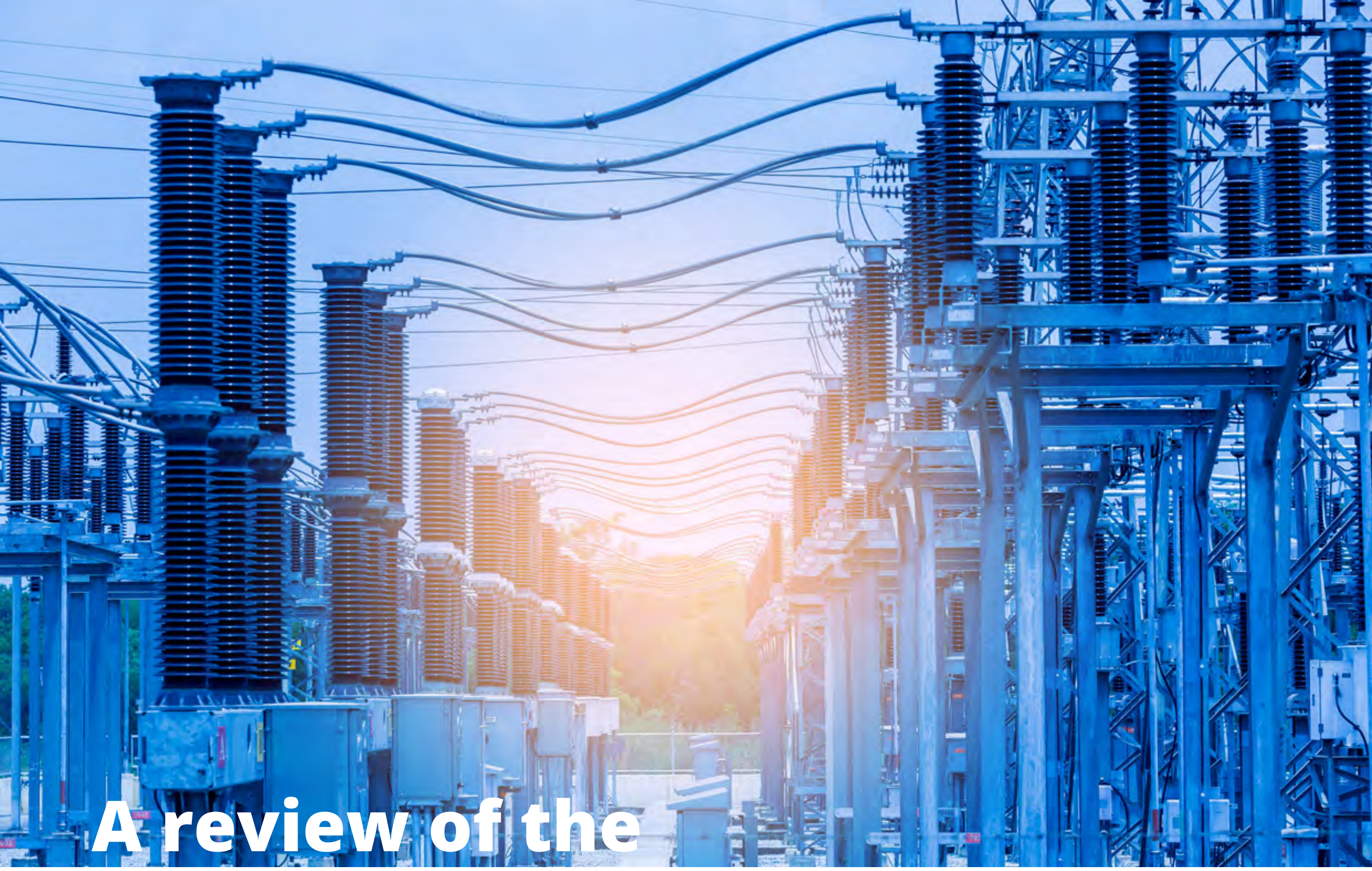

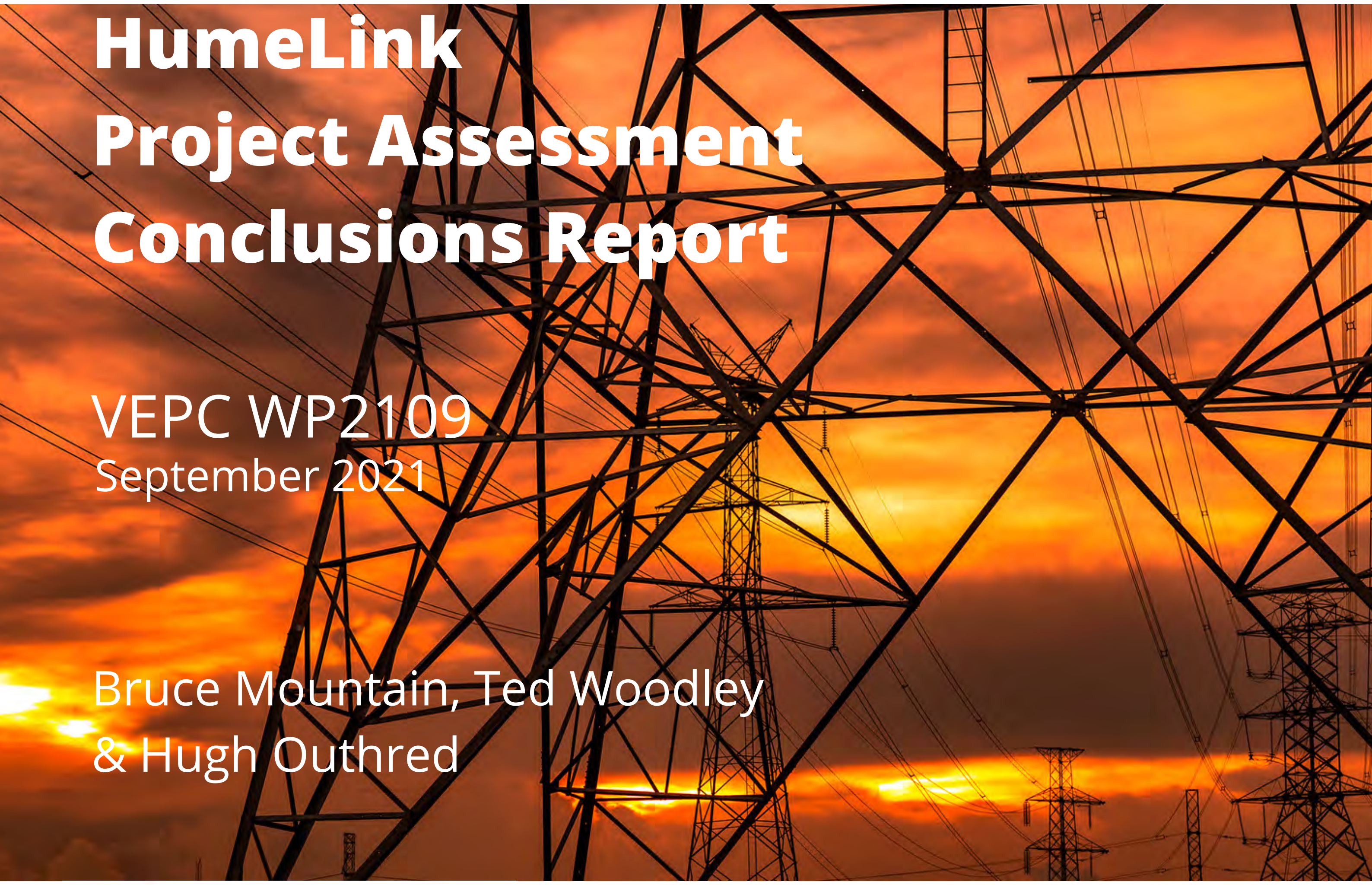

A review of the HumeLink Project Assessment Conclusions Report

VEPC WP2109
September 2021

Bruce Mountain, Ted Woodley
& Hugh Outhred

A review of the HumeLink Project Assessment Conclusions Report[1]

VEPC Working Paper WP2109
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Bruce Mountain, Ted Woodley, Hugh Outhred[2]

Abstract

HumeLink will be the most expensive transmission project in the history of the Australian electricity industry, and one of the biggest, with TransGrid's preferred option comprising 330 km of 500 kV double-circuit lines and construction or augmentation of three 500/330 kV substations in southern New South Wales (NSW). HumeLink is essential for the 2,040 MW Snowy 2.0 pumped hydro station, the largest single-point load ever to be connected to the National Electricity Market and the largest generator for 35 years. TransGrid's recent Project Assessment Conclusions Report (PACR) reveals that HumeLink's estimated cost has increased from $1.3bn in the Project Assessment Draft Report, to $3.3bn (accuracy of -30%/+50%). NSW transmission tariffs will increase by about 40% if the total cost is borne by electricity consumers. The PACR has incorrectly treated Snowy 2.0 as a sunk cost in the cost/benefit analysis. HumeLink is a necessary complement to Snowy 2.0 and the economic analysis of HumeLink should include the cost of Snowy 2.0, since the benefits of Snowy 2.0 are also counted. When the cost of Snowy 2.0 is included in the cost/benefit analysis, HumeLink is found to impose a deadweight loss exceeding $4bn. If HumeLink nonetheless proceeds, Snowy Hydro should be required to pay its fair share of the cost, especially since Snowy 2.0 is the main determinant of HumeLink's route, size and timing. In addition to the fundamental error in the cost/benefit analysis, our review finds many other errors and inconsistencies in the PACR and a failure to justify the preferred HumeLink option relative to other options. There is an urgent need for an independent transmission planning review process in NSW.

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[1] Project Assessment Conclusions Report "Reinforcing the NSW Southern Shared Network to increase transfer capacity to demand centres (HumeLink)", TransGrid, 29 July 2021.

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PART A: ECONOMIC OVERVIEW

Cost/benefit analysis, such as done in the Regulatory Investment Test, is a method of analysis that originates in the field of welfare economics. The purpose is to determine whether the benefits of a project is likely to exceed its cost, and so be welfare-enhancing.

In the Australian electricity regulatory system, if the benefits of a transmission project exceeds its costs in the Regulatory Investment Test, the project is deemed to be eligible to be included in the regulated asset base and hence its costs recovered from electricity users according to the arrangements set out in the National Electricity Rules.

The benefits are the "avoided costs" (both capital and operating) that arise as a result of the project. In the case of major transmission augmentations, typically the largest element of the avoided cost is the capital cost of new generation or storage that the transmission augmentation avoids. The second largest benefit is typically fuel cost savings that arise when generation with higher production cost is replaced by generation with lower production cost.

The costs and avoided costs that are eligible to be included in a cost/benefit analysis are, in principle, costs that arise in future. The capital costs of existing generation are excluded because these costs are sunk. In other words, a new transmission line might advantage some existing generators and disadvantage other existing generators, but the capital expenditure in these generators has already been sunk and so a new transmission line does not affect that sunk expenditure, it only affects the operation of those generators.

The PACR treats Snowy 2.0 as a sunk cost, as if it were an existing generator and so does not include Snowy 2.0's capital costs when assessing whether the benefits of HumeLink exceed its costs. But the estimation of the benefits of HumeLink does count those that arise as a result of Snowy 2.0.

Is this correct? In short, no.

The Australian Government, through Snowy Hydro, would not have committed to Snowy 2.0 without being confident that a new transmission line capable of shipping its production (from generation) and supplying its demand (for pumping), would be built. Without HumeLink, Snowy 2.0 would be largely stranded, with very limited transmission capacity via the existing 330 kV transmission system, whose capacity is already used when the existing Snowy Hydro generators produce electricity. Usage of the line by Snowy 2.0 would curtail the operation of those existing generators when Snowy 2.0 was generating.

HumeLink is therefore a *necessary* complement to Snowy 2.0 and any plausible cost/benefit analysis of Snowy 2.0 would have had to include the costs of expanding transmission in order to accommodate its production and demand (this was not done in the cost/benefit analysis of Snowy 2.0). For the same reasons, in the cost/benefit analysis of HumeLink the cost of Snowy 2.0 should have been included (and we note that again that has not been done).

A counter-argument to including the cost of Snowy 2.0 in the cost/benefit analysis of HumeLink is that the Australian Government has already committed to Snowy 2.0 and Snowy Hydro has already commenced construction (18 months ago). Therefore, the argument goes, even though Snowy 2.0 is not yet operational it should be treated as a sunk cost and so not counted in the cost/benefit analysis of HumeLink, just like existing generators.

This counter-argument is flawed for two reasons. Firstly, simply because Snowy Hydro has committed to Snowy 2.0 before TransGrid has applied for regulatory approval to pass the costs of HumeLink on to NSW electricity consumers, is no reason in economics to treat Snowy 2.0 as a sunk cost. If this was not the case, then any transmission proponent could undermine any cost/benefit analysis by simply claiming that a proposed generator is committed and so its costs should not be counted in the analysis for a new line whose primary purpose is to serve that newly proposed generator.

Excluding Snowy 2.0 from the cost of HumeLink is like doing a cost/benefit analysis of a railway extension that only counts the cost of the track because a commitment had already been made to build the stations.

Secondly, most of the cost of Snowy 2.0 is not sunk, it is marginal and can be avoided (although no doubt financiers and constructors will charge exit fees and there will be remediation costs to rectify the impact of monies already spent).

It might nonetheless be suggested that if the cost of Snowy 2.0 is to be included in a cost/benefit analysis of HumeLink, only the amount not yet incurred should be included since it is not yet sunk. We reject this too: the decision to invest in Snowy 2.0 depended on the subsequent construction of HumeLink, just like the decision to build train stations depends on the decision to build a rail track to connect them. The fact that Snowy Hydro has already started to build Snowy 2.0 before TransGrid has applied for regulatory approval, does not in substance justify classifying that part of the expenditure already incurred as sunk.

Clearly an economically sound cost/benefit analysis of HumeLink should compare the costs of Snowy 2.0 plus HumeLink on the one side, against the costs that would be avoided (i.e. the “benefits”) if Snowy 2.0 and HumeLink were not constructed on the other side. If such benefits exceed the costs then HumeLink can be concluded to be a welfare-enhancing transmission augmentation that, under the National Electricity Rules, NSW electricity consumers can legitimately[3] be required to pay for.

The benefits of HumeLink (including those resulting from connecting Snowy 2.0) presented in the PACR are (correctly) based on TransGrid’s estimate of avoided costs that would otherwise be incurred by other participants (such as gas generators, batteries, possibly other pumped hydro and flexible demand) that do not need HumeLink in order to function. In addition, HumeLink also provides benefits not related to Snowy 2.0 (such as capacity that would be used by new wind farms in southern NSW or from greater interconnection to South Australia – Project EnergyConnect). The PACR has (correctly) also included its estimate of replacing these benefits if HumeLink was not built. Though we note that we do not necessarily agree with the PACR’s estimates.

Notwithstanding, the many reservations set out in Part B about TransGrid’s calculation of the costs and benefits of HumeLink, for the purpose of the economic analysis presented here we simply use the PACR’s estimates *ipso facto*. In addition, we add the costs of Snowy 2.0 based on Snowy Hydro’s latest estimate of “about $6bn”.

When we set the estimate of the cost of Snowy 2.0 plus HumeLink against the estimate of the benefits (i.e. avoided costs and competition benefits) of HumeLink, we find a net loss of $4.4bn for Option 3C (the preferred option). The loss is larger for the other options presented.

[3] Note that in using the term “legitimate” we are not suggesting that it is necessarily economically sensible to recover the costs of transmission from consumers, and not from producers or a combination of producers and consumers. Rather we are indicating only that if the benefits exceed the costs, then TransGrid is entitled to recover the costs of HumeLink through regulated charges.

Figure A1 summarises the results, including (in the lower part of the table) the case that if Snowy 2.0 cost $8bn rather than $6bn (which is arguably more likely). This shows a net loss of $6.1bn.

Evidently, from the data in the PACR's analysis it is possible to obtain the services provided by HumeLink much more cheaply from the alternative sources that TransGrid and its advisors have identified in the estimation of the avoided costs of HumeLink. In other words, after correctly accounting for the cost of Snowy 2.0 and HumeLink and using TransGrid's own estimates, building HumeLink will result in a deadweight economic loss for the people of NSW exceeding $4bn. If HumeLink was not built, this economic loss would be avoided.

As noted, we consider the PACR estimates of the avoided costs are likely to be over-stated and so the actual loss is likely to be greater than estimated using the PACR's estimates of the avoided costs.

Costs, benefits and net benefits	**NPV (disc 5.9%)**
Snowy 2.0 construction cost estimate $6bn	-$4,942m
HumeLink benefits minus costs (Houston Kemp)	$43m
Net benefit Snowy 2.0 $6bn + HumeLink 3C excl comp'n benefits	-$4,898m
Competition benefits (Ernst and Young Table 2, p 6 Central)	$407m
Net benefit Snowy 2.0 $6bn + HumeLink 3C incl comp'n benefits	-$4,442m
Snowy 2.0 construction cost estimate $8bn	-$6,589m
HumeLink benefits minus costs (Houston Kemp)	$43m
Net benefit Snowy 2.0 $8bn + HumeLink 3C excl comp'n benefits	-$6,546m
Competition benefits (Ernst and Young Table 2, p 6 Central)	$407m
Net benefit Snowy 2.0 $8bn + HumeLink 3C incl comp'n benefits	-$6,139m

Figure A1 Net benefit, HumeLink Option 3C and Snowy 2.0

Snowy Hydro and the Australian Government chose to proceed with the construction of Snowy 2.0 before the full cost and ramifications of the transmission connection were determined. There was no urgency to proceed with Snowy 2.0 prior to finalising its transmission connection. We and others warned at the time that the likely total costs would far exceed the benefits.

It is now clear – using TransGrid's own analysis – that HumeLink and Snowy 2.0 will be a massive impost on taxpayers and consumers.

The logical (and appropriate) course of action for Snowy Hydro and the Government now, would be to cut their losses. Terminating the project at this point would, we understand, mean billions of dollars of expenditure and nothing to show for it, except for extensive earthworks in Kosciuszko National Park requiring rehabilitation. This would, nonetheless, be a less-worse outcome than were Snowy Hydro to throw yet more good money after bad, not least since much more has yet to be spent than has already been spent.

If Snowy Hydro refuses to terminate Snowy 2.0 and if HumeLink is rammed through regulatory approvals, there can be no reasonable basis to pass the cost of HumeLink onto electricity consumers. The NSW Government should protect the interests of electricity consumers and demand that Snowy Hydro pay its fair share of the cost of HumeLink, so that the economic losses of HumeLink do not fall so squarely on the shoulders of the NSW electricity consumer.

PART B: DETAILED COMMENTS

1 Key Points

Part B provides additional detailed comments on the economic and technical aspects of the PACR, as presented.

- The estimated cost of HumeLink has increased by $2 billion. The PACR estimate of $3,317m is 250% more than the Project Assessment Draft Report (PADR) estimate of $1,350m, released in January 2020, but is still classified as having 'a high degree of uncertainty' (-30%/+50%).
- TransGrid's regulatory asset base will expand by 50% and its revenues and transmission tariffs will rise by around 40%.
- NSW household tariffs will increase by around 4% – a household with a typical annual electricity bill of $1,500 will pay an extra $60 or so a year.
- The PACR has numerous inconsistencies and errors and does not provide a coherent or compelling case for the preferred HumeLink option.
- Selection of the best option should be based on more than the estimated net benefit.
- The estimated benefits are overstated, particularly the avoided generator fuel costs due to an overestimated operation of Snowy 2.0, averaging 1,200 MW continuously.
- HumeLink can be re-configured to claw back some value, but its cost will exceed its benefits, even ignoring the fundamental issue covered in Part A.
- Snowy 2.0 is driving the need for, routing, size, timing and cost of HumeLink – it will account for 80% of HumeLink's firm capacity (2,570 MW).
- Connecting HumeLink and Snowy 2.0 to the existing Lower Tumut Switching Station has merit compared to the proposed Maragle Substation.
- Using existing easements, or adjacent land, could save hundreds of $millions and minimise environmental and landholder impacts.
- Undergrounding should be seriously considered, either in part or whole (with HVDC).
- There is a need for an independent expert review of HumeLink, potentially involving AEMO, to identify the least-worst design to connect Snowy 2.0. A second review task would be to recommend a new, robust transmission planning procedure for NSW.

2 Summary of the PACR[4]

2.1 Purpose of PACR

"Overall, a key purpose of this PACR is to provide interested stakeholders the opportunity to review the analysis and assumptions and have certainty and confidence that the preferred option has been robustly identified as optimal."

2.2 Need for HumeLink

"The driver for the [seven] credible options considered in this PACR is to deliver a net economic benefit to consumers and producers of electricity and support energy market transition through:

- *increasing the transfer capacity between the Snowy Mountains and major load centres of Sydney, Newcastle and Wollongong;*
- *enabling greater access to lower cost generation to meet demand in these major load centres; and*
- *facilitating the development of renewable generation in high quality renewable resource areas in southern NSW as well as southern states, which will further lower the overall investment and dispatch costs in meeting NSW demand whilst also ensuring that emissions targets are met at the lowest overall cost to consumers."*

These sources of market benefit were included as the identified need for HumeLink in the 2020 ISP.

This PACR also finds that there are significant benefits expected from the preferred option through increasing the competitiveness of bidding in the wholesale market (referred to as 'competition benefits' under the RIT-T)."

2.3 Options

"This PACR assesses seven credible options for increasing transfer capacity between southern NSW and Sydney, Newcastle and Wollongong, reflecting three alternative network topologies and two different operating capacities [330 kV vs 500 kV]:

- *Topology 1 – a 'direct' path between Maragle and Bannaby (Options 1A, 1B & 1C)*
- *Topology 2 – a path between Maragle and Bannaby via Wagga Wagga that would open up additional capacity for new renewable generation in southern NSW (Options 2B & 2C)*
- *Topology 3 – a wider footprint via Wagga Wagga, that would open up both direct and additional capacity for new renewable generation in southern NSW (Options 3B & 3C)"*

2.3 Conclusion

"This PACR finds that Option 3C, involving new 500 kV double-circuit lines in an electrical 'loop' between Maragle, Wagga Wagga and Bannaby is expected to deliver approximately $491 million in net benefits over the assessment period (on a weighted- basis) and is the preferred option identified under this RIT-T. Option 3C is found to have approximately 23 per cent greater estimated net benefits than the second ranked option (Option 2C)."

Figure 1, extracted from the PACR, shows the key information for the seven 'credible' options. This paper focusses on Options 1C, 2C and 3C, as they have been determined by the PACR to be the top three (in reverse order).

[4] Assembled from extracts from the PACR.

5. Seven options have been assessed (continued)

Table 5-1 Summary of the 'topology 1' credible options assessed in this PACR

TOPOLOGY/OPERATING CAPACITY	A. FIXED 330 KV	B. FLEXIBLE 500 KV	C. FIXED 500 KV
1 Two new transmission lines between Maragle and Bannaby	**OPTION 1A** Two new 330 kV high capacity transmission lines, switchgear and phase shifting transformer	**OPTION 1B** Two new 500 kV transmission lines operated at 330 kV, switchgear and phase shifting transformer	**OPTION 1C** Two new 500 kV transmission lines, tie transformers and switchgear
	Additional firm capacity 2,050 MW	**Additional firm capacity** 2,170 MW initially 2,570 MW if upgraded to 500 kV	**Additional firm capacity** 2,510 MW
	Indicative capex Lines and substations: $1,470m Biodiversity offset cost: $1,060m Total capex: $2,530m	**Indicative capex** Lines and substations: $1,990m Biodiversity offset cost: $1,320m Total capex: $3,310m	**Indicative capex** Lines and substations: $1,725m Biodiversity offset cost: $1,340m Total capex: $3,065m

Note: Lines represent circuits only and are not intended to represent transmission line routes.

Table 5-2 Summary of the 'topology 2' credible options assessed in this PACR

TOPOLOGY/OPERATING CAPACITY	B. FLEXIBLE 500 KV	C. FIXED 500 KV
2 New transmission lines between Maragle, Wagga Wagga and Bannaby	**OPTION 2B** Four new 500 kV transmission lines operated at 330 kV, switchgear and phase shifting transformers	**OPTION 2C** Four new 500 kV transmission lines, tie transformers and switchgear
	Additional firm capacity 2,000 MW initially 2,500 MW if upgraded to 500 kV	**Additional firm capacity** 2,510 MW
	Indicative capex Lines and substations: $3,150m Biodiversity offset cost: $1,150m Total capex: $4,300m	**Indicative capex** Lines and substations: $2,585m Biodiversity offset cost: $815m Total capex: $3,400m

Note: Lines represent circuits only and are not intended to represent transmission line routes.

Table 5-3 Summary of the 'topology 3' credible options assessed in this PACR

TOPOLOGY/OPERATING CAPACITY	B. FLEXIBLE 500 KV	C. FIXED 500 KV
3 New transmission lines in an electrical 'loop' between Maragle, Wagga Wagga and Bannaby	**OPTION 3B** Three new 500 kV transmission lines operated at 330 kV, switchgear and phase shifting transformer	**OPTION 3C** Three new 500 kV transmission lines, tie transformers and switchgear
	Additional firm capacity 2,030 MW initially 2,570 MW if upgraded to 500 kV	**Additional firm capacity** 2,570 MW
	Indicative capex Lines and substations: $2,560m Biodiversity offset cost: $1,220m Total capex: $3,780m	**Indicative capex** Lines and substations: $2,380m Biodiversity offset cost: $935m Total capex: $3,317m

Note: Lines represent circuits only and are not intended to represent transmission line routes.

Figure 1 The seven credible options (Table 5-1 in PACR)

3 A clearer depiction of the options, including the LTSS alternative

The schematic representations in Figure 1 don't indicate the routing features of the options. Accordingly, Figure 2 has been prepared to provide an indicative geographical representation.

The PACR is quite confusing on the route for Option 3C, so Figure 2 presents it in two forms – 3C-1 reflects the schematic representation in Figure 1, whilst 3C represents what is thought to be the physical representation. The three colours represent the three legs of the HumeLink 'triangle'.

Figure 2 also introduces Options 2L and 3L, moving the Snowy 2.0 connection point to the existing Lower Tumut Switching Station (LTSS), as recommended in this paper, rather than the proposed new substation at Maragle.

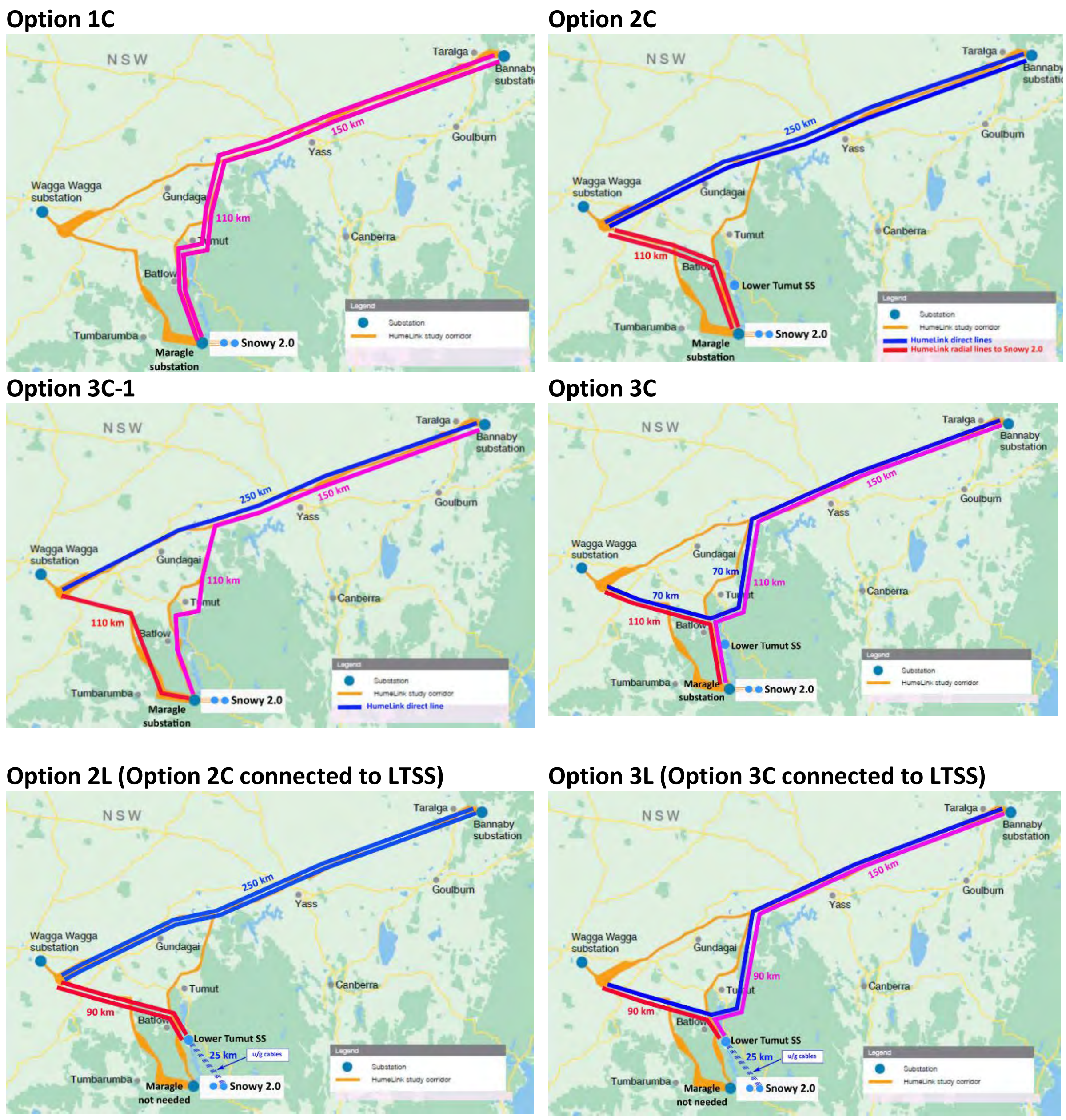


Figure 2 The options presented geographically, showing individual circuits

This paper also suggests a variation of Option 3L (termed Option 3LX) that appears to have some advantages over Options 3C and 3L (see Section 12).

Whilst we recommend the connection of HumeLink to Snowy 2.0 be at LTSS for all options, to avoid confusion with the PACR, the text in this paper refers just to the Maragle connection. But, in this paper, all references to Maragle are interchangeable with a LTSS connection.

Figure 3 provides a ready reference of key data for the PACR's top three options 1C, 2C and 3C. It also includes Option 1D, which is Option 1C configured with double-circuit lines (see Section 5.3).

Some data in the PACR is not consistent within the PACR itself and between the PACR and the Market Modelling Report ("EY") and the HoustonKemp NPV Model ("HK"). The inconsistencies cause confusion and raise doubts about the robustness of the PACR conclusions (see Section 4.3).

	1C	1D	2C	3C
Capex (HK)				
Lines – infrastructure	$1,411m		$1,933m	$1,796m
Lines – biodiversity offset cost	$1,294m		$787m	$894m
Lines - total	$2,705m		$2,720m	$2,690m
Substations – infrastructure	$289m		$611m	$547m
Substations – biodiversity offset cost	$24m		$16m	$29m
Substations - total	$313m		$627m	$576m
Total infrastructure – lines + substations	$1,700m		$2,544m	$2,343m
Total biodiversity offset cost	$1,318m		$803m	$923m
Total Capex – infrastructure + bio	$3,019m		$3,347m	$3,266m
Capex (PACR Table 5.1)				
Total infrastructure	$1,725m		$2,585m	$2,380m
Total biodiversity offset cost	$1,340m		$815m	$935m
Total Capex (1D extrapolated – see Section 6.3)	$3,065m	$2,417m	$3,400m	$3,317m
Total Capex infrastructure (PADR) (no bio)	$1,060m		$1,380m	$1,350m
Market benefit (Central Scenario-EY)				
Excluding competition benefits	$1,710m	$1,710m	$2,093m	$2,114m
Including competition benefits			$2,542m	$2,570m
Net market benefit (PACR)				
Net benefit (excl competition benefits)	-$220m	$380m	-$44m	$39m
Net benefit (incl competition benefits)			$400m	$491m
i) with Tallawarra B and Kurri Kurri			$246m	$334m
ii) with VNI West delayed			$280m	$373m
iii) with 25% higher network capex			-$100m	-$17m
Net benefit with i) + ii) + 12.5% capex increase			-$124m	-$38m
Line corridor length	260 km	260 km	360 km	330 km
Individual circuit length	520 km	520 km	720 km	660 km
Additional firm capacity (MW)	2,510	2,510	2,510	2,570

Figure 3 Comparison of the 'C' Options (PACR, HK, EY)

4 Capex estimate increases 250% from the PADR

The estimated capital cost of Option 3C has increased by $2 billion from $1,350m in the Project Assessment Draft Report (PADR), released in January 2020, to $3,317m in the PACR, July 2021.

> *"The estimated capital cost of Option 3C is approximately $3,317 million ($2020/21) and is comprised of:*
> - *55 per cent transmission lines costs (5 per cent of which is land costs);*
> - *17 per cent substation costs (1 per cent of which is land costs); and*
> - *28 per cent biodiversity offset costs."*

The inclusion of biodiversity offset costs ($935m) is part of the reason, though no explanation is provided on how they were derived (see later).

Also, infrastructure costs (transmission and substations) have surged $1,030m (75%) from $1,350m to $2,380m. Again, no explanation is provided other than they have been 'estimated to a greater degree of accuracy … and been through a detailed cost estimation':

> *"The capital cost of all credible options has been estimated to a greater degree of accuracy than presented in the PADR. Specifically, all credible options have been through a detailed cost estimation based on:*
> - *concept designs for both transmission lines and substations;*
> - *desktop geotechnical assessments;*
> - *biodiversity offset assessments;*
> - *updating market construction rates based on recent transmission projects;*
> - *site testing and inspections requirements; and*
> - *property desktop evaluation reports."*

4.1 'High degree of uncertainty' in estimates

Nevertheless, despite going 'through a detailed cost estimation', the PACR classifies the latest estimates as 'Class 4' with a 'high degree of uncertainty in relation to the accuracy', of between -30% and +50%. That is, the cost lies somewhere between $2,300m and $5,000m – a $2,700m range!

> *"There is currently a high degree of uncertainty in relation to the accuracy of the capital cost estimates (which are 'class 4' estimates), consistent with the stage that the project is currently at. We also note that a substantial proportion of the costs of HumeLink will relate to biodiversity offset costs, which are determined by external processes."*

It seems more likely that the capex will increase again rather than decrease. The PACR foreshadows further detailed cost analysis:

> *"We will be undertaking further detailed analysis in relation to the costs of the preferred option as part of progressing this project, following the initial CPA [Critical Path Analysis]. Any increase in the estimated costs of the project resulting from this analysis would result in AEMO needing to issue a 'feedback loop' confirmation that the project remains consistent with the ISP optimal development path, before we could lodge a further CPA. Consumers can therefore have confidence that any increase in the cost estimate for the preferred option will only result in the project proceeding if AEMO confirms that it remains part of the ISP at the higher cost."*

Industry experts commented at the time it was released that the PADR cost estimates appeared to be wildly understated.

4.2 The increase in capex for Option 3C on a like-for-like configuration is $3 billion (315%)

The PADR estimate of $1,350m for Option 3C was based on single-circuit lines, whereas the PACR estimate of $3,317m is based on a cheaper design with double-circuit lines. The PACR estimate for single-circuit lines is $4,253m:

> *"Option 3C-0 is constructed as a 100 per cent single-circuit configuration (which is the 'ISP candidate option' identified in the 2020 ISP) – estimated capital cost of $4,253 million."*

So, the like-for-like increase in capex is $2,903m [$4,253m – $1,350m], 315%.

4.3 Inconsistent cost estimates

Infrastructure capex

None of the estimates in the PACR match up with those in the HK Report (see Figure 3), varying by up to $41m. For example, Option 3C lines and substation capex in the PACR is $2,380m, but in HK is $2,343m.

Biodiversity offset

Similarly, none of the estimates in the PACR match up with those in the HK Report, varying by up to $22m. Option 3C's biodiversity offset cost in the PACR is $935m, but in HK is $923m.

The PACR provides no information on how the biodiversity offset costs were estimated, other than a one-sentence reference, *"We also note that a substantial proportion of the costs of HumeLink will relate to biodiversity offset costs, which are determined by external processes".*

The estimated biodiversity offset cost of $894m for the lines (Option 3C Figure 3) averages $2.7m per kilometre of double-circuit line [$894m/330 km]. This is half the cost of building the line itself - $5.4m/km [$1,796m/330 km]. Assuming a 70-metre-wide easement, this equates to $400,000/hectare.

Note that the biodiversity cost for Option 2C's lines ($787m) is $107m lower than Option 3C ($894m), but its corridor length is 30 km longer (360 km versus 330 km). One would think that the relative costs should be the other way round. Possibly the estimate for Option 3C was inadvertently based on the longer 3C-1 variant or 3C traverses land with higher environmental value.

Total capex

Again, the estimates in the PACR don't match up with those in the HK Report, varying by up to $53m. For example, Option 3C's total capex in the PACR is $3,317m, but in HK is $3,266m.

Figure 1 (Table 5-1 from the PACR) contains an addition error in the total capex for Option 3C. Adding the estimate for lines and substations ($2,380m) to the biodiversity offset cost ($935m) gives a total capex of $3,315m, not $3,317m.

Also, $1m differences appear in the capex estimates for Option 1C (Table 5-1 indicates $3,065m, Section 5.1.3 indicates $3,066m) and Option 2C (variously stated as $3,399m and $3,400m).

Opex

The opex estimate of 0.5% of capex applied in the HK Report and the calculation of net benefits seems low[5]. Opex costs are typically 1% for transmission lines and 3% for substations.

[5] AEMO 2021 Transmission Cost Report p22.

5 NSW transmission tariffs will rise 40%

The cost of HumeLink (3C) will increase TransGrid's Regulatory Asset Base from $6,371m[6] to approximately $9,688m, a 52% increase. This single project will constitute one-third of TransGrid's assets.

As a result, we estimate that TransGrid's revenues will rise by approximately 40%, and Transmission Use of System tariffs (TUOS) in NSW will increase by the same percentage[7].

Transmission charges make up approximately 10% of retail tariffs[8], so electricity prices in NSW will increase approximately 4% because of HumeLink. Large commercial and industrial consumers, whose transmission component is a greater proportion of their charges, will experience a much higher percentage increase.

A household with a typical annual bill of $1,500, will pay an extra $60 or so per year.

Residential prices are trending down. Over the period 2019/20 to 2022/23, prices are expected to decrease by 2.2%, largely due to increasing solar penetration[9]. HumeLink will cancel out five years of declining prices.

The recent report by the NSW Legislative Assembly, "Sustainability of energy supply and resources in New South Wales"[10], includes relevant findings and recommendations on transmission:

> *"The NSW Government should make sure that transmission infrastructure projects don't result in price rises for consumers, or impact on network reliability."*

[6] TransGrid Transmission Determination 2018 to 2023, Australian Energy Regulator - Section 1.4.
[7] Indicative estimate provided by transmission expert based on the 'annual building block revenue requirement' in Table 1-2 of the Transmission Determination.
[8] Final Decision: TransGrid 2018-23, AER, May 2018
[9] Residential Electricity Price Trends 2020, Australian Energy Market Commission (Section 2.3).
[10] Sustainability of energy supply and resources in New South Wales, Legislative Assembly of New South Wales Committee on Environment and Planning Report 2/57 – August 2021.

6 Whittling down the options

6.1 From seven credible options to two

The PACR is solely focussed on the net financial benefits of the options, with Option 3C being preferred simply because it is estimated to have the highest net benefit (though not by much).

The PACR applied a two-stage approach to the benefits assessment. Firstly, undertaking a 'positioning assessment', excluding competition benefits, of all seven credible options across each of the four AEMO ISP scenarios, followed by 'the formal RIT-T assessment', including competition benefits, but only for the top two ranked options due to the complexity of the calculation.

In the first stage, before accounting for competition benefits, only Option 3C had a positive net benefit of just $39m. Option 2C is next with minus $44m and then Option 1C with minus $220m (Figure 4).

> *"On a weighted-basis, Option 3C is the top-ranked option and is expected to deliver approximately $39 million in net benefits (excluding competition benefits), which is around $83 million more net benefits than the second-ranked option (Option 2C) in present value terms."*

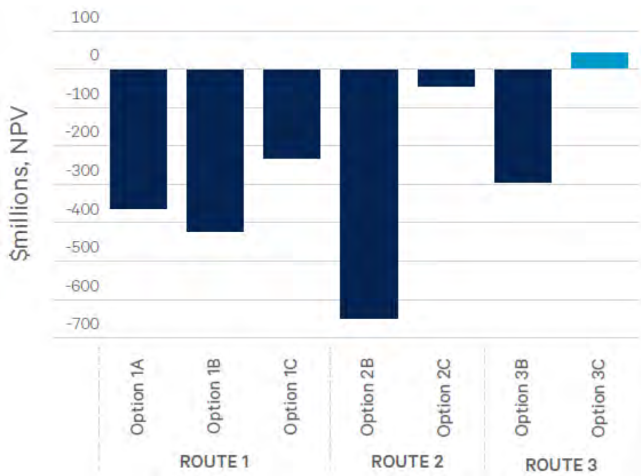


Figure 4 Estimated net benefits weighted, excluding competition benefits, (PACR Figure 26)

The PACR eliminated all but the top two of the seven credible options before calculating the competition benefits in the second stage, which resulted in Option 3C having a net market benefit of $491m and Option 2C of $400m.

6.2 Selection of 3C over 2C

> *"Under all scenarios, the benefits for Option 3C are primarily driven by avoided, or deferred, costs associated with generation and storage build. Avoided generator fuel costs, competition benefits and avoided transmission capital costs to connect new REZs make up the vast majority of other market benefits estimated, with their relativities varying across the scenarios."*

The preference of Option 3C over 2C is explained:

> *"On a weighted-basis, Option 3C is expected to deliver approximately $491 million of net benefits and is ranked first out of the options assessed (with estimated net benefits that are 23 per cent greater than the second-ranked option, Option 2C). Option 3C is therefore the preferred option overall under the RIT-T."*

It is noted that whilst a 23% difference in net benefits sounds significant, it is just $91m, which is less than 3% of the project cost of $3,317m. The PACR adds:

> *"We note that the PACR now finds that Option 3C is more strongly preferred over Option 2C than it was at the PADR stage for numerous reasons, including it now having significantly lower costs than Option 2C and greater estimated competition benefits."*

However, the two reasons for 'more strongly preferring' Option 3C appear to be overstated:

- 'Significantly lower costs' – the difference in estimated costs in the PADR was $30m ($1,380m versus $1,350m), whereas the difference in the PACR is $83m ($3,400m versus $3,317m). That is, a 2.2% difference in the PADR versus 2.5% in the PACR.
- 'Greater competition benefits' – the estimated competition benefits are $449m and $456m, respectively (EY), a difference of only $7m (1.6%).

The PADR rated Options 2C and 3C 'equal first'. There appears to be no reason to change that conclusion on the basis of the updated PACR estimates of costs and benefits.

6.3 Option 1D should also be rated 'equal-first'

The PACR estimated the net benefit, excluding competition benefits, of Option 1C to be minus $182m, resulting in this option being eliminated from further consideration.

However, the net benefit was based on a double-circuit line for half its length rather than the full length, as for Options 2C and 3C (PACR Note 74). If Option 1C were double circuit for its full length (termed Option 1D), its capex would be reduced by approximately $600m, from $3,065m to $2,417m[11].

A $600m (20%) reduction in capex improves the net benefit of Option 1D, excluding competition benefits, from negative $220m to positive $380m, $424m better than Option 2C and $341m better than Option 3C.

As Option 1C is deemed 'credible', Option 1D should be re-evaluated on the same basis and extent as the two favoured options.

Option 1D could also be regarded as the initial stage of Option 3C, with the 500 kV link between Maragle and Wagga Wagga being constructed when/if needed.

6.4 Selection of best option should be based on more than the net benefit

Other factors beyond a simple mathematical estimate of the net financial benefits should be considered when selecting the preferred choice. This is especially relevant when the differences in net benefits are relatively small.

For example, Option 2C is superior to Option 3C on other criteria:

- takes the shortest route for the grid backbone from Sydney to (ultimately) Melbourne – direct between Bannaby and Wagga Wagga – rather than both circuits deviating, one by an extra 40 km and the other by an extra 120 km via Maragle;
- higher transfer capacity between Bannaby and Wagga Wagga, as both circuits are the same

[11] Cost of Option 2C is $3,347m for 360 km of double-circuit line plus three substations. If Option 1C is 260 km of double-circuit lines and two substations its indicative capex is $2,417m [$3,347m*260/360].

length and impedance;

- lower heating losses due to the duplication of lines and shorter length between Bannaby and Wagga Wagga;
- less exposure of the Bannaby to Wagga Wagga grid backbone to outages due to lightning strikes and bushfires; and
- less network flow constrictions at Wagga Wagga (see later).

Most of these advantages have a financial benefit, which will more than offset any marginal difference in net market benefits.

7 Comments on the estimated benefits

Part A presents an economic overview, contending that the costs and benefits of HumeLink should also include the costs and benefits of Snowy 2.0 when assessing the net benefits.

Setting aside that fundamental issue, this section provides more detailed comments on the PACR's estimated benefits. We make no further comment on the estimated cost and its 'high degree of uncertainty'.

7.1 Likely sensitivity scenarios reduce net benefit to zero

The PACR undertook several sensitivity analyses.

Construction of the 400 MW Tallawarra B and 750 MW Kurri Kurri gas power stations reduces the benefit for Option 3C by $180m, from $2,570m to $2,390m (EY Central Scenario). One would expect the two gas stations to be reasonably certain to proceed, given $83m in government support for Tallawarra B and $600+m for Kurri Kurri. HumeLink's benefit would reduce further if the proposed 635 MW Port Kembla gas-hydrogen power station is constructed. It too has received government support ($30m) and recently been declared as Critical State Significant Infrastructure.

A delay in VNI West from 2028/29 to 2034/35 reduces the benefit for Option 3C by $121m, from $2,570m to $2,449m (EY). It seems unlikely that VNI West will be constructed by 2028/29.

The PACR notes that a 24% increase in infrastructure capex would reduce Option 3C's $491m estimated net benefit to zero.

As shown in Figure 3, the net benefit drops below zero if Tallawarra B and Kurri Kurri are constructed, VNI West is delayed, and capex increases a further 12.5% – all plausible scenarios.

7.2 PACR modelling

We have not undertaken a detailed assessment of the modelling of costs and benefits, but make a few preliminary comments:

- The results are dependent on a number of assumptions. For example, varying the discount factor from 6% to 7% reduces the net benefit of Option 3C by over $200m.
- The PADR estimated a cost of $1,350m and a net present value (NPV) of benefits of $1,200m (Option 3C Central Scenario). Yet the estimated NPV in the PACR only decreased by $709m (to $491m), despite a cost increase of $1,967m.
- Discounting costs and benefits back to June 2021, rather than the start of construction (~2025), provides relative advantages to the valuation of benefits compared to costs (because costs are incurred at the start and benefits accrue over a longer period). The NPV calculation should begin when the main expenditures are made. The NPV analysis should value the costs and benefits at the time they arise, not at the time when regulatory approvals are sought.
- The latest AEMO forecasts predict the installation of substantially greater storage than the PACR, which would result in less benefits attributable to HumeLink (see Attachment A).

7.3 Snowy 2.0 benefits overstated

Snowy 2.0's assumed operation seems to be substantially overstated (Attachment A), which if true would reduce the benefits of HumeLink:

- The Base Case (i.e. the 'do-nothing option' without HumeLink) predicts a Snowy 2.0 annual capacity factor[12] ramping up to 20% for generation and 27% pumping by 2035:
  - this equates to Snowy 2.0 generating at 2,040 MW for an average of 4.8 hours/day and pumping for 6.5 hours/day for 365 days a year; and
  - even if it were economic for Snowy 2.0 to operate for such periods, which we contend is implausible, there is insufficient transmission capacity. The only available transmission line is Line 64, to be tied into Maragle Substation (see later), which is rated at around 1,000 MW and is already utilised by the existing Snowy Scheme.
- Option 3C predicts a Snowy 2.0 capacity factor of 25% for generation and 33% for pumping, totalling 58%:
  - this equates to 6 hours/day generation and 8 hours/day pumping at 2,040 MW, 14 hours/day in total. Or double that duration if operating half capacity (1,020 MW), though there are not enough hours in the day;
  - the assumed capacity factors are even higher than in Snowy 2.0's Business Case model (22% generation: 30% pumping), that independent analysts considered to be substantially overstated;
  - such usage would far exceed any pumped hydro station in Australia – the similarly-sized Tumut 3 pumped hydro station (1,800 MW generation, 600 MW pumping) has operated with a pumping capacity factor of less than 2%;
  - the theoretical maximum capacity factor for a pumped hydro station is about 43% generation and 57% pumping. The practical limits are much less, due to being constrained to times when there are opportunities to purchase cheap energy and sell expensive energy. Also, one has to take account of the fact that the plant will rarely operate at full capacity and will have down-time for maintenance; and
  - Snowy 2.0's Feasibility Study states that *"in any given year prior to 2040, the Project will be operated at full capacity [i.e. 2,040 MW] for less than 87 hours/year".*
- For those periods when it would be economic for Snowy 2.0 to generate, it will be in competition with other storages, particularly batteries. Batteries will outcompete Snowy 2.0 in the prominent diurnal storage market, due to greater efficiency in the storage/generation cycle (90% versus 75%), faster response rates (milliseconds versus minutes) and lower transmission costs and losses (closer location to loads).
- Also, Snowy 2.0 will be in 'competition' with existing Snowy Hydro generators, all of which will have operational priority to comply with water delivery requirements for downstream needs.

To summarise, the PACR assumes that Snowy 2.0 will operate (generate or pump) at an average of 1,200 MW for 24 hours/day every day of the year. This would imply that Tumut 3 and other pumped hydro stations were also operating at similar elevated levels.

Scaling back this assumption to a more realistic level will result in lower estimated benefits for HumeLink.

[12] Annual Capacity Factor is the ratio of electrical energy actually generated/consumed versus the amount that would be generated/consumed if running at maximum capacity throughout a year.

7.4 How ‘certain’ are the benefits

> *“Under all scenarios, the benefits for Option 3C are primarily driven by avoided, or deferred, costs associated with generation and storage build. Avoided generator fuel costs, competition benefits and avoided transmission capital costs to connect new REZs make up the vast majority of other market benefits estimated, with their relativities varying across the scenarios.”*

It is noted that the claimed benefits are based on 25-year projections of the National Electricity Market (NEM) – a decidedly heroic exercise in a rapidly changing industry – and that ‘avoided generation/storage costs’ make up half the total ($1,311m of $2,570m). It is difficult enough to project to the end of this decade, let alone to 2045.

There is no question that HumeLink capex will be an upfront cost, paid for by consumers, but the estimated benefits for customers are not anywhere near as certain. Though the PACR makes the reassuring comment that *“the market benefits are expected to be passed through to customers in the long run.”*

Either way, it appears that the cost of HumeLink will exceed its benefit.

At first look, the PADR’s estimated cost of $1,350m looked to be a reasonable investment for a net benefit of $1,200m. However, it is clear from the PACR estimates that this is no longer the case.

Considerably more work is needed to refine the costs and clarify the benefits before the quantum of the net loss is known.

8 Confusion on Option 3C double-circuit

Throughout the PACR Options 2C and 3C are now stated to be 'complete double-circuit':

> *"As part of this PACR, we have investigated different circuit configurations of the top performing network topologies and operating capacities in the PADR analysis (i.e., 'Option 2C' and 'Option 3C'). Specifically, we investigated:*
>
> - *Three variants of the preferred network topology and operating capacity in the PADR and PACR analysis, i.e., Option 3C:*
>   - *Option 3C is constructed as 100 per cent double-circuit configuration – estimated capital cost of $3,317 million.*
>   - *Option 3C-0 is constructed as a 100 per cent single-circuit configuration (which is the 'ISP candidate option' identified in the 2020 ISP) – estimated capital cost of $4,253 million.*
>   - *Option 3C-1 is constructed primarily as a single-circuit configuration but with a 132 km double-circuit portion west of Bannaby – estimated capital cost of $3,509 million.*
> - *Two variants of the second-ranked network topology and operating capacity in the PADR analysis, i.e., Option 2C:*
>   - *Option 2C is constructed as 100 per cent double-circuit configuration – estimated capital cost of $3,399 million.*
>   - *Option 2C-1 is constructed primarily as a single-circuit configuration but with a 132 km double-circuit portion west of Bannaby – estimated capital cost of $3,770 million.*
>
> *Overall, the outworking of these studies is that Option 2C and Option 3C from the PADR are presented in the PACR as complete double-circuit options, which allows significant cost reductions relative to where they are constructed as either a single-circuit, or a combination of single- and double circuit, configuration."* [Section B.1.2]

There is no confusion that Option 2C, with double-circuit lines and a capex of $3,399m or $3,400m, has been chosen over Option 2C-1.

However, there is confusion on the physical construction of Option 3C with double-circuit lines in light of the schematic representation in Figure 1 of a triangular arrangement. This paper assumes what is proposed is reflected in Figure 2, showing a Y arrangement, made up of double-circuit lines.

This Y arrangement would be improved from a technical perspective by including a switching station at the junction point with a busbar to which all lines are connected via circuit breakers and an associated protection scheme. That would overcome the flow balance problem and should give some improvement in reliability. Though there would be an additional cost.

Alternately, locating the Y junction at LTSS would add cost but also versatility (see Options 3L and 3LX later).

8.1 TransGrid information provided to AEMO indicates single circuits

To add to the confusion, the AEMO Transmission Cost Report, Aug 2021 was issued after the PACR indicating three single-circuit 500 kV lines between Bannaby, Wagga Wagga and Maragle at a cost of $3,315m, based on information provided by TransGrid (Figure 5).

The PACR Option 3C schematic in the AEMO report (identified there as Option 1) also repeats the confusing PACR triangular routing schematic in Figure 1.

It is noted that the AEMO report includes TransGrid options for an additional link between Bannaby and Wagga Wagga, of either a 500 kV line costing $953m, or a HVDC circuit costing $2,038m.

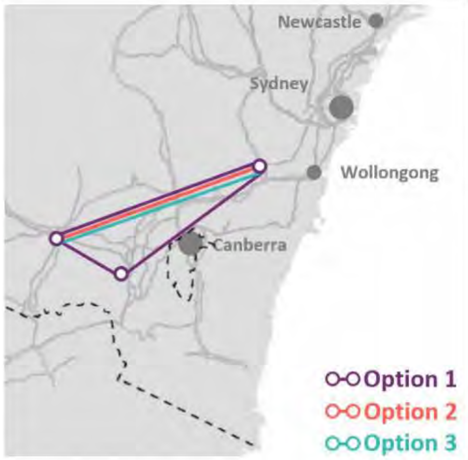
3.8 Southern New South Wales to Central New South Wales

Summary

The transmission network between Southern New South Wales (SNSW) and Central New South Wales (CNSW) provides access for the hydroelectric generation in the Snowy mountains, renewable generation in SNSW, and import from Victoria and South Australia to New South Wales major load centres.

HumeLink is a proposed transmission network augmentation that reinforces the New South Wales southern shared network to increase transfer capacity to New South Wales load centres. This is an actionable 2020 ISP project. TransGrid is currently undertaking a RIT-T for this network augmentation. The Project Assessment Draft Report (PADR), the second report of the RIT-T, was published in January 2020.

Subsequent to HumeLink, two options are proposed to increase the maximum network transfer capability between SNSW and CNSW to access increased import from Victoria and South Australia with increased generation in SNSW to NSW major load centres.



Existing network capability

The maximum transfer capability from SNSW to CNSW is 2,700 MW at peak demand and summer typical and 2,950 winter reference periods. The maximum transfer capability is limited by thermal capacity of Yass–Marulan or Crookwell-Bannaby 330 kV lines following a credible contingency.

The maximum transfer capability from CNSW to SNSW is 2,320 MW at peak demand and summer typical and, 2,590 MW at winter reference periods. The maximum transfer capability is limited by thermal capacity of Yass–Canberra or Marulan–Yass or Gullen Range–Bannaby 330 kV lines following a credible contingency.

Augmentation options

Description	Additional network capacity (MW)	Expected cost ($ million)	Cost classification	Lead time
Option 1 (HumeLink) • New 500 kV single-circuit from Maragle to Bannaby. • New 500 kV single-circuit from Maragle to Wagga Wagga. • New 500 kV single-circuit from Wagga Wagga to Bannaby. • Cut-in Lower Tumut to Upper Tumut 330 kV line at Maragle. • Three 500/330 kV 1,500 MVA transformers at Maragle. • Two 500/330 kV 1,500 MVA transformers at Wagga Wagga. • 500 kV Line shunt reactors at the ends of Maragle – Bannaby, Maragle – Wagga Wagga and Wagga Wagga – Bannaby lines. *Provided by TransGrid – see Section 1.1.*	2,200 MW in both directions REZ N6+N7: 2,200 MW	3,315	Unknown*	2026-27
Option 2 • An additional new 500 kV line between Wagga Wagga and Bannaby *Pre-requisite: HumeLink*	2,000 MW in both directions REZ N6: 1,500 MW	953	Class 5b (±50%)	Long
Option 3 – HVDC between Wagga Wagga and Bannaby:	2,000 MW in both directions	2,038	Class 5b (±50%)	Long

Figure 5 AEMO 2021 Transmission Cost Report (information from TransGrid)

9 Claimed need for HumeLink

"The driver for the credible options considered in this PACR is to deliver a net economic benefit to consumers and producers of electricity and support energy market transition through:

- *increasing the transfer capacity between the Snowy Mountains and major load centres of Sydney, Newcastle and Wollongong;*
- *enabling greater access to lower cost generation to meet demand in these major load centres; and*
- *facilitating the development of renewable generation in high quality renewable resource areas in southern NSW as well as southern states, which will further lower the overall investment and dispatch costs in meeting NSW demand whilst also ensuring that emissions targets are met at the lowest overall cost to consumers."*

It would appear that the aim 'to deliver a net economic benefit' is unachievable.

9.1 No increase in NEM demand for ten years

The EY Report provides an AEMO chart showing a slightly declining NEM demand till 2032, and then a gradual increase, except the Slow Change Scenario (Figure 6).

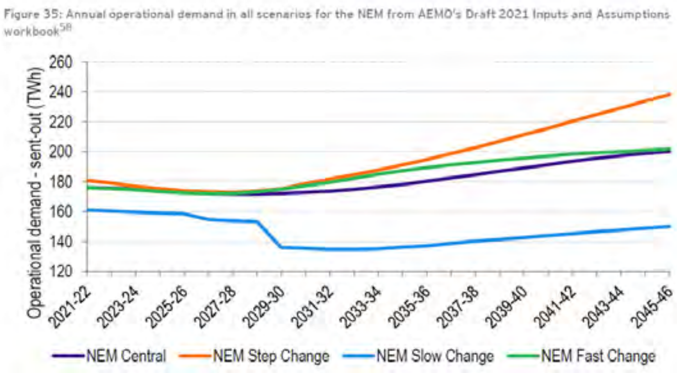


Figure 6 NEM demand (EY Figure 35)

Of course, a NEM-wide increase in demand may not require any additional transmission between Bannaby and Wagga Wagga. No information is provided to show the amount of spare capacity within the southern network at present or in the future, particularly after the retirement of base load coal plant and consequent reduction in interstate transfers.

9.2 HumeLink, as configured, will have only marginal impact on relieving existing congestion

"Reinforcement of the Southern Shared Network will be required to allow the transfer of energy to demand centres. Existing congestion at times of high demand limits access to the existing generation capacity of the Snowy Mountains Scheme at times of peak demand."

The connection of HumeLink to Maragle will be isolated from the existing Snowy network, except for the tie-in of the Upper Tumut to Lower Tumut 330 kV line (Line 64). This tie-in will provide some easing of congestion from the Snowy Scheme but connecting HumeLink and Snowy 2.0 to LTSS would have a greater benefit (discussed later).

9.3 HumeLink provides minimal benefit for new generation

HumeLink is estimated to contribute $369m to 'avoided REZ transmission capex' (HK Tab Pos chart tables Central Scenario). This indicates that just 11% of HumeLink's cost could be attributable to connecting new generation, apart from Snowy 2.0.

9.4 HumeLink provides minimal benefit for connection to Victoria

The sensitivity analysis for a delay in VNI West from 2028/29 to 2034/35 estimated a reduced market benefit of $121m (Option C).

As a prime purpose for VNI West is to strengthen the Victoria-NSW connection, the analysis implies there is minor value from HumeLink providing additional interstate capacity.

9.5 HumeLink needs to accommodate Snowy 2.0, new generation and EnergyConnect

> *"There are currently substantial new renewable generation developments anticipated in southern NSW, with projects in construction or under development currently totalling 1,900 MW. In addition, Snowy 2.0 will provide a new source of generation to meet future demand in the major load centres of NSW and to 'firm' supply from the new renewable generation."*

Snowy 2.0 is reported to have six 340 MW units, totalling 2,040 MW.

So, Snowy 2.0 will take up 80% of the firm capacity of HumeLink (2,570 MW Option 3C), leaving just 500 MW. This is well short of the reputed 1,900 MW of new renewable generation in southern NSW plus imports from South Australia to Wagga Wagga via Project EnergyConnect (capacity of 800 MW), plus any additional transfers from Victoria.

Ameliorating considerations are that:

- Snowy 2.0 will rarely operate, despite the optimistic assumptions in the EY Report (mentioned earlier).
- There will be diversity between the various users of HumeLink. Rarely will all wish to run concurrently at capacity.
- The EY Report indicates that TransGrid anticipates 330 MW of additional solar and wind generation in the Wagga Zone (EY Report Table 14), which is significantly less than 1,900 MW.

But there may be occasions when Snowy 2.0, or new generation or EnergyConnect is constrained by the transmission capacity of HumeLink. The question for Option 3C is would Snowy 2.0 gain 'priority' due to its injection point being closer to Sydney than the more distant generation.

It is also noted there is a 370 MW anomaly between the PACR estimate of HumeLink's capacity of 2,570 MW and the information provided by TransGrid to AEMO of 2,200 MW (Figure 5). It is assumed that the PACR estimate is the correct one.

9.6 Wagga Wagga constriction?

Another interesting network issue relates to the connections beyond the new 500/330 kV Wagga Wagga Substation.

HumeLink includes three substations – the existing 500/330 kV Bannaby Substation and two new 500/330 kV substations at Maragle and Wagga Wagga. The connections beyond Bannaby (north, south, east and west) and Maragle (east to Snowy 2.0) are clear, but beyond Wagga Wagga are not so clear.

The PACR states that the new 500/330 kV Wagga Wagga substation is to be connected to the existing 330/132 kV Wagga Wagga Substation by a 330kV double-circuit line. There is no mention of any other connections to the new substation at this stage. Presumably, this new double-circuit line will parallel the existing 330 kV line from LTSS to Wagga Wagga 330/132 kV Substation.

Firstly, it is unclear if the cost of the new 330 kV double-circuit line (about 15 km) and the extra bays required at the existing 330/132 kV substation have been included in the HumeLink estimate. Without this connection, the 500/330 kV Wagga Wagga Substation would be isolated, so the full cost should be attributed to HumeLink.

Secondly, and more importantly, there appears to be a constriction point at the new Wagga Wagga 500/330 kV Substation. This is due to the firm capacity of the double-circuit 330 kV line from the existing substation (unlikely to be more than 1,500 MW) being less than that of the double-circuit 500 kV line(s) to Bannaby and Maragle (2x 2,750 MW Option 2C) or to Bannaby (2,750 MW Option 3C).

If VNI West is connected to the new substation, it will enable increased flows north and south. However, it will not ease any constrictions from the mooted 1,900 MW of new generation and EnergyConnect, as they are expected to be connected to the existing 330/132 kV substation. Though it is noted that the 330 kV line from the existing Wagga Wagga Substation to LTSS provides another route to bolster the firm capacity from the existing substation.

No doubt TransGrid has undertaken load flow studies of this arrangement to determine what constrictions might apply. The PACR should include such analysis and a comprehensive account of HumeLink's integration into the southern NSW network.

9.7 Have physical constrictions been accounted for in the benefits estimate?

The physical constriction issues that may preclude the full transmission of power from new generation, EnergyConnect and Snowy 2.0 are not mentioned in the PACR.

Any such constrictions would reduce the estimated benefits of HumeLink.

9.8 Proceeding with the proposed HumeLink will provide negative economic benefit

> *"The modelling in this PACR shows that, in the absence of investment under this RIT-T, alternative additional investment by market participants in technologies such as solar, gas-fired generation and other technologies such as large-scale batteries and pumped hydro investment in NSW in addition to that anticipated under the NSW government's Electricity Infrastructure Roadmap would be needed in the next twenty five years, in order to continue to meet New South Wales demand and system stability and security requirements, as existing dispatchable generation in New South Wales retires. Overall, the net cost to the market (and therefore ultimately to consumers) is expected to be higher under the 'do nothing' path, than if investment under this RIT-T proceeds."*

Rather than the net cost being higher under the 'do-nothing' path, the opposite is the case. If the RIT-T proceeds as proposed, there will be a net cost to consumers.

10 Snowy 2.0 is a prime determinant of HumeLink

Whilst HumeLink is promoted as providing wider benefits in reinforcing the southern NSW network, and it would to some extent, the prime determinant for its route, size, timing and cost is Snowy 2.0.

> With its 2,040 MW nameplate rating, Snowy 2.0 represents the largest single-point load to ever be connected to the NEM and the largest generator for 35 years. Snowy 2.0 dwarfs all other forthcoming loads and generators to be connected to the NEM and is in a size category of its own. Also, it is relevant to note that Snowy 2.0 effectively obtains double the benefit of connection, compared to a stand-alone load or stand-alone generator.

10.1 HumeLink was initially termed 'SnowyLink North'

When Snowy 2.0 was first mooted, its transmission connection was termed 'SnowyLink" (AEMO ISP 2018):

"AEMO understands that a final decision to go ahead with the Snowy 2.0 project is likely before the end of 2018. SnowyLink can be delivered in two stages – a north component ("SnowyLink North") connecting Snowy 2.0 to Sydney, followed by a south component ("SnowyLink South") that enhances interconnection between Victoria and New South Wales."

SnowyLink North has morphed into HumeLink and SnowyLink South into VNI West. HumeLink is being constructed primarily to provide Snowy 2.0 with capacity to transmit energy from its generators and to its pumps.

10.2 Clearly, Snowy 2.0 cannot operate to full capacity without HumeLink

The Snowy 2.0 Feasibility Study, December 2017, notes:

"The Project will not be feasible without adequate and deep transmission augmentation to increase the capacity of the transmission lines between the Scheme and the load centres in NSW and Victoria. The Project requires this transmission augmentation so the benefits and products can be delivered both north and south."

10.3 Inclusion of Option 1C as credible confirms HumeLink is primarily for Snowy 2.0

All options considered in the PACR terminate at a new substation at Maragle, which is the connection point that Snowy Hydro has nominated for Snowy 2.0. Of the seven credible options, Options 1A, 1B and 1C involve a simple direct connection from Maragle to Bannaby. Options 1A, 1B and 1C provide no additional capacity for new generators or interstate transfers - they serve Snowy Hydro exclusively.

Option 1C was preferred to Options 1A and 1B but the only reason given for eliminating it was because its net benefit was less than the preferred Option 3C, not that it didn't satisfy the need for reinforcement of the southern NSW network.

However, as discussed earlier, if Option 1C were constructed with double-circuit lines (i.e. Option 1D), it has a higher net benefit (excluding competition benefits) than Options 2C and 3C, though probably still negative.

10.4 Impact of Snowy 2.0 on HumeLink

Without Snowy 2.0, HumeLink may not have been warranted at this time, especially at 500 kV.

However, if HumeLink is warranted in 2026 regardless of Snowy 2.0, it would have entailed a simple direct connection of one or two 330 kV or 500 kV lines between Bannaby and Wagga Wagga to reinforce the southern NSW network. There would have been no requirement for the Bannaby-Maragle-Wagga Wagga dogleg deviation, which is effectively a 'Connection Asset'[13] specifically for Snowy 2.0.

It is the need to transmit the enormous capacity of Snowy 2.0, to and from the grid for generation and pumping, that has shaped HumeLink's configuration, route, length, cost, timing, reliability, capacity, environmental footprint and community impact:

i) **Additional substation** – were it not for Snowy 2.0, Maragle 330 kV/500 kV Substation would not be built.

ii) **Additional line** – if reinforcement of the southern NSW network warrants just one 500 kV line between Bannaby and Wagga Wagga, then the second line (via Maragle) is entirely for Snowy 2.0's connection to the grid.

iii) **Route change** – on the other hand, if reinforcement of the southern NSW network warrants two lines between Bannaby and Wagga Wagga, then the connection to Snowy 2.0 has resulted in both of those lines having to take a substantial dogleg deviation via Maragle (Option 3C).

iv) **Longer length** – the deviated lines are up to 50% longer than the direct route between Bannaby and Wagga Wagga – 290 km and 370 km compared to 2x250 km.

v) **Higher capital cost** – the longer route is entirely due to Snowy 2.0, as is Maragle Substation.

vi) **Higher operating cost** – extra operating and maintenance costs will also apply due to the additional length of line and substation.

vii) **Timing** – HumeLink may not have been needed till after Snowy 2.0's scheduled commissioning in 2025/26. (The initial AEMO ISP timing was 2035 without Snowy 2.0.)

viii) **Lower reliability** – HumeLink's reliability will be reduced due to the exposure of an extra 160 km of overhead line to outages from mechanical failure, lightning strikes, high winds and bushfires, particularly through many tens of kilometres of State Forest. This reduces the resilience of the entire interstate backbone connecting NSW, Victoria and South Australia.

ix) **Reduced transmission capacity** – as the two HumeLink lines will have differing lengths (and electrical impedance), the maximum power that can be transmitted between Bannaby and Wagga Wagga, and hence between NSW and Victoria, will be less than had both lines taken the direct route.

x) **Additional environmental impact** – the deviation entails an additional 80 km of landscape (much of significant beauty and value) being visually impacted, and 6 square kilometres of agricultural and public lands subjected to a permanently cleared easement and access tracks.

xi) **Larger community impact** – hundreds of additional landholders, neighbours and local communities are recoiling at the prospect of massive towers and lines blighting their landscape and affecting farmland use.

[13] A Connection Asset is used exclusively by a generator or load, whereas a Shared Asset is used by all market participants. The purpose of the Bannaby-Maragle-Wagga Wagga line is to connect Snowy 2.0 to the grid, even though once constructed it would form part of the grid.

10.5 Snowy Hydro determined the Maragle location, which became the lynch-pin for HumeLink

Snowy Hydro determined that its cheapest option to connect Snowy 2.0 to the NSW network was by overhead lines for the shortest possible distance to exit Kosciuszko National Park. That resulted in the proposal to build four overhead 330 kV circuits for eight kilometres due west from Lobs Hole to the Park boundary and then a further kilometre to meet up with Line 64. At this location, a 500/330 kV substation is proposed to be built (Maragle).

Maragle Substation doesn't exist, nor do the 500 kV lines to Wagga Wagga and Bannaby. The substation and at least the dogleg deviation of HumeLink are only being constructed for Snowy 2.0.

The decision by Snowy Hydro on the location of Maragle has been the starting point for the design of HumeLink. No consideration was given to alternative locations, such as the far more obvious LTSS, as that would have incurred a greater cost for Snowy Hydro. No account was taken of the cost savings for HumeLink or the benefits to the network.

11 Snowy Hydro should pay its fair share of HumeLink

11.1 The PACR avoids apportioning costs and benefits

The PACR notes that the RIT-T process does not apportion benefits to particular stakeholders:

> *"We note that the RIT-T identifies where transmission investment is expected to provide an overall net benefit to the market as a whole. That is, investments as a result of which customers across the NEM will benefit in the long-run by more than the cost of the investment incurred. Cost allocation, and the sharing of risk as between different stakeholders in the energy market and the extent to which a market benefit serves to the greater advantage of one party than the other is a public benefits assessment that is separate to the market benefit analysis of the RIT-T processes."*

Further, the PACR states that concerns expressed as part of the PADR consultation process on the apportionment of costs and benefits is a matter for others:

> *"Accordingly, PIAC's concerns, echoed by ERM Power and EnergyAustralia are considerations that are not within the purview of a RIT-T process and instead is the subject matter for consultation and engagement by governments and regulators in broader market reform and regulatory processes."*

11.2 Snowy Hydro resists any suggestion it should contribute to HumeLink

Snowy Hydro's Managing Director, Mr Paul Broad, acknowledges that HumeLink and other transmission upgrades are essential for Snowy 2.0[14]:

> *"We have said right from day one that Snowy 2.0 will not work without transmission upgrades to get the electricity to customers north and south."*

Paradoxically, he contends that the necessary transmission and its cost has nothing to do with Snowy Hydro. Rather, it is up to others (TransGrid) to design and build the substation and lines at the expense of NSW electricity consumers. In answer to a question on transmission costs at Senate Estimates on 25 May 2021, he stated:

> *"Transmission, as I have said many times here, is not part of 2.0. The transmission is to enable the transition to renewables. The cost of all that transmission is in the hands of others, not in our hands. I can't comment on transmission."*

Equally inconsistently, in an article "Behind Snowy's battery bet"[15], Mr Broad contends that the Snowy 2.0 transmission connection is 'for the common good', with Snowy 2.0 using it infrequently:

> *"We've said this 150,000 times. Transmission is for the common good. Everyone benefits from it. We [Snowy 2.0] use it about 10 per cent of the time and the other 90 per cent it's used by everybody else, particularly on the renewable side."*

Presumably, Mr Broad is referring to Snowy 2.0 using HumeLink for 10% of the time for generation. If so, Snowy 2.0 will need to use HumeLink for an additional 15% of the time for pumping, totalling

[14] "Snowy Hydro News", June 2017 https://www.snowyhydro.com.au/wp-content/uploads/2018/06/SHLNews_June2017_LR.pdf

[15] "Behind Snowy's battery bet" The Australian 14 September 2019

25% of the time (6 hours/day), though it may not all be at full capacity (2,040 MW).
We note that such usage is less than half that assumed in the PACR and Snowy 2.0 Business Case. As discussed in Section 7.3, the PACR assumes Snowy 2.0 will operate (generate or pump) for 58% of the time at full capacity (2,040 MW), or 100% of the time at over half capacity (1,200 MW).

11.3 Snowy 2.0 is both a load and a generator

The PACR is focussed on connecting new generation sources.

However, the cost of connecting Snowy 2.0 needs to be considered in the context of its operation as a load as well as a generator. All new loads are required to pay for their grid connection, as should the Snowy 2.0 pumping load.

11.4 No inherent benefit in Snowy 2.0 warranting public funding

Some may contend that connecting Snowy 2.0 to the grid brings a wider benefit to the NEM and the transition to renewable energy, and therefore it may be appropriate to consider public funding for its transmission connection.

Snowy 2.0 is no different to any other battery, except being very large, far less efficient and located hundreds of kilometres away from generators (for pumping energy) and load centres (for generation delivery). It will not bring down electricity prices as claimed by some politicians – Snowy Hydro's own modelling shows that NSW electricity prices will rise as a result of Snowy 2.0[16].

Snowy Hydro should not be treated any differently to other developers just because it is owned by the Commonwealth Government and operates the iconic Snowy Scheme. Nor should it be treated more favourably than its competitors in the NEM.

11.5 VNI West yet to come?

It is noted that a similarly sized transmission project, VNI West, will be needed if Snowy 2.0 is to have unconstrained capacity to Victoria. Whilst that project has been mooted for some time it has yet to be formally proposed and costed.

Will Snowy Hydro be required to contribute to the cost of VNI West if it proceeds?

[16] Snowy 2.0 will push up electricity prices, 22 Oct 2019

12 LTSS is a better connection point than Maragle

Connecting Snowy 2.0 and HumeLink to Lower Tumut Switching Station (LTSS), rather than Maragle, provides benefits for the NEM, AEMO, TransGrid, Snowy Hydro and consumers, and results in substantially less environmental impacts on Kosciuszko National Park and Bago State Forest. Electrically, LTSS is a superior connection point than Maragle for all PACR options.

The distance from the underground station to LTSS is 25 km, (only) an extra 13 km than to Maragle.

Examination of routing alternatives is covered in the NPA EIS Submission Snowy 2.0 Transmission Connection Project, 8 Apr 2021 and the Background Paper and Addendum to the Open Letter to Minister Stokes and Kean, 18 Jan 2021. Attachment B provides extracts from the NPA EIS Submission on the benefits of underground transmission.

Figure 7, extracted from the EIS Submission, shows alternate underground routes from Snowy 2.0 to Maragle and LTSS. The most promising route to LTSS is likely to be Alternative D, entailing a 25 km tunnel. Alternative C involves submarine cables down Talbingo Reservoir.

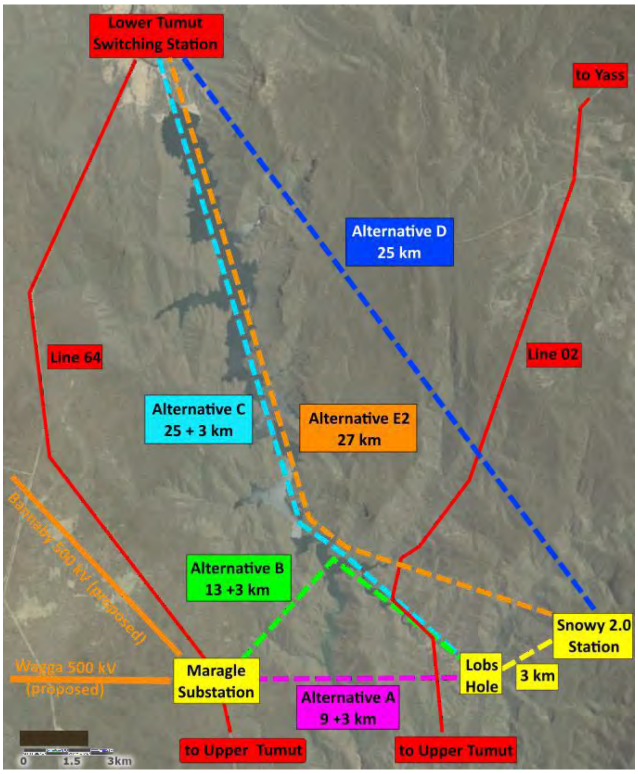


Figure 7 Alternative underground routes from Snowy 2.0 to Maragle and LTSS

Tunnelling technology is well proven, but the cost will be significantly more than overhead lines. However, there are offsetting benefits and savings, including avoiding the need for:

- 330 kV cables for 3 km from the underground station to Lobs Hole Cable Yard
- Lobs Hole Cable Yard
- four 330 kV transmission lines for 9 km from Lobs Hole to Maragle (~$200m)
- two 500 kV lines for 20 km from Maragle past LTSS (~$200m).

There will also be savings in building and operating the new connection point at an existing site, rather than a greenfield site.

For ease of comparison, Figure 8 depicts Options 2L and 3L, connected at LTSS. Option 1DL is a further option connecting to LTSS, but not shown.

Option 2L **Option 3L**

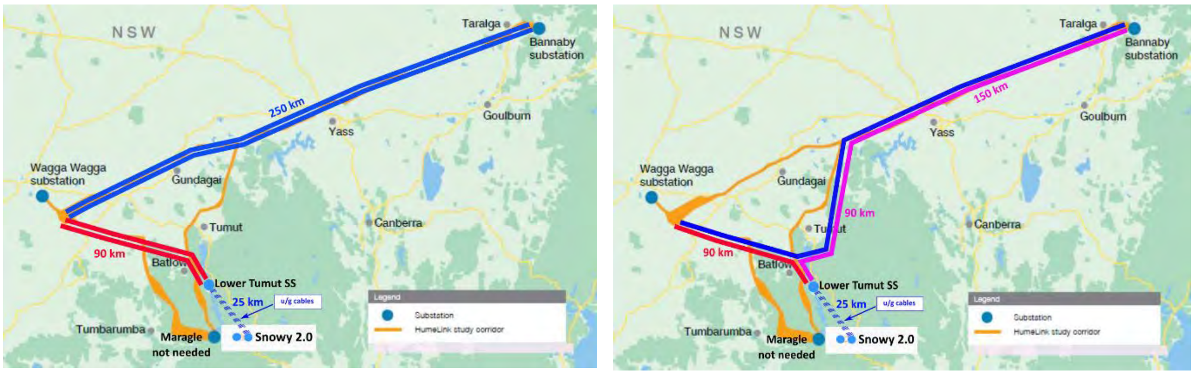


Figure 8 Options 2L and 3L

12.1 Advantages of LTSS

NEM and AEMO	• LTSS becomes a more substantial electrical hub, with improved flexibility, reliability, and transmission capacity. • The number of connections to LTSS increases from five to seven, and its transmission capacity increases from 5,000 MVA to 11,000 MVA. • Less transmission heating losses. • A shorter and cheaper HumeLink, with reduced exposure to outages from lightning strikes and bushfires. • No overhead lines in Kosciuszko National Park and far less in Bago State Forest.
Snowy Hydro	• Improved transmission capacity to/from the Snowy Scheme, reducing constraints and occasional loss of revenue. • Far shorter and more reliable connection of Snowy 2.0 to the main grid. • Avoids scaling back Snowy 2.0's generation/pumping capacity by about two-thirds when one 500 kV line is out of service. If one of the six cables from Snowy 2.0 to LTSS is out of service, the Station's capacity is only reduced by 17% (to 1,670 MW). • Snowy 2.0's commissioning is not reliant on HumeLink being completed in time. • Possible reduced costs for Station drainage and access, using the cable tunnel.
TransGrid	• Augmentation of an existing substation rather than constructing a new substation in a remote location, with cost and operational benefits. • Less construction of new lines and less ongoing maintenance. • Possibly less opposition to HumeLink from local communities.
Electricity consumers	• Cost savings from a shorter HumeLink and lower transmission losses due to lower loadings (losses increase by the square of the current). • A marginally more reliable service from Snowy generators.

The environment	• Fewer and shorter overhead lines. • No overhead transmission lines, easements, or access tracks in Kosciuszko National Park or Bago State Forest. No substation in Bago State Forest. • 6 square kilometres less clearing for easements and access tracks. • Substantially less new overhead transmission lines blighting the countryside.
Local communities	• Replacing the existing 330 kV line between LTSS and Wagga Wagga (Line 051) with a new 500 kV double-circuit line limits the impact to landholders along the existing line (not ideal, but better than other options). • Similarly, the existing 330 kV line between LTSS and Yass (Line 03) could be replaced with a new 500 kV double-circuit line (Options 1DL, 3L and 3LX).

Figure 9 Benefits of connecting to LTSS rather than Maragle

Figure 10 shows the LTSS hub, with the five existing 330 kV connections, to Murray, Upper Tumut, Canberra, Yass and Wagga Wagga, and the two 500 kV HumeLink connections for Option 2L.

The existing Line 051 could be 'replaced" with a 500 kV double-circuit line for its full length to the new Wagga Wagga 500 kV substation, as could Line 03 to Yass for Option 3L (see later).

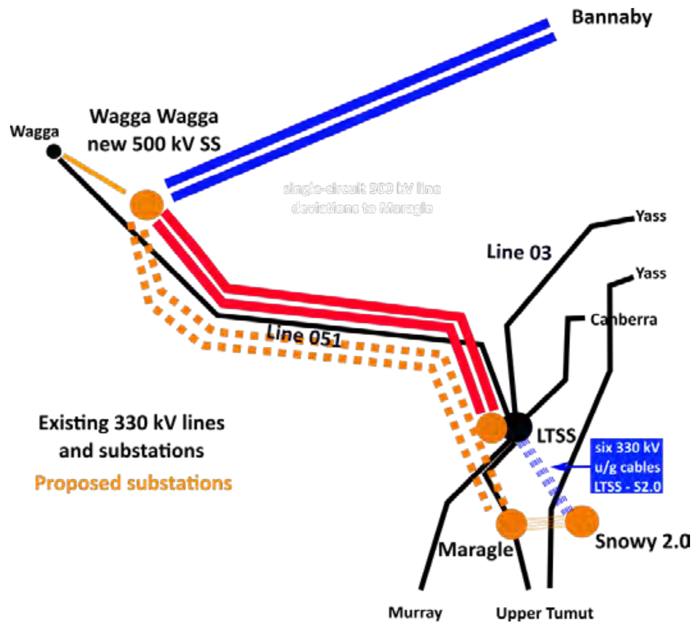


Figure 10 Connecting to LTSS rather than Maragle (Option 2L)

12.2 Disadvantages of Maragle

Connecting HumeLink to Maragle provides less benefit to the NEM compared to LTSS. Maragle is merely an intermediate point for connecting Snowy 2.0 to the 500 kV grid and a link to the existing 330 kV Line 64.

Other disadvantages of Maragle include:

- located in the middle of Bago State Forest, a lighting and bushfire prone area, as are its eight overhead line connections;
- extends the length of HumeLink by 40 line-kms;
- Snowy 2.0's connection to the 500 kV grid backbone totals 382 km – six cables for 3 km to Lobs Hole, plus four 330 kV lines for 9 km to Maragle, and then 110 km of 500 kV line to Wagga Wagga and 260 km of 500 kV line to Bannaby; and

- the four circuits from Lobs Hole to Maragle and the two circuits thereafter provide far less redundancy than the six cables to LTSS. When one of the 500 kV lines is out of service, Snowy 2.0's pumping/ generation would need to scale back, possibly to 700 MW or lower, to avoid system issues if the second line tripped.

During the devastating bushfires in January 2020, when one-third of Kosciuszko National Park, including the Lobs Hole/Ravine area and Cabramurra township, were razed, and the NSW/Victoria transmission networks were separated[17], Mr Broad warned[18]:

> *"rising bushfire risk along the east coast has spurred the need for critical electricity transmission lines to be built connecting Victoria and NSW, but through the west of the states in non-forested areas that are less prone to fires."*

Following his advice, Maragle and HumeLink should be located well away from Bago State Forest and Kosciuszko National Park.

A cable tunnel from Snowy 2.0 to LTSS, for connection to HumeLink, substantially reduces the risk of bushfire interruptions and damage.

If Snowy 2.0 were connected to Maragle, it would not be able to generate or pump during a repeat of the January 2020 bushfires. However, it would be able to operate if connected to LTSS.

[17] The January 2020 bushfires resulted in outages for some days in the Snowy, and separation of the NSW/Victoria transmission networks. Damage to TransGrid's assets in the Snowy region was *"north of $15 million to $20 million, which was not insurable"* [TransGrid CEO]. Snowy Hydro lost supply capability *"costing the company millions"* [Snowy Hydro CEO].

[18] "Fire sparks Snowy Hydro call to link NSW, Victoria power" Australian Business Review 9 January 2020 https://www.theaustralian.com.au/business/fire-sparks-call-to-link-nsw-victoria-power/news-story/4543f7131e74e960691182020c73c609

13 Other options

13.1 Option 3LX

This paper suggests consideration of another option which is a variation of Option 3L, termed 3LX (Figure 11).

Figure 11 Option 3LX

Aspects of Option 3LX include:

- Four, rather than two, additional transmission connections to LTSS (at 500 kV), via two double-circuit lines, making for a more resilient and flexible substation hub.
- Both circuits between Wagga Wagga and Bannaby are of equal length, thereby maximising the transfer capability. (However, Option 2L is better in this regard as the Wagga Wagga to Bannaby backbone link is 80 km shorter, 250 km versus 330 km).
- The line corridor length (330 km) is similar to Option 2L (340 km) and Option 3L (330 km).

13.2 Option 3D

The PACR included an alternative Option 3D in Appendix B.1.4, with:

- a new 500/330 kV substation at Blowering (new site, undefined location);
- a new 330 kV switchyard at Maragle;
- two double-circuit 330 kV lines from Blowering to Maragle;
- double-circuit 500 kV line from Blowering to Bannaby; and
- double-circuit 500 kV line from Blowering to Wagga Wagga.

"However, late in the assessment, it came to light that the 330 kV double circuit lines would be required to use high temperature conductors, which added significantly to cost. The overall capital cost of this option is expected to be in the order of $3,453 million and, since this option was not found to deliver significantly greater market benefits than the other options, we concluded that it is not a credible option (and it is not economically feasible) and have not included it in the body of this PACR."

There is no mention of where Blowering might be located, nor why LTSS wasn't considered as the site for the new substation, as the two locations are likely to be nearby.

The capital cost of Option 3D is only $136m (4%) more than Option 3C and only $53m more than Option 2C. So, it's not clear why it was eliminated as not being a credible option.

However, it is noted that Options 1L, 2L, 3L and 3LX are superior to Option 3D, as they are significantly cheaper, do not require lines to Maragle and involve augmenting LTSS rather than building two new substations at Blowering and Maragle.

14 Replacing existing 330 kV lines with 500 kV double-circuit lines

The PACR does not consider utilising existing 330 kV lines and easements for HumeLink. There appear to be opportunities to do this for all three sides of the HumeLink 'triangle'.

Ideally, the new 500 kV lines would replace existing 330 kV lines. The easement may not need to be widened and the only impact would be taller towers, though potentially more widely spaced.

The major network issue is the removal of an existing line before its 'replacement', for a period of two years or so during construction; though construction could be staged so that sections of the new line are connected to the existing line to enable it to be operational (at 330 kV) for critical periods (e.g. the middle of summer or winter).

If that was not possible, then the new 500 kV line could be built adjacent to the existing 330 kV line, after which the 330 kV line could be dismantled. Effectively, this involves 'moving' the existing easement sideways and then relinquishing the existing easement. It should be possible to overlap part of the 500 kV line easement with the existing 330 kV line easement.

Replacing an existing 330 kV line with a 500 kV double-circuit would minimise the additional environmental and landholder impact. It could also avoid some of the biodiversity offset and easement acquisition costs. The biodiversity offset cost for Option 3C is $935m and the easement cost is $90m [5% of $1,796m line cost].

Figure 12 shows the southern NSW network. Consideration should be given to using the easements for the 330 kV lines from LTSS to Wagga Wagga (Line 051), from LTSS to Yass (Line 03), and from Yass to Bannaby (direct or via Marulan).

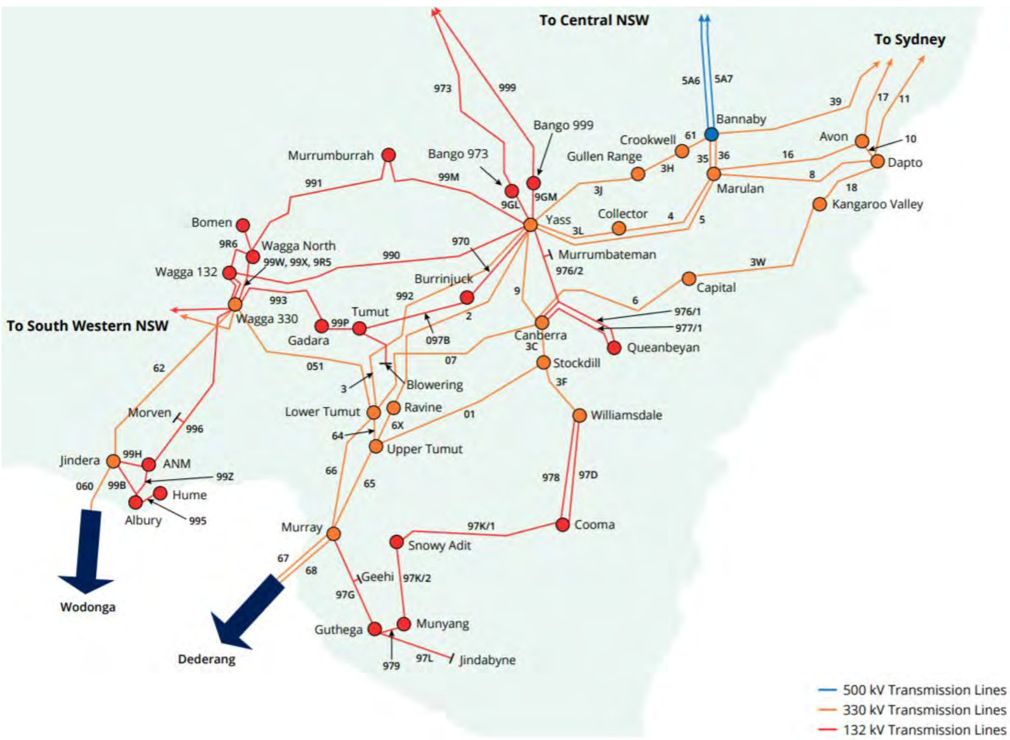


Figure 12 Southern NSW Network (TransGrid 2021 Planning Report Fig 2.16)

All future transmission augmentations should first consider the opportunity of utilising existing lines and easements before proposing additional lines.

15 Undergrounding HumeLink

Undergrounding of new transmission in NSW should be seriously considered, particularly where land of high value is likely to be affected.

Transmission lines have the potential to provide a common good, but also have a major adverse impact on the environment and on landholders and communities – a monetary payment is rarely adequate compensation. And such payments do not extend to neighbours, who sometimes experience a bigger visual impact.

Opposition to HumeLink along its entire corridor (originally 470 km, now reduced to 330 km) is growing, as it is for transmission extensions in western Victoria and Tasmania. Locals are being traumatised and, in some cases, lives destroyed. This is a major social and political issue.

The pitfalls of gaining community acceptance for HumeLink are well documented in the [Review of HumeLink engagement process, July 2021] by the Landowner and Community Advocate. The Advocate concluded:

> *"Overall the engagement process on the HumeLink project was found from a landowner perspective to not meet best practice standards to date as:*
> - *it has not been seen by landowners as being open and transparent;*
> - *all the appropriate people have not been included in the process;*
> - *landowners have not always felt that they have been treated with respect;*
> - *engagement tools have not always been appropriate, up to date and user friendly; and*
> - *landowners definitely do not feel that they are being heard."*

The Review's twenty recommendations have been accepted by TransGrid, but landholders are incensed and continue to oppose HumeLink.

Hay bale protest HumeLink, Apr 2021

Plough protest Victoria, Aug 2020

500 kV lines are the tallest, bulkiest, and most imposing of all transmission lines in Australia, completely dominating the landscape for tens of kilometres.

Undergrounding is the most obvious and effective solution. Whilst the initial capital cost will be higher, there are many offsetting benefits including higher reliability, no exposure to weather events, no sparking of bushfires, lower operating cost, far less environmental impact and much less local opposition. Quelling public opposition is itself a significant 'cost saving'. As noted in the PACR:

> *"Going forward, we note that development of the project may be subject to delays including any objection processes. The cost of such delays is at this point indeterminate."*

A pragmatic approach to choose underground circuits has been adopted elsewhere, e.g. Murraylink (180 km), Directlink (63 km) and the on-shore connection to the proposed Star of the South (the Bass Strait 2,000 MW wind farm) (Attachment B).

Other services are undergrounded – gas, petroleum and water pipelines; telecommunication lines; electricity distribution in new suburbs. Undergrounding electricity transmission is standard practice in many overseas countries and should also be seriously considered in NSW.

It would not be practical to underground all HumeLink, though significant sections could be. Alternately an underground HVDC link for the entire route is technically feasible and should be fully investigated. (TransGrid estimate the cost for a 2,000 MW capacity HVDC link between Bannaby and Wagga Wagga to be $2,038m – Figure 5.)

Following on from the earlier discussion on replacing existing 330 kV lines with 500 kV double-circuit lines, if those new circuits were underground cables they could potentially be laid within the existing easements. The underground cables could be built without impacting operation of the existing lines, incurring minimal biodiversity offset or easement costs, saving up to $1,025m – a significant dent in the extra cost of underground cables (AC or DC).

Adopting undergrounding would consolidate the progressive, new-technology, clean and green thrust of the NSW Electricity Infrastructure Roadmap.

16 A way forward

The approval for Snowy 2.0's main works to commence, well before its transmission connection was resolved, was premature (something that energy experts warned at the time). Waiting till the full implications and costs of transmission were determined could well have resulted in the project being deemed to be uneconomic. (Energy experts had said that the project was uneconomic even without taking account of its transmission costs, pointing out its overstated benefits and remote location, as well as it's devastating environmental impacts on Kosciuszko National Park.)

Even at this stage, the best economic option is to stop Snowy 2.0 and consider downsizing and delaying HumeLink.

If Snowy 2.0 is to be constructed, it becomes a matter of determining the least-worst option and ensuring that NSW consumers do not contribute to costs incurred by Snowy 2.0. In this case, it is suggested the following matters be fully addressed:

i) Resolving the inconsistencies and errors in the PACR.
ii) Providing accurate estimates of costs and benefits.
iii) Assessing all options (1D, 1DL, 2C, 2L, 3C, 3L, 3LX and possibly others) on all relevant grounds, not just the estimated net market benefit.
iv) 'Moving' Maragle Substation to LTSS.
v) Minimising line corridors and the impact on public and private land and the environment, and providing adequate compensation to all affected landholders, not just those whose land is traversed.
vi) Replacing existing 330 kV lines with 500 kV double-circuit lines.
i) Undergrounding sections of the lines with HVAC cables, or altogether with HVDC cables (in existing easements).
vii) Requiring Snowy Hydro to pay its fair share of HumeLink.

16.1 Need for an independent transmission planning review process

The evidence suggests that the planning process for HumeLink has been flawed from the outset.

It appears that Snowy Hydro determined the Maragle location to minimise its own costs, thereby dictating the sizing, route, timing and cost of the HumeLink connection. There appears to have been no assessment to determine the optimum configuration from the perspective of the NSW network.

HumeLink will be the largest NSW transmission project for decades, costing well over $3 billion. The PACR's lack of rigour in fully assessing the options and their ramifications is unsatisfactory.

NSW needs an independent transmission planning review process, especially at this time of rapid expansion of the network to accommodate new generation sources and batteries throughout the state.

The urgent first task is to re-assess the configuration of HumeLink and its funding apportionment, and determine the least-worst design if Snowy 2.0 proceeds. It would be convenient to request AEMO to undertake the relevant studies, especially after the recent release of its Transmission Cost Report that encompassed HumeLink and other related network augmentations. A second task would be to recommend a new, robust transmission planning procedure for NSW.

Such a review should not delay the ultimate construction of HumeLink, as much of the initial route planning is well advanced.

Attachment A Treatment of Snowy 2.0 and competing options in EY Report

Page	***Quote* or Comment**
4	*"EY calculated the least-cost generation dispatch and capacity development plan for the National Electricity Market (NEM) associated with three groups of HumeLink augmentation options across a range of voltage variants, scenarios and sensitivities"* *"To determine the least-cost solution, a Time Sequential Integrated Resource Planning (TSIRP) model is used that makes decisions for each hourly trading interval in relation to the dispatch of generators and commissioning of new entrant capacity, while taking into account several operational and technical constraints. From the hourly time-sequential modelling we computed the following costs, as defined in the RIT-T:* > *capital costs of new generation capacity installed (Capex),* > *total Fixed Operation and Maintenance (FOM) costs of all generation capacity,* > *total VOM costs of all generation capacity,* > *total fuel costs of all generation capacity,* > *total cost of voluntary (demand-side participation, DSP) and involuntary load curtailment (Unserved energy, USE),* > *transmission expansion costs associated with REZ development."* *"For each simulation with a HumeLink augmentation option and in a matched no augmentation counterfactual (referred to as the Base case), we computed the sum of these cost components and compared the difference between each option and the Base case."* *"The difference in present values of costs is the forecast gross market benefits due to the HumeLink transmission augmentation, as defined in the RIT-T. The forecast gross market benefits capture the impact on transmission losses to the extent that losses across interconnectors and intra-connectors affect the generation that is needed to be dispatched in each trading interval. The forecast gross market benefits also capture the impact of differences in losses in storages, including Pumped Storage Hydro (PSH) and large-scale battery storage between each HumeLink augmentation option and the counterfactual Base case."*
5	*"In addition, EY evaluated competition benefits for selected options in line with the Frontier Economics approach."* *"Gross market benefits were forecast for three HumeLink augmentation topologies, each with different voltage variants, across four scenarios covering a broad range of reasonable possible futures for the NEM."*
13	*"Snowy 2.0 is included from July 2025."* Thus Snowy 2.0 appears in both the Base Case and each HumeLink augmentation option scenario.

16

Figure 3: Forecast cumulative gross market benefit[31,32] for Option 3C under the Central scenario (excluding competition benefits), millions real June 2019 dollars discounted to June 2021 dollars

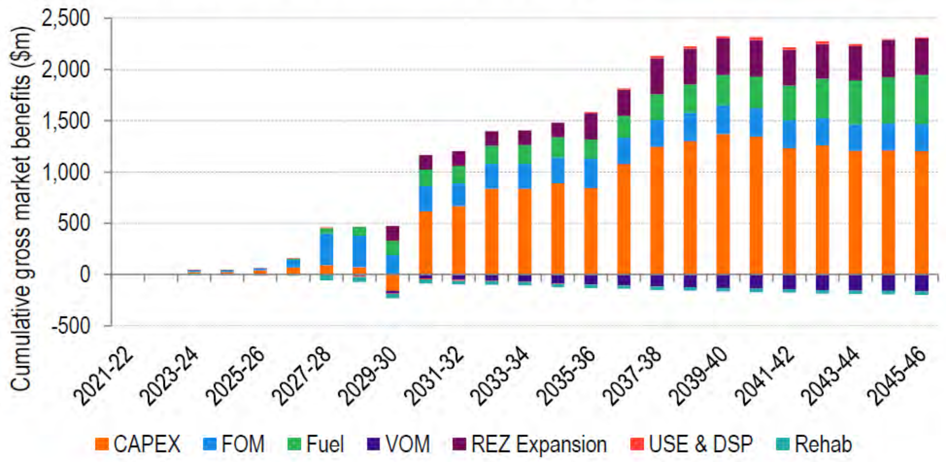


Figure 4: Difference in NEM capacity forecast between Option 3C and Base case in the Central scenario

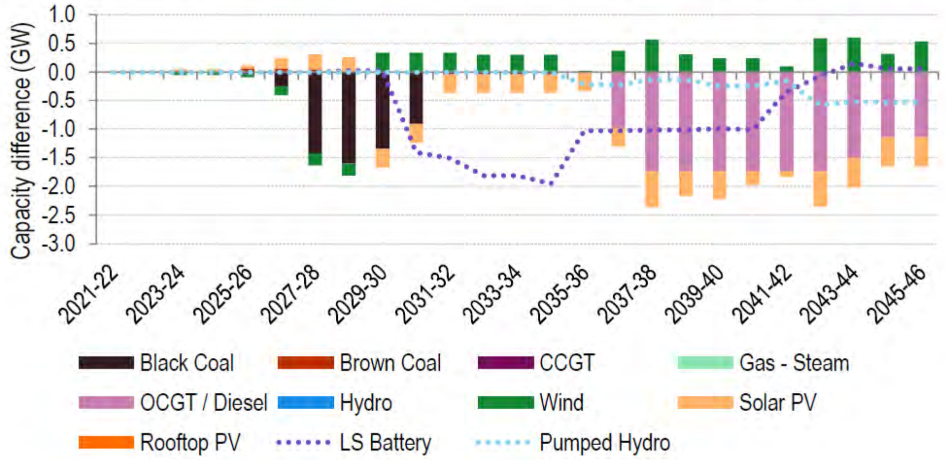
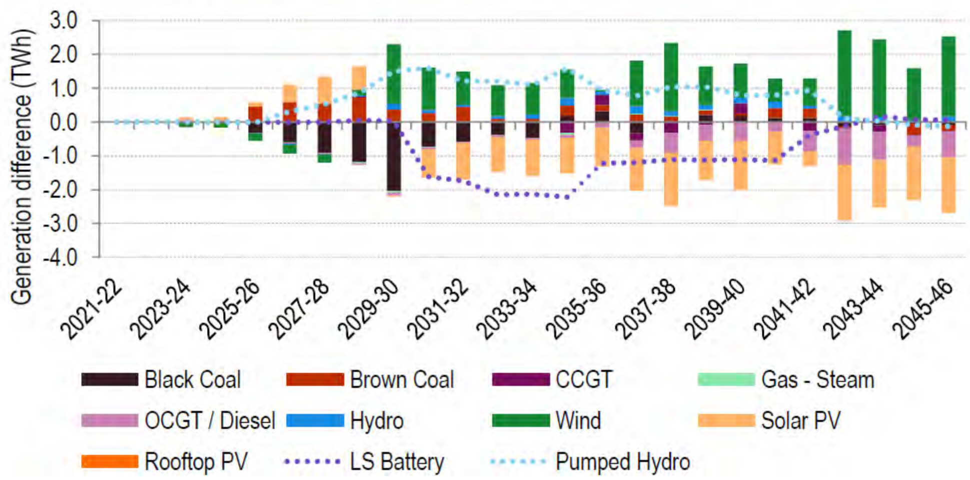


Figure 5: Difference in NEM generation forecast between Option 3C and Base case in the Central scenario



Figures 3 & 4 show cumulative benefits for Option 3C and capacity differences compared to the base case for the Central Scenario. From Figure 3, most of the market benefits are expected to come from displaced Capex. From Figure 4, Option 3C is credited with bringing forward black coal retirements by a few years, deferring LS Battery investment for many

	years and, from the late 2030's, displacing OCGT/diesel and preferencing wind investment compared to large PV investment. The underlying assumption seems to be that Snowy 2.0 would be able to capture the benefits by pumping when spot prices are low due to high-penetration wind & PV. However, it is likely that wind and PV developers would be increasingly likely to co-locate battery storage to retain most of the benefits of low-value wind or PV generation. Owners of rooftop PV and EVs are likely to adopt the same strategy. EV's and domestic storage are mentioned on page 49 with respect to preparing the hourly demand forecast but are not treated as active storage devices. Hydrogen is not mentioned. Likewise, it is implausible that Snowy 2.0 will displace nearly 2 GW of OCGT/Diesel in the 2040's as the latter is very unlikely to be built rather than other options with additional benefits that Snowy 2.0 can't provide. Note that the difference between Option 3C and the Base case is due to the change in operation of Snowy 2.0 between the two cases. As discussed with respect to pages 29-30, EY states that, for the Central Scenario, Snowy 2.0 is projected to generate at 15-20% capacity factor in the Base case, compared to ~25% capacity factor in the Option 3C case. Thus, all the effects shown in Figure 4 are due to Snowy 2.0 operation increasing by around 6.5% (see below). Figure 5 shows the change in generation annual energy between the Option 3C case and the Base case for the Central Scenario. It shows wind displacing large PV, brown coal displacing black coal and Pumped Hydro displacing batteries. Pumped Hydro generation is expected to increase by more than 1 TWh/yr (say 120 MW average or ~6% capacity factor for Snowy 2.0), while battery generation reduces by a larger amount.
29-30	EY Figures 21 & 22 compare Snowy 2.0 operation (generation & pumping) for all scenarios in the Base Case configuration and the HumeLink Option 3C augmentation configuration. Figure 21 shows that the EY model predicts that, in the Base Case configuration, Snowy 2.0 would operate without HumeLink, reaching highest capacity factors of 27% pumping and 20% generation in the Central Scenario. Note that MJA estimated Snowy 2.0's capacity factor to be ~22% (MJA Figure 30, p 82). Pumping would not compete with existing Snowy generation. If existing Snowy generation was constrained by inflow constraints, upper reservoir issues or downstream release constraints, Snowy 2.0 pumping, if sufficiently cheap, would allow Snowy Hydro to obtain more commercial value from Snowy 2.0 generation at other times. However, whether that would be profitable is another matter. In the HumeLink Option 3C augmentation configuration, EY expects Snowy 2.0 to reach highest capacity factors of 35% pumping and 27% generation in the Central Scenario. Note that Figures 21 & 22 indicate that EY simulated round trip losses for Snowy 2.0 at about 25-27%.
30	*"Snowy 2.0 operation increases on average around 6.5% in the Central, Step and Fast Change scenarios, and 5.3% in Slow Change."* The additional 6.5% capacity factor is effectively the EY estimate of additional operational activity for Snowy 2.0 due to HumeLink.

Figure 21: Annual capacity factor for Snowy 2.0 generator and pump for the Base case in all scenarios

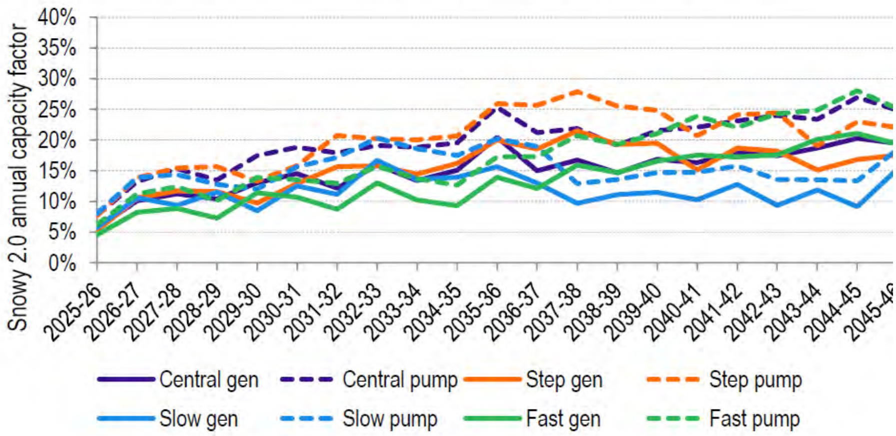
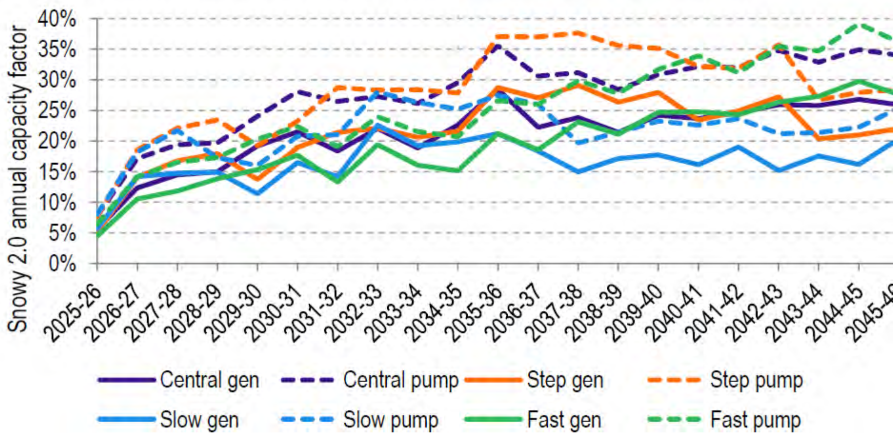


Figure 22: Annual capacity factor for Snowy 2.0 generator and pump for Option 3C in all scenarios



61 EY Figures 42 and 43 show trends in Capacity and Annual Energy by resource type for the Central Scenario Base Case over the study period. Large scale batteries and pumped hydro are both projected to rise slowly and only reach ~ 10 GW by 2045-46. However, AEMO's Generation Information page for July 2021 shows for (large) Battery Storage 261 MW existing, 489 MW committed, 18 MW anticipated, and 21,263 MW proposed. For Water, the corresponding figures are 7,992 MW, 2,290 MW and 9,936 MW. (https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information).

AEMO's 2021 ESOO, p 10 states "For storage, there is already a pipeline of publicly announced storage projects (beyond those already operating and committed for operation) that includes 21 GW of battery storage and 6.3 GW of medium to long-term duration storage across the NEM." Of these, around 10 GW of batteries are proposed for Victoria and NSW (2021 ESOO, Figure 13, p 32).

Conclusions

1. EY predicts Snowy 2.0 to generate at up to 20% capacity factor without HumeLink, presumably via Line 64, the 330 kV line close to the proposed Maragle substation and possibly Line 2, the 330 kV line close to Lobs Hole (though that has not been mentioned in any TransGrid or Snowy Hydro documents). Note that the MJA report (MJA Fig 30) estimated that the generating capacity factor for Snowy 2 would be ~22%.
2. EY predicts that, in the Central Scenario, building HumeLink Option 3C would allow the Snowy 2.0 generating capacity factor to increase by ~6.5% or ~1.1 GWh per year, to a generating capacity factor of ~25% and pumping capacity factor of ~33%, the combined duty approaching 60% or ~14 hours per day assuming Snowy 2.0 always operated at full capacity. This additional operation by Snowy 2.0 is expected to displace up to 2 GW of large-scale batteries as well as cause wind generation to displace large PV. It is hard to see why this increase in Snowy 2.0 operation would have such a substantial effect.
3. EY does not appear to pay sufficient attention to the additional advantages that batteries and EV's have compared to Snowy 2.0. Also, there is no apparent consideration of flexible demand, including emerging options such as hydrogen production.

Attachment B Extracts from NPA EIS Submission Snowy 2.0 Transmission Connection 08/04/21

7. Underground transmission

7.1 A common technology

High voltage underground cables are a viable alternative to overhead lines and are installed widely in cities and areas with high agricultural and conservation value. Almost all new transmission links are underground throughout Europe and much of Asia.

For instance, in 2010 the Netherlands introduced regulations that every additional kilometre of overhead line must be compensated by undergrounding an equivalent length of existing transmission lines. Many governments have instituted programs to underground existing overhead lines.

7.2 Underground examples

Examples of transmission lines that have been undergrounded partly or purely for environmental reasons, include:

- the 'Directlink Interconnector' between Mullumbimby and Terranora in northern NSW; 63 km long, 180 MW rating and costing $100 million;
- 'Murraylink', between Red Cliffs in Victoria and Berri in South Australia; 180 km long, 220 MW rating and costing $177 million;
- the 87 km, 220 kV cable along the edge of Western Port Bay to connect the Victorian desalination plant;
- undergrounding 132 kV transmission lines at Olympic Park prior to the Sydney 2000 Olympics, mainly for aesthetic reasons for world-wide TV audiences, at a cost of $37 million;
- the 'Hinkley Connection Project' in the UK[19]; 57 km long, consisting of 48.5 km of 400 kV overhead line and 8.5 km of underground cable *"through the Mendip Hills Area of Outstanding Natural Beauty (AONB[20])"* [akin to a National Park];
- the 140 km, 400 kV Aalborg to Aarhus line/cable in Denmark[21] is another example of using cables to protect areas of natural beauty along a portion of the route, albeit at a higher cost; fourteen km (10%) of the circuit was installed underground, across the Mariager Fjord and through the Gudenaa Valley, costing €35 million (25% of the €140 million total cost);
- fifty underground cable projects are listed by Barber[22] and Moorabool Shire Council[23]; and
- Attachment G provides some articles on international undergrounding projects for environmental reasons.

Another recent Australian example is the announcement of a 200 km underground connection from Hazelwood (Victoria) to a 2,000 MW offshore wind farm in Bass Strait.

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[19] "Hinkley Connection Project" https://hinkleyconnection.co.uk/category/ourproject/

[20] An AONB is an area of countryside in Britain that has been designated for conservation due to its significant landscape value. AONBs enjoy levels of protection from development similar to those of National Parks.

[21] "Underground High Voltage Cables: Wiring Europe for the Future" https://www.stjornarradid.is/library/01--Frettatengt---myndir-og-skrar/ANR/ANR---Raflinur-i-jord/33-Underground-high-voltage-cables-Leonardo.pdf

[22] "Achievement and experience in service of long length High Voltage AC electrical links by insulated power cables", CIGRE Latin American Workshop 2013, Ken Barber. https://www.jicable.org/Other_Events/WETS_Brazil_13/slides/Presentation_Barber.pdf

[23] "Comparison of 500 kV Overhead Lines with 500 kV Underground Cables", Moorabool Shire Council, September 2020. https://www.moorabool.vic.gov.au/sites/default/files/largefiles/20200924%20MSC%20Transmission%20Comparison%20Overhead%20with%20Underground.pdf

7.3 Snowy 2.0 underground cables

The Snowy 2.0 Main Works is already approved to install six sets of 330 kV, 450 MVA cables from the Snowy 2.0 underground Power Station to Lobs Hole Cable Yard in a multi-purpose tunnel used for emergency egress, cables, and ventilation. These cable sets (18 individual cables in total) will each be three km long – already a quarter of the distance to the proposed Maragle Substation.

7.4 Benefits of underground cables

Whilst the up-front capital cost of undergrounding is higher than for overhead lines, there are many offsetting benefits, including minimal environmental impact, higher reliability, lower losses, reduced maintenance, and less vulnerability to outages from bushfires, lightning and storms. Underground cables are:

- less prone to physical damage; and
- no exposure to weather events – bushfires, lightning, storms, extreme winds, etc.

Such events are expected to become more frequent and intense with climate change, causing more outages, physical damage, more repair costs and lost revenue, sometimes costing tens of $millions from a single event (as was the case with the January 2020 bushfires for TransGrid and Snowy Hydro)[24].

- Higher reliability, though taking longer to repair. (The longer repair time should rarely be a concern, as if one cable is out of service the remaining five generators/pumps can still operate up to a combined capacity of 1,670 MW).
- The loss of one cable circuit due to a fault should not result in the need to back off Snowy 2.0 output/load to cover a subsequent cable loss. Whereas the loss of a double-circuit overhead line from a fault (or bushfire or lightning strike) would result in backing off output/load to cover for a subsequent loss. Also, the proximity of two overhead double-circuit lines poses a system security risk that is not applicable for underground cables[25].
- Ready physical access for repairs and maintenance if in a tunnel.
- Lower operating costs (potentially one-tenth that of overhead lines)[26], though higher repair costs.
- Lower electrical losses (reputed to be around 30% lower).
- Far less or zero easement clearing and maintenance cost.
- Little or no release of greenhouse gasses from vegetation clearing.
- No potential to start bushfires, as can occur from overhead lines through fallen towers, conductor clashing or breaks, and subsequent insurance claims[27].

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[24] The January 2020 bushfires resulted in outages for some days in the Snowy, and separation of the NSW/Victoria transmission networks. Damage to TransGrid's assets in the Snowy region was *"north of $15 million to $20 million, which was not insurable"* [TransGrid CEO]. Snowy Hydro lost supply capability *"costing the company millions"* [Snowy Hydro CEO].

[25] "Queensland and South Australia system separation on 25 August 2018" AEMO, 10 January 2019 https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2018/qld---sa-separation-25-august-2018-incident-report.pdf

[26] "Overview of the Potential for Undergrounding the Electricity Networks in Europe" prepared for the European Commission, 28 February 2003. https://ec.europa.eu/energy/sites/ener/files/documents/2003_02_underground_cables_icf.pdf

[27] "Black Saturday bushfire survivors secure $500 million in Australia's largest class action payout" ABC News, 15 July 2014 https://www.abc.net.au/news/2014-07-15/black-saturday-bushfire-survivors-secure-record-payout/5597062

- And, most importantly, underground cables have substantially less environmental impact and no visual blight[28], other than a relatively narrow easement if trenches are used.

In addition to the above benefits, all underground cabling alternatives allow the cables from the underground Power Station to be extended to the TransGrid connection point (Maragle or LTSS), avoiding the need for the Cable Yard and overhead transmission lines, thereby saving those environmental impacts and costs.

7.5 NPA alternative routes and options

The Background paper identified five example underground alternatives (Figure 8). No doubt there are others. The Addendum examined Alternative D in more detail.

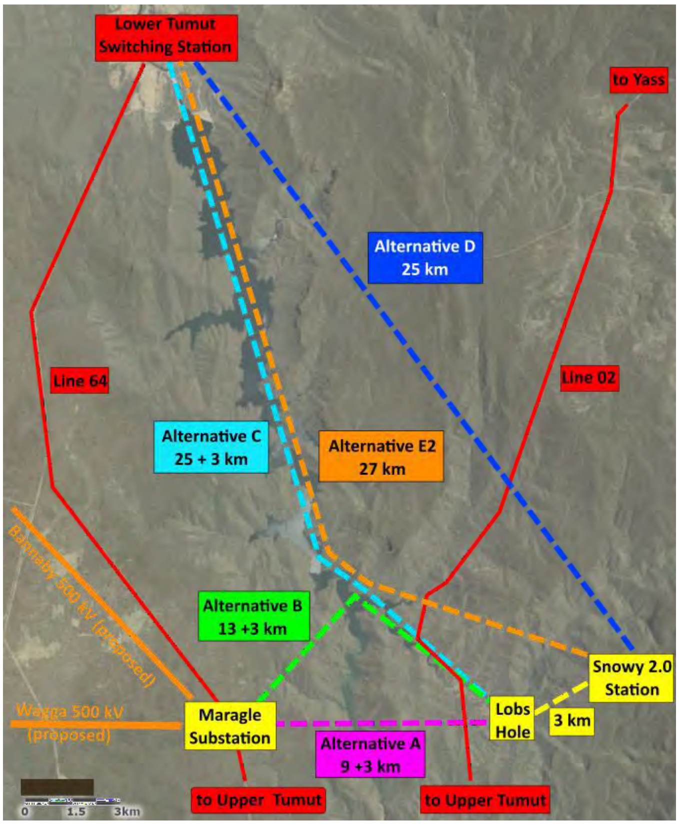

Figure 8 Alternative Routes for Underground Cables from Snowy 2.0 to Maragle and LTSS

A. Extending the three km of underground cables from the Snowy 2.0 Station to Lobs Hole Cable Yard, generally following the direct route of the proposed overhead lines, for the remaining nine km to Maragle. The cables could be in a trench, HDD conduit or tunnel, or combination.

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[28] "Valuing the social benefits of avoiding landscape degradation from overhead power transmission lines: Do underground cables pass the benefit–cost test? Ståle Navrud ,Richard C. Ready,Kristin Magnussen &Olvar Bergland, 12 May 2008 *"the social benefits of avoiding negative impacts [from overhead transmission lines] on the landscape exceed the costs of burying the lines as underground cables … based only on an assessment of the aesthetic impacts [urban setting]. Impacts of overhead power lines on wildlife and human health would likely make burial of power lines even more attractive."*
https://www.tandfonline.com/doi/abs/10.1080/01426390802045921

B. Laying cables in a trench from Lobs Hole along, or near, the road to the Snowy 2.0 excavated spoil dump in Talbingo Reservoir, at the junction of the Yarrangobilly and Tumut Rivers, and then via a trench/ tunnel/ HDD to Maragle (about 13 km). Approximately half the route is under the road and therefore of straightforward construction, with no additional clearing or environmental impact.

C. As per Alternative B to the junction of the Yarrangobilly and Tumut Rivers, and then in, or adjacent to, Talbingo Reservoir to the existing Lower Tumut Switching Station (LTSS), located next to Tumut 3 Pumped Hydro Station at Talbingo (about 25 km). This alternative effectively relocates Maragle Substation to LTSS, with ongoing new connections to the main grid being constructed from LTSS, rather than from Maragle (see Figure 12).

D. Laying cables in a tunnel from the Station directly to LTSS (avoiding the need for cables from the Station to Lobs Hole).

E. Laying cables in the tailrace tunnel from the Station to its inlet at Talbingo Reservoir, and then via a trench/ tunnel/ HDD to Maragle (E1), or via the Reservoir to Lower Tumut SS (E2).

The EIS included some cursory comments on Alternatives A and C, rejecting them for spurious reasons. The EIS made no mention of the more promising Alternatives B and D.

The EIS 'analysis' is termed 'high level' and is essentially a list of potential issues and challenges, leading quickly to the conclusion that undergrounding is too difficult. There is no question that undergrounding has challenges, but so too do overhead lines and every other aspect of Snowy 2.0. The challenges of underground transmission are dwarfed by those involved in the Main Works construction of 27 kms of 11 metre diameter water tunnels and an underground power station in two enormous caverns.