works Delivery	27.75
	Land and Environment	5.29
	Stakeholder and Community Engagement	6.94
	Procurement Costs	3.30
	Insurance	2.64
	Total Indirect Cost	**68.39**
	Total Expected Project Cost	**894.37**

Cost of project 1.3: Shepparton to Dederang via Glenrowan.

The additional 400 MW hosting capacity for V6 REZ Central Victoria in 2030 would require another 220 kV circuit to Shepparton. This could be achieved by either:

- Building another single circuit line 175 km from Shepparton to Dederang via Glenrowan on an existing spare transmission easement; or
- Constructing on a new easement for the 155 km to Bendigo and then 120 kms to Ballarat; or
- Building a double circuit 220 kV line due to its economies of scale; or
- Building a double circuit 500 kV line from New Kerang to New Shepparton 500 kV /220 kV substation as proposed in the Draft 2023 Transmission Expansion Options Report for only twice the cost per km but 14 times the capacity according to AEMO's latest cost estimates!

For the` purpose of the estimated cost of AEMO's ISP/PACR, Option (a) has been costed as it is all that is needed and uses existing easements. Transmission Project REZ V6 Option 1, a similar project but with a double circuit 220 kV line on a new easement and much larger Paw-Paw conductors has been estimated by AEMO to cost $666 million as summarised in the table below. Adjusting this cost estimate to (a) use the existing vacant easement reduces its cost by $130 million; (b) using Lemon conductor reduces its cost by $49 million; (c) Building as single circuit reduces its cost by 35% resulting in an adjusted project cost of $317 million, or $1.81 million per km which seems reasonable.

Network Element Number	Network element	Total Network Element costs ($million)
1	Substation: Glenrowan 220 kV	12.53
2	220kV Line: Shepparton - Glenrowan - Dederang	567.06
3	Substation: Shepparton 220kV	9.15
4	220 kV Line: Shepparton - Glenrowan	2.53
5	Substation: Dederang 220kV	23.45
	Total Network Element Cost	614.72
	Indirect Costs	
	Project Development	16.72
	Works Delivery	20.65
	Land and Environment	3.93
	Stakeholder and Community Engagement	5.16
	Procurement Costs	2.46
	Insurance	1.97
	Total Indirect Cost	**50.90**
	Total Expected Project Cost	**665.62**

Cost of project 1.7: 220 kV D/C network for V2 (Murray River REZ).

The VNI West PACR has increased the 850 MW hosting capacity of Option 5 in the Consultation report to 1,075 MW and increased that further to 1,580 MW hosting capacity for Option 5A without explanation. Entirely the opposite should be expected since Option 5A is 50 km longer than Option 5 and every additional km reduces VNI-West's southwards transmission capacity by 2 MW. This means that the VNI-West transfer capacity should really be 1,550 MW for Option 5A compared with 1,650 MW for Option 5.

GHD's Project EnergyConnect Steady State Market Integration Studies published 29th May 2023[38], confirms that as soon as Project EnergyConnect is energised, the glut of renewable generation in south-west NSW will flood into Red Cliffs via the quadrupled capacity of the Buronga to Red Cliffs 220 kV transmission line. This will severely congest

[38] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/technical-report---phase-1-project-energy-connect-integration.pdf?la=en

both existing 220 kV transmission lines in V2 REZ increasing further the curtailment of renewable energy. The GHD report appears to be the first time that post-contingent power flows have been conducted using the full AC network model for what is colloquially known as the "rhombus of regret". Even so, it does not appear to have identified some of the severe loading issues on the 220 kV transmission line between Red Cliffs and Horsham or between Buronga and Balranald, such as:

1. The Red Cliffs-Horsham 220 kV line (via Kiamal and Murra-Warra) will have around 900 MW wind and solar connected, but it only has a rating of 417 MVA. Thus, there will be non-contingent overloads during the day which will be exacerbated by import from SA at Buronga. The PEC will be constrained during the day due to the presence of more than 1,000 MW solar in Vic and south west NSW

2. The 220 kV line from Buronga to Balranald to Darlington Point has the same 417 MVA rating but has 450 MW at Balranald and 250 MW from Broken Hill. The potential overload when flows go towards Sydney will also result in PEC Stage 1 curtailment during the day.

3. Opening of a circuit breaker at Horsham on the Red Cliffs line (perhaps not even due to a fault) will require extremely rapid tripping of most of the generation in the region to prevent voltage collapse on the 220 kV networks.

The large number of post-contingent overloads of up to 60% means that Project EnergyConnect will be constrained to low levels during the daytime to avoid a cascading collapse of the Victorian 220 kV network.

The 220 kV network in V2 must be substantially augmented before PEC is energised (or by switching out the new Buronga to Red Cliffs line all day, every day) and before VNI West is energised. Contrary to AEMO's claim, VNI-West will not increase the renewables hosting capacity of Murray River V2 REZ as it does not upgrade the ~275km 220 kV line that runs from Red Cliffs to the New Kerang 500 kV /220 kV substation. This single 400 MW line already has 353 MW of solar farms connected and will also carry NSW and South

Australian solar power down to Melbourne via the vastly upgraded Buronga to Red Cliffs line (part of **S**tage 1 Project Energy Connect to be energised next year)**.**

Addressing this serious issue and delivering the promised +1,580 MW hosting capacity will require the equivalent of two (not just one) new 220 kV lines of 800 MW capacity each from Red Cliffs to New Kerang**.**

These new 220 kV transmission lines are only part of the extensive program of 5 new 220 kV lines and 3 new 500 kV transmission lines listed in the Victorian Renewable Energy Zones Development Plan Directions Paper issued in February 2022.

Cost of project 1.5: New 500 kV S/C from Sydenham to Mortlake.

AEMO's VNI-West PACR modelling results shows a 2 GW step increase in the installed capacity of wind farms in South-west Victoria REZ in 2033. This is obviously not an incremental increase but is driven by the modelled closing of the Loy Yang B power station the year before. The PACR confirmed that a new 500 kV augmentation is included for South-West Victoria REZ in 2033 and it would appear that this is the Sydenham to Moorabool to Mortlake 500 kV line. This project is needed in the PACR by 2033 to reinforce South-West Victoria REZ to enable the 2000 MW increase in its transmission hosting capacity. Whilst there is no information in AEMO's ISP or the VNI-West PACR on the locations of these new renewables within V4, it is assumed that they would only require additional transmission hosting capacity as far west as the Mortlake 500 kV substation.

This means a third 500kV single circuit between Sydenham and Moorabool and Mortlake. This project would be required to be operational by 2033 and its capital cost has been estimated by AEMO in its Draft 2023 Transmission Expansion Options Report at $831 million as summarised below and further details are included in sheets B and C of REZ SWV1 Option 1, Victorian REZ Transmission Cost Estimate Reports.[39]

[39] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-cost-estimate-reports.zip?la=en

The cost of the Sydenham to Moorabool section has been estimated to be $271 million as part of Plan B below and this has been added to the $831 million (see Plan B Project for details) to give a total cost of $1,102 million.

Table 17. Cost of new 500kV S/C from Moorabool to Mortlake

Network Element Number	Network element	Total Network Element costs ($million)
1	OHL1: Mortlake - Moorabool 500 kV	688.03
2	SS1: Mortlake 500kV	41.99
3	SS3: Moorabool 500kV	37.36
	Total Network Element Cost	767.37
	Indirect Costs	
	Project Development	20.87
	Works Delivery	25.78
	Land and Environment	4.91
	Stakeholder and Community Engagement	6.45
	Procurement Costs	3.07
	Insurance	2.46
	Total Indirect Cost	**63.54**
	Total Expected Project Cost	**830.91**

There is no requirement in the ISP or PACR for an additional 500 kV transmission line to Portland before 2035.