Submission
No 44

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

Organisation: RE-Alliance

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Submission to the NSW Inquiry into the feasibility of undergrounding the transmission infrastructure for renewable energy projects

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About RE-Alliance

RE-Alliance is working to secure an energy transformation that delivers long-term benefits and prosperity for regional Australia. We do this by listening to the needs of communities most impacted by the transition, facilitating collaboration across the renewables industry to deliver social outcomes and advocating for meaningful benefits for regions at a policy level.

RE-Alliance operates across Australia's eastern seaboard - from northern Queensland to north-west Tasmania. We play a unique role, as allies of and advocates for renewable energy host communities and assisting renewable energy developers seeking to deliver best practice community engagement, community funds and to build social licence. We are recognised as a leading voice on community engagement and social licence in Australia.

RE-Alliance is actively engaged in New South Wales on community engagement and environment issues associated with renewable energy and transmission projects, in nominated and designated Renewable Energy Zone (REZ) regions. We are actively engaged in and represented in the Central West Orana REZ.

In general, there are many ways for transmission lines to be designed and planned in response to community feedback. Improvements to community engagement are critical for renewable energy developers and for transmission. This engagement should specifically include:

- Landholders and asset owners who host, or could host energy infrastructure (be they generation assets, transmission lines or other network infrastructure).
- Local community members and groups
- Local Councils and State Planning Departments

- First Nations and Traditional Owner groups[1]
- Environment and other special interest groups.

We also note there are major equity and environmental challenges to undergrounding of transmission. Underground lines are significantly more expensive for energy consumers and have environmental and land-use impacts from the extensive digging required to build and ongoing access requirements to operate and maintain buried assets.

Building new transmission lines is essential to connect renewable energy generated in high volume wind and solar locations to our homes, schools and workplaces and to rapidly decarbonise our energy system in line with climate goals. We note that the current regulatory structures are not supporting communities or industry to ensure we build transmission fairer and faster.

We provide a series of short statements in response to the key questions which the Standing Committee on State Development is inquiring into and reporting on. Our comments draw from existing reports, research and experience in Australia and internationally and are informed by on the ground perspectives from our community coordinators. We have also provided some additional comments and further resources for information.

Comments in response to the Inquiry's Terms of Reference

The feasibility of undergrounding the transmission infrastructure for renewable energy projects with particular reference to:

(a) the costs and benefits of undergrounding

Undergrounding of transmission is — unequivocally — more expensive than overhead lines. Recent analysis by AEMO looking at major transmission projects — Humelink in NSW[2] and VNI West in Victoria[3] — put the cost multiple at anywhere between three and fourteen times more expensive to underground this infrastructure along those routes. In addition to the cost multiple, the added complexity of undergrounding is also likely to delay these projects by a number of years, potentially putting electricity reliability at risk. Added together, the delay in build, many more times expense to underground and system capacity and reliability impacts add to costs, which will add to energy bills for all NSW consumers compared to overhead lines.

AEMO's deep dives into the above mentioned transmission projects highlighted key challenges and factors affecting the costs for undergrounding options. RE-Alliance is confident that AEMO is well informed and presents factual information. From these deeper studies, the following points are relevant:

- *Cost factors for undergrounding transmission*

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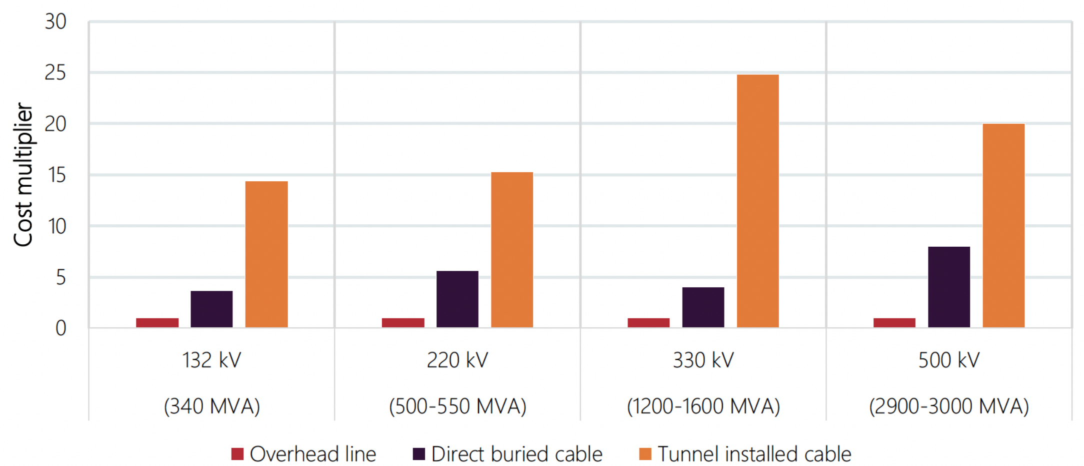
[1] See in particular, the First Nations Clean Energy Network's guidance document: Best Practice Principles for Clean Energy Projects https://assets.nationbuilder.com/fncen/pages/183/attachments/original/1680570396/FNCEN_-_Best_Practice_Principles_for_Clean_Energy_Projects.pdf?1680570396
[2] AEMO Transmission Cost Report 2021 (page 23).
[3] AEMO VNI West Project Assessment Conclusions Report 2023 (page 105).

- At a high level, and on a length per cable basis, the [AEMO Transmission Cost Database] indicates that undergrounding HVAC cables costs are approximately four to 20 times higher than overhead lines. Direct buried cables are at the lower end of this range, while tunnel installed cables are at the upper end. This price differential considers the cable only, not transition stations, which are required at locations where the circuit transitions between underground and overhead. Each transition station is similar in size to a small transmission switching station, and typically costs approximately $105 million per station.
- The cost of underground cable installation is highly dependent on the terrain and soil characteristics along the route. A complete in-depth study and characterisation of the subsurface and electrical environment is necessary to accurately cost the undergrounding of a specific section of transmission.

- AEMO's 2021 transmission cost report included the following comparison chart:

Figure 5 Indicative unit cost multiplier from HVAC overhead lines to HVAC underground cables



Notes:

- This chart shows cost factor increases relative to the respective overhead option on a generic unit cost basis. Underground 500 kV HVAC options cost more than 330 kV HVAC options, but the cost factor increase is higher when undergrounding a 330 kV HVAC option compared to undergrounding a 500 kV HVAC option.
- This chart has been prepared using AEMO's Transmission Cost Database and may not provide an appropriate comparison for all projects due to local circumstances.
- This cost comparison is indicative of the variable per unit cost of overhead lines and underground cables. The total project cost is sensitive to factors such as terrain, geotechnical constraints, and fixed cost factors associated with transition stations.

- *Technical, workforce and operational factors for undergrounding transmission*
  - Undergrounding HVAC has technical limitations
    - Underground HVAC cable lengths are limited by the laws of physics. This limitation is largely why the longest underground 500kV HVAC lines, globally, are around 30km to 40km in length.
    - The major expansions proposed for Australia's new Renewable Energy Zone transmission links are proposed to be at 500kV or 330kV, and to a lesser degree 275kV. At these high voltages, the costs to underground are also very high. While lower costs may be possible for lower voltage lines, for new bulk ("backbone") transmission projects in NSW, higher voltages are proposed.[4]

[4] The recent AEMO Transmission Expansion Options Report summarises the proposed flow paths at Section 4 which show that the NSW backbone transmission projects being proposed (Humelink, VNI West, Sydney Ring - Hunter and QNI-New England REZ) would likely be built at capacities of 330kV or 500kV. See: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/2023-teor/draft-2023-transmission-expansion-options-report.pdf

        - Alternating current (HVAC) has higher power losses compared to direct current (HVDC) over long distances, which presents as a capacitive power loss in underground HVAC. To overcome these losses, additional reactive compensation is required at regular intervals on underground installations, every ~30km. This adds to the project cost, construction and environmental footprint, as additional equipment requires an installation space of approx. 200m x 200m.
    - Available expertise required to manufacture underground cables is limited, which may delay the delivery compared to an overhead technology.
    - Limited supply of underground expertise available.
        - The expertise available to install and repair underground cables gets more rare the higher the voltage.
        - There are only a handful of personnel who have tcable expertise at 500 kV and most of these are tied to a cable supplier, further limiting availability. Further, there are currently no 500 kV underground cable installations anywhere in Australia, so the local technical expertise at this voltage is limited.
    - Operational challenges and management of outages.
        - The duration can vary widely, depending on the circumstances of the failure and the availability of parts. These must be planned around the availability of suitably skilled repair personnel.
- *Differences in reliability and fault restoration*
    - Overhead and underground lines are exposed to different types of outage and reliability risks.
        - Overhead lines are exposed to weather-related outages, such as those caused by lightning strikes. When a fault or failure occurs, this can usually be located almost immediately and repaired within hours or, at most, a day or two. In a worst-case scenario where a tower has failed, the majority of supply can be restored, even on temporary structures, within 3-5 days.
        - Underground cables need a large number of cable joints and these increase the risk of failure. In the event of a cable fault, locating and repairing the fault can be challenging and time-consuming, and may take several weeks/months to repair. The duration of outages varies widely, depending on the circumstances of the failure, the availability of parts, and the skill level of the available repair personnel. The typical outage of a 500 kV cable fault is estimated from 3-6 months and may involve the excavation of hundreds of metres of the cable depending on the type of fault and the extent of the damage. During this time, the circuit capacity will be significantly reduced.
- *Other factors*
    - Shorter asset life expectancy of underground cables
        - Underground cables have higher life-cycle costs than overhead transmission lines, with a design life of ~40 years.
        - Overhead transmission lines can have a design life of 80-100 years.

When is undergrounding 'the right option'?
Sometimes, energy generators or distribution businesses will choose underground lines - usually HVDC or lower-voltage - for a specific distance. This may be based on visual and place based concerns from host communities and a desire to build social acceptance. It may be where there are above-ground restrictions, or as a pathway to expedite the project.[5]

[5] This last point seems counter-intuitive, however, as there are significant technical, environmental and siting issues that come into play which will add to the time for project delivery.

As reported in AEMO's Project Assessment Conclusions Report for VNI West, responsible agencies and transmission companies "*acknowledge the importance of considering partial undergrounding in exceptional circumstances driven by significant technical, environmental and/or social factors. These factors are route-specific and can therefore only be investigated as part of the project's early works stage*".[6]

At the high voltage transmission scale, HVDC is used in more targeted applications such as point-to-point interconnection. Undergrounding of transmission has been chosen and built for Basslink and Murraylink. It is the chosen option for Marinus Link. It is identified as a good option for connecting individual inverter-based resources to an AC network, for example offshore wind (see Star of the South box below). This option requires a converter station at each end of the cable, and at any connection point along the cable, to convert between DC and AC.

Choosing to underground transmission adds additional excavation and land disruption during construction and requires additional converter stations along the route. These elements add to land requirements, easements and costs on top of the cables and converter stations.

(b) existing case studies and current projects regarding similar undergrounding of transmission lines in both domestic and international contexts

We have included a couple Australian examples and summary references.

AEMO's transmission cost reports and database
At a high level, and on a length per cable basis, the AEMO Transmission Cost Database indicates that undergrounding HVAC cables costs are approximately four to 20 times higher than overhead lines. Direct buried cables are at the lower end of this range, while tunnel installed cables are at the upper end. This price differential considers the cable only and does not consider the costs of constructing the transition stations, which are required at locations where the circuit transitions between underground and overhead. Each transition (converter) station is similar in size to a small transmission switching station, and typically costs approximately $105 million per station. As noted in its 2021 Transmission Cost Report, AEMO can assume undergrounding may be chosen for areas where overhead transmission lines are not expected to be feasible on the following basis: ● HVAC underground cable is suited to lengths below approximately 50 km. Beyond 50 km length, AC lines at high voltage level will be subject to very large charging currents, requiring significant reactive compensation and design considerations. ● For HVDC options, a long length of underground cable is feasible. ● Direct burial of cables is cheaper than tunnel installation, but is only suitable in non-urban areas. Built up areas will typically require tunnel-installed cable to avoid existing infrastructure. Maintenance is easier on tunnel-installed cables due to simpler access of the cable.

HumeLink - Undergrounding cost study[7]
Transgrid released a study into the costs of [undergrounding the new Humelink transmission line]() between Wagga Wagga, Bannaby and Maragle. It will connect the pumped hydro project Snowy 2.0 to Sydney, Newcastle and Wollongong, where the power is most needed.

[6] AEMO VNI West Project Assessment Conclusions Report 2023 (p. 104)
[7] Underground Humelink would triple cost, Transgrid *https://www.re-alliance.org.au/undergrounding_humelink_report*

The report found that the cost of undergrounding the HumeLink transmission lines is estimated to be $11.5 billion (for Option 2A-1, high voltage direct current lines), which is at least three times more than the entire project's then current cost of $3.3 billion. In addition, this option is expected to take seven years to build, compared to four to five years for the overhead option. There are also significant environmental impacts associated with clearing vegetation and digging of trenches for undergrounding[8] which can also include removal and replacement of soil with conductive sand to allow cooling of cables (depending on the soil)[9].

Increased costs are driven by a range of factors, most obviously the need to dig the trenches. Other costs include labour, materials, plant and equipment, engineering and project management costs. In all options investigated there are significant biodiversity offset and land costs. For a 70m easement, biodiversity offset costs are estimated at $2,090,000/km and land costs (payments to landholders) are estimated at $475,000/km. The report also notes that internationally there is high demand for equipment and few suppliers, which is leading to reduced competition on projects and less competitive pricing. Community responded to the study's findings saying they were 'unconvinced' especially with regard to the upper-end of the cost range.

Star of the South Offshore Wind Project - Transmission undergrounding

The Victorian offshore wind project Star of the South plans to build a HVDC connection through Gippsland that is undergrounded. If developed to its proposed potential, Star of the South would add 2.2 GW of new capacity, powering around 1.2 million homes across the state.

The project includes a transmission network of cables and substations to connect the offshore wind farm to the existing high-voltage transmission infrastructure located in Latrobe Valley. To connect to this infrastructure, Star of the South is proposing to use underground cables. They have assessed different route options, gathered feedback and have selected a transmission alignment which they are progressing through a detailed planning and approvals process. This project is still years away from connecting to the grid, and there is a lot of change happening in the energy market. Star of the South have identified a back-up route that could be used if connection at Loy Yang is not possible.

Mortlake South Wind Farm - Connection Undergrounding

One example of undergrounding in a limited, lower voltage context, is the undergrounding of the 15km, 220kV connection from Mortlake South Wind Farm to the nearby 500kV transmission line to Melbourne at the Terang Terminal Station. We can assume that the underground option cost more to deliver, but as the length was limited - 15km - and the voltage medium - 220kV - the additional cost was not onerous. Two factors to do with community considerations are also likely to have factored in the decision:

- Including Mortlake South WF, there are at least four wind farms connecting to Terang Terminal Station in the close vicinity of the town of Mortlake, so concerns about 'spaghetti connections' - where multiple generation projects run their own connections to large scale transmission, resulting in multiple, uncoordinated overhead lines in a district - were high.
- These concerns were further heightened by the recently completed 50km, 66kV Salt Creek Wind Farm connection, also at Terang. The line was unusually long and due its low voltage of 66kV did not require a separate planning permit. The line was unpopular and was widely seen to be 'zigzagging' across the countryside.

(c) any impact on delivery timeframes of undergrounding

Undergrounding transmission - for the big backbone projects - has been estimated to add at least two years to the delivery timeframe, or longer.[10]

[8] Undergrounding Humelink would triple cost, Transgrid *https://www.re-alliance.org.au/undergrounding_humelink_report*
[9] https://www.sciencedirect.com/science/article/abs/pii/S0360544221010513
[10] The HumeLink Undergrounding Study, commissioned by a collaborative Steering Committee, showed that it would take a further five years to build.

The major issues affecting this include more complex design, land requirements, additional environmental and site-specific studies along the route, expanded land access needs and the installation activities (see next section). Additional time impacts may flow from workforce and material supply factors noted at **(a)**.

(d) any environmental impacts of undergrounding

While undergrounding may ease some concerns around the look and feel of a place, they are not necessarily better for the environment or landholders. There are significant land disturbance issues associated with the initial trenching works, and accessing underground lines for maintenance is more invasive as soil including any crops on top of the line must be dug up if there are faults. In contrast, overhead lines accommodate the majority of agricultural land uses.[11]

There are significant environmental impacts associated with trenching for underground projects, which generally requires clearing of vegetation. This direct impact is multiplied by the environmental footprint required to accommodate the transition stations along the route for undergrounding.

The installation of underground transmission cables involves:

- Clearing
- Trenching/blasting
- Laying of conduit
- Joint vault installation
- Backfilling
- Cable installation
- Site restoration.

The required continuous trench for the construction of underground lines causes greater soil disturbance than overhead lines. This limits the ability to avoid directly impacting environmental and culturally sensitive areas.

By contrast, overhead line construction disturbs the soil mostly at the site of each transmission tower and can be micro-sited to avoid sensitive areas. Some overhead HV transmission lines are being constructed at 'increased height' to allow for traversing over treed areas with reduced environmental impacts.[12]

Additional comments, follow up and further resources

Fire *risk and transmission*[13]

Electric sparks can ignite fires. In Australia, it is common for lightning strikes to start bushfires. The risk of fires being started by transmission lines is extremely low, and they are designed and managed to minimise these risks.

[11] Undergrounding Humelink would triple cost, Transgrid *https://www.re-alliance.org.au/undergrounding_humelink_report*
[12] Extra-tall transmission towers can reduce impact in highly biodiverse areas https://www.re-alliance.org.au/tall_tx_towers_cairns
[13] RE-Alliance Transmission and Fire fact sheet (forthcoming).

In recent decades across Australia, there have been no instances where transmission lines have caused a fire.[14]

When bushfires do burn near to transmission lines, there are increased risks, but energy and emergency management agencies work hard to retard fire near to these assets and minimise the risk to ongoing power supply There have been fires started or exacerbated by some types of distribution lines - not transmission lines. Those were a particular type of Single Wire Earth Return lines, as found by the Royal Commission into the Victorian Black Saturday Bushfires.

Transmission lines, when managed and maintained properly, pose a very low risk of starting a fire. Transmission networks are unlikely to start or be damaged by fire because:

- Transmission lines are supported on tall towers (up to 80m high)
- The lines have dedicated easements (corridors) with an average width of 5Om, which allow access to private land in order to maintain infrastructure
- There is greater control of vegetation growing immediately underneath the lines, which reduces the risk of contact from trees and branches
- If transmission component failures do occur, they often occur in extreme weather events that are usually accompanied by rain (e.g. cyclones and thunderstorms)
- Individual transmission line conductors are separated by great distances and are not likely to clash during extreme weather events

The design of transmission lines and network assets is required to consider and address fire risk. Where lines are located in environments deemed to be high risk, additional measures must be put in place. These will likely include more frequent condition inspections and higher standards for asset and easement maintenance.

Fire mitigation actions during the construction of transmission lines include complying with restrictions on days of high fire danger, and staff being equipped with and trained to use firefighting equipment.

Transmission companies apply asset management and maintenance practices to minimise risks and look after the transmission lines and surrounding easements.

No transition without transmission, and no transition without regional and rural communities

Transmission design and delivery takes a long time to develop and Australia has spent decades talking about what we needed and not building any, until now. And now, we are doing this in parallel with a significant build of renewable energy generation in the same regional and rural areas. Less than optimal communication about why this is needed now and what the impacts will be is leading to an understandable concern within communities that are hosting or may host new energy infrastructure.

We see a very strong need for governments to recognise and support rural and regional Australia in dealing with and responding to the significant scale of infrastructure coming to them. Decisions that don't involve community input, or are experienced as a tick-box process create significant space for the unknown and unfamiliar to become the unwanted. This

[14] Validated with transmission companies in Queensland, NSW and Victoria

undermines all of the drivers for a just energy transition that delivers for consumers, the community and climate.

Climate action needs renewable energy and transmission - the risk of delay is catastrophic

In general, and for the transport of energy from large wind, solar, pumped hydro, and energy storage facilities, transmission lines that we have today, and need to build more of, will be high voltage alternating current (HVAC). These overhead lines are faster to build, cheaper and have less environmental and land impact than undergrounding.

If we do transmission right by people and nature, all of us can benefit

There are areas and locations where undergrounding of sections should be considered and deeply investigated. Allowing for technology change and innovative solutions should also be considered where and when this is feasible for bulk transmission infrastructure.

We note that the potential risk of ‘spaghetti network’ may warrant more detailed investigation into undergrounding lower voltage connection infrastructure specifically for generation assets around in-demand grid connection locations. This limited length and specific circumstance is less likely to add unduly to consumer bills.

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