Supplementary Submission No 29b

INQUIRY INTO FEASIBILITY OF UNDERGROUNDING THE TRANSMISSION INFRASTRUCTURE FOR RENEWABLE ENERGY PROJECTS

Name: Professor Simon Bartlett

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Comments on TransGrid Evidence provided 7th August - Undergrounding Inquiry

Page 1 Para 3

The US is lagging the world in the application of HVDC with its last HVDC transmission line commissioned 37 years ago and has never undergrounded HVDC. Below is a diagram of Europacable's HVDC undergrounding arrangements (Europacable is responsible for 90% of Europe's underground HVDC cables) showing the four cables for a 2,000MW, 320kV underground HVDC line, and a photograph of an overhead 3,500 MW overhead 500 kV HVDC transmission line demonstrating that they are much lower visual impact than a the Humelink-style 500 kV, 2,200 MW AC line along side. For project Marinus, we are leaving an 8 m space between the two pairs of cables to facilitate cable repairs in the unlikely event of a cable repair being necessary, without disturbing the other pair of cables

Question for TransGrid : Please provide a sketch showing why such a wide easement is required to underground Humelink using 2 pairs of underground HVDC cable, and specifically why cultivation cannot continue directly above the cables, as is the case for Basslink and Project Marinus on land in Gippsland?

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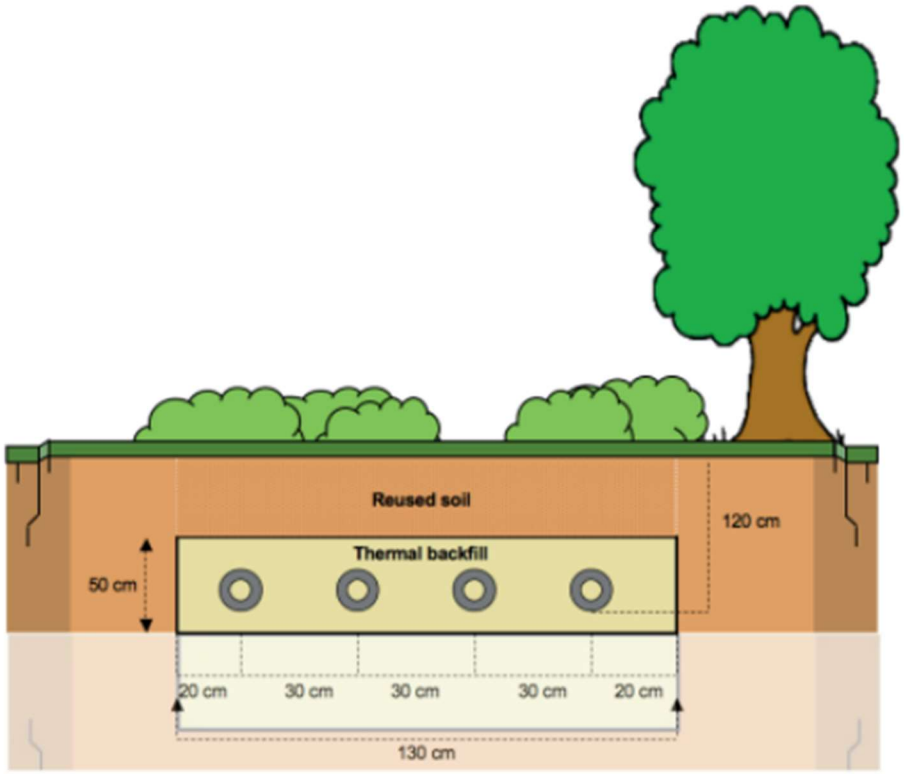
europacable

2) HVDC: 2 Bipole, 320 kV, 2 GW



Page 1 Para 2

This is not correct. The HVDC is the “super-highway” carrying large amounts of renewable power long distances far more efficiently than 500 kV AC. Renewable generators never connect to the 500kV AC or HVDC “super highway” In Australia all solar farms and wind farms use 330 kv (or 132kV or 220 kV or 275kV) lines to connect the renewable generators to the main transmission grid because it is much cheaper. It is the role of the 330kV network in NSW to act as the distributor system to connect to the renewable generators. In designing Humelink, TransGrid forgot to upgrade the 330kV/220kV network so that it has the necessary capacity to perform that role. That is why the existing solar farms in south-west NSW are now curtailing approximately 50% of their potential energy generation and why 20% of the renewable energy that is able to get onto the overloaded grid is wasted in transmission losses. Because of this extreme wastage, new investments in renewables in NSW virtually ceased in 2019 (for wind power) and 2022 for solar farms). TransGrid should be expediting the upgrade of its existing overloaded 220 kV and 330 kV lines.

Questions for TransGrid Please provide details of any 500 kV connections to renewable generators in Australia, including the voltage of the transmission lines running to the renewable generator? What has TransGrid actually done to reinforce its 220kV and 330 kV transmission networks in South-west NSW REZ and Wagga Wagga REZ, to reduce the very high congestion on those networks causing curtailment of solar farm generation exceeding 40% and marginal loss factors as low as 0.80. What is TransGrid's explanation for the virtual cessation of new solar farm investments from 2022 onwards, other than it being because of the financial losses of solar farms in south west NSW due to the high levels of transmission congestion and high transmission losses on those TransGrid networks.

Page 2 para 2

It is correct that there should be only two HVDC converter stations, one at Wagga Wagga and the other at Sydney with a 3,500MW 525kV HVDC line, or cable running the whole 400 km in between, not stopping at Barnaby but going into Sydney South substation. This would replace both Humelink and the Southern Sydney loop, now being planned by AEMO and TransGrid for completion by 2027. There is no way the line to Sydney can be an overhead 500 kV line and must be undergrounded. It is much cheaper to simply run the HVDC right through to Sydney. A capacity of 2,000MW to 3,000MW would be suitable for the renewables in South-West NSW REZ and Wagga Wagga REZ and Project Energy Connect. There is no way that it could also carry the power from Snowy 2.0. Neither can Humelink. That is why TransGrid and AEMO are now planning Humelink 2. When, and if, Snowy 2.0 is completed, a second HVDC line or cable could be constructed, running from the snowy Scheme to Wagga Wagga. It would need a capacity of 2,000MW at 330 kV HVDC and the Wagga Wagga to Sydney 3,500MW

Questions for TransGrid: Is TransGrid considering undergrounding the Southern Sydney Loop due to the anticipated unacceptability of new overhead 500 kV double circuit transmission line through Sydney's outer suburbs. If not, why not? Can TransGrid please comment on the net benefits of terminating Humelink and Southern Sydney Loop at Bannaby, rather than running approx. 500 kms of underground cable from Wagga Wagga, Snowy 2.0 and Sydney South, with converters connected to the 330kV network at these locations?

Page 2 Para 2

The 98% availability of HVDC is a completely different concept to the 99.998% overall supply of electricity to NSW electricity users by TransGrid's entire transmission network. The 98% is the percentage of time that HVDC systems, globally are available and not suffering some sort of breakdown. The availability of each component of TransGrid's transmission network would be expected to be similar to 98%. TransGrid has some transmission equipment with much lower availabilities, such as the Kemp's Creek SVC which caught fire some years ago. TransGrid are misleading the Inquiry by their statistical comparison between a single HVDC line compared with the overall delivery of energy by their heavily meshed and redundant transmission Network. The more relevant measure of reliability is the likelihood of a complete failure of major transmission equipment, requiring its complete replacement, which may take weeks to months. The statistics for the world's HVDC converters show that it is extremely rare for one of the duplicated

AC/DC converters to be completely destroyed as it is designed with thousands of independent and redundant power electronic components. In the case of AC transmission, it fails more frequently due to lightning, bushfires, destructive winds and flooding that do not affect underground HVDC. HVAC equipment is more likely to have insulation failures and when that occurs in substation equipment like transformers and reactors, they usually explode and catch fire and are completely destroyed. The global failure rate of HVAC transformers is 0.6% p.a. meaning there is a 30% chance of a transformer failing in a 50-year period. As Humelink has 8 transformers and 6 reactors, there is likely to be 4 failures in the 50-year lifetime of Humelink necessitating full replacement of that equipment, with likely collateral damage to other equipment.

Questions for TransGrid: Please explain why it is appropriate to compare the 98% availability of HVDC systems globally with the 99.998% of NSW electricity needs supplied by TransGrid's entire meshed and redundant transmission network? What is the average availability of TransGrid's transmission lines, power transformers and reactors, and the Kemp's Creek SVC? Given that CIGRE's survey reports 0.6% p.a. failure rate for transformers operating near 500kV, how many failures does TransGrid expect to occur on Humelink given its 8 500 kV transformers and 6 500 kV line reactors. How long would it take to replace these equipment failures and what would be the implications for the secure capacity of the three substations during these periods.

Page 2 Para 2

We note that TransGrid estimate the cost of each converter to be nearly $bn0.5 totalling $bn1.5 for the three. It is expected that around 20% of Humelink's $bn4.9 is the cost of the three 500 kV substations totalling $bn1.0, so the additional cost of the three converters is $bn0.5. The remaining $bn3.9 for Humelink is for the 500kV lines, easements and environmental offsets, averaging $10.8/km. The cost of an overhead 525kV HVDC transmission line is less than half of the cost of a 500kV transmission line as the towers are half the height and they only have 2 sets of wires instead of 6 and require a narrower easement, yet it can transmit up to twice as much power as Humelink. Assuming $m4.5/km for the HVDC overhead line would save $m6.3/km. In just 80km, the savings in transmission line costs would pay for the additional costs of the three converters. Allowing for the 490 kms from Wagga Wagga Snowy 2.0 to Sydney would save another $bn 3.0, meaning that the 3 million NSW electricity customers would each save $1,000.

Given that it is known internationally that underground HVDC cable is 2 to 3 times the cost of overhead HVDC, the cost of the HVDC underground cable would be at most $m13.5m/km or $m9.0/km extra than the cost of the overhead HVDC line. If the $bn3.0 savings is used to underground 330km of the 490km, it would leave only 160km as overhead HVDC line. In fact, the Southern Sydney loop is going to cost much more in $/km than Humelink and most of the route will have to be undergrounded as 500 kV AC costing much, much more costly than underground HVDC cables. An underground HVDC cable would have a lower rating than an overhead HVDC line, however it would still be around 3,500MW almost twice that of Humelink, meaning that Humelink 2 will no longer be required saving another $bn4.9.

Questions for TransGrid: Please advise the total cost of the three 500 kV Humelink substations including all land and other works included in the $bn4.9 cost estimate. Please advise the total cost of easements, environmental offsets and all transmission line expenditure for Humelink, included in the $bn4.9 cost estimate and the reasons for any expenditure not included in these two components. Please advise the likely approximate cost of the Southern Sydney Loop Project should it be necessary to underground the 500kV overhead line though the outer suburbs and environs of Greater Sydney. Please provide a high-level estimate, consistent with TransGrid's $bn0.5 estimated converter cost estimate for an underground HVDC cable system between Wagga Wagga, Snowy 2.0 and South Sydney, with the converter connected to the existing 330 kV networks, and the capacity being either approx. 2,200MW (i.e. 350 kV HVDC) or approx. 3,500MW (i.e., 525 kV)? Why hasn't TransGrid considered these options instead of Humelink and Humelink 2 (as contemplated in AEMO's Transmission Options Report)?

Page 2 Para 3

It would appear from the above that TransGrid can achieve its goal of minimising the adverse impacts on landowners whilst still complying with the AER's maximum net benefit requirement

Question for TransGrid: Could TransGrid please comment on whether the above option would be likely to deliver greater net market benefits than building at 500kV AC Humelink, Sydney Southern Loop (undergrounded) and Humelink 2?

Page 4 para 5

TransGrid is not compensating adjoining property owners who will still be adversely affected by 80m high 500 kV AC transmission lines. Powerlink Queensland compensates all property owners within 1 km of a 500 kV line. That is much fairer. TransGrid and the NSW government should do the same. This would increase the cost of the 500kV AC line to reflects its true cost to adjoining properties, further increasing the savings of undergrounding.

Question for TransGrid: Please comment on Powerlink Queensland practice of compensating adjoining landowners up to 1km from a 500 kV new powerline? Why hasn't TransGrid adopted the same practice?

Page 6 Para 3

It is not correct that the 500 kV substation equipment would have to be installed for the HVDC option. At Sydney South, the AC/DC converter would convert from the voltage at that substation, presumably 330 kV. All that would be required would be two bays of 330kV switchgear and a short length of 330 kV line(s) to the converter station. At Snowy 2.0, the converter could convert to 330 kV being the voltage of the transmission lines from Snowy 2.0. At Wagga Wagga, the converter could convert to 330 kV connecting direct to the existing Wagga Wagga 330 kV substation. There would be no need for the Gugga 500 kV substation. Nor would there be any need to spend large amounts to increase the Voltage of PEC between Dinawan and Wagga Wagga from 330kV to 500kV.

It is not correct that the evidence given at Tumult excluded the costs of the Converters. They were included in the overall cost of the HVDC option. The analysis above includes the costs of the converters and demonstrates that the entire cost of the HVDC system, when extended to Sydney may be actually lower that the cost of Humelink and Southern Sydney Loop.

Question for TransGrid Please provide proof that the Tumult Inquiry clearly excluded the cost of HVDC converters?

Page 6 Para 7.

It is agreed that the cost of undergrounding 500 kV AC is extremely high. This is relevant to TransGrid and AEMO's proposal to use HVAC for the Southern Sydney Loop. There is no doubt that will have to be undergrounded. Hence the savings of extending the underground HVDC to Sydney South are much, much greater than estimated above. This will make the undergrounding of Humelink and South Sydney Loop with HVDC cable much lower cost and much more viable than using 500 kV AC.

Question for TransGrid Please provide the estimated cost of undergrounding the last 50kms of the Southern Sydney loop 500 kV double circuit line?

Page 7 Para 2.

There is no underground HVDC in all of the US. As the witness has only worked in the US and NSW, she could not have seen or have any knowledge or experience with the undergrounding of HVDC. The comments about not being able to underground just parts of Humelink indicate that the witness has no knowledge or experience in the use of graded protection, high speed fault location, the use of fibre optic sensors to detect local cable overheating. The witness appears to be assuming that it is essential to auto-reclose on an HVDC line and cable as is standard practice for HVAC. However, that is generally not standard practice on HVDC, where instead the DC voltage can be gradually ramped up following the tripping of the line or cable.

Question for TransGrid Please advise the need to auto-reclose after a fault occurs on a mixed overhead/underground HVDC line? Please advise on the practicality of gradually reloading a HVDC line after a fault, the use of high-speed fault locators to identify the location of any fault, and the use of fibre optic sensors to detect possible hot spots on an underground HVDC cable>?

Page 7 para 2

Ot is not correct that having to reselect the route for an HVDC cable will set the project back for 5 years. An AC cable can be run along existing transmission line easements, alongside roads, and stock routes, there is also much less concern from landowners. They have "locked the gates "to TransGrid but have told them they will be pleased to co-operate with TransGrid if they underground the transmission line. Quite likely the entire project from Wagga Wagga to Sydney will be completed sooner if it is undergrounded, and may never be completed is TransGrid insist on overhead 500 kV AC.

Question for TransGrid: Please reconsider your statement that undergrounding Humelink would set the commissioning date back 5 years, noting that TransGrid does not have access to many of the impacted properties to survey and that underground cable could be run along existing TransGrid easements, along the sides of roads or along stock routes?

Page 7 Para 4.

It is incorrect that that Humelink with improve the reliability of electricity supply to NSW. The reverse is true. Building a double circuit single 500 kV line means that both 500 kV circuits will be supported by a single tower, in fact 1,800 single towers. Should any one of those 1,800 towers collapse due to extreme winds, be struck by severe lightning, have a wildfire pass under or across it, be in the path of widescale flooding. or be the victim of sabotage, both circuits will be forced out of service. AEMO and TransGrid have advised that they have not planned for such an event, yet they happen regularly in NSW and other states. If Humelink is carrying a high load at the time, it is almost certain to trigger a cascading collapse of the southern NSW power system resulting in widescale blackouts. And extended electricity rationing until the damage can be repaired.

In the past, whenever a new voltage class is introduced the transmission lines are single circuit lines to avoid the risk of the only two high-capacity circuits tripping at the same time. That was the plan for Humelink at first, but TransGrid changed the design in the PACR, just to reduce the cost so it would pass the AER Regulatory Test. Humelink has been declared by the Energy Ministers of all states to be Critical National Infrastructure under the 2020 Critical Infrastructure Federal Legislation, which should have prevented TransGrid from taking the certain risk of widescale blackouts. Yet they do not appear to have complied with that legislation.

Page 13 Para 1

Humelink was built to connect Snowy 2.0, not for the other reasons given in the evidence. Project Energy Connect was planned and approved without Humelink. Project PEC is running several years late. Because the existing 220kV networks have not been reinforced in NSW by TransGrid or in Victoria by AEMO and because there is so many solar farms near the Murray River on both sides of the border, it will not be technically possible for PEC to be loaded to anywhere near its promised 800MW. So Humelink is not needed for PEC. Snowy 2,0 is delayed until at least 2029 and may never be completed. The solar power in South West NSW cannot help to keep the lights on in NSW during the peak daily loads as they occur before and after the solar power is running. Humelink barely connects to the existing Snowy scheme so t's of no use to bring more power from Snowy Hydro. In any case the Snowy scheme only has enough water inflow to operate for around 2.5 hours a day flat out, and the Murray River scheme is generally used to supply Victoria. The only relevant generation is the gas turbine power station near Wagga Wagga however the existing 330 kv grid has sufficient capacity during peak loads to transmit that power to Sydney.

The reason for the reduction in the capacity of Humelink from 2,570MW to 2,200MW is because the length of VNI West has increased by some 150km because of community opposition to the 500 kV lines in Victoria and the adverse

environmental impacts of overhead transmission lines crossing the Murray River area. Had VNI been undergrounded using HVDC in the first place it would have been run along the easement of the existing VNI transmission line and one of the existing 330kV lines between the Snowy Mountains and Sydney. This would have saved $bn6.8 (based on avoiding an extra 500 km of overhead 500 kV line and substations costing $m13.6/km (based on Humelink's average cost of $m4,900/360 km) This $bn6.8 savings would have covered TransGrid's estimated $bn1.5 cost for three converters (at Sydney, Snowy and Melbourne) and would have paid to underground 70% of the 840km distance, with the remaining 30% being justified by the extra interconnector capacity of 3,500MW compared with VNI West's 1,600MW. The entire interconnection is now so long that it will hardly work electrically as the electricity will go the shortest route via the existing VNI and overload it.

Question for TransGrid: Could you please provide the reason for the reduction in Humelink's capacity to 2,200MW and the low 1,600MW capacity of VNI West and whether it's because of the additional length of VNI West because it has been moved further west in Victoria and NSW because of environmental and landowner objections?

Page 14 Para 2
Given that Humelink has been derated to 2,200 MW and has to transmit 2,040 MW from Snowy 2.0, 3,000 MW from south west NSW, 1,800MW from VNI West, 800MW from PEC and 600MW from the Wagga Wagga gas turbines, it's obvious that TransGrid and AEMO have included Humelink 2 and other new lines as they know the ISP will make them Actionable Projects. This would not be necessary had Humelink been a ~3,500MW HVDC 525kV with two pairs of underground cable.

Question for TransGrid Could you please advise whether increasing the capacity of Humelink and South Sydney Loop to approx. 3,500MW would obviate or significantly defer the need for the Southern NSW to Central NSW augmentation (Humelink 2)?

Page 15 Para 3

High Voltage transmission line do start fires. When insulator strings or conductor joints fail, the conductor falls to the ground still energised causing a large arc that usually starts a fire. This has happened on a number of occasions in Queensland.

Question for TransGrid Could you please comment on the likely hood of a high voltage transmission line starting a fire when the energised conductor falls to the ground due to a failure of the insulators supporting the conductor, a conductor joint failure, or a tower failure causing the energised conductors to get within a metre of the ground?

Page 15 Para 9

Project Marinus will use directional boring to bore holes underground up to a km long for 525kV HVDC cables. The US has never undergrounded HV DC cables so it is no wonder the witness has never seen this happen. It is incorrect that it is not possible to do any kind of agricultural work above underground HVDC cables,

Page 17 Para 1. It is incorrect that the break-even distance for HVDC is 1,000km. The US Dept of Energy recognises that, with the reduction in HVDC costs, that has come down to around 500km however that does not recognise the many other technical and socio-environmental benefits of HVDC.

Question for TransGrid Could you please comment on Project Marinus' plan to use directional boring for up to a km to bore the holes for the conduits for the 525kV underground DC cable?

Page 19 para 4

The Contingent Project Application Process is deeply flawed. It requires AEMO to run a TOOT process meaning Take One project Out at a Time.

What they do is just remove Humelink from their economic analysis and observe the reduction in benefits and compare that with the increased cost of the project.

This is exactly like removing one link from a bicycle chain and observe what that does to the value of the bicycle. Of course, the whole chain falls off and the bicycle wont work. So, the value of that one link is calculated to be the value of the whole bicycle.

There are five links in the Sydney to Melbourne interconnector chain – South Sydney Ring, Humelink, PEC, VNI West and WRL. Every one is valued by TOOT as being the value on the whole interconnection. Even the current 50% blowout in Humelink costs will be justified using the TOOT method, which has been enshrined in the National Electricity Rules by the AEMC, the ESB and AER acting upon AEMO's recommendation.

Every dollar that TransGrid spends will be charged to NSW customers plus inflation over the next 50 years.

Question for TransGrid Could you please comment of the TOOT methodology and whether removing just PEC or Hume link will result in exaggerated net benefits, as its like removing one link from a bicycle chain and valuing that one link as the value of the complete bicycle?

Page 20, bottom of page

HVDC Converters are a "turn-key contract" where the supplier does virtually everything and provides the skilled people to do it. TransGrid don't need to have the skilled people to do the work and training will be provided by the contractor

Question for TransGrid. Given that HVDC converters and underground cables are "turn-key" projects, could you please advise what additional skills and expertise will be required by TransGrid to oversee these parts of the Humelink project if it is undergrounded using HVDC?

Page 2 Para 5

It is stated that TransGrid spend around 50% of their direct maintenance expenditure each year relates to mitigating fire risk. Overall TransGrid's operation and maintenance expenditure is forecast by TransGrid (in their submission to the AER) to average $m203 pa over the next five years plus they are forecasting to spend another $m159 pa to refurbish and replace components of their network assets. These total $m362 p.a. According to TransGrid's same revenue reset submission to the AER, the regulated value of TransGrid's assets averages $m10,500 over the next five years. Hence their total annual expenditure to operate, maintain and refurbish components of their assets expressed as a percentage of the value of their assets is 3.4% pa.

Yet the Humelink PACR assumed that there are ZERO maintenance costs for the easement portion of the Humelink capital costs and only 0.5% pa on the remaining works. In comparison the VNI West PACR claims 1% pa, and PEC claimed 0.25 % pa and the AEMO ISP claims 1% pa. The Nov 2022 AER TNSP Benchmarking Report can be used to show that TransGrid spent 3.5% pa over the last five years to operate, maintain and refurbish its assets.

To compensate for every 1% pa understated over the 50 years economic life of Humelink is equivalent to a 15 % increase in the capital cost of Humelink being $m735. So, understating annual maintenance costs by 3% pa (i.e., 3.5% - 0.5% pa) is equivalent to omitting 45% of the cost of Humelink being $bn2.2, in the case of the overhead 500 kV option.

On the other hand, when TransGrid evaluated the underground option, they assumed unreasonably high annual maintenance costs. According the EuropaCable the supplier of 90% of Europe's underground HVDC cables, the annual costs of maintaining underground cables is virtually nil. However, it is likely to be necessary to replace the power electronics parts of the converters after 25 years. Allowing for the discounting of costs, and based on completely replacing the entire three converters would be equivalent to 0.5% p.a. of Humelink's $bn4.9 total cost. It would appear that the combination of understating the annual costs of Humelink and overstating those of underground HVDC is equivalent to adding $bn2.2 to the cost of Humelink enough to justify undergrounding another 240km which is 90km more than the remaining 150km. This appears to indicate that HVDC undergrounding of Humelink and Southern Sydney Loop would win the AER's Regulatory Investment Test with a further $m540 savings to NSW electricity users equivalent to around $180 per household.

Question for TransGrid; Could you please explain the discrepancy between your statement that "approximately half of TransGrid's direct maintenance budget is spent annually on mitigating fire risks on TransGrid's easement" and the Humelink and VNI West PACR's that excluded easement costs when estimating annual O&M costs at only 0.5% pa and 1.0% pa of the cost of these assets? We also note that TransGrid's Revised Revenue Proposal submitted to the AER on 22nd December 2022 shows that TransGrid's annual operating, maintenance and refurbishment (REPEX) costs average 3.4% p.a. of TransGrid's regulated asset base, and that the AER's 2022 Benchmarking report appears to demonstrate these costs have averaged 3.5% p.a. over the last 5 years. Could you please explain why TransGrid has assumed only 0.25% p.a., 0.5% p.a. and 1.0 % p.a. in the PACR's for Project Energy Connect, Humelink and VNI west respectively. Could you also please

comment on whether correcting for this discrepancy would result in DC undergrounding of Humelink and Southern Sydney Loop winning the AER's Regulatory Investment Test compared with Humelink and Southern Sydney Loop as currently proposed?