Western Renewables Link

ATTACHMENT

II Assessment of feasibility for an underground 500kV transmission line for Western Renewables Link

II

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Key terms

Acronym/Term	Definition
AC	Alternating current
AEMO	Australian Energy Market Operator
ATCO Power	Alberta Trailer Co. Power
AusNet	AusNet Transmission Group Pty Ltd
AVP	AEMO Victorian Planning Division
CASA	Civil Association Safety Authority
CIGRE	International Council on Large Electric Systems
DC	Direct current
EES	Environment Effects Statement
EE Act	*Environment Effects Act 1978*
ESCI	Energy Sector Climate Information Project
HDD	Horizontal Directional Drilling
HVAC	High voltage alternating current
HVDC	High voltage direct current
MVA	Megavolt amperes
MW	Megawatt
NEM	National Electricity Market
PACR	Project Assessment Consultation Report
PADR	Project Assessment Draft Report
RIT-T	Regulatory Investment Test for Transmission
TPZ	Tree Protection Zone
WRL	Western Renewables Link
WVTNP	Western Victoria Transmission Network Project

1. Introduction

This report outlines AusNet Transmission Group Pty Ltd's (AusNet) assessment of the feasibility of a fully (i.e., end-to-end) underground 500kV transmission line as an alternative for Western Renewables Link (the Project), herein referred to as 'undergrounding'.

The Project is the subject of an environment effects statement (EES) under the *Environment Effects Act 1978* (Vic) (EE Act). EES scoping requirements issued by the Department of Transport and Planning in November 2023 (scoping requirements) (DTP, 2023) inform the scope of the EES for the Project. To address scoping requirements, this report explains the Project's criteria for evaluating the feasibility of a fully underground transmission line for Western Renewables Link (Project objectives and National Electricity Rules) and why it was not evaluated as a feasible alternative within the EES.

The scoping requirements provide that the EES must consider feasible alternatives, where they avoid or minimise adverse environmental effects, while meeting the project objectives. The assessment of feasible alternatives, including an investigation of undergrounding a section of the route at Darley (partial undergrounding), is presented in **EES Attachment I: Project development and assessment of alternatives** and **EES Chapter 5: Project development** of the EES. The assessment of feasible alternatives for the Project did not include an assessment of a fully underground project, as it would not meet the Project objectives or the National Electricity Rules (NER)and is therefore, not a feasible alternative. This is further discussed in Section 5.

Transmission augmentation projects such as WRL, form part of the National Electricity Market (NEM) and are subject to the Regulatory Investment Test for Transmission (RIT-T) process. Transmission augmentation projects are projects that expand the transmission system or increase its capacity to transmit electricity. The RIT-T assesses the economic and technical impact of, and preferred timing for, all major network investments in the NEM. Major grid augmentation projects are subject to the RIT-T process because they must recover costs from electricity customers via regulated transmission charges and the RIT-T process ensures the investment decisions are in the long-term interests of customers. The process involves a cost benefit analysis of different options that could meet the technical need of the grid augmentation. In contrast, Marinus Link is a subsea underground transmission augmentation project that was subject to the RIT-T process. The Marinus Link project is designed to unlock existing hydro capacity in Tasmania and to transfer the energy into the NEM via a Bass Strait crossing. Only undergrounding options were considered for Marinus Link because there are no overhead transmission options that are technically feasible for a sea crossing that would meet the project need and unlock the hydro capacity in Tasmania. Other private companies construct transmission lines that are not governed by the RIT-T and they earn revenue from trading in the wholesale electricity market rather than recovering costs from energy consumers. These private sector companies can make commercial decisions about projects based on their business model. Wind and solar generators that supply power into the NEM have private transmission lines and are therefore able to make commercial decisions when developing projects based on their business model. There are very few projects at a similar capacity and throughput to WRL that are built as underground projects due to the costs of undergrounding projects of this size. However in other jurisdictions there are other laws and requirements that govern the development of transmission infrastructure as well as market influences and local conditions that determine the best project and design to meet the project need.

This report has also been prepared in response to feedback from the communities, stakeholders and landholders along the Project corridor that an underground project should be considered, particularly where the visual impact of overhead transmission lines is a community concern. A summary of community feedback (including undergrounding) is provided in **EES Technical Report F: Social Impact Assessment** and **EES Attachment IV: Stakeholder and community engagement consultation report**. Acknowledging the community's interest in undergrounding of the Project, this report presents what an underground concept design would include for a double circuit 500kV transmission line of approximately 190 km long, explains why it is not feasible and provides a high-level overview of potential environmental, amenity, land use and heritage issues that may need to be considered for an underground solution. High voltage direct current (HVDC) is the preferred technology for the conceptual underground project as it is more cost effective than high voltage alternating current (HVAC) for long distances which is required for the 190km project.

This report considers the differences in construction methods, route selection criteria, cost, and program implications for an underground 500kV transmission line. This report also explains why undergrounding of the Project does not meet the Project objectives (Section 5). To further understand the trade-offs between overhead and underground transmission lines, this report also includes a review of the potential technical, economic, environmental, amenity, land use, and cultural heritage issues typically associated with both options. As a fully underground project is not considered a feasible alternative. A detailed assessment of costs, timelines, potential approvals and Project impacts was not undertaken and instead a level of assessment was undertaken that was appropriate for assessing feasibility of options.

This report:

- Outlines the Western Renewables Link Project objectives and functional requirements.
- Outlines the differences between overhead and underground transmission technologies and operational requirements and identifies the preferred technology for a conceptual underground project (HVDC).
- Presents a conceptual underground project, connecting Bulgana Terminal Station to Sydenham Terminal Station via an underground HVDC 500kV transmission line.
- Outlines the criteria and technical considerations for developing an alignment for an underground or overhead transmission line.
- Presents indicative timelines and cost for the development and construction of a conceptual underground project.
- Provides and overview of the trade-off of the potential environmental, amenity, land use and cultural heritage issues that are generally associated with underground projects when compared with overhead transmission projects.

This report does not address the rationale for the Project. This is addressed in **EES Chapter 2: Project rationale**.

1.1. Information sources

The sources of information relied upon to prepare this report are:

- The Project objectives (Table 2.1), developed by the Australian Energy Market Operator (AEMO) and AusNet, having regard to the Western Victoria Regulatory Investment Test for Transmission (RIT-T). The Project objectives are aligned with the relevant matters the Minister referenced in the National Electricity (Victoria) Act (NEVA) Orders made in February and May 2023 regarding the Project.

- Electric power transmission and transmission line technologies information (see Section 3.1) which were informed by AusNet's experience in building and operating high voltage transmission networks, including overhead and underground transmission lines.
- CIGRE publications. CIGRE is a global community committed to sharing knowledge, experience and expertise in power systems.
- Route and site selection criteria used to inform the proposed overhead routes and criteria specific to underground linear infrastructure (see Appendix B). These criteria are typically used for route and site selection for linear infrastructure projects.
- The high voltage direct current (HVDC) underground conceptual project described in Section 3, based on a conceptual HVDC design prepared in 2023 by Mott MacDonald. The design addresses the transmission network requirements as defined by AEMO and the terms of the RIT-T. The HVDC solution was informed by AEMO which defined the transmission network requirements and Mott MacDonald, HVDC experts who designed an equivalent RIT-T solution and an optimal underground concept design.
- The estimated costs of the HVDC underground project in Section 3 are based on a cost estimate prepared by quantity surveyors using the conceptual HVDC design prepared by Mott MacDonald (2023). The unit rates used to prepare the cost estimate were developed using information provided by equipment manufacturers and suppliers. Contingency and sensitivity analysis was applied to the costs.
- Examples of Australian and international overhead transmission lines and underground cables are based on publicly available information sourced from publications and company websites.
- AusNet consulted with Tetra Tech Coffey to identify the potential environmental, amenity, land use and cultural heritage issues outlined in Section 4. This section considers the issues identified in existing environmental and planning approvals for underground transmission projects, including Basslink (HVDC overhead transmission and underground cable) and Marinus Link (HVDC underground cable), and Tetra Tech Coffey's experience developing approvals for the North West Transmission Developments (high voltage alternating current (HVAC) overhead transmission).

The full list of references used in the preparation of this report are provided in Section 7.

1.2. Peer review

This report has been subject to a technical peer review by independent consultants (Bureau Veritas) engaged by Department of Transport and Planning Impact Assessment Unit, which has resulted in revisions to this report. In this section we have summarised the one outstanding recommendation raised by the peer reviewer and have provided justification for why the report remains as written. The outcome of the peer review is available in Appendix E.

Assessment framework

The reviewers recommended consideration of other industry standard approaches such as 'Triple Bottom Line' to evaluate economic, environmental, and social impacts of the Project, in addition to the current assessment framework. Regarding economic considerations, transmission augmentation projects such as WRL, form part of the NEM and are subject to cost benefit analysis as part of the RIT-T process. The RIT-T is industry standard and required under the NER. Regarding environmental and social considerations, an environmental impact assessment has not been completed for an underground project as it is not a feasible alternative (refer to Section 1 and Section 5). The purpose of Section 4 is to provide contextual information about the potential environmental, amenity, land use and heritage issues typically resulting from overhead transmission lines and underground cables noting the ultimate extent of impacts is dependent on the specific project description (e.g., location, design, construction method) and the values present (i.e., existing conditions at proposed locations). This approach aligns with the purpose of the report to address EES scoping requirements relating to the evaluation of feasibility of potential alternatives, and to respond to feedback from the communities, stakeholders and landholders along the Project corridor that an underground project should be considered.

2. Project objectives and functional requirements

The Victorian transmission network is part of the National Electricity Market (NEM). In carrying out its planning function for the NEM, AEMO must plan the transmission network in accordance with the power system security requirements of the National Electricity Rules (NER). Where augmentation is recommended, AEMO must undertake a regulatory investment test – transmission (RIT-T) in accordance with the National Electricity Law and NER or as otherwise specified by the Victorian Minister for Energy and Resources under the *National Electricity (Victoria) Act 2005* (NEVA).

The Victorian transmission network is a shared network asset that provides access to all generators and retailers subject to the requirements of the NER and Victorian electricity legislation. The RIT-T is required to demonstrate that the investment and preferred option offers the highest net market benefits. The purpose of the NER is to provide appropriate regulation of the NEM, set out rights and responsibilities of market participants, and so that consumers do not pay more than necessary for their electricity (Australian Energy Market Commission website, accessed November 2024).

Development of the Project began in early 2020 following the Western Victoria Renewable Integration RIT-T process. The project was included in AEMO's 2018 Integrated System Plan (ISP) as a committed project. AusNet was engaged by AEMO to develop and deliver the Project in December 2019.

The Project objectives were developed by AEMO and AusNet having regard to the RIT-T. The objectives were reinforced by the NEVA orders issued in February and May 2023 in relation to the Project by the Victorian Minister for Energy and Resources.

Through development of the Project, AEMO and AusNet have engaged with the community, landholders, government and industry. The outcome of engagement has also informed the project development and route selection.

An underground project would also be required to provide the capacity and connection to facilitate development of the western Victoria Renewable Energy Zone (REZ), and meet the Project objectives and the NER.

The Project objectives and functional requirements are outlined below and presented in **EES Chapter 5: Project development**. An assessment of the feasibility of an underground cable for the Project to meet the Project's objectives, functional requirements, and the NER is provided in Section 5.

2.1. Project objectives

The Project objectives are provided in Table 2.1. The Project objectives aim to address the capacity, security, and reliability constraints facing Victoria and the NEM as described in **EES Chapter 2**: **Project rationale**.

The Project objectives also align with the Victorian Government's energy policy goals (DEECA 2024) which are:

- Increase the affordability and accessibility of energy services.

- Ensure the energy system is secure, reliable and safe.
- Reduce greenhouse gas emissions from Victoria's energy system.
- Increase consumer control over household energy costs.
- Increase jobs and economic development in the energy sector.

Table 2.1 Project objectives

Project objectives
Maintain the security and reliability of the transmission network for customers by: • increasing electricity transmission capacity in western Victoria to minimise the congestion constraining current and future electricity generation in the region; and • ensuring the Project complies with the power system security requirements of the National Electricity Rules
Create opportunities for strategic development of the NEM by: • increasing electricity transmission capacity, thereby facilitating more efficient connection and dispatch of electricity generation in and from the region. • enabling future transmission network expansion from Victoria to New South Wales.
Deliver infrastructure which realises a net benefit for Victorians by: • delivering the Project in a timely and cost-efficient manner; and • delivering transmission infrastructure which, by increasing capacity, facilitates the further development of renewables in western Victoria, encouraging further investment in the industry and associated economic growth.

2.2. Functional requirements

The Project is required to provide the capacity and connection to facilitate development of the AEMO's western Victoria REZ. The Project's functional requirements (as defined by AEMO), the Project objectives and the NER are the key criteria that have guided the assessment of feasible potential alternative corridors, routes and project components. Alternative options to increase the thermal capacity of the Western Victoria power system and reduce constraints on existing and new generation were considered in the RIT-T, however, were not considered in the EES because these alternatives were not the preferred option in the RIT-T and therefore do not meet the NER or the subsequent NEVA orders and on that basis were not feasible alternatives for consideration in the EES.

The functional requirements define the technical requirements for the Project and the transmission network augmentations AusNet is engaged to deliver. The functional requirements are listed in Table 2.2.

Table 2.2 Project functional requirements

Components	Description
Connection at Bulgana Terminal Station	• Redevelopment of the existing 220kV Bulgana Terminal Station, including the expansion of the existing 220kV switchyard and changed bay terminations for the existing Bulgana to Horsham and Bulgana to Crowlands 220kV transmission lines, and the Bulgana Wind Farm W1 and W2 transformer connections
New 220kV transmission line connection	• Construction of a new 220kV double circuit transmission line from the new terminal station to the existing Bulgana Terminal Station
New terminal station near Bulgana	• Establishment of a new 500/220kV terminal station located approximately two kilometres east of the existing Bulgana 220kV Terminal Station, including a 500kV switchyard, installation of two new 1,000MVA 500/220kV transformers and provision for the future development of a 220kV switchyard
New 500kV transmission line	• Construction of a new 500kV double circuit transmission line from the new terminal station near Bulgana to Sydenham Terminal Station
Connection at Sydenham Terminal Station	• Modification of the 500kV bay and a new 500kV bay extension with associated infrastructure at the Sydenham Terminal Station
Other activities	• Alterations to the existing 220kV Elaine Terminal Station, including: – Extension of No.2 Bus and formation of two new 220kV switchyard bays for the termination of two Ballarat to Elaine 220kV transmission lines, plus new single circuit breaker switched connections for the two existing Mt Mercer wind farm 220kV transmission line circuits – Connection of the existing Ballarat to Moorabool No 2 220kV transmission line to Elaine Terminal Station, forming the Ballarat to Elaine No 2 line and the Elaine to Moorabool No 2 line – The existing Ballarat to Elaine and Elaine to Moorabool 220kV transmission lines to be circuit breaker switched and renamed as Ballarat to Elaine No 3 line and Elaine to Moorabool No 3 line • Secondary (protection, control, monitoring and communications) system modifications at the existing Sydenham, Bulgana, Bulgana Wind Farm, Moorabool, Elaine, Ballarat, Waubra, Ararat, Crowlands, South Morang, Hazelwood and Horsham terminal stations • Validation of the capabilities of the existing earthing systems at Ararat, Ballarat, Crowlands, Elaine, Horsham and Waubra terminal stations and the connected 220kV transmission lines tower earthing systems and upgrade as required to provide for the increased fault levels at each location • The addition of two physically independent route communication links between Bulgana Terminal Station and the new terminal station, and between the new terminal station and Sydenham Terminal Station

3. Conceptual underground project

To assess the feasibility of undergrounding the Project from Bulgana Terminal Station to Sydenham Terminal Station, a conceptual underground project was considered. Developing an underground project has different considerations and criteria to an overhead project. This section describes the following considerations:

- Different transmission technologies used for overhead and underground transmission line projects.
- Route selection criteria and potential routes for a conceptual underground project.
- Potential costs and delivery timelines for a conceptual underground project.

3.1. Transmission technology

The development of the conceptual underground project considered different technical aspects of overhead and underground transmission lines. This section provides a summary of the technical factors considered in the design and development of transmission lines, and the preferred technology for a conceptual underground project.

Victoria's electricity transmission network is split into transmission and distribution assets. Transmission lines transmit electricity between nodes (terminal stations and substations) in the network and distribution lines transmit electricity from the substations to energy users. The transmission network operates at voltages from 66kV up to 500kV. The distribution network operates at voltages between 240V and 66kV, with 66kV distribution lines connecting substations to terminal stations.

A conceptual underground design was developed for a double circuit 500kV transmission line approximately 190 km long from Bulgana to Sydenham. The actual power transfer of transmission lines depend on the amount of power generation, demand for electricity and transmission network system constraints at the time.

3.1.1. HVAC and HVDC circuits

Electricity is the transfer of energy through a conducting medium or material, for example transmission line conductors or wires. Higher power transfer capacity can be achieved by increasing the voltage. High voltage allows for lower current within the conductor material and therefore reduces energy losses caused by heat within the conductor.

Electricity can be transmitted by overhead or underground transmission lines using HVAC or HVDC technologies. A comparison of the different technologies for HVAC and HVDC underground cables and overhead transmission line technology is summarised below and in Figure 3.1 for illustrative purposes.

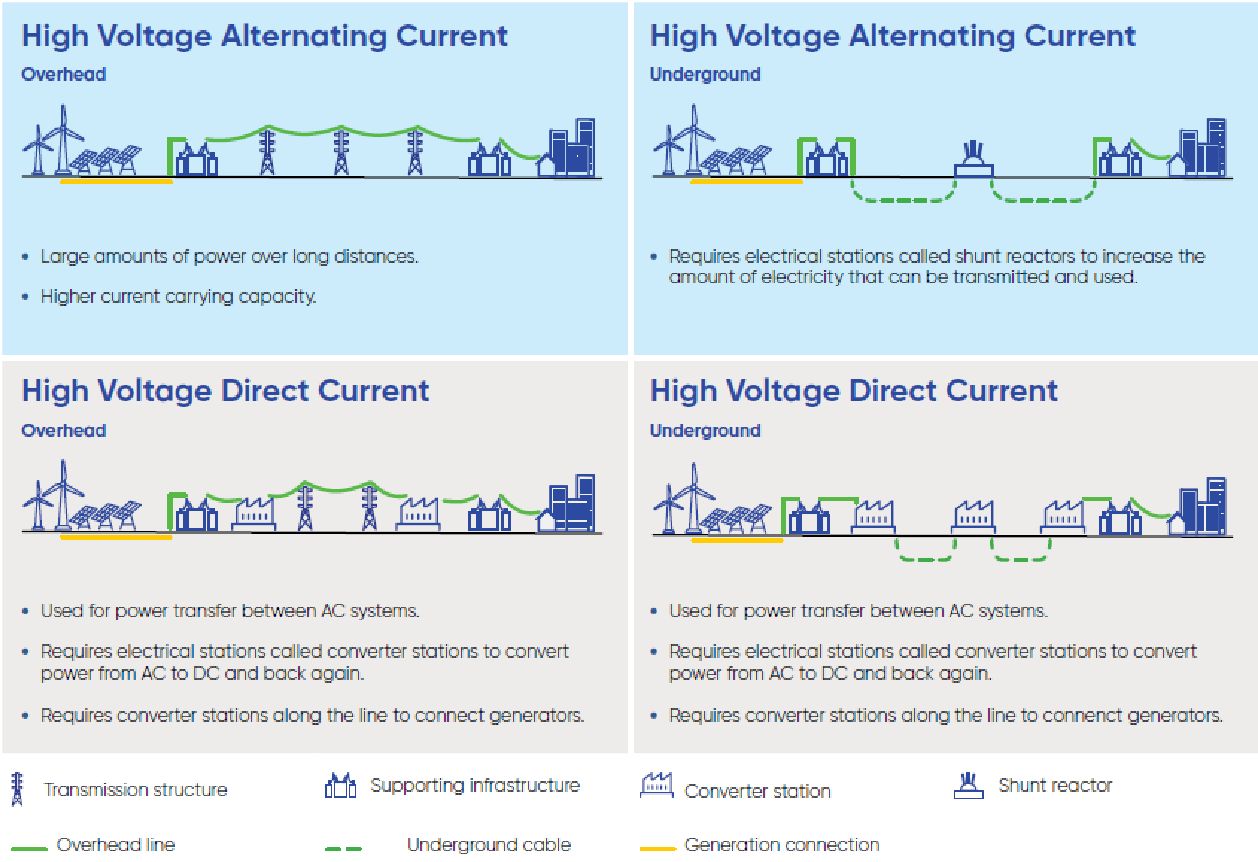


Figure 3.1 Examples of transmission infrastructure types (Source: AusNet)

Alternating current (AC) electricity is the common form of electricity used in homes and most industries. With few exceptions, Australian electricity transmission networks are AC to enable cost efficient connection of generators and energy users. Renewable energy sources like solar and wind typically generate DC electricity which is converted into AC electricity using inverters.

A key objective of the Western Renewables Link is to facilitate renewable energy development in western Victoria by providing cost efficient connections for renewable energy generators. This objective will be achieved more cost efficiently with HVAC transmission as converter stations are not required for connections. This is an important consideration when designing transmission lines and selecting technologies for the Project.

In Victoria, overhead transmission using HVAC transmission is commonly used because it is easier to maintain, more cost efficient, and allows for the connection of new generation and storage along the line without the need for a converter station (VicGrid, 2024).

Due to the high electrical capacitance of HVAC transmission cables, HVAC underground cables require reactive compensation stations (e.g., shunt reactors) approximately every 25 km to 30 km to counteract the resulting transmission losses. Reactive compensation enables the voltage to be maintained over long distances, albeit not as cost effectively as HVDC transmission lines. A HVDC solution for the Project was initially considered in the RIT-T Project Specification Consultation Report (PSCR) (AEMO, 2017). The feasibility of an HVDC solution was further explored in the RIT-T Project Assessment Draft Report (PADR). The PADR concluded that an HVDC solution is unlikely to address the identified need or be technically or commercially feasible, primarily due to the lack of flexibility for facilitating future generation connections. Connecting generators to HVAC transmission lines will require a substation (and transformers) and connecting generators to HVDC transmission lines will require a multi-terminal converter station (and transformers). Converter stations are substantially more costly than substations. In the PADR (AEMO, 2018), HVDC was assumed to be far costlier than an AC solution while delivering similar benefits.

3.1.2. Differences in technologies and configuration

HVAC and HVDC underground cable circuits are configured differently and subsequently require different infrastructure to support the transmission of electricity. An illustration of a conceptual HVAC and HVDC circuit is provided in Figure 3.2 and Figure 3.3 respectively.

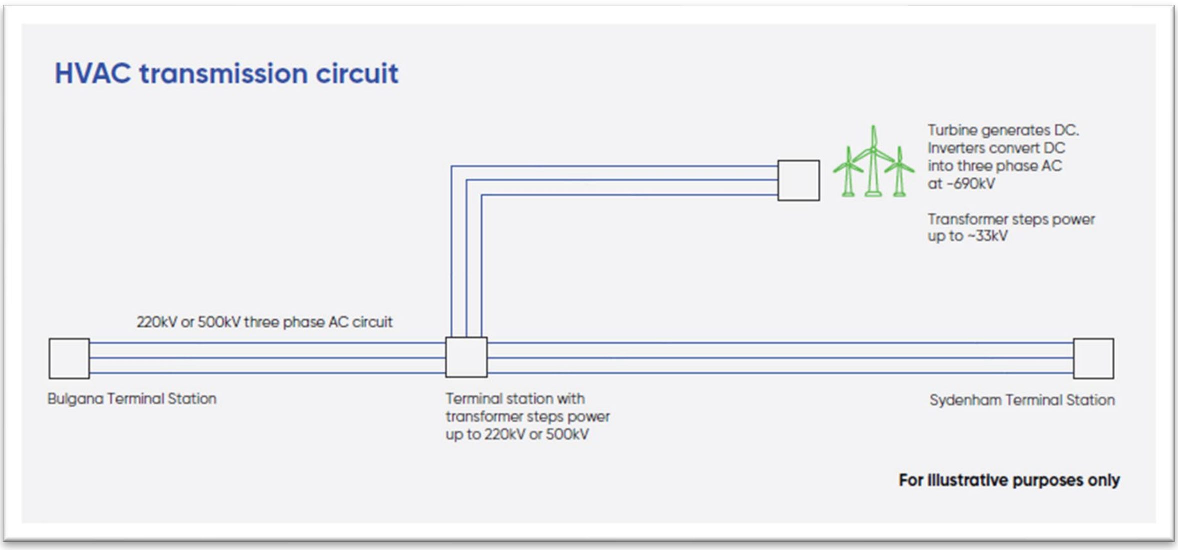


Figure 3.2 Illustration of conceptual HVAC transmission circuit (Source: AusNet)

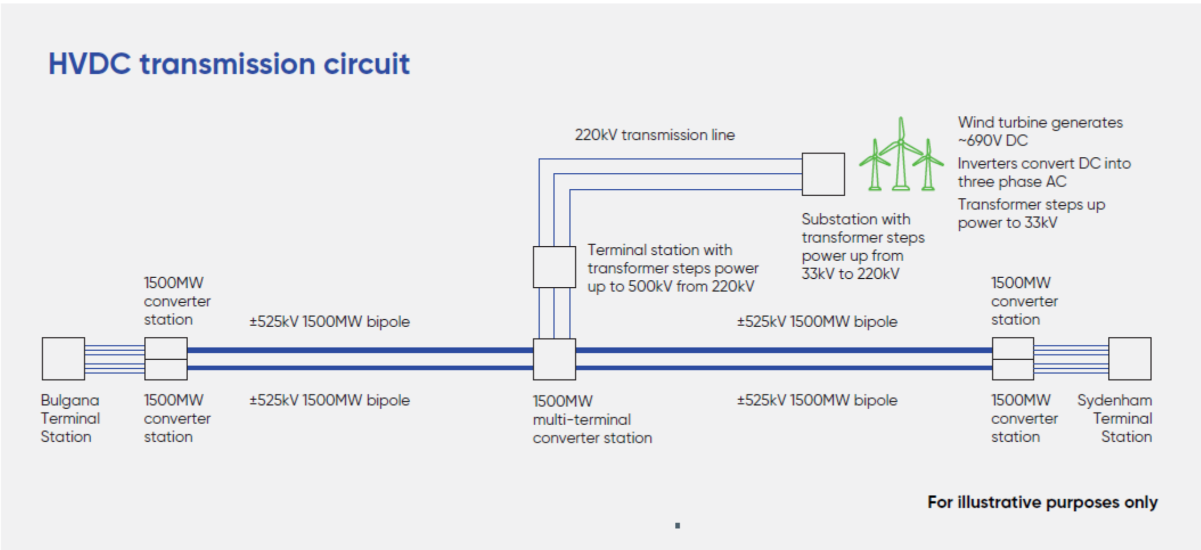


Figure 3.3 Illustration of a conceptual HVDC circuit (Source: AusNet)

The key differences between the two technologies if designed to achieve the transmission capacity and contingent events required for WRL are summarised in Table 3.1, and described in further detail in Appendix A.

Table 3.1 Differences between HVAC and HVDC underground cable technology based on a conceptual underground project for WRL

	HVAC	HVDC
Cables	HVAC transmission lines have three phases, each phase requires a separate cable with additional cables necessary for increased power transfer capacity. Typical outside cable diameters are 145 mm for 500 kV circuits. In total, 18 cables would be required for the Western Renewables Link high-capacity double circuit 500 kV transmission lines.	HVDC underground cables can be configured in three ways: • Asymmetrical monopoles comprise of one power or pole cable with a metallic return cable, • Symmetrical monopoles comprise of two power or pole cables. • Bipoles comprise of two power or pole cables and a metallic return cable. Typically, bipoles have higher power transfer capability and can continue operating if one pole fails. HVDC cables are typically 125mm to 135mm (outside diameter) for 500kV circuits. This cable range is typical of bipoles and symmetrical monopoles. Two 1500 MW bipoles would be required to achieve the capacity of the Western Renewables Link high-capacity double circuit 500kV transmission lines. The two 1500 MW bipoles would enable a 750 MW contingency event to be managed, the current contingency event specified by AEMO.
Trenches	Two trenches, one for each circuit. Each trench would be approximately 5m wide, 1.5m deep and at least 5m apart. The trench walls need to be splayed in unstable soil with approximately 1m separation to each trench from the access track required for stability and safety reasons.	Two trenches, one for each circuit. Each trench would be approximately 5m wide and 1.5m deep and at least 5m apart. The trench walls need to be splayed in unstable soil with approximately 1m separation to each trench from the access track required for stability and safety reasons.
Cable joints	Six joint pits would be required every 550m to join the 18 cables. A workspace approximately 30m by 180m would required for installation of the cable joint pits.	HVDC cables could be joined in cable joint pits or joined and direct buried. Where joined in cable pits, two cable joint pits would be required approximately every 550 to 1100m to join the six cables. A workspace approximately 30m by 60 m would be required for installation of the cable joint pits.

	HVAC	HVDC
Easement	A 30m wide easement would be required to protect underground HVAC 500kV double circuits	A 25m to 35m wide easement would be required to protect underground HVDC circuits depending on the configuration of the circuits (bipoles or monopoles).
Efficiency	Higher losses compared to HVDC.	Lower losses compared to HVAC.
Above ground infrastructure	Underground HVAC cables connect at terminal stations or switching stations. Reactive compensation stations (up to 4 ha in size) are required to offset the capacitance of the cable approximately every 25 km to 30 km along a 500kV transmission line.	Underground HVDC cables connect to converter stations (each up to 6 ha in size). Converter stations are required at each end of the HVDC links to connect into the HVAC grid and at terminal stations where generators connect.
Connections for energy generators	A terminal station with traditional step-up power transformers.	A terminal station with AC to DC converter stations is required for intermediate locations where generators connect, making it significantly more expensive to connect new generators such as wind farms where new terminal stations are required.

3.1.3. Preferred technology for an underground project required for transmission over long distances

HVDC becomes more cost effective than HVAC for long distances. The key advantages of HVDC underground cable technology are:

- Lower transmission losses than HVAC underground cable circuits.
- Ability to connect electricity grids with different frequencies.
- Ability to stabilise electricity grids through instantaneous and precise control of the transmission circuits, a benefit for connecting weak transmission networks.

HVDC transmission lines require AC to DC converter stations to enable energy generators to connect to the broader HVAC network. An HVDC transmission line would be a point-to-point connection, from Bulgana to Sydenham, and would therefore not easily or cost-effectively facilitate connections from energy generation sources without a multi-terminal converter station, as shown in Figure 3.3.

3.2. Conceptual route development

A conceptual HVDC underground project was developed in response to community feedback and requests for consideration of an underground project. It provides further information to explain why undergrounding is not a feasible alternative when considered against the Project objectives and functional requirements for the Project, criteria for route selection and design requirements.

3.2.1. Route selection criteria

Environmental, cultural heritage and social criteria together with functional requirements have informed the route selection and planning for overhead transmission lines and underground cables.

The route selection criteria for both underground cables and overhead transmission lines are provided in Appendix B. The key criteria that are different for route selection of an overhead transmission line and a conceptual underground cable are discussed in the sections below.

Terrain

Terrain is an important factor in underground cable route selection. An underground cable route must consider the existing topography to avoid constructing across slopes, where practicable. The route should aim to align perpendicular to slopes, preferentially following ridges and spurs if sufficient workspace is available. Running underground cables across slopes typically necessitates constructing a road to provide a stable workspace for trenching and cable installation. The area must provide sufficient space for the circuit-to-circuit separation required where double circuit transmission lines are proposed.

The primary concern are cables in side slopes being exposed to mass movements (e.g., landslides) that can stress the cables, causing them to fail. Further, crossing side slopes is undesirable due to the extent of earthworks required to establish a safe workspace. Instead, routes running perpendicular to slopes and along spurs and ridge crests are preferred. Deeply incised watercourses introduce constructability issues, particularly where horizontal directional drilling (HDD) is proposed. Gently sloping watercourse valleys and crossings are preferred. Typically, underground cable routes cannot easily cross difficult terrain as a trench needs to be excavated for the entire length of an underground cable route, except where trenchless construction methods (e.g., HDD). Due to geotechnical constraints and cost, it is not practicable to install cables using trenchless construction methods for the entire length of the route.

Overhead transmission lines can typically span difficult terrain and features and require less construction area.

Visual and landscape

Overhead transmission lines are visible in the landscape unless partially or fully screened by topography or vegetation. An overhead transmission route must consider utilising existing topography to reduce views to the infrastructure, where practicable, and provide a backdrop to overhead transmission lines and avoid or reduce skyline silhouette of structures and conductors.

Where practicable, overhead transmission routes must also consider locating structures adjacent to road reserves to maximise clearance over roads and to align with existing transmission infrastructure to minimise visual clutter.

Underground transmission lines are not visible in the landscape, however their easements may be visible through vegetated areas where they need to be kept clear. Above ground facilities such as terminal stations have the potential to generate a visual impact for underground transmission cable projects, as they can for overhead transmission lines, unless appropriately sited, designed and effectively screened.

Surface water

An overhead transmission line route must consider locating overhead structures outside of areas subject to watercourse erosion or channel migration, referring to the natural migration of a watercourse within its associated floodplain area.

An underground cable must consider whether there is sufficient space available either side of the watercourse to facilitate trenchless construction methods, where feasible. The length of the crossing is also an important factor as cable joints in ducts under watercourses should be avoided as they are not accessible during operation. Where trenchless construction methods are not feasible, watercourses also limit where underground cables are able to be used. For example, an underground cable would need to go around a reservoir, as the crossing is longer than the required length between cable joint pits.

3.2.2. Consideration of local conditions and existing infrastructure

Developing an underground project requires the consideration of the local conditions including land use, topography, soil type, geotechnical conditions, existing easements, and environmental (physical, biological and social) values. Different factors will influence underground cable route selection and underground cable design compared to overhead transmission lines. Route selection and design is not simply a case of building an underground cable on an overhead transmission line route.

For long linear infrastructure projects, local conditions have the potential to change significantly along the route. Consequently, impacts on environmental values will be different along the route. Proven mitigation measures are put in place in manage impacts of both overhead and underground construction.

Using other infrastructure or linear corridors

Made and unmade road reserves, rail reserves and stock routes may provide opportunities for underground cable routes. This section provides an overview of key factors to consider when identifying suitable linear corridors for underground cables.

Available space

- Sufficient space is required between the road or rail formation and road or rail reserve boundary to construct, operate and maintain the transmission line. Where sufficient space is not available in road reserves, consideration must be given to opportunities to install cables under one or both carriageways.
- Lane or road closure may be required to install and maintain the underground cables. Where land or road closures are required, consideration must be given to whether local road authorities will support lane or road closures.
- Traffic management may be required during construction, including limited working hours.
- Cable joint pits, if required, are typically placed outside carriageways to facilitate easier access to testing and repairs. If insufficient space is available in the road reserve they would need to be located in adjacent land.

Third-party infrastructure

- Sufficient space is required in the road and rail reserve to support the existing linear infrastructure and proposed underground cables.

- Where sufficient space is available to support the proposed underground transmission lines and the existing linear infrastructure, consideration must be given to whether the proposed transmission line is technically compatible with the existing third-party infrastructure e.g., can the underground cables be safely co-located with a steel pipeline?

Asset owner requirements

- The location of underground cables in road or rail reserves may restrict the ability of road or rail authorities to maintain or upgrade the road or rail line, including duplication, realignment and widening.

Biodiversity values

- Road or rail reserves may include significant roadside vegetation, threatened ecological communities and threatened species habitat. The location of these values must be considered in the selection of a suitable corridor.
- VicRoads and municipal councils have prepared and implemented roadside management plans to manage road reserves and protect biodiversity values. Moorabool Shire Council (Moorabool Shire Council, 2001), Pyrenees Shire Council (Pyrenees Shire Council, 2014) and Northern Grampians Shire Council (Northern Grampians Shire Council, 2008) have developed comprehensive roadside management plans that set out the conservation objectives for the management of remnant vegetation in road reserves. Rail reserves contain biodiversity values including threatened ecological communities and species habitat. VicTrack's Corporate Biodiversity Management Plan sets out VicTrack's policy for protecting biodiversity values and provides the framework for biodiversity management plans for areas of high biodiversity value.

Cultural heritage

- Road and rail reserves and adjacent land at watercourse crossings can contain Aboriginal cultural heritage, as evidenced by finds in road and rail reserves during the Victorian Government's level crossing removal program. The location of these values must be considered in the selection of a suitable corridor.
- Historic bridges and drystone fences are examples of historic heritage found in road and rail reserves.
- Watercourse terraces are highly prospective for Aboriginal cultural heritage.

Existing transmission lines

Existing transmission line corridors also provide opportunities for co-location of underground cables. This section provides an overview of key factors to consider when identifying suitable linear corridors for underground cables within existing transmission line corridor.

Available space

- Sufficient space is required in the easement to support the tower foundations and earth grids. Consideration must be given to whether the adjoining developments and land use have the potential to constrain widening the easement to accommodate a larger workspace. For example, Figure 3.4 shows the Ballarat–Horsham 220kV transmission line easement north of Ballarat where the easement cannot be widened, and available workspace is limited.

Third-party infrastructure

- The construction of third party infrastructure in or adjacent to the existing transmission line easement may constrain the availability of space.
- Water supply and gas transmission pipelines have been constructed in transmission line easements in Victoria and Tasmania. For example, a water main owned by Central Highlands Water main runs in and adjacent to the Ballarat–Bendigo 220kV transmission line easement.

Compatibility

- The proposed transmission line infrastructure must be compatible with the existing transmission line.
- This is an important consideration for HVAC to HVAC if the circuits are different voltages and HVAC to HVDC circuits. Technical constraints may require greater separation meaning the proposed transmission line cannot be accommodated in the existing transmission line easement.

Safety

- Working on an HVAC transmission line easement under existing live conductors introduces safety issues, particularly where excavators and cranes are required to operate. Electrical safety requirements may place restrictions on equipment types and operation of equipment during construction, potentially increasing construction timeframes and costs.

Security

- A corridor facilitating a geographically diverse transmission network enhances network security by distributing the load across multiple corridors.
- Geographically separate transmission corridors avoid all circuits in one location being affected by an extreme weather event or other incident.

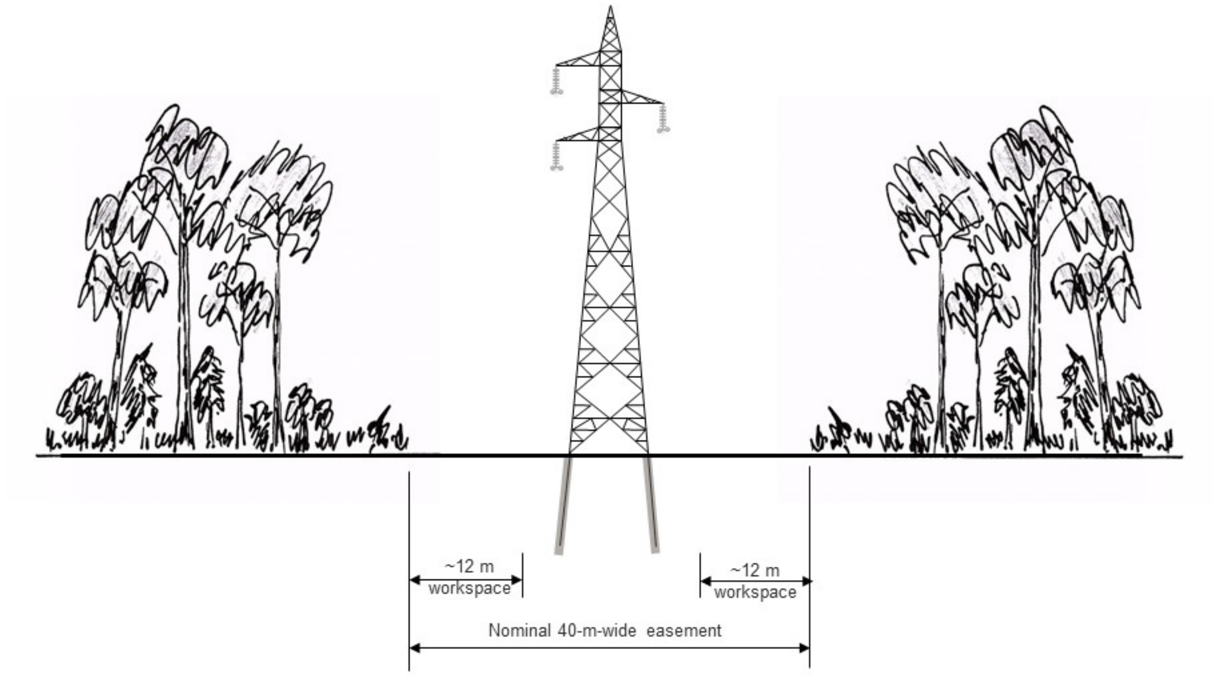


Figure 3.4 Available workspace in the existing Ballarat-Horsham 220kV transmission line easement

3.2.3. Conceptual underground route and design requirements

As discussed in Section 3.1.3, a conceptual underground project would be best delivered by HVDC technology for projects that require transmission over long distances such as is required for WRL. An underground HVDC cable would be a point-to-point connection, from Bulgana to Sydenham.

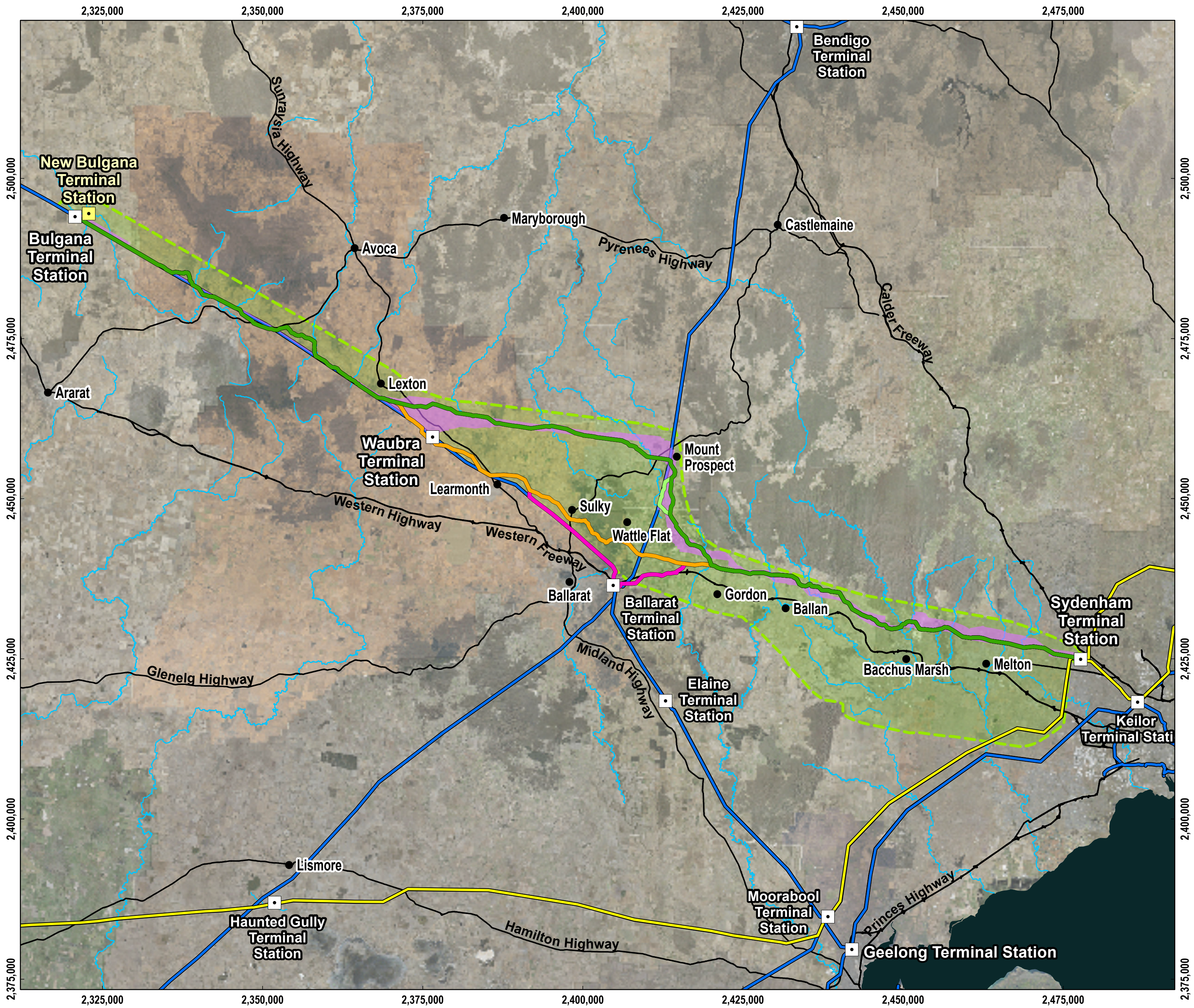
Potential routes

Four potential full conceptual underground routes were identified by AusNet, as shown in Figure 3.5 and described in Appendix D. All the proposed underground routes follow the same alignment at the western and eastern end, with variations in the central section. Routes 1a and 1b go via Mount Prospect, route 2a goes via Creswick Plantation and route 2b goes via Ballarat Terminal Station.

The routes were identified considering the environmental, cultural heritage and social criteria and technical considerations detailed in Appendix B. The same criteria and technical considerations inform the overhead route selection. When developing the potential underground routes, AusNet sought to minimise the overall length of the proposed underground cables to minimise costs and impacts.

Two of the potential underground routes (routes 1a and 1b, via Mount Prospect) generally follow the least constrained corridor identified for the proposed overhead transmission line. The other routes (Route 2a via Creswick Plantation and 2b via Ballarat Terminal Station) take more direct routes between Ballarat and Creswick, with route 2b connecting to Ballarat Terminal Station.

AusNet considered the Western Freeway and existing Ballarat-Horsham 220kV transmission line identified by community members and consultants to Moorabool Shire Council as potential routes for a full underground project. These options were not further investigated for the reasons outlined in Appendix C.



Western Renewables Link

Delivered by AusNet

LEGEND

- Proposed terminal station
- Existing terminal station

Potential full underground route alternatives

- Potential route 1a via Mount Prospect
- Potential route 1b via Mount Prospect
- Potential route 2a
- Potential route 2b via Ballarat Terminal Station
- Single corridor
- Area of interest
- 220kV circuit
- 500kV circuit
- Major road
- Watercourse

Source:
Proposed routes and corridor from AusNet.
Area of interest from Jacobs (2021).
Roads and watercourses from VICMAP (2024).
Imagery from VicGrid2020 Online.

0 7.5 15 km

SCALE 1:850,000
PAGE SIZE: A4
PROJECTION: GDA2020 Vicgrid

AUSNET

WESTERN RENEWABLES LINK

FIGURE 3.5

Potential underground routes identified by AusNet

TETRA TECH COFFEY

Jacobs

DATE: 28.03.25 PROJECT: 754-MELEN356379 FILE: 356379_R05_F003.5_GIS

SAVED BY: HELEN.UNKOVICH | 07.01.25 2:04 PM
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Potential design

To develop a conceptual underground project, AusNet engaged Mott MacDonald to develop a solution for an underground project that met AEMO's network specifications.

The underground project concept was configured as bipoles, rather than symmetrical monopoles to reduce the number of circuits, thereby reducing the number of links and required cable joints which are the primary source of faults for underground circuits. Adopting HVDC circuits as bipoles would require two trenches, one for each circuit. The arrangement of the trenches is shown in Figure 3.6, which also shows the required workspace and nominal easement. The arrangement is based on required cable separation for thermal performance and Safe Work Australia Excavation Work Code of Practice March 2015.

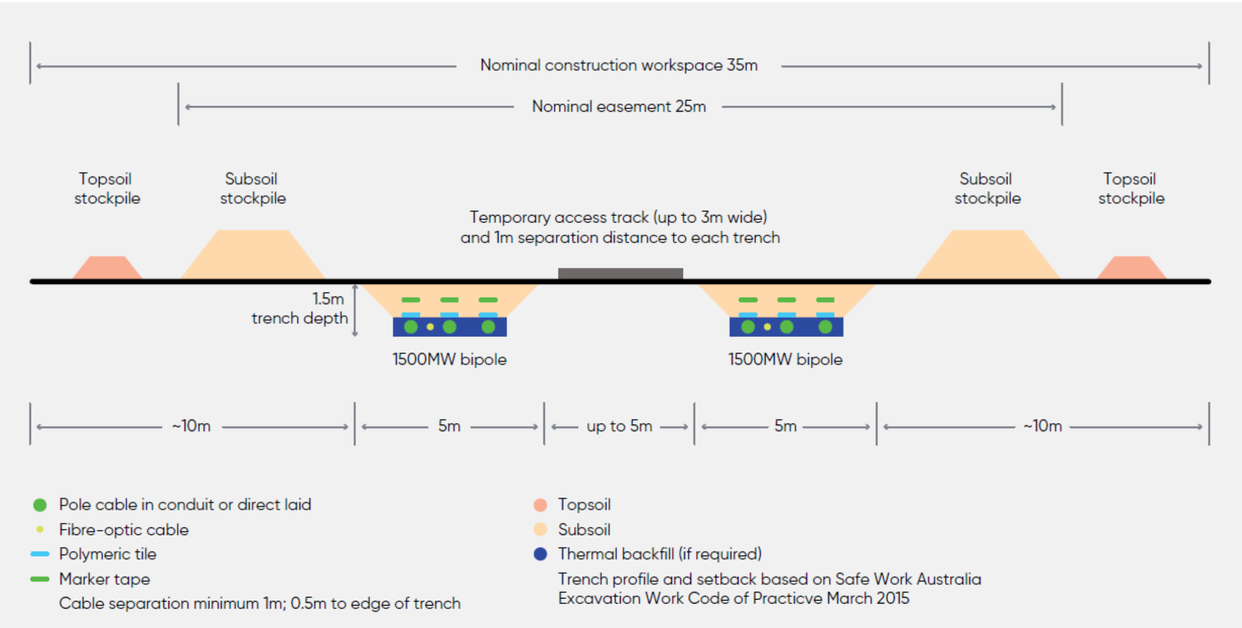

Figure 3.6 Typical arrangement of HVDC twin bipole construction corridor and easement

3.3. Cost estimates

AEMO considered the cost of project options through its development, which is discussed in **EES Chapter 5: Project development**. The Western Victoria Renewable Integration RIT-T PADR (AEMO, 2018) included a preliminary cost estimate model of options considered. The cost estimate was developed by AEMO primarily to compare the different types of 'credible options' presented in the RIT-T and their associated costs.

AEMO considered the cost of building the proposed transmission line entirely underground. The PADR (2018) concluded that an underground project was expected to cost 'up to 10 times more per kilometre' than an overhead transmission line and was not expected to deliver 'net market benefits', as defined by the terms of the RIT-T and the NER.

An underground project was therefore not considered to be a credible option, given the anticipated cost ratio of overhead transmission lines to underground cables.

However as stated earlier in this report, there has been significant community, stakeholders and landholders feedback about considering an underground project. To respond to the stakeholder feedback, a cost estimate was prepared for a conceptual HVDC underground project for comparison to a HVAC overhead project. Schematics and details (such as standard trenching details), as well as other power transmission specialist equipment and materials suppliers / manufacturers costings were used to prepare a cost estimate that was also presented as unit rates for key items. The level of detail of the cost estimate was suitable for planning phase cost estimate. For a like-for-like comparison, desktop geological information was considered to inform trenching requirements i.e. amount of rock to be encountered, along with road and waterway crossings but terrain and other local conditions specific to a particular route were not considered.

This section provides an overview of AusNet's cost estimate that was prepared for the conceptual underground project described in Section 3.2.3. It also provides an overview of cost estimates that have been prepared for other underground transmission line projects and are publicly available.

The cost estimates and cost ratios discussed in this section are presented to illustrate the cost difference between overhead transmission lines and underground cables.

Generally, the installation of high voltage underground cables costs more than placing them overhead. The main cost difference relates to the higher cost of materials and construction, and additional associated infrastructure (converter stations) required for HVDC underground projects. Key factors in construction costs associated with underground cables are the speed of installation and materials handling.

Currently, there are a limited number of companies in the world able to manufacture underground cables at 500kV. Unlike low voltage underground cables used in rural residential and residential subdivisions, high voltage cables at the voltage required for the Project are bespoke (project specific) designs that need to be ordered and allocated a manufacturing slot. In contrast, overhead transmission line conductors are manufactured to standard specifications for the voltage and power transfer requirements.

The bespoke (project specific) design of underground cables, the limited number of manufacturers, and number of projects currently in planning, design and construction are limiting the supply and resulting in increased cost.

The costs for other projects and case studies presented below demonstrate that high voltage underground cables generally cost more to manufacture and construct than overhead transmission lines.

3.3.1. AusNet

Acknowledging community interest in undergrounding of the Project, AusNet engaged quantity surveyors to prepare an independent cost estimate based on a conceptual design developed by Mott McDonald (2023). The cost estimate prepared for the conceptual underground project was developed to assess the feasibility of an underground project in meeting the Project's objective of delivering timely and cost-efficient infrastructure.

The cost estimates were developed by estimating the quantities of key construction materials assumed to be required for an underground project, and applying direct cost rates and percentages for preliminaries, design and overheads, and margins appropriate for the market at the time. The estimate of quantities was based on a line length of 188km and a conceptual underground project design develop by Mott McDonald in 2023.

The cost estimates were based on the information from equipment manufacturers and suppliers including for the DC converter station and developed in accordance with the method outlined in the Victorian State Project Cost Estimation Manual. The cost estimates applied risk percentages appropriate for the stage of the design ranging from 15% to 30% dependent on the solution, consistent with planning phase cost estimation. The cost estimate represents a point in time only and represent 2023 dollars. The costs have not been updated to reflect current costs.

The design proposed by Mott McDonald that was costed included:

- Two HVDC (+/- 525kV) 1500MW bipole converter stations at Bulgana and Sydenham.
- +/- 525 kV (DC) double circuit underground cables with two sets of converter stations (each set represent a bipole, i.e., total six cable runs for the two bipoles).

The cost per km of the HVDC double circuit underground cables is approximately 4 times the cost of the HVAC overhead transmission line excluding the costs of the two 1500 MW bipole converter stations required for the HVDC design which if included would increase the cost difference to approximately 8 times the cost of the HVAC overhead transmission line (2023 dollars). The cost estimate does not include the project development and impact assessment and approvals re-work that would be required to progress a full underground concept for the Project as this level of costing is not appropriate for the purpose of assessing feasibility of options.

This cost estimate aligns with the conclusions of a range of other studies, as described in the section below, that a HVDC underground transmission line is substantially more expensive than an above ground HVAC transmission line.

3.3.2. Other undergrounding cost estimates

Amplitude Consultants (2021)

Moorabool Shire Council commissioned Amplitude to explore the feasibility of an alternative to the Project using underground cables. Amplitude (2021) presented conceptual options and a high-level cost estimate for delivering an alternative project, and a high-level comparison of HVAC and HVDC overhead and underground options.

Amplitude reviewed information provided by Moorabool Shire Council, in addition to publicly available information to develop parameters for the Western Victoria Transmission Network Project (WVTNP) Option C2 (preferred option as described in **EES Chapter 5: Project development**).

Amplitude developed an alternative base case concept HVDC System to replace the proposed 220 kV and 500 kV AC overhead transmission lines between Bulgana Terminal Station and Sydenham Terminal Station, with an underground HVDC transmission system.

Amplitude's high-level estimate for the cost of the base-case HVDC solution, which aligns with the transfer capacities of the AEMO preferred Option C2 (500kV from Sydenham to north of Ballarat, and 220kV to Bulgana), was AU$2.7 billion. This cost is approximately five times the cost of Amplitude's high-level estimate for an overhead 500kV and 220kV transmission line. Amplitude has not provided a revised cost estimate for the conceptual HVDC design that was developed by Mott MacDonald and costed by AusNet.

The Amplitude and AusNet cost estimates for conceptual underground HVDC transmission designs are not directly comparable as the cost estimates have been developed using different designs, assumptions and levels of detail.

Parsons Brinckerhoff (2012)

The lifetime costs (capital and operation and maintenance) of overhead and underground transmission circuits (both HVAC and HVDC), including ongoing operational costs for maintenance, were investigated by Parsons Brinckerhoff in association with Cable Consulting International Ltd (2012). The study considered capital costs and operation and maintenance costs for 400kV double circuit transmission lines in England and Wales (overhead and underground) over 50 years for different lengths of transmission circuits, different technologies and different construction methods.

The cost of operating and maintaining HVDC overhead or underground transmission circuits (as opposed to capital costs for construction) were assessed by the study, which found that the lifetime cost of underground options were estimated to be anywhere from 5 to 14 times higher than overhead options. The increase in cost ratio depends on the line route length, power transfer capacity, and type of underground system used (noting that only examples of subsea transmission lines were used for HVDC options).

Transgrid (2022)

Transgrid, the network planner and operator for NSW, considered the feasibility of undergrounding the proposed 360km HumeLink (a new 500kV transmission line to connect Wagga Wagga, Bannaby and Maragle in NSW). The study found, when compared to the cost of the proposed 500kV double circuit overhead transmission line, undergrounding HumeLink would cost 3.5 times the cost for an HVDC option and 10 times the cost for an HVAC option, depending on the configuration and technology adopted.

Transgrid has published estimated operating and maintenance costs for the proposed HumeLink Project (GHD, 2022). The cost estimate includes the cost of lost generation in the event of faults or maintenance outages and finance costs. The assessment estimated operation and maintenance costs for HVDC underground transmission circuits are more than 60% higher than for HVAC overhead transmission circuits.

NSW Government (2024)

The feasibility of undergrounding transmission lines in developing renewable energy zones was further investigated by the NSW Parliament (NSW Parliament Legislative Council, March 2024). The assessment completed for HumeLink was evaluated by the committee along with submissions from communities and technical specialists. The committee concluded that HumeLink, as proposed was the appropriate solution, noting that the current regulatory framework required costs to consumers to be minimised.

VicGrid (2024)

VicGrid issued a report in March 2024, including the preferred alignment for new transmission lines to service the proposed offshore wind projects in Gippsland and that the lines will be overhead due to costs. The analysis found that putting the project underground would cost between $2 billion and $4.5 billion compared with an estimated $700 million to $1.5 billion for overhead transmission lines. VicGrid noted in the media release that the additional costs would be paid for by all Victorian homes and businesses through higher power bills.

VNI -West PACR

The case studies presented above are consistent with the findings of the VNI-West Project Assessment Consultation Report (PACR) (AVP and Transgrid (May 2023), p 43) states that:

"Options to underground the lines were raised in submissions to the PADR (and the PSCR) and were suggested by stakeholders and communities as possible solutions that could help minimise social and environmental impacts associated with the project. Under the regulatory requirement to develop the most prudent and efficient option that will maximise benefits to energy consumers, and minimise risk of over-investment, full undergrounding is considered a cost-prohibitive solution to respond to community and stakeholder concerns, while still meeting the identified need. It would also take much longer to deliver."

3.4. Conceptual timeline

The Project is required to be delivered in a timely manner to maintain the reliability and security of Victoria's electricity supply as demand for electricity grows, coal-fired generation retires, and utility scale renewable energy becomes the main source of power for the National Electricity Market. AEMO forecast that Victoria will face risks to the reliability of electricity supply from 2027 onwards, with five coal power stations, including Yallourn Power Station, expected to retire, but these risks could be realised earlier. The risks to reliability of the system to meet energy demand requires urgent investment to meet Victoria's energy needs.

Transmission augmentation is a critical part of the response to the challenges facing the NEM, facilitating investment in renewable energy generation and allowing transmission of the energy generated. As presented in **EES Chapter 2: Project rationale**, the challenges facing Victoria with ensuring energy reliability are acute and short-term.

An underground project would require recommencing the project with a business case, feasibility study and developing a project alignment suitable for the proposed underground cable. The landholder engagement, design development, environmental assessments would also need to recommence for an underground project design which would follow a different alignment to the proposed overhead Project. Subject to obtaining project approvals, the construction would take substantially longer for an underground project thus not meeting the project objective with regards to timely delivery.

This project development, approvals process and construction could not be achieved in the required timeframe for delivery of the Project. The Project was originally planned to enter service by mid-2026. The changes to the Project as a result of the February and May 2023 NEVA Orders in relation to the Project, have extended the expected completion date for the Project. The Project is currently targeting to be in service by late 2028.

AusNet has enquired about delivery times for HVDC cable and converter stations, which would be the preferred technology if an underground solution was feasible for the project as discussed in Section 3.1.3. The manufacturer advised that a conservative estimate would be a 7-to-8-year lead time for supply of HVDC converter stations. AusNet has prepared a conceptual schedule for a full underground project, as shown in Figure 3.7, assuming an optimistic lead time of 5 years for ordering converter stations. The conceptual schedule has been developed with a less conservative and more optimistic approach, particularly having regard to the time taken to prepare the EES for the Project and the manufacturer lead time for HVDC converter stations.

Taking into consideration the need to define, tender, refer, assess and build an underground transmission line, a full underground project could not be delivered in a timeframe required to ensure the reliability and security of the state's electricity supply is maintained is As indicated by Figure 3.7, the timeline for development and delivery of an underground project would not align with the need to deliver the Project to address power supply constraints.

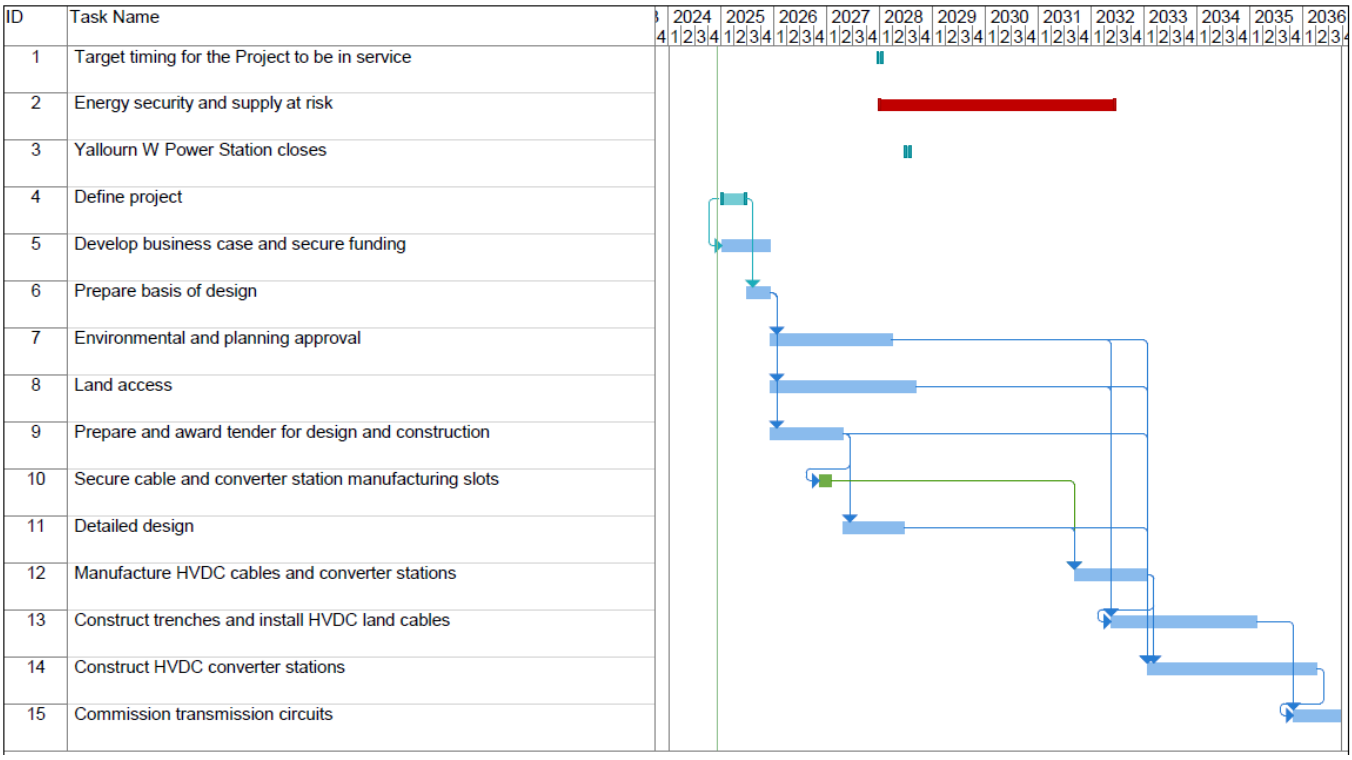

Figure 3.7 Indicative schedule for conceptual underground project using HVDC technology, assuming 5 years lead time for converter station manufacturing

Given the estimated timeframe associated with an underground project concept, there is a significant delay cost associated with an underground project concept. The cost of this delay would impact the availability of cost-efficient electricity and have flow on effects to electricity consumers bills.

4. Environmental, amenity, land use and heritage issues

The Australian Government's commitment to reducing greenhouse gas emissions is underpinned by policies, plans and strategies to develop and expand both renewable energy generation and the transmission networks that distribute electricity across the NEM.

To support the connection of renewable energy generation facilities to the NEM, new transmission network infrastructure is required. Community members have expressed concerns about the potential impacts of new overhead transmission lines on visual amenity, land use, environmental and cultural heritage considerations.

Overhead transmission lines and underground cables have different footprints, construction methods, and requirements for operation and maintenance. As such, overhead and underground transmission lines present different environmental, amenity, land use and cultural heritage challenges.

This section presents an overview of potential environmental, amenity, land use and cultural heritage issues for both overhead transmission lines and underground cables. An impact assessment has not been completed for an underground project as it is not a feasible alternative, as discussed in Section 1 and Section 5. The discussion of issues outlined below is based on considering existing available information about other projects and the information sources listed in Section 1.1. Detailed impact assessment for the proposed Project (overhead transmission line) is provided in the EES (**Technical Reports A to T** and **Chapters 8 to 28**).

The purpose of this section is to provide contextual information about the potential environmental issues typically resulting from overhead transmission lines and underground cables. This section discusses overhead cables broadly (i.e. HVDC and HVAC transmission technologies). This section does not inform the assessment of feasibility of an underground transmission line (the conceptual HVDC underground project defined in Section 3.2.3) as the ultimate extent of environmental, amenity, land use and heritage issues from overhead transmission lines and underground cables are dependent on the specific project description (e.g., location, design, construction method) and the values present (i.e., existing conditions at proposed locations).

4.1. Environmental issues

An underground project may have greater impacts on the following environmental values, when compared to an overhead project:

- Geology, landform and soils
- Surface water
- Groundwater; and
- Ecology.

This section also considers the generation of greenhouse gas emissions associated with materials and construction of underground cable and overhead transmission line, as well as the impact of climate change and natural hazards on overhead and underground project infrastructure.

Geology, landform and soils

Overhead transmission lines may have less environmental issues than underground cables on geology, landform and soils for construction. In addition, overhead construction methods may be less exposed to unfavourable geotechnical conditions.

Overhead transmission lines are typically less exposed to unfavourable geology, landforms and soils due to span length and the relatively small footprint of transmission structures at approximately 450m spacings. Landslip prone areas and steep slopes are able to be overflown and structures in those areas avoided.

Underground cables are typically more exposed to unfavourable soil conditions and unstable landforms due to the construction of a trench for the entire route, with the exception of areas where trenchless construction methods are used. Trenchless construction methods (typically HDD) are used for underground cable crossing of sealed roads, watercourses and environmentally sensitive areas, where geotechnically feasible. Boulders, fractured rock and saturated weak soils are not suitable for trenchless construction as drill strings may become stuck or deflect, drilling fluids might escape to the surrounding environment (known as a frac-out), and boreholes may collapse respectively. Trenchless construction requires larger workspaces either side of the feature being crossed and is expensive compared to excavating trenches. Due to logistical constraints (e.g., avoiding cable joints within HDD ducts, limiting the maximum HDD length by the length of cable able to be accommodated on a drum) and cost, trenchless construction is typically not used over long distances. Typically, trenchless construction can cost more than six times the cost of excavating trenches per metre depending on the size of the boreholes and geotechnical conditions.

Disturbing sodic (highly dispersive) and acid sulfate soils and landslip prone landforms increases the risk of impact to environmental values. Disturbance has the potential to cause or exacerbate gully, sheet and tunnel erosion causing sedimentation and water quality issues. The construction of underground cables in these areas may increase the risk of landslides.

Overhead and underground construction produce excess soil that is required to be classified, treated, reused or disposed to a lawful place in accordance with the General Environmental Duty and *Environment Protection Act 2017* (Vic), if contaminated or suspected of being contaminated. The Waste Regulations and Waste Duties provide a framework for classifying, transporting and disposing of waste as at lawful place. There is a duty to notify the Victorian EPA, as soon as practicable if the contamination is or suspected of being notifiable contamination, as defined in the *Environment Protection Regulations 2021* (Vic).

Underground construction activities typically produce more excess soil than overhead construction due to trench construction and the requirement for thermal backfill to replace native soil, where necessary, to support performance of the cables.

Surface water

There are fewer potential issues effecting surface water from construction and operation of overhead transmission lines than underground cables.

For both underground and overhead transmission lines, watercourse crossings and construction activities adjacent to watercourses also create potential issues to aquatic ecology, principally from erosion and sedimentation and contaminated surface water runoff.

Poor water quality and smothering of instream flora and habitat has the potential to reduce food sources and refuges for fish and macroinvertebrates affecting dependent species.

Overhead transmission lines have the potential to span across watercourses generally avoiding disturbance to associated riparian vegetation. Overhead transmission line structures can be sited in floodplains in a way that avoids creating obstacles to overland surface water flows.

Underground cables do not impede overland surface water flows. There is potential for poorly reinstated trenches to create preferential flow paths affecting floodplain function and cause erosion and sedimentation of watercourses and in extreme cases, change watercourse channels. This risk is reduced by appropriate reinstatement and rehabilitation of construction areas. Watercourse beds and banks are disturbed where trenching is required due to unsuitable geotechnical conditions for trenchless construction methods such as HDD.

During construction the integrity of an HDD bore may fail due to geotechnical or mechanical reasons. The failure of the HDD bore has the potential to lead to a frac-out, releasing drilling fluid into the surrounding strata and watercourse. Drilling fluid, although an inert clay-based material may reduce water quality and smother instream habitat.

Groundwater

Overhead construction has less potential to interact with groundwater than underground cables, however the issues would be the same where groundwater is intercepted during construction.

Overhead and underground construction activities have the potential to intercept shallow groundwater. Dewatering activities may reduce water quantity and flow to beneficial uses. Overhead construction may require dewatering in some locations, however this would likely be brief (less than a day) at any location. Trenches for underground cables require appropriate reinstatement and rehabilitation to reduce the potential to create preferential flow paths for shallow groundwater. Placement of thermal backfill in trenches may also interrupt subsurface flow by creating a barrier to groundwater flow if it is intercepted.

Disturbed acid sulfate soils or contaminated soils may leach into groundwater reducing water quality affecting beneficial uses and groundwater dependent ecosystems.

Terrestrial ecology

The removal of native vegetation for the construction of overhead and underground transmission line projects has the potential to create issues for terrestrial ecology. If native vegetation is unable to be avoided in route selection, which is the primary mitigation measure, the extent of native vegetation loss is a key issue for both underground and overhead transmission projects. However, there are more opportunities to avoid vegetation with an overhead line, which is discussed further below.

All vegetation is required to be cleared from overhead transmission line tower structure sites and access tracks for construction. Tall vegetation is also required to be cleared from the overhead transmission line easements to maintain the required electrical safety clearances during operation. The extent of clearance depends on the design, with structure height and span length influencing the level of ground clearance. With an appropriate design and safety assessment, and where terrain permits, some vegetation (including trees below 3m) are able to be retained and overflown, for example along riparian corridors. . Overhead transmission lines have less potential to impact on native grasslands and understorey vegetation as structures are generally 450m to 550m apart and disturbance between adjacent structures is able to be minimised. With the exception of access tracks, construction activities are generally contained within the easement.

While both distribution and transmission lines can pose a risk for bird collision distribution power lines account for the majority of recorded bird strikes due to the smaller diameter conductors. BirdLife International (2007) specifically delineate smaller (less than 100kV) power lines as of particular concern for bird collision risk given size and spacing. Particularly susceptible bird species include wedge-tailed eagles, white-bellied sea eagles and black swans which occur in the area of interest for the Project. Transmission line conductors are larger and more visible, particularly where quad-bundles are used, as is proposed for the Project. Collision risks from the overhead line in key areas are considered through the use of bird divertors or equivalent measures reducing impacts.

The installation of underground cables require the clearance of all vegetation in the construction corridor to be cleared for trenching, with the exception of areas where trenchless construction methods are used (typically HDD). The construction corridor for underground cables is wider than the operating easement, affecting more vegetation than required to be managed in operation. Deep rooted trees are not able to be grown in underground cable easements. Underground cables consequentially impact native grasslands including the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) listed critically endangered Natural Temperate Grassland of the Victorian Volcanic Plain. Native grassland communities also provide habitat for such species as the vulnerable golden sun moth (*Synemon plana*) and endangered matted flax-lily (*Dianella amoena*). Other flora and fauna species will also be adversely impacted by the removal of vegetation.

Installing underground cables may impact tree roots, extending the impact beyond the trench and the construction corridor. Australian Standard 4970–2009 *Protection of trees on development sites* states that all services should be placed outside the tree protection zone (TPZ). The standard applies to native and ornamental trees. The size of the TPZ varies with the diameter at breast height of the tree. For mature trees, the TPZ may be up to 15 m radius from the trunk. Where trees are located adjacent to compacted soils or hard surfaces (e.g., sealed roads), the TPZ is typically smaller. If more than 10% of the TPZ is disturbed, a tree is deemed to be lost. Therefore, the TPZ is an important factor in selecting underground routes, determining project impacts and where impacts are unavoidable, informing the required environmental offsets.

Greenhouse gas emissions

Terminal stations required to connect overhead and underground transmission circuits to the transmission network use sulfur hexafluoride gas (SF_6) in circuit breakers. SF_6 is the most potent greenhouse gas. The volumes of SF_6 held in circuit breakers is small, however leaks may occur over long periods. HVDC solutions require fewer circuit breakers when compared to HVAC solutions and therefore are expected to have a lower volume of SF_6 overall.

More concrete and steel is used in constructing overhead transmission lines than laying underground cables. Therefore, overhead construction has higher indirect greenhouse gas emissions in the construction stage than underground cables.

Climate change risks

Climate change is predicted to increase the prevalence of conditions which favour the formation of storms, and change weather conditions with potentially more severe droughts and extreme rainfall events. Climate change risks could impact the construction and effect the resilience of overhead and underground infrastructure during operation.

Overhead transmission lines are less exposed to climate change risks than underground projects in construction. For underground cables there is a larger area of disturbance for the construction corridor and trenching. This increases the area potentially exposed to storm damage and at risk of erosion, slope failure and watercourse scour and migration in flooding events. The length of open trench will determine the risk of construction activities being affected and the severity of impacts.

The Electricity Sector Climate Information (ESCI) project was developed in response to the recommendations made in the *Independent review into the future security of the National Electricity Market: Blueprint for the future*, also known as the 'Finkel Review'.

As an outcome of a workshop with key stakeholders in the electricity sector, the ESCI project identified five key climate change hazards and electricity system vulnerabilities (ESCI 2021). These include:

- Rising temperatures:
  - Extreme temperatures leading to reduction in generator and network capacity, increasing demand.
- Increased frequency, severity and extent of bushfire poses a risk to most electricity infrastructure, however heat and smoke are a particular risk to operational overheard transmission lines.
- Extreme winds reducing the capacity, and compromising the integrity of overhead transmission lines.
- Increased variability or reduction in rainfall and flooding may lead to reduced soil moisture:
  - Reducing the thermal conductivity of underground power lines
  - Increasing the risk of damage from lightning on underground power lines
- Compound extreme weather events (e.g., Increase in frequency and magnitude of extreme events) has the potential to cause substantial disruption to the electricity sector.

The above hazards and vulnerabilities show that overhead transmission lines and underground cables are exposed to different climate change risks.

Natural hazards

Overhead transmission lines and underground cables are both exposed to natural hazards in operation, albeit to different extents. Underground cables are generally better protected from natural disasters or extreme events. For example, underground cables are not exposed to heat, radiation and fire storms induced by extreme fire behaviour. Similarly, underground cables are not exposed to gale-force winds associated with extreme storm events. Underground cables may be exposed to storm damage including:

- Exposure due to soil erosion by overland and watercourse flood flows. Watercourse channels may scour and migrate in major flood events. Overland flows may erode and scour drainage lines exposing underground infrastructure.
- Prolonged heavy rainfall may saturate soils and cause tunnel erosion and slope failure which may result in slumping or landslides in areas with erosive or highly dispersive soils

and landslip hazard. Lateral forces may damage underground cables causing them to fail. Sodic soils, which are highly dispersive occur throughout the area of interest.

Overhead transmission lines are exposed to extreme storm events that produce storm bursts or tornados. Such storms occurred in South Australia in September 2016 and November 2022, and in Western Victoria in January 2020 and February 2023. During these events, the transmission circuits were damaged and required repair. The transmission lines were able to be temporarily repaired and returned to service within 2 to 3 weeks, while permanent repairs took longer. New design standards are proposed for the Project to make the proposed transmission line more resilient to such risks.

Fires burning in the Project Area are unlikely to cause extreme winds (e.g., pyro-convection) that would cause a tower to collapse. The probability of this occurring is considered very low, particularly with the application of design standards. That is, transmission lines are designed to prevent tower collapse and / or transmission lines falling to the ground under reasonably foreseeable extreme wind conditions or due to structural failure. Design is carried out in conformance with AS/NZS 7000:2016 *Overhead line design* (Standards Australia, 2016) and AS/NZS 1170.2-2021 *Structural design actions. Part 2: Wind actions* (Standards Australia, 2021). Design for this type of structure must account for at least a 400-year return period wind gust. Underground cables are not exposed to extreme winds or pyroconvection.

Overhead transmission lines may need to be de-energised during a bushfire due to dense smoke to avoid flashovers. However, this rarely occurs and would only do so with agreement from emergency service agencies and AEMO. Aerial firefighting activities need to consider the location of overheard transmission lines. Such consideration is not required with underground cables.

Underground cables may also need to be de-energised during a bushfire if soil temperature was high enough for the cable to exceed operational limits. Noting the thermal backfill placed around the cables aims to protect the cable from such changes in temperature.

Vegetation management in accordance with bushfire mitigation plans required under the *Electricity Safety (Bushfire Mitigation) Regulations 2023* (Vic) is designed to minimise the risk of damage to these assets from bushfires and risk of transmission lines starting fires. Overhead transmission line structures and conductors are designed to withstand and not fail under high temperatures. Improved protection systems have reduced fault clearance times and the potential for faults to cause fires. Faults are managed in accordance with the NER.

4.2. Amenity, land use and cultural heritage issues

Overhead and underground projects affect amenity, land use and cultural heritage differently, with overhead projects typically affecting landscape and visual, aviation and agriculture, and forestry and extractive industries more than underground projects. Underground projects typically affect Aboriginal and historical cultural heritage, air quality, and traffic and the road network more than overhead projects. These aspects are discussed below.

Aboriginal and historical cultural heritage

Unlike overhead transmission lines where structures (and associated disturbance) are generally confined to transmission tower sites between 450 and 550m apart, underground cable installation requires the disturbance of ground for the width of the construction corridor along the entire route, with the exception of areas where trenchless construction (e.g., HDD) is used. Consequently, underground cables are likely to have greater impacts on Aboriginal cultural and historical heritage material and sites. They also pose a risk to historical heritage, where archaeological material occurs or where sites which are unable be avoided.

Overhead transmission lines and underground cables may also impact Aboriginal cultural heritage places where they detract from the stories and intangible values associated with the place or the context of the site or place. During operation, overhead transmission lines may conflict with or detract from landscape values associated with Aboriginal cultural and historical heritage sites. In comparison, underground transmission lines have a lower visual impact on these sites and settings.

Route selection and transmission line design are the primary method for avoiding or mitigating potential impacts on Aboriginal cultural and historical heritage.

Air quality

Dust from construction activities is the key risk to air quality. Overhead transmission line construction sites have a smaller footprint than underground cable construction corridors, and therefore a likely lower potential for air quality issues. During operation, both overhead and underground transmission lines do not emit air pollutants.

Traffic and road network

Construction vehicles, plant and equipment generated by both overhead and underground transmission line projects will increase traffic. When compared to overhead transmission lines, the construction of underground cables has the potential to create more issues for traffic and road networks, particularly when underground construction is in residential areas.

Underground cables may be installed under roads or in road reserves, potentially creating instances where traffic may be significantly disrupted for extended periods due to construction activities associated with cable laying and cable joining. Lane and road closures may be required to manage traffic during construction. However, road crossings using trenchless construction methods (e.g., HDD) do not typically require lane or road closures. Overhead transmission lines can overfly road or rail infrastructure and use temporary protection works such as hurdles to avoid damage to existing infrastructure and traffic impacts.

Overhead transmission line construction and underground cable installation generate traffic, with most traffic generated at overhead transmission tower structure sites and underground cable joint pits.

Heavy lift cranes and concrete trucks are required for overhead transmission line construction. Underground HVDC cable may be joined in cable joint pits or joined and direct buried. Underground cable drums weighing between 30 and 50 tonne (t) need to be delivered to cable joint pits, if required. These heavy vehicles and loads required for overhead transmission lines and underground cables may damage road pavements and may require bridge and culvert upgrades.

Landscape and visual

Overhead transmission lines are visible, particularly in flat to gently undulating landscapes where native vegetation has been extensively cleared for farming and topography does not provide effective screening. Underground cables are not visible in such landscapes, except for above ground facilities such as reactive compensation stations or transition stations.

Overhead transmission lines may impact landscape and visual amenity where they are in the field of view of sensitive viewing points including scenic lookouts, scenic drives, and dwellings with views of surrounding landscapes. The setting, extent of views, extent of modification of the landscape, and distance to the infrastructure are all relevant to the degree of impact on landscape and visual amenity.

HVAC underground circuits require reactive compensation stations at approximately 30km intervals. At 500kV, these substations are substantial facilities that will be visible until effective screen planting is established, where practicable. HVDC underground circuits have no above ground structures except at each end of the transmission circuits where the converter stations are located. In addition, HVAC transmission lines would be required to connect renewable energy generators to terminal stations at each end of the HVDC transmission line, increasing the length of overhead transmission lines in the landscape unless underground cables were used. In other words, undergrounding would not remove the need for overhead transmission lines to be constructed to connect renewable energy projects to the Project.

Underground cable easements also have the potential to lead to visual impacts. Like overhead transmission line easements, underground cable easements may be noticeable where the construction corridor and easement are cleared through vegetation. Retained vegetation on overhead transmission line easements may, in some instances, break up the hard lines of the cleared easement reducing landscape and visual impact. In contrast, hard lines are a permanent feature of underground cable easements due to the need to prevent deep rooted plant regrowth in the easement, i.e., only grasses and shallow rooted ground cover vegetation may be retained on the easement except where HDD is used.

Aviation

Overhead transmission lines are an obstacle to low flying aircraft including aerial firefighting aircraft and aerial fertilising and spraying aircraft. Overhead transmission lines may pose an obstacle for airport and aerodrome runway flight paths however are regularly navigated safely by aircraft. The overhead transmission line design will need to comply with Civil Association Safety Authority (CASA) requirements and aviation safety assessments.

Overhead transmission lines may also penetrate obstacle limitation surfaces for regulated airports and certified aerodromes, but avoidance is preferred. Regulated and unregulated aerodrome and airport operations need to include procedures for safe approach over transmission lines. Low level aerial operations are required to consider the constraints imposed by transmission lines, distribution power lines and topography. Underground cables do not pose a constraint on low level aerial operations.

Helicopters may be used to string the overhead transmission line necessitating other aircraft observing safe operating distances for this activity during construction.

Agriculture, forestry and extractive industries

Both overhead and underground transmission lines impact and restrict land use within the area they are located. Impacts on land use from overhead transmission lines and underground cables have the potential to be managed or mitigated to some extent through design and alignment refinement.

For example, overhead transmission line structure heights and locations, and span lengths can be varied to increase ground clearances for farm machinery and irrigators and reduce impacts on paddocks. Underground cables may be buried deeper to allow heavy machinery to traverse and work on the easement. Increasing structure heights and deeper burial does however increase construction and material costs. Deeper burial of underground cables also reduces thermal efficiency, requiring larger cables or derating the cables under high loads affecting transmission capacity.

Underground cables and overhead transmission lines have the potential to adversely impact agricultural land, plantations and native vegetation forestry, and mineral and extractive resources. Overhead transmission lines have the potential to better manage this issue due to flexibility in structure siting and height and span length. Some flexibility exists in agricultural land, plantations and production forests where overhead transmission line and underground cable routes have the potential to be aligned with paddock fences or cleared areas of plantation reducing the impact on agricultural activities, production and harvesting activities, and reducing the loss of timber resources. Underground cable routes have less flexibility where topography constrains the route. In these situations, underground alignments may not align with fences or cleared areas, thereby affecting agricultural activities, production forests and extractive quarries,

The easements for overhead transmission lines and underground cables define the area where restrictions will apply to certain land uses and some farming practices. Overhead transmission lines require a larger easement compared to underground cables increasing the encumbrance. Overhead transmission lines place restrictions on over-height machinery, gun irrigators and aerial fertilising and spraying. Centre-pivot and lateral irrigators are permitted to operate up to 5m in height under overhead transmission lines. Appropriate design and AusNet's approval is required for centre-pivot and lateral irrigators operating over 5m in height under overhead transmission lines. Over height machinery is permitted to work under overhead transmission lines where the required electrical safety clearances are incorporated in the design and with AusNet's approval. Aerial spraying and seeding may be affected by required safety distances to overhead transmission lines.

Buildings and dwellings are not permitted on overhead transmission line easements or underground cable easements. Placing materials and soil in a way that reduces the required ground clearance is not permitted on overhead transmission line easements. Soils and materials (e.g., silage and silage bales) cannot be stockpiled on underground cable easements, as they could cause differential heating in the cables and potential failure.

Excavating trenches and augering for fence posts is prohibited on underground cable easements unless approved and supervised by AusNet. Landholders require AusNet approval to build fences (i.e., with fence posts), install underground water lines and irrigation pipes and use heavy machinery on the underground easement. In addition, landholders are unable to re-profile land in an underground cable easement as reducing the depth of cover over the cables may change the thermal properties of the soils affecting cable performance.

Ground-growing crop types will be allowed within the overhead easement without an AusNet safety assessment or permit provided the crop is at least 5m away from the base of any tower steelwork and any associated digging or earth movement is no deeper than 300mm. For earth movement changes greater than 300mm in depth, a Before You Dig Australia enquiry and subsequent AusNet safety assessment must be completed.

All vegetation will be cleared in the underground construction area along the length of the underground route, except where trenchless construction methods are used. Underground cables can be buried deeper to allow cropping, although deeper burial increases cost due to reduced thermal efficiency.

Agroforestry, plantation and production forestry are not permitted on overhead transmission line or underground cable easements, as trees exceed the required electrical safety clearances and have deep root systems affecting thermal performance. These restrictions result in permanent loss of land for timber production.

Overhead transmission lines and underground cables may restrict blasting activities where the infrastructure is located within the air blast and ground vibration buffers respectively. Fly rock poses an issue for overhead transmission lines requiring appropriate separation distances from blasting activities. These setbacks and safety zones may restrict quarry operations and access to extractive resources where blast designs are unable to be modified.

Electric and magnetic fields

Electric and magnetic fields are not generated during the construction of overhead and underground transmission lines.

Operational overhead transmission lines and underground cables generate electric and magnetic fields. Electric fields are screened by the metallic sheath built into underground cables. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has endorsed the International Commission on Non-ionizing Radiation Protection (ICNIRP) principles (ICNIRP 2020) and guidelines (ICNIRP 2010) for limiting exposure to electric and magnetic fields. These include exposure reference levels for exposure of the general public to electric and magnetic fields. Magnetic fields may affect sensitive implantable medical devices, sensitive medical and scientific equipment, sensitive electrical and electronic equipment, and the sensory systems of humans and animals. Electric fields cause corona noise and may affect radio and television reception and mobile communications. The sensory systems of humans and animals may be affected by electric fields.

Overhead transmission line minimum ground clearances ensure the public is not exposed to electric fields above the Project limit of 7 kilovolts per metre (kV/m) which is based on referenced ICNIRP basic restriction calculations, or magnetic fields above the general public exposure reference level of 200 microtesla (μT) set by ICNIRP and endorsed by ARPANSA. Underground cables generate higher magnetic fields than overhead transmission lines at an equivalent height (1m) above ground level. Figure 4.1 shows the difference between magnetic fields from overhead transmission lines and underground cables of equivalent voltage (400kV).

Magnetic field strength from overhead transmission lines is lower than for underground cables at an equivalent height above ground level but extend further from the conductor than magnetic fields from underground cables. Magnetic fields produced by HVDC underground cables are steady and uniform and decrease rapidly with distance compared to HVAC underground cables. HVAC underground cables produce varying magnetic fields that can be higher than magnetic fields produced by HVDC underground cables at certain distances.

For both underground and overhead transmission lines, there is no risk of health effects from exposure to magnetic fields noting electric fields are screened in underground cables.

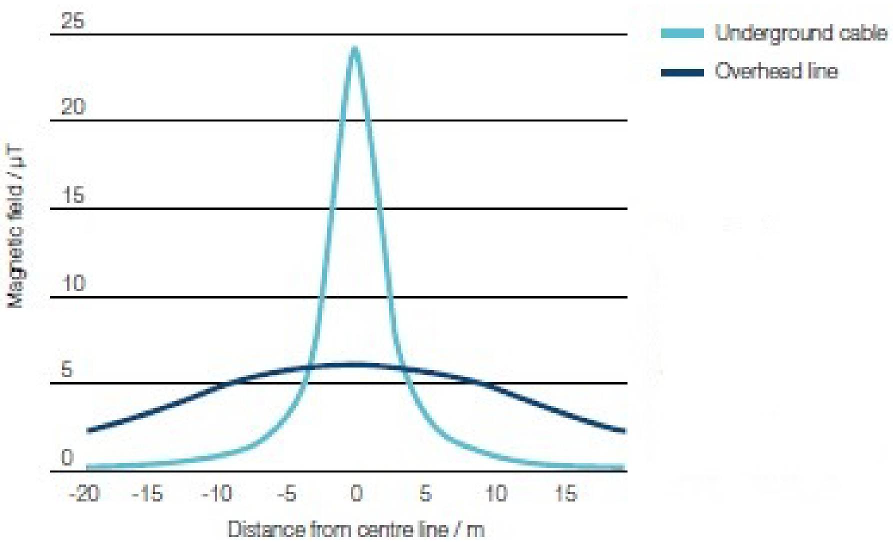

Figure 4.1 Radiation from overhead lines and underground cables (Source: ICNIRP 2020)

5. Considering the Project objectives

Avoiding and minimising potential environmental issues is a key objective of the Project's development, but they are not the only objectives. The Project must meet the objectives defined through the RIT-T process required by the NER and confirmed in the February and May 2023 NEVA orders in relation to the Project.

The Project objectives aim to address the capacity, security and reliability constraints facing Victoria and the NEM as identified by AEMO. The Project objectives are discussed in Section 2 and listed in Table 5.1. The EES scoping requirements provide that the EES must consider feasible alternatives, where they avoid or minimise adverse environmental effects whilst meeting the project objectives.

The Project objectives are the overarching key criteria that have guided the assessment of feasible alternatives. Alternatives that did not meet the Project objectives were not assessed in the EES. The following sections discuss how the conceptual HVDC underground project, as described in Section 3.2.3, does not meet all of the Project objectives.

Table 5.1 Project objectives

Project objectives
Maintain the security and reliability of the transmission network for customers by: • increasing electricity transmission capacity in western Victoria to minimise the congestion constraining current and future electricity generation in the region; and • ensuring the Project complies with the power system security requirements of the National Electricity Rules.
Create opportunities for strategic development of the NEM by: • increasing electricity transmission capacity, thereby facilitating more efficient connection and dispatch of electricity generation in and from the region. • enabling future transmission network expansion from Victoria to New South Wales.
Deliver infrastructure which realises a net benefit for Victorians by: • delivering the Project in a timely and cost-efficient manner; and • delivering transmission infrastructure which, by increasing capacity, facilitates the further development of renewables in western Victoria, encouraging further investment in the industry and associated economic growth.

5.1. Objective 1 – Maintain security and reliability of the transmission network

The conceptual HVDC underground project, as described in Section 3.2.3, would meet the Project's objective of maintaining the security and reliability of the transmission network for customers in western Victoria, as it would increase the electricity capacity in western Victoria. The conceptual HVDC underground project would also connect electricity grids and maintain the network through stabilising the grid with instantaneous and precise control of the underground circuits.

A HVAC overhead project would also meet this objective and help secure the success of the Western Victoria REZ.

5.2. Objective 2 - Create opportunities for strategic development of the NEM

A key component of HVDC underground cables is the converter stations required to convert the electricity from DC to AC, as electricity generators and consumers predominately require an AC supply (see Section 3.1.1). Connection between electricity generators and the transmission line would be facilitated through terminal stations (for the transformation of energy) and converter stations (to convert AC to DC).

The conceptual underground project is a point-to-point HVDC connection from Bulgana to Sydenham, and would not easily facilitate connection for electricity generators in the Western Victoria Renewable Energy Zone as outlined in section 3.1. Due to the cost, time and land required for converter stations, it would be difficult for generators to establish cost efficient connection to a HVDC transmission line. This does not meet the Project objective of facilitating cost efficient connections and may limit the dispatch of power in and from the region by insufficient transmission capacity.

The connection of a generator to an overhead HVAC transmission line would be enabled through terminal stations. There are several existing terminal stations across the Western Victoria network and REZ which would provide efficient connection points for generators.

5.3. Objective 3 - Deliver infrastructure which realises a market benefit for Victorians

The conceptual underground transmission project would cost more and take longer to deliver. Based on the AusNet and other case studies summarised in section 3.3 it is estimated an underground project would cost in the order of 3 to 14 times more than an overhead transmission line. The PADR concluded that an underground project was expected to cost 'up to 10 times more per kilometre' than an overhead transmission line and was not expected to deliver 'net market benefits' (AEMO, 2019).

Based on the cost estimates prepared for the Project from 2019 – 2021 by AusNet and AEMO, delivery of the conceptual underground project (as an HVDC transmission line providing a point-to-point connection from Bulgana to Sydenham) would not be economically justifiable under the terms of a regulatory investment test for transmission under the NER.

Under the current regulatory framework, project costs are passed through to consumers. Any increased cost in providing the transmission capacity that is necessary to ensure reliability and security of the state's electricity supply will be paid by the consumer.

An underground HVDC connection would provide a secure connection and provide a benefit to the NEM. However, an underground HVDC connection would not easily facilitate the connection of renewable energy generators, thereby not enabling market benefits to be realised. HVAC and HVDC underground solutions would not be cost effective or be able to be delivered in a timely fashion to meet the urgent need for additional transmission capacity therefore this project objective is not met.

6. Conclusion

Western Renewables Link was initiated to solve the network constraints identified by AEMO in 2018. AEMO undertook the RIT-T process in accordance with the NER to inform the development of the technical solution proposed for the Project.

The Project objectives were developed by AEMO and AusNet having regard to the RIT-T. The objectives were reinforced by the *National Electricity (Victoria) Act 2005* (NEVA) orders issued in February and May 2023 in relation to the Project by the Victorian Minister for Energy and Resources. The NEVA orders specified changes to the Project which, if approved, would require the construction of a new 500kV double circuit transmission line from Bulgana Terminal Station to Sydenham Terminal Station.

The scoping requirements provide that the EES must consider feasible alternatives, where they avoid or minimise adverse environmental effects whilst meeting the project objectives. The Project objectives and NER are the key criteria for assessing the feasibility of an underground transmission line from Bulgana to Sydenham as a technical solution for the Project.

EES Attachment I: Project development and assessment of alternatives for the Project did not include an assessment of undergrounding as a fully underground project would not meet the Project objectives or the NER and is therefore, not a feasible alternative. However, in response to community interest in undergrounding of the Project, AusNet considered what a possible underground concept could be for the project, and the potential issues that would need to be considered. A conceptual underground project was developed to consider the differences in construction method, route selection criteria, cost and program implications for an underground project. The assessment considered whether a conceptual HVDC underground project would meet the Project objectives, and the potential technical, economic, environmental, amenity, land use and cultural heritage issues associated with the construction, operation and maintenance of both underground and overhead transmission projects.

The preferred transmission technology for an underground project (Section 3) would comprise an HVDC, point-to-point connection from Bulgana to Sydenham due to the distance of the transmission required. An HVDC underground cable would not cost efficiently and easily facilitate connections from renewable energy generators in the Western Victoria REZ, which is a key Project objective. HVDC cables would also require terminal stations with AC to DC converter stations for electricity generators to be able connect to the transmission line.

Multiple reports have assessed the economic considerations of underground transmission projects and are summarised in Section 3.3.2. The assessments concluded that due to the significant additional costs associated with underground construction methods, an underground project was not likely to represent a cost-efficient solution for the transmission network requirements considered in those assessments. Consistent with the findings of these reports, the capital costs estimated for a conceptual underground project (Section 3.3) are higher when compared to an overhead project cost. The costs for an underground project are different for each project and subject to local conditions.

The conceptual project timeline (Section 3.4) indicates that a full underground project would take at least 7 years to deliver, in addition to the time required need to define, tender, refer, assess, and build an underground transmission line. AusNet's enquiry about delivery times for HVDC converter station manufacture indicate the current lead times for the supply of converter stations are up to 8 years. This indicates that a full underground project would be further delayed and not meet the Victorian power supply needs in the required timeframe.

Consideration of typical environmental, amenity, land use and cultural heritage issues for both overhead transmission lines and underground cables (Section 4) highlights that an underground project, while having some advantages, typically affects some environmental values more than an overhead transmission line, for example, Aboriginal cultural heritage. An underground project is likely to provide benefits associated with reduced greenhouse gas emissions, improved visual and landscape outcomes, and better outcomes associated with some land uses, aviation, and natural hazards.

However, underground projects typically present more issues associated with extensive ground disturbance for the whole alignment that impact cultural heritage, geology, landform and soils, traffic, and biodiversity. Therefore, underground and overhead transmission projects both result in impacts to landholders along their alignments and the ultimate extent of impacts are dependent on the specific project description (location, design, construction method etc.) and the values present (i.e., existing conditions at proposed locations).

Both underground cables and overhead transmission lines located on private land create a permanent encumbrance on the land restricting certain land uses and farming, forestry and extractive industry practices. Both options do not allow the construction of buildings or structures in the easement, limit the depth into the soil and height of activities and require AusNet approval for certain activities.

The technical considerations associated with an HVDC underground project (Section 3.1) highlight that while an underground cable may be a feasible technical solution, additional requirements, cost and schedule implications result in an underground project not meeting the Project objectives. An underground project also would not meet the Victorian Government energy policy goal to increase the affordability and accessibility of energy services.

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Appendix A: Differences between HVAC and HVDC underground circuits

HVAC underground circuits

Electricity is generated in three phases. Consequently, HVAC underground circuits typically comprise of three phases, with a minimum of one cable per phase required to transmit electricity. Additional cables are required to be installed on each phase where high capacity is required. A high capacity 500kV single circuit transmission line could require nine cables, with a high capacity 500kV double circuit transmission line requiring twice as many cables.

Underground cables are laid in trenches and may be installed with or without conduits. The cables are laid in a bedding material, called thermal backfill, to protect them from damage. Thermal backfill is required where the native soil properties do not facilitate uniform heat dissipation. Thermal backfill is a form of stabilised sand that promotes even heat dissipation ensuring the cables are able to operate within their design rating and minimises differential heating which could affect the integrity of the cables.

Underground cables are joined in pits with one phase or one circuit per pit. Depending on the number of cables per phase, additional cable pits per cable joint may be required.

Figure 1 shows a typical arrangement of a double circuit HVAC 500kV underground cable easement and Figure 2 shows an example of a HVAC underground cable trench.

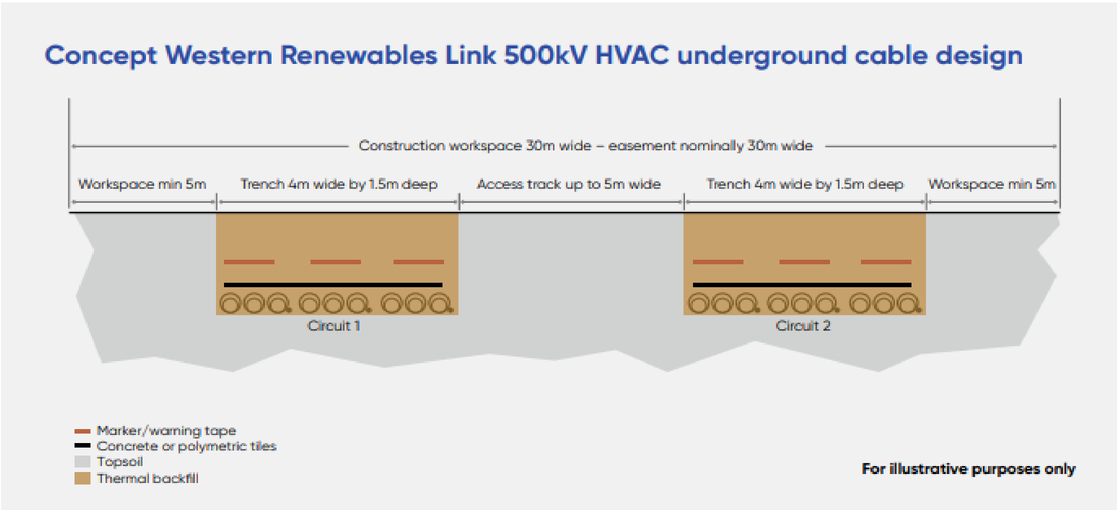

Figure 1 Typical arrangement of a HVAC double circuit 500kV underground cable easement (Source: AusNet)

Source: Cabling-29.jpg (580×376) (emc-global.com)

Figure 2 Example of a single circuit 400kV underground cable trench on Sas Al Nakheel to Mussaffah Project

Alternating current has higher power loses compared to direct current over long distances. The losses are directly proportional to distance or the length of a transmission line. HVAC underground cables have higher losses than overhead HVAC transmission lines if reactive compensation is not installed. Reactive compensation reduces the capacitance that builds up in underground cables, which if not managed reduces power flow.

Reactive compensation is provided by a type of transformer known as a shunt reactor, with one shunt reactor required for each phase of the transmission circuit. Reactive compensation is required at regular intervals, approximately 30km apart for a 500kV transmission line. Reactive compensation stations are approximately 210m by 190m (4 ha) for 500kV transmission lines. A typical example of a shunt reactor is shown in Figure 3.

Figure 3 Conceptual image of a typical shunt reactor (type of reactive compensation plant) in a substation. *Source: (Hitachi Energy, 2024)*.

HVDC underground circuits

Direct current has less losses compared to HVAC and is more efficient for transmitting large amounts of electricity over long distances. Due to its inherent stability control, direct current is increasingly being used to connect transmission networks with different system strengths. Where HVDC circuits connect transmission networks that use alternating current, electricity is converted from alternating current to direct current and vice versa at the other end of the transmission circuit.

The conversion of alternating current to direct current occurs via converter stations, using various technologies to convert AC to DC and DC to AC. The two technologies currently in use are line commutated converters and voltage source converters, with voltage source converters providing advantages over line commutated converters. An example of a 525kV voltage source converter station is shown in Figure 4. Converter stations of this size typically require at least 6 ha to construct and operate and maintain. Similar size converter stations would be required for a HVDC solution for the Project.

Figure 4 Schematic of Viking Link's Bicker Fen converter station. The facility comprises two voltage source converters. *Source: (National Grid UK, 2024)*

Two or three cables are required for HVDC circuits depending on the configuration. For example, symmetrical monopoles have two cables per circuit whereas a bipole with metallic return has three cables per circuit.

HVDC underground cables are similar in size to HVAC underground cables depending on the number of cables per phase and power transfer capacity of the cables. Cable length per cable drum is similar to HVAC (i.e.,550 m to 1100 m). As with HVAC underground cables, the cables can have aluminium or copper conductors. Copper conductors are used where high-power transfer capacity is required. Each cable drum weighs approximately 30 t, however cable drums up to 50 t are used in some applications. Heavy or specialised vehicles are required to transport the cable drums.

HVDC underground cables are joined in pits with one circuit per pit. Figure 5 shows a conceptual arrangement of a HVDC underground cable trench for one circuit configured as a bipole and the other as a symmetrical monopole. Figure 6 shows a typical cable drum and cable being pulled into a trench. Figure 7 show an example of HVDC underground cables installed in a trench.

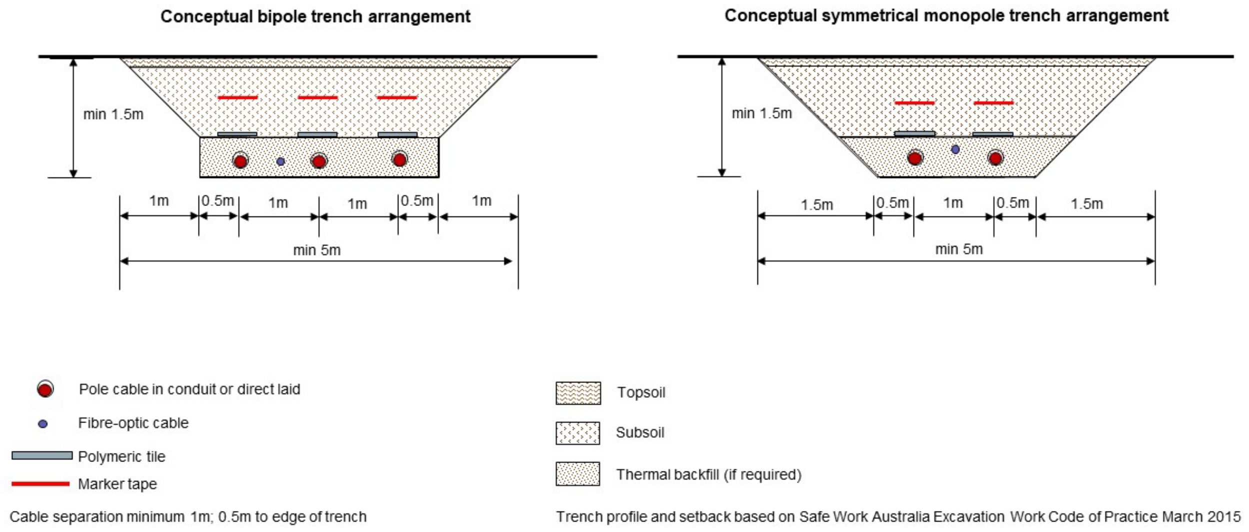

Figure 5 Conceptual arrangement of HVDC underground cable trenches for a single circuit using bipole and symmetrical monopole technologies

Figure 6 Example of a HVDC cable drum. *Source: WWW TenneT Suedlink*

Figure 7 Example of HVDC 525kV cables being laid for SuedLink *Source: WWW TenneT Suedlink*

HVDC transmission lines are typically end-to-end links with no provision for intermediate connections due to technical considerations and the significant cost of making such connections.

Technical considerations

In 2009, CIGRE undertook a review of the service experience of HVAC and HVDC underground and submarine cable systems (CIGRE, 2009) which was subsequently updated in 2020 (CIGRE, 2020). The review examined 29,350 km of HVAC underground cables and 1,045 km of HVDC underground cable performance in the 10 years to December 2015 and included reports of 742 faults on HVAC underground cables and 2 faults on HVDC underground cables. The review found most faults occur in the first ten years of operation, with the most faults occurring in the first two to three years of operation.

Third party mechanical damage (e.g., cables being dug or ripped up by excavators or bulldozers or damaged by augering or fence post or pile driving) accounted for more than 24% of cable faults, with manufacturing defects and cable installation issues accounting for most other faults. Most installation faults occur at joints.

CIGRE (2020) reported repair times for HVAC and HVDC underground cables were between two and four weeks for cable faults and up to one month for cable joint faults. There was no significant change from the findings of the earlier review in 2009.

While HVAC overhead transmission lines experience more faults, the majority of the faults are transient and are resolved through auto-reset capability or can be repaired within hours or days. The ease with which faults can be detected and repaired has significant advantages for the operation of the Victorian transmission network.

Table 3.1 of Attachment II presents a comparison of overhead and underground construction for key technical aspects. The comparison considers HVAC and HVDC technologies.

Appendix B: Criterial and technical considerations for route selection of an underground project

The environmental, cultural heritage and social criteria and technical considerations that AusNet used to guide overhead transmission line and underground cable route selection are set out in the table below. These criteria are based on the experience of AusNet and its technical advisors. Where a 'x' is indicated it means that the criteria was not relevant for the assessment.

Route Selection Criteria

Criterion	Overhead transmission line routes	Underground cable routes
Environment, cultural heritage, and social criteria		
Avoid national parks, state parks and reserves, where practicable. Where avoidance is not practicable, minimise impacts on values protected by park or reservation.	✓	✓
Avoid land zoned Public Conservation and Recreation, where practicable. Where avoidance is not practicable, minimise impacts on values protected by zone.	✓	✓
Avoid significant landscape overlays in planning schemes where practicable. Where avoidance is not practicable, minimise impacts on scenic values protected by overlay.	✓	✓
Utilise topography, where practicable to reduce views to overhead transmission lines, to provide a backdrop to overhead transmission lines and to avoid or reduce skyline silhouette of structures and conductors.	✓	✗
Maximise separation to dwellings and other sensitive facilities, where practicable. The minimum separation is the edge of the easement. Transmission line easements and transmission lines (overhead or underground) are designed to provide the required electrical safety clearances and protect people from electric and magnetic fields.	✓	✓
Avoid critically endangered and endangered ecological communities and species habitat, where practicable. Where not practicable, preferentially use natural breaks or degraded or previously disturbed areas within those communities and habitat. Where practicable, reduce length of route in these communities and habitat. For overhead transmission lines, consider opportunities to overfly vegetation.	✓	✓
Avoid registered Aboriginal and historic cultural heritage sites and heritage overlays in planning schemes where practicable. Where not practicable, avoid or reduce impacts on the values protected by the site or listing.	✓	✓
Avoid cemeteries and crematoriums, where practicable, noting that overhead transmission lines can overfly cemeteries.	✓	✓
Avoid reservoirs and large waterbodies, where the infrastructure may constrain recreation and/or management activities where practicable. Where not practicable, design infrastructure to minimise constraint on recreation and management activities.	✓	✓

Criterion	Overhead transmission line routes	Underground cable routes
Environment, cultural heritage, and social criteria		
Avoid large wetlands and wetlands supporting threatened species habitat where practicable. Where not practicable, site infrastructure to reduce impacts on threatened species, e.g., align with bird flight paths.	✓	✓
Avoid areas subject to inundation, where practicable. Where not practicable, design infrastructure having regard to the risks associated with that inundation. Where practicable, preferentially avoid watercourse crossings in areas with evidence of channel avulsion, i.e., where river channels may move during a major flood event.	✓	✓
Avoid riparian corridors where practicable, and/or where watercourse crossings are required. Align crossings perpendicular to watercourse, where practicable. Preferentially use natural breaks in riparian vegetation or degraded or previously disturbed areas. Where practicable, identify crossings that enable riparian vegetation to be retained.	✓	✓
Avoid diagonal crossings of paddocks where practicable, noting the property boundaries in some sections of the route are generally north–south, east–west such that diagonal cuts will be necessary in some instances.	✓	✓
Align route with property back boundaries and made and unmade road reserve boundaries where practicable, noting that made and unmade road reserves may contain threatened native vegetation and species habitat.	✓	✓
Reduce potential for sterilising agricultural land by aligning route with internal fences, cultivated paddocks and paddock headland areas, where practicable. Where practicable, locate route to keep structures at or close to fences, cultivated paddock access lanes and headlands. Aligning electricity infrastructure with fences necessitates segmenting and isolating the fence to protect people and stock from induced and fault current.	✓	✓
Preferentially avoid shelter belts and windrows where practicable, noting that shelter belt and window trees can be preserved by limited trimming at overhead transmission line crossings, or avoided in underground construction by HDD or other trenchless construction methods where feasible to employ such methods.	✓	✓
Avoid tree protection zones, where practicable, noting that the extent of tree protection zones varies with species and ground conditions. Adopt 15m separation as a default target to avoid impacts on tree root systems.	✓	✓
Reduce impacts on plantations by aligning route with access roads and firebreaks where practicable. Avoid, where practicable, creating small areas of plantation coupes outside the easement that would be uneconomic to manage and sterilise that resource.	✓	✓

Criterion	Overhead transmission line routes	Underground cable routes
Environment, cultural heritage, and social criteria		
Reduce impacts on mineral and extractive resources by locating route in or adjacent to infrastructure areas, worked out areas and amenity/safety buffers where practicable.	✓	✓
Avoid blasting safety zones associated with hard rock quarries where practicable. A 250m buffer is recommended to protect the public, structures and infrastructure from fly rock and blast overpressure in accordance with Earth Resources (2021) The Victorian Planning Authority has applied blasting buffers in recent precinct structure plans.	✓	✓

Technical Criteria

Criterion	Overhead transmission line routes	Underground cable routes
Technical considerations		
Avoid sharp bends, where practicable. Bends increase friction on underground cables when they are being pulled through ducts. A series of tight bends may cause pulling tensions to exceed the safe limit for the cable, potentially damaging the cable. Overhead transmission line bends require strain structures where the deflection angle is greater than 10 degrees. Bends greater than 10 degrees require substantially larger structures increasing the physical bulk, foundation requirements and cost.	✓	✓
Avoid constructing underground cables across slopes, where practicable. Try to align route perpendicular to slopes; preferentially follow ridges and spurs if sufficient workspace available. Running underground cables across slopes necessitates constructing a road to provide a stable workspace.	✗	✓
Where practicable, locate overhead transmission line structures outside areas subject to watercourse channel avulsion or migration.	✓	✗
Where practicable, make perpendicular crossings of roads and watercourses.	✓	✓
Where practicable, make perpendicular crossings of rail lines away from bridges and other structures.	✓	✓
Avoid highly erosive soils and landslip hazard areas, where practicable.	✓	✓

Criterion	Overhead transmission line routes	Underground cable routes
Technical considerations		
Avoid watercourse crossings in deeply incised narrow valleys, where practicable, as topography may preclude HDD or other trenchless construction methods if geotechnical feasible.	✓	✓
Allow sufficient space either side of watercourses, sealed roads and rail lines for HDD or other trenchless construction methods if these methods are feasible, i.e., allow sufficient space for pulling ducts through the boreholes. Ducts, the length of the borehole, need to be laid out in line with the borehole.	✗	✓
Where practicable, avoid co-locating with incompatible linear infrastructure where management of potential impacts would be technically difficult and costly.	✓	✓
Where practicable, locate overhead transmission line structures adjacent to road reserves to maximise clearance over roads, ideally within quarter span.	✓	✗
Where practicable, select route to reduce length of access tracks required to access structure sites, cable joint pits and HDD sites.	✓	✓

Appendix C: Underground routes suggested by community

If undergrounding was feasible for the Project, an end-to-end full underground solution a HVDC solution would reduce losses and the need for reactive compensation stations when compared to a HVAC solution. Two circuits would be required for a HVDC bipole solution and four circuits for a HVDC symmetrical monopole solution to meet the required power transfer capacity and contingency.

Separate trenches (bipole or symmetrical monopole solution) would be required for each circuit to provide the required thermal performance and enable a circuit to be safely repaired while the other circuit is maintained in service. The trenches would need to be at least 5m apart.

Western Freeway

Installing two trenches and if required, cable joint pits in the Western Freeway reserve is theoretically possible where sufficient space is available in the road reserve outside the carriageways, and where environmental values can be effectively managed. However, tree root protection zones, threatened ecological communities and species, and Aboriginal and historic cultural heritage may impose significant constraints on the available workspace.

Where insufficient space exists, the trenches would need to be installed under each emergency lane and part of the carriageways or in adjacent farmland and rural residential areas. There are numerous sections of the Western Freeway reserve where this would be necessary.

Examples of limited available space are the Western Freeway at Gordon and at Bacchus Marsh. Figure 1 shows the Western Freeway at Gordon and Figure 2 a conceptual arrangement of HVDC bipole trenches. The Western Freeway at Bacchus Marsh is shown in Figure 3 and a conceptual arrangement of HVDC bipole trenches in Figure 4.

Source: Google Maps (Street view) Image capture 2018 © 2021 Google

Figure 1 Looking west along Western Freeway at Gordon where the freeway is located in a cutting

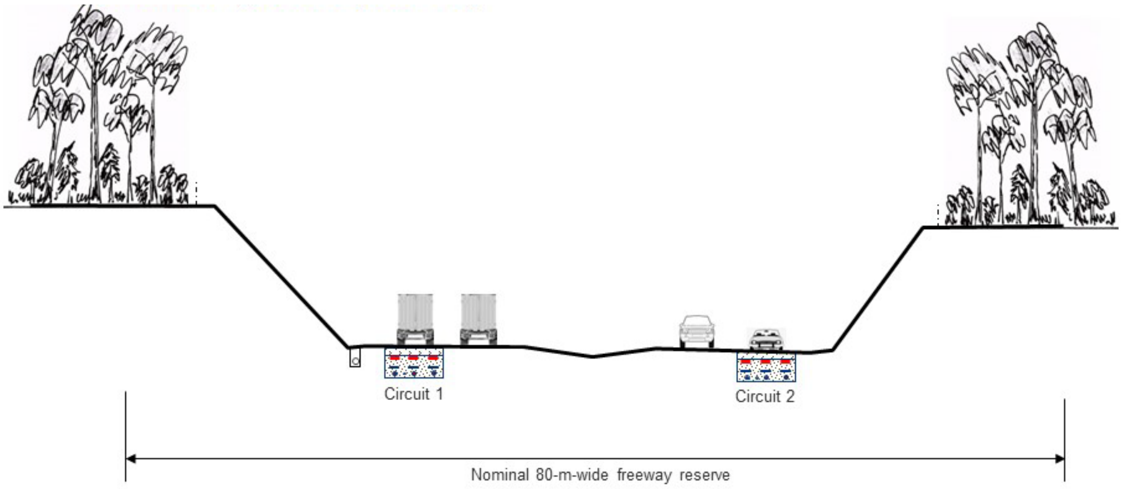

Figure 2 Conceptual arrangement of HVDC bipole cable trenches in westbound and eastbound carriageways of Western Freeway at Gordon

Source: Google Maps (Street view) Image capture 2021 © 2021 Google

Figure 3 Western Freeway at Bacchus Marsh where available workspace outside the carriageways is reduced to approximately 5m due to the narrower freeway reserve

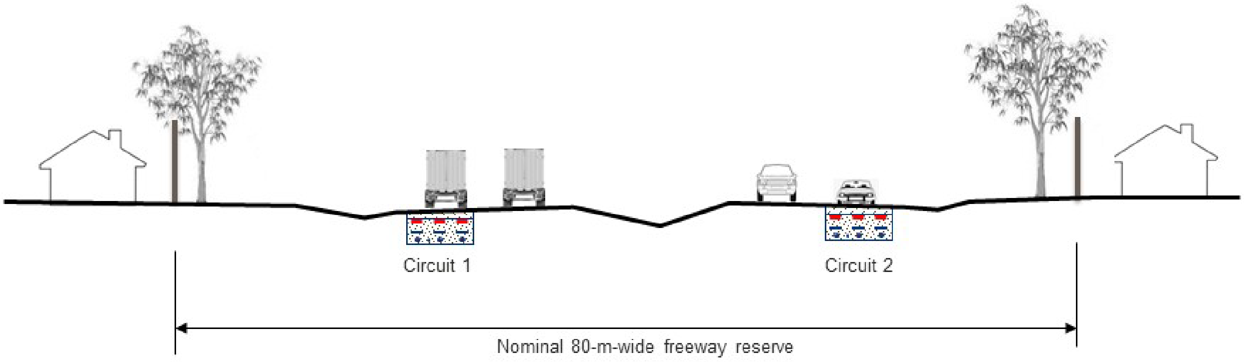

Figure 4 Conceptual arrangement of HVDC bipole cable trenches in westbound and eastbound carriageways of Western Freeway at Bacchus Marsh

Where the freeway is elevated, the cables would need to be installed in ducts strapped to bridges and culverts. Where such arrangements are not technically feasible or are not approved by the road authority, the underground cables would need to be re-routed into adjacent farmland and rural residential areas. Figure 5 shows the constraints at Pykes Creek Reservoir, which is an example of the complexities associated with elevated sections of freeway.

Source: Google Maps (Street view) Image capture 2018 © 2021 Google

Figure 5 Western Freeway at Pykes Creek Reservoir where underground cables would need to be attached to bridge structures if approved by road authority

Cable joint pits (if required) need to be located in accessible places not under road carriageways. The pits and associated link boxes need to be accessible for testing and repairs if a fault occurs at the joint, the most common point of failure on the underground cable. Cable joint pits would typically be located outside road reserves in adjacent land where more workspace is available.

The cost of relocating underground utility services (water, sewerage, power, telecommunications and stormwater) could also be substantial. For example, the proposed Western Freeway route identified by Amplitude in 2021 that, in part, uses High Street (Figure 6) and Melton Valley Drive (Figure 7) through Melton would require utility service relocation to make space for the underground cables.

Construction in freeway and road reserves over long distances introduces significant cost and disruption due to the constrained workspace, double handling of materials and traffic management. Lane closures would be required for extended periods restricting traffic and causing congestion. The complexities, time, cost and safety risks associated with detecting and repairing cable faults within freeway and road reserves can be significant. Road authorities have advised that they have concerns about overhead and underground transmission lines in freeway and road reserves as they may constrain planned and future road upgrades.

For these reasons, underground routes in freeway and road reserves are not favoured. Short sections are possible where no technically feasible alternatives exist, and constructability issues can be effectively managed.

Source: Google Maps (Street view) Image capture January 2021 © 2021 Google

Figure 6 High Street, Melton where workspace is limited by landscape planting, power lines and underground utility services

Source: Google Maps (Street view) Image capture February 2020 © 2021 Google

Figure 7 Melton Valley Drive at Melton where workspace is limited by roadside trees, power lines, Melton Valley Golf Club and underground utility services

Ballarat–Horsham 220kV transmission line

An underground route along the existing Ballarat–Horsham 220kV transmission line easement is constrained in places by terrain, rural residential and residential properties.

The steep hills and ridges in the vicinity of Glenlofty, Mount Lonarch, Lexton and Waubra provide significant constraints on the ability to identify feasible underground routes adjacent to the existing Ballarat–Horsham 220kV transmission line. These constraints necessitate routes around the steep hills and ridges some distance from the existing transmission line.

Steep terrain, particularly side slope, introduces constructability and operation and maintenance issues. To avoid major earthworks to establish a working bench for the trenches and cables being exposed to lateral forces from slope failure (e.g., slumping or landslips) cables are typically run perpendicular to the slope. While short sections in steep terrain are manageable, avoidance is a key objective.

Rural residential and residential subdivisions constrain workspace in the Ballarat–Horsham 220kV transmission line north and east of Ballarat. Figure 8 shows the workspace constraints at Brown Hill east of Ballarat. The abutting subdivisions, and the land uses and developments located within them, provide significant constraints on identifying feasible underground routes in this area. For example, Figure 9 shows how two HVDC bipole trenches would need to be arranged to address the constraints. If a symmetrical monopole solution was adopted, the four circuits would need to be arranged in two sets of two circuits either side of the existing transmission line.

Figure 8 Residential development abutting Ballarat–Horsham 220kV transmission line easement at Brown Hill (existing transmission line shown in blue, underground route shown in yellow)

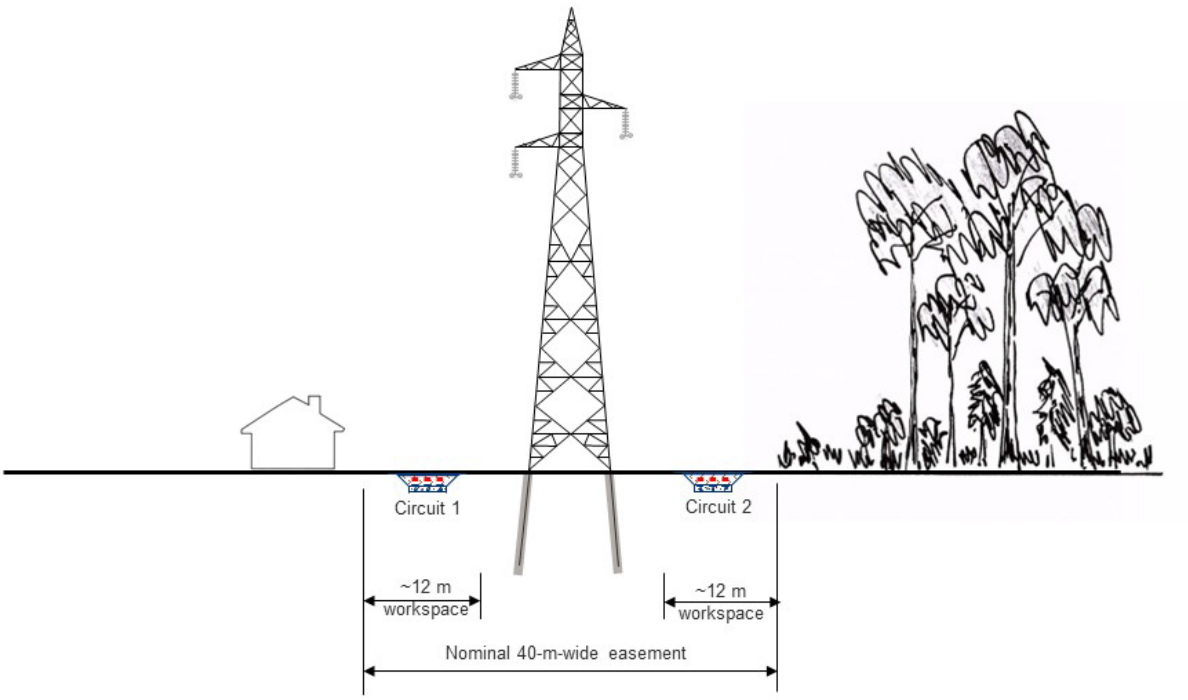

Figure 9 Cross section of Ballarat–Horsham 220kV transmission line showing conceptual arrangement of HVDC bipole underground cable trenches in easement

Appendix D: Conceptual full underground routes

The conceptual full underground routes developed by AusNet and their lengths are described below.

Conceptual full underground (UG) route 1a (via Mount Prospect) (191km)

The route commences at Bulgana and runs parallel to the Ballarat–Horsham 220kV transmission line adjacent to the easement to provide adequate construction workspace.

The route deviates from the existing transmission line to avoid watercourses close to the easement and steep sided hills at Glenlofty, near Amphitheatre, near Lexton, at Waubra and near Learmonth.

At Lexton the route diverges from the Ballarat–Horsham 220kV transmission line to pass north of Waubra wind farm. The route follows Mount Beckworth Road (Coutts Road) and mostly property boundaries east to Allendale where it turns southeast to pass north of Kingston and south of Hepburn Lagoon to the Ballarat–Bendigo 220kV transmission line at Mount Prospect.

The route generally follows Blampied–Mollongghip Road south to Dean–Mollongghip Road. After crossing this road, the route continues southeasterly to Springbank where it turns east to run mostly along property boundaries to near Greendale. The route passes north of Pykes Creek Reservoir, unavoidably traversing 'Glen Pedder' historic property due to constraints imposed by the waterbody, terrain and landslip hazard areas along the escarpment north of the reservoir.

Turning southeasterly, then easterly the route passes between Darley and the Lerderderg State Park, traverses the sand quarry infrastructure areas, crosses Merrimu Reservoir via the Diggers Rest–Coimadai Road and follows property boundaries where practicable to Sydenham Terminal Station.

Conceptual full UG route 1b (via Mount Prospect); variation on Route 1a (192km)

This route is the same as conceptual full UG route 1, except it follows the Ballarat–Bendigo 220kV transmission line, where practicable, from Mount Prospect to Dean. The Central Highlands water main, farm dams and steep side slopes on Bullarook Hill force the route away from the existing transmission line in places.

Conceptual full UG route 2a (via Creswick Plantation) (187km)

This route follows conceptual full UG route 1 to Blowhard. At Blowhard, the route leaves the Ballarat–Horsham 220kV transmission line to run easterly to Sulky avoiding the constraints along the existing transmission line as it approaches Ballarat.

At Sulky, the route enters Creswick Plantation. The route follows Larkins Track and then Codes Forest Road and James Hill Road through Glen Park State Forest to Wattle Flat. The route utilises these plantation access roads and forest access roads to reduce impacts on adjacent vegetation. The route traverses White Swan Reservoir catchment avoiding historic gold mining water races in Glen Park State Forest.

Passing south of Pootilla and Bullarook, the route generally follows property boundaries to the Moorabool River West Branch where it joins and follows conceptual full UG route 1 to Sydenham Terminal Station.

Conceptual full UG route 2b (via Ballarat Terminal Station); variation on Route 2a (191km)

This route is the same as conceptual full UG route 3 except that it continues to follow the Ballarat–Horsham 220kV transmission line through Ballarat to Ballarat Terminal Station. The route uses Dorringtons Road, Old Melbourne Road and Mahers Road before turning northeast to the Western Freeway. Running in farmland, it follows the Western Freeway to near Wallace where it turns northeast to cross the Ballarat Line and Western Freeway to join conceptual full UG route 1 at Springbank. The route then follows conceptual full UG route 1 to Sydenham Terminal Station.

Appendix E: Peer review

Technical Memorandum

Memo No: TM 25C5-002-22545274 Rev A

Issue to: Impact Assessment Unit
Department of Transport and Planning
Level 17, I Spring Street, Melbourne, VIC 3000

Melbourne, 15th May 2025

Dear Sir/Madam,

Technical Memo: Independent Peer Review of the Feasibility Assessment for an Underground 500kV Transmission Line for the Western Renewables Link

Introduction:

The Western Renewables Link incorporates a new overhead double circuit 500kV transmission line, approximately 190km long, from near Bulgana in Victoria's west to Sydenham in Melbourne's north-west ("the Project"). The Department of Transport and Planning (DTP), formerly the Department of Environment, Land, Water, and Planning (DELWP), commissioned Bureau Veritas (BV) to conduct an independent peer review of the "Assessment of feasibility for an underground 500kV transmission line for Western Renewables Link" (the "Undergrounding Report") developed by AusNet Services (the "Proponent") as a part of their Environment Effects Statement for the project.

The Western Renewables Link Project includes:

- Construction and operation of a new overhead double circuit 500kV transmission line from a new terminal station near Bulgana Terminal Station to Sydenham Terminal Station;
- Construction and operation of a new terminal station near Bulgana Terminal Station;
- Expansion of existing Bulgana Terminal Station and connection to the proposed new terminal station via a single circuit 220kV transmission line;
- Connection works at Sydenham Terminal Station including bay modification and extension;
- Upgrade of Elaine Terminal Station through diversion of an existing line; and
- Protection system upgrades at connected terminal station sites.

BV Scope:

The independent peer review focused on the Undergrounding Report [1] and the RLB Cost Report [2], evaluates the suitability, adequacy, and accuracy of the draft Undergrounding Report. Further, the peer review assesses the reliability of the analysis, assumptions, and conclusions related to the potential modes of construction outlined in the Underground report, in the context of the Environmental Effects Statement (EES) scoping requirements. This technical memorandum summarises the review process, key findings, improvements implemented following BV's recommendations, and limitations which have been considered during the review process.

Technical Memorandum

Memo No: TM 25C5-002-22545274 Rev A

BV Key Personal:

The following multi-disciplinary team from Bureau Veritas with expertise in electrical engineering, environmental and financial analysis conducted the independent peer review.

- Lukas Bulinski (Senior Electrical Engineer);
- Mehedi Hasan (Senior Electrical Engineer);
- Pamitha Gunaratne (Electrical Engineer); and
- Stuart Hitchcock (Senior Financial and Environmental Specialist).

Documentation:

BV have reviewed the following key and supplementary documents listed below:

- Key documents:
  - V3_1-001-ANS-0000-EAP-RP-0001_0.16_Undergrounding Report [1]; and
  - TM504_WRL_FINAL (RLB Report 28.08.23) _Redacted_3 [2].
- Supplementary documents:
  - V5_1-001-ANS-0000-EES-RP-0003_0.3_Chapter 6 - Project Description Final Draft [3];
  - WRL final EES scoping requirements [4];
  - Mott MacDonald HVDC System Design and Meeting Minutes including Amplitude comms [5];
  - WRL Underground Report - RFI - timeline assumptions - Rev A [6];
  - Western Victoria Renewable Integration RIT-T PADR [7]; and
  - Guideline 3: Cost estimation for essential public assets [8].

BV Independent Peer Review Methodology:

The following steps have been undertaken:

1. *Documentation Review*: Review of Undergrounding Report [1], RLB Cost Report [2], and the associated documents as listed above;
2. *Risk Assessment*: Preparation of a red flag report (including Comments Resolution Sheet (Excel) attached as an appendix A to this technical memo) highlighting possible technical risks considering their impact on project construction, operation, revenue generation, environment, health, safety, and social aspects. Findings were classified based on likelihood and consequences/severity of risks using the Risk Matrix in Table 1.
3. *Stakeholder Engagement*: Three meetings were held with the Proponent and DTP (January 29th 2025, March 17th 2025, and April 1st 2025) to discuss the Undergrounding Report and Comments Resolution Sheet; and
4. *Final Assessment*: Review of the updated Draft Undergrounding Report received from the Proponent following the BV recommendations on April 24, 2025 (ref: V4_1-001-ANS-0000-EAP-RP-0001_0.20 [9]).

Technical Memorandum

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Table 1: BV Risk Rating Matrix

Risk Rating	Brief Description of the Risk
Seek Clarification	Request further information
None	No risk and no mitigation measures required, or insufficient information to assess the risk
Low	Low risk and mitigation measures may not be required
Medium	Medium risk may have considerable material impact and may require significant monitoring and mitigation
High	High risk may have high material impact and require immediate mitigation strategies to avoid high economic losses

Key Findings:

The findings of BV's review are documented in the attached Comments Resolution Sheet Excel (Appendix A). These findings identify potential risks, their severity, and recommended mitigation measures where applicable. The assessment considers technical feasibility, cost, environmental and social implications, and alignment with project objectives for the options considered.

Limitations of the Review

The following list the limitations associated with the review process.

- Undergrounding Report Limitations:
  - An environmental impact assessment has not been provided for an overhead or underground transmission line options;
  - No Overhead HVAC design cost estimate is provided for BV's review;
  - Community stakeholder engagement documentation was not provided for BV's review;
  - No technical reports were provided justifying the selection of preferred undergrounding options (HVAC vs HVDC);
  - EES Attachment I - Assessment of Alternatives (i.e. partial undergrounding) was outside the scope of BV's review;
  - No detailed routing studies specific to overhead or underground cable installation were provided; and
  - Community consultation records regarding specific overhead or underground route concerns were not provided for BV's review.
- RLB Report Limitations:
  - The scope of services and design documentation referenced in Attachment B of the RLB Cost Report was not provided for BV's review;
  - Conceptual HVDC transmission line design option documentation prepared by Mott MacDonald (2023) was not provided for BV's review;

- Life cycle costs were excluded as no detailed design was available to calculate the cost of losses; and
- Cost estimates were noted to be for general comparison purposes only between technologies and therefore would currently range from Class 4 to Class 5 under the Victorian State Project Cost Estimation Manual estimate classification system.

Conclusion

The Project is at its early development stage. The primary purpose of the Undergrounding Report [9], is to explain why a fully underground transmission line project is not feasible to stakeholders including the local community and respond to EES scoping requirements. The Report provides a high-level comparison between overhead and conceptual underground transmission line options, including their respective technologies, construction methods, route selection criteria, costs, technical, environmental and social implications.

Bureau Veritas' independent peer review of the Undergrounding Report [1] and RLB Cost Report [2] has identified several changes to improve the clarity of the Underground Report. While the Proponent addressed many specific suggestions, they maintained that the current level of detail in the updated Underground Report [9] is sufficient for its intended purpose. BV acknowledges this position while noting the recommended improvements (such as but not limited to: inclusion of the Electric and magnetic fields section, additional references and assumptions were added, etc.) would have strengthened the overall assessment.

Regarding financial comparison, BV considers the analysis of conceptual HVDC underground transmission line options in the RLB Cost Report to be satisfactory considering this early stage of development. The design information used for the estimate is conceptual in nature, and therefore under Victorian State Project Cost Estimation Manual estimate classification system [8] Class 4 to Class 5 estimate is appropriate for this stage of project planning. While the financial comparison provides sufficient information to determine the significant cost of the conceptual HVDC underground transmission line options, BV notes that the RLB Cost Report does not include costs such as environmental and planning approvals, environmental mitigation measures, land acquisition, and compensation that would likely further increase costs.

The Underground Report only provides a very high-level comparison regarding how the overhead and underground transmission line options affect environmental and social values. BV understand that every Project is unique and has its own environmental and social concerns, which may have severe impact on the Project. BV reasonably agrees with the high-level desktop assessment of social and environmental impacts included in the Underground Report. However, the assessment outcomes are not supported by any project-specific studies, reports, or data. In the absence detailed analysis, the outcomes presented in the Underground Report may not accurately reflect the actual conditions of the project. Given the scale of the project, BV consider that the assessment framework should have considered other industry standard approaches such as Triple Bottom Line [10] to evaluate economic, environmental, and social impacts of the Project, in addition to the current assessment framework.

In BV's opinion, the report reasonably demonstrates that the fully underground transmission line solution does not meet the Project objectives established by the Australian Energy Market Operator (AEMO) and the Proponent under the National Electricity (Victoria) Act 2005 (NEVA) [11]. Furthermore, the Underground Report reasonably responds to the EES scoping requirements by considering the feasible project alternatives[1], including the rationale for the preferred mode of construction (i.e. full overhead or full underground).

Issued in Melbourne on 15/05/2025

On behalf of BUREAU VERITAS

Asset Integrity and Reliability Services Pty Ltd

[1] The assessment is limited to a comparison between fully overhead and fully underground transmission line options, excluding any consideration of partial undergrounding alternatives.

REFERENCES

[1] AusNet, "Assessment of feasibility for an underground 500kV transmission line for Western Renewables Link," 2025.

[2] R. L. Bucknall, "Western Renewables Link (WRL) DC options," RLB, 2023.

[3] AusNet, "EES Main Document, Chapter 6: Project Description," 2024.

[4] V. S. G. D. o. T. a. Planning, "Scoping Requirements Western Renewables Link Environment Effects Statement," 2023.

[5] M. Macdonald, "Western Renewables Link (HVDC System Design Alternative)," 2023.

[6] "AusNet response to RFI from Bureau Veritas," AusNet, 2025.

[7] "Western Victoria Renewable Integration," AEMO, 2018.

[8] "Guideline 3: Cost estimation for essential public assets," Emergency Management Victoria, Department of Justice and Community , 2019.

[9] AusNet, "V4_1-001-ANS-0000-EAP-RP-0001_0.20_Undergrounding Report (clean)," 2025.

[10] "Providing Certainty to Electricity Transmission Investment," Energy Grid ALLIANCE, 2021.

[11] V. Legislation, "National Electricity (Victoria) Act 2005," [Online]. Available: https://www.legislation.vic.gov.au/in-force/acts/national-electricity-victoria-act-2005/033. [Accessed 7th May 2025].

Technical Memorandum

Memo No: TM 25C5-002-22545274 Rev A

DISCLAIMER:

Appendix A

COMMENTS RESOLUTION SHEET WITH RISK RANKING
Department of Transport and Planning, Western Renewables Link

Client:	Department of Transport and Planning
Project Title:	Assessment of feasibility for an underground 500kV transmission line for Western Renewables Link
Project No:	22545274
Reference Document:	V3_1-001-ANS-0000-EAP-RP-0001_0.16_Undergrounding Report and TM504_WRL_FINAL (RLB Report 28.08.23)_Redacted_3
Document number (CSR)	25C5-002-22545274

					Current Comments			Round 1							Round 2			
Item No.	Reference No.	Rev. No.	Subject	Status	Reviewer Initials	Risk Ranking	Date	BV Comment (Round 1)	Reviewer Initials	Risk Rating	Date	Client Response (Round 1)	Responder Initials	Date	BV Comment (Round 2)	Reviewer Initials	Risk Rating	Date
V3_1-001-ANS-0000-EAP-RP-0001_0.16_Undergrounding Report																		
1	SECTION 1	Draft	General	CLOSED	MH	Low	4/24/2025	**Risk:** The feasibility assessment in the report lacks consistency when comparing overhead and underground options. While the report mentions evaluating an 'underground 500 kV transmission line as a feasible alternative,' in some sections (Section 1.1), it refered only HVDC for underground and HVAC for overhead, (Section 3.1.2), it compares HVDC underground to HVAC underground. Additionally, Figure 3.1 in the Undergrounding Report compares "HVAC overhead and underground" with "HVDC overhead and underground". This inconsistency throughout the report creates confusion regarding the options the Proponent is considering as viable. **Comment:** BV recommends that the Proponent clearly articulate the preferred options for Underground Vs Overhead considered in the Introduction (see Section 1,5, and 6) of the Undergrounding Report. Furthermore, the RIT-T Project Assessment Draft Report (PADR) (AEMO, 2018) concluded that the HVDC option is unlikely to address the identified need or be technically or commercially feasible, primarily due to its lack of flexibility in facilitating future generation connections.Therefore, in BV's opinion, the Undergrounding Report should have focused on comparing the feasibility of overhead HVAC vs underground HVAC options also, as the PADR has already identified the HVDC underground option as infeasible.	MH	Medium	4/3/2025	Accepted. Report reviewed and revised (sections 1, 5 and 6) to clarify that it is a conceptual HVDC underground project being compared to a HVAC overhead project with section 3.1 explaining the difference between HVAC and HVDC circuits and providing the justification for HVDC being the preferred underground technology, and section 3.2 providing the conceptual design. E.g. refer to new text in section 1 that states - *High voltage direct current (HVDC) is the preferred technology for the conceptual underground project as it is more cost effective than high voltage alternating current (HVAC) for long distances which is required for the 190km project* . References to the 'conceptual underground project' throughout the report relate to the conceptual HVDC underground project described in section 3.2.3. Context on the differences between HVAC and HVDC for both overhead and underground is retained as the purpose of this report is to provide further explanation to stakeholders and the community who may not be familiar with differences between the technologies. Agree with BV's comment that the PADR has already identified the HVDC underground option as not feasible. The purpose of this report (Attachment II) is to provide stakeholders and the community with additional explanation of why HVDC underground option is not feasible, including consideration of environmental, amenity and cultural heritage issues which were not considered in the RIT-T process at the time.	Proponent	4/14/2025	Accepted with comment. Closed	MH	Low	4/24/2025
2	SECTION 1	Draft	General	CLOSED	MH	None	4/17/2025	**Risk:** The underground report does not include a high-level summary of the key findings from EES Attachment I – Assessment of Alternatives. **Comment:** BV recommends including a high-level summary of EES Attachment I – Assessment of Alternatives in Section 1 (Introduction) of the Undergrounding Report. This will provide the reader with a clear overview of preferred options, making it easier to understand without reading other documents and improving the overall flow and coherence.	MH	Low	4/3/2025	No change proposed. The reference to EES Attachment I - Project development and assessment of alternatives is provided for context so that the reader is aware separate works were undertaken for the proposed overhead transmission line to address EES scoping requirements. EES Attachment I provides a summary of the development of the proposed overhead route, site selection for associated infrastructure such as laydown areas, assessment of alternative overhead routes as suggested by stakeholders and community, and an investigation into the potential to partially underground a small section of the route at Darley. The content of EES Attachment I is not relevant to EES Attachment II - Assessment of feasibility for an underground 500kV transmission line for WRL and therefore a summary of it's contents has not been included. The purpose of EES Attachment II is to provide further explanation to stakeholders and the community as to why a fully underground project is not considered feasible.	Proponent	4/14/2025	Accepted, Closed	MH	None	4/17/2025
3	APPENDIX B	Draft	Social	CLOSED	LB	None	4/17/2025	**Risk:** The Route Selection Criteria Table (Appendix B) in Underground Report does not address the Aviation Impact (e.g., Melton Aerodrome, Source: Google Maps – Melton Air Services). **Comment:** BV recommends including Aviation Impact in the Route Selection Criteria Table (Appendix B) in Underground Report.	LB	Medium	4/3/2025	No change proposed. Aerodromes are considered sensitive facilities in the following route selection criteria - *Maximise separation to dwellings and other sensitive facilities, where practicable* . Sensitive facilities include aerodromes, schools, public facilities such as parks and recreation areas etc.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
4	FIGURE 3.2	Draft	Social	CLOSED	LB	None	4/24/2025	**Risk:** Figure 3.5 caption is missing **Comment:** BV Recommend adding the caption of "Potential underground routes investigated by AusNet" in Figure 3.5 to ensure clarity and proper referencing.	LB	None	4/3/2025	Accepted. Figure title updated to - Potential underground routes identified by AusNet.	Proponent	4/14/2025	Updated. Closed	LB	None	4/24/2025
5	SECTION 3.2	Draft	Social	CLOSED	LB	None	4/17/2025	**Risk:** The route selection criteria outlined in Section 3.2 and Appendix B of the Undergrounding Report appear to be generic. The Proponent does not specify site-specific criteria relevant to the selected routes (e.g., state forests, lakes, rivers, cultural heritage sites). **Comment:** In BV's opinion, the route selection criteria in Section 2.2 and Appendix B should be refined to incorporate site-specific considerations.	LB	Low	4/3/2025	No change proposed. Agree that site-specific criteria are relevant to route selection. This is discussed in section 3.2.2 Consideration of local conditions and existing infrastructure. Route selection criteria capture site-specific values. For example, "Avoid national parks, state parks and reserves, where practicable." is applicable to all state forests along the route. Likewise, "Avoid registered Aboriginal and historic cultural heritage sites and heritage overlays in planning schemes where practicable" is applicable to all registered culture heritage sites and heritage overlays along the route. It is not practicable to list all individual places, values, infrastructure etc. in the criteria as the route is 190km long.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
6	TABLE 3.1	Draft	Electrical	CLOSED	LB	None	4/17/2025	**Risk:** The statement in the Proponent's DC Undergrounding Report, Table 3-1, regarding the requirement for a 30 km compensation station appears excessive. **Comment:** In BV's opinion, it is recommended to reference the compensation station interval distance specific to the project, along with any studies undertaken to date, and the influence of load and future generation connections on compensation sizing. BV seeks clarification on the technical basis for the proposed compensation station spacing (eg: 30 km).	LB	Seek Clarification	4/3/2025	No change proposed. The level of detail requested is not proportionate to the conceptual level of design presented in the report. The level of design developed does not allow the distance between compensation stations to be definitively listed. Given the number and size of cables required the spacing of 30km is considered reasonable by AusNet. There is not much literature on this as there are no 500kV AC cables longer than 40km.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
7	SECTION 3.4	Draft	General	CLOSED	MH	None	4/17/2025	**Risk:** The estimated lead time of 7 to 8 years for supplying the HVDC converter stations is notably long, raising concerns about potential delays. **Comment:** BV recommends reviewing this lead time to align with current market offerings. **Reference:** Hitachi Energy built a 500 kV converter station within 18 months, as noted in the Marinus Link Community and Stakeholder Information Pack 2024.	MH	Medium	4/3/2025	No change proposed. The 18 month timeframe referenced in the Marinus Link Community and Stakeholder Information Pack is referring to the time that is expected to be required to physically construct the converter station - "*The first converter station building will take up to 18 months <u>to build</u>* " Environmental approvals and associated impact assessment are interested in the duration of impact associated with construction activities (i.e. for how long local communities/residents/the environment) would be impacted. The impact assessment does not consider the lead time required to order, manufacture and transport the converter station components as part of the design planning stage as this would occur under existing permits and does not require additional approval. Also noting the Marinus Link converter station referred to has not been built yet and is an estimate only. The Project has not yet received environmental and planning approval. The order for the Marinus Link HVDC equipment was placed early 2024 and it is planned to be commissioned in 2030 (https://www.hitachienergy.com/in/en/news-and-events/customer-success-stories/marinus-link). This 6+year timeframe excludes the time needed to scope, design and tender prior to the contract being awarded. The 7 to 8 year timeframe referenced in the Undergrounding Report was provideded by a supplier in July 2023. The supplier advised that the estimated lead time for new orders of equipment from design through to energisation for two sets of HVDC (+/-kV) 1500MW bipole converter stations is in the order of 7 to 8 years. AusNet considers the reference to this timeframe in the Undergrounding Report is appropriate to inform an indicative timeline for a conceptual project.	Proponent	4/14/2025	Accepted, Closed	MH	None	4/17/2025
8	SECTION 4	Draft	Environmental	CLOSED	MH	Low	4/24/2025	**Risk:** The Underground Report (Section 4) does not include the Electromagnetic Fields (EMF) impact comparison between overhead and underground transmission lines. **Comment:** BV recommends including a high-level summary of the EMF comparison assessment for overhead and underground transmission lines in Section 4.1.1 of the underground report. **Reference:** *https://eecs.uq.edu.au/files/24316/01_Comparison_Table-1.pdf *https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/measuring-magnetic-fields	MH	High	4/3/2025	Accepted. Discussion of a comparison of impacts related to electric and magnetic fields for overhead and underground transmission lines is now provided in Section 4.2 'Amenity and cultural heritage issues'.	Proponent	4/14/2025	Updated. Closed	MH	Low	4/24/2025

9	SECTION 3.3.1	Draft	Electrical	CLOSED	LB	None	4/17/2025	**Risk**: The statement regarding hindered connections for future projects may be inaccurate, as the technical details of future REZ projects are not yet known. There are significant technical and commercial risks associated with connecting renewable plants directly to transmission lines (whether AC or DC). The risks of DC undergrounding may also be overstated. **Comment:** Section 3.1.1 states: "A key objective of the Western Renewables Link is to facilitate renewable energy development in western Victoria by providing cost-efficient connections for renewable energy generators. This objective will be achieved more cost-efficiently with HVAC transmission, as converter stations are not required for connections..." This statement is highly dependent on the location of future projects and their capacity requirements. In general, DC transmission over longer distances is more economical, as demonstrated by HVDC Light [Ref: "Evolution of HVDC Light," ABB, accessed Jan. 25, 2025. Available: https://new.abb.com/news/detail/4224/evolution-of-hvdc-light] and other voltage-source-based technologies. Additionally, the Proponent suggests that the 500 kV AC option will provide access to REZs, and that selecting the DC option will limit REZ opportunities. However, it is highly likely that neither the DC nor the AC options will be able to connect to REZs along the transmission line, and the only feasible connection point may be at the terminal stations/substations. The REZ expansion risk for both the 2x AC line and the DC direct link is similar, as it would not be commercially viable for renewable generators to connect directly to a 500 kV system (AC or DC). Another option to consider is that installing a new AC or DC line could help offload the existing AC line, enabling REZ connections to the existing towers.	LB	Medium	4/3/2025	No change proposed. The first comment is not relevant to the risk identified (future connections to WRL) as it is about the economics of long HVDC system. The referenced HVDC link does not provide any economic details of the projects, nor does it claim that HVDC light is more cost-efficient than HVAC. The Proponent also notes that the longer distance project noted in the link provided is overhead HVDC which we are not assessing. As stated in the report HVDC is the preferred technology for the conceptual underground project as it is more cost effective than HVAC for long distances which is required for the 190km project. Regarding the second comment "it is highly likely that neither the DC nor the AC options will be able to connect to REZs along the transmission line" is incorrect based on: • the inability of HVDC to accommodate connection of unknown future projects. It is not possible to connect to a HVDC network unless the details of the connections are known and designed into the HVDC network before it is built. Even if the HVDC network is designed for known future connections the cost of adding this functionality to the initial build and then the cost of the connection to a HVDC network later are so high developers would choose to build at an alternative more economical location. • The ability to connect to HVAC networks can be seen by the multiple connections that have occurred within Victoria over the past years.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
10	SECTION 3.1.1	Draft	Electrical	CLOSED	LB	Low	4/24/2025	**Risk:** It is unclear whether this is an opinion or an independent statement in Section 3.1.1 "In Victoria, overhead transmission using HVAC transmission is commonly used because it has better power transfer capacity, is easier to maintain, more cost-efficient, and allows for the connection of new generation and storage along the line without the need for a converter station…" **Comment**: In BV's opinion, the statement should have given referance. Moreover, existing DC link operators in Victoria could be consulted on operational costs, maintenance efforts, etc. **Reference: "**Murraylink APA." Hitachi. [Online]], [Ref: "Basslink APA." APA. [Online]].	LB	Seek Clarification	4/3/2025	Accepted. Added reference to source material as suggested - VicGrid, 2024. Overhead and underground transmission fact sheet, March 2024. https://www.energy.vic.gov.au/__data/assets/pdf_file/0014/700106/Overhead-and-underground-transmission-factsheet.pdf The source material for the referenced statement is considered sufficient and additional consultation is not warranted.	Proponent	4/14/2025	Updated. Closed	LB	Low	4/24/2025
11	SECTION 3.3	Draft	Financial	CLOSED	LB	None	4/17/2025	**Risk:** Section 3.3 quotes the respected and peer-reviewed Parsons Brinckerhoff HVAC and HVDC comparison costing model, which was peer-checked by the National Grid Statement [Ref: "Electricity Transmission Cost Study"]. **Comment:** The peer review confirmed that the total life cycle cost is the same for both overhead and underground options, but the capital cost of the underground option is about 10 times the cost of an overhead line. The report [Ref: Electricity Transmission Cost Study] concludes that decisions should be made on a case-by-case basis after consultation with communities and government. It is noted that both the Parsons Brinckerhoff and National Grid statements are over 10 years old. It may be prudent to consult OEMs on new technologies that may optimize the cost of new equipment.	LB	Seek Clarification	4/3/2025	No change proposed. The peer review (National Grid, 2012, Electricity Transmission Cost Study: How does the independent report compare to National Grid's view?) refers to the Parsons Brinckerhoff (2012) study with the following statement - *The report [PB 2012] finds that, excluding build costs , the cost of operation, maintenance and energy losses over the life of the connection is broadly the same for undergrounding and overhead lines* . Note this is referring to O&M costs only and specifically excludes consideration of captial costs. It is not speaking to "total life cycle costs" as interpreted by BV in Comment #11. The peer review then goes on to state in relation to their own data - *Our own calculations on total life time costs are also broadly in line with the report's [PB 2012] findings*. That is, National Grid's data aligns with the capital cost (build cost) + O&M cost presented in the PB (2012) study. Attachment II Undergrounding Report is based on information available at the time of drafting. In addition to the Parsons Brinckerhoff (2012) study, reference to additional, more recent case studies is provided in the report including Transgrid (2022) and NSW Government (2024) for the HumeLink Project and VicGrid (2024) for new transmission lines to service the proposed offshore wind projects in Gippsland. The purpose of the report is to provide further explanation to stakeholders and the community as to why a fully underground project is not feasible for WRL. The Proponent considers the cost estimates provided are sufficient in summarising the general industry understanding of the difference between overhead transmission lines and underground cables.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
12	TABLE 3.2	Draft	Financial	CLOSED	LB	None	4/17/2025	**Risk:** The cost estimate for the DC option appears inconsistent compared to other estimates. **Comment:** A report by UQ and Curtin researchers suggests that the underground/overhead ratio of capital expenditure is 4-4.6x based on reference cases, which is significantly different from the cost estimates quoted in the report of 6-30x. BV notes that RLB report estimates the cost associated with undergrounding DC options. BV recommends comparing the RLB estimates with proposed AC overhead options and including them in the report to reflect the project-specific cost comparison. **Reference:** *Murraylink: 220MW, 150kV, 176 km [Ref: "Murraylink APA." Hitachi. [Online]] – A directly buried cable with a similar length to the Western Renewables Link project. *The estimated cost for the Murraylink DC link extension (200 km) was $191M in 2012 [Ref: "Murraylink Transmission Company Pty Ltd Contingent Project Proposal." [Online]].	LB	Medium	4/3/2025	No change proposed. Cost estimates for HVAC overhead transmission lines and comparison to underground transmission lines is provided through reference to the PADR (2018), Amplitude (2021), Parsons Brinkerhoff (2012), Transgrid (2022) and VicGrid (2024) that provides multiple lines of evidence that the cost of underground is materially higher compared to overhead transmission lines. A conceptual underground project was developed by Mott MacDonald to inform Attachment II: Assessment of feasibility for an underground 500kV transmission line for WRL and an independent cost estimate. The purpose of the report is to provide further explanation to stakeholders and the community as to why a fully underground project is not feasible. The Proponent considers the cost estimates provided are sufficient in summarising the general industry understanding of the cost difference between overhead transmission lines and underground cables which is the purpose of section 3.3. Also of note is that the project referenced by BV, MurrayLink, is not a comparable project as it's capacity (220MW) is 13.6 times lower than the 3000MW HVDC capacity or 23 times lower than the 5400MVA HVAC capacity of WRL. The following response is also provided in response to Comment #30 regarding the University of Queensland and Curtin University report. The study by Madigan et al (2023) explains that costs of underground cables are approximately four to 20 times higher than overhead lines depending on the type of installation. HVDC options in this study only considered subsea cables of 2 different AC/DC converter technologies. Land based HVDC lines were not considered in their study. The report states that maintenance requirements for overhead and underground line components of HVDC are expected to be similar of HVAC overhead and underground. They do note also that the additional maintenance requirements associated with AC/DC converter stations would be significant resulting in overall higher lifetime maintenance requirements. There is no data source provided for the basis of the assumed 1.5% (HVAC Overhead) and 0.15% (HVAC Underground) of the total capital cost per annum are the typical O&M costs for transmission line projects used by Teegla and Singal (2015). The author has also assumed that maintenance requirements for overhead and underground line components of HVDC are expected to be similar of HVAC overhead and underground. However, it is noted that the additional maintenance requirements associated with AC/DC converter stations would be significant resulting in overall higher lifetime maintenance requirements. Without being able to verify the source of the data which could vary considerably based on project location and technical parameters that is the basis of the assumed % cost of maintenance it can not be referenced or relied upon for costing. The costs quoted are also noted that they are only for general comparison purposes between overhead and underground technologies and should not be applied to specific projects.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
13	FIGURE 3.2	Draft	Financial	CLOSED	LB	None	4/17/2025	**Risk:** The report does not specify which areas are considered high risk in the context of overhead transmission lines. The map specified, Potential Underground Routes Investigated by proponent, does not specify risk areas in the area of interest. **Comment:** A high impact assessment assigned to specific geographic areas may offer additional technical options, including hybrid solutions where only part of the line route is overhead. Referred to Line No. 16 (Comment 4)	LB	Medium	4/3/2025	No change proposed. The purpose of the report is to assess the feasibility of an underground 500kV transmission line as an alternative to the proposed overhead transmission line, specifically a full (point to point) underground project, to resond to community interest as to why such a project is not feasible. The scope of the report does not include consideration of hybrid solutions where only part of the route is overhead. Four potential full conceptual underground routes were identified by AusNet as presented in Figure 3.5 and described in Appendix D. The Proponent considers the conceptual level of detail provided is sufficient in meeting the purpose of the report which is to assist in responding to stakeholder and community interest as to why a fully underground project is not feasible. EES Attachment I - Project development and assessment of alternatives provides mapping and detailed discussion of environmental, social and cultural heritage constraints along the proposed overhead transmission line and for alternative overhead routes. Impact assessment is also provided in Attachment I for an assessment of potential partial underground routes at Darley including discussion for why partial undergrounding was not considered suitable at other locations along the proposed route. The location speciifc impact assessment and level of detail provided in Attachment I is required to meet the EES scoping requirements.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
14	SECTION 3.1.1	Draft	Electrical	CLOSED	MH	None	4/17/2025	**Risk:** In Section 3.1.1 (paragraph 3), it is mentioned that "Renewable energy sources like solar and wind also typically generate AC electricity." **Comment:** Solar generates DC electricity. If the connection point is AC, it is converted from DC to AC. Moreover, most wind turbine output is unregulated AC (both voltage and frequency are unregulated), which is first converted to DC and then to regulated AC (with both voltage and frequency controlled). In BV's opinion, future renewable energy sources, connection point and methodologies should have mentioned to justify the feasible option	MH	None	4/3/2025	Accepted. Sentence revised to - "Renewable energy sources like solar and wind typically generate DC electricity which is converted into AC electricity using inverters."	Proponent	4/14/2025	Updated. Closed	MH	None	4/17/2025
15	SECTION 1	Draft	Environmental	CLOSED	LB	None	1/29/2025	**Risk:** As highlighted in Section 1 and 4, community concerns are identified as one of the most sensitive issues for the proposed project. However, this issue is not properly considered in the Route Selection Criteria Table (Appendix B) in Underground Report. **Comment:** BV recommends including community concerns as one of the criteria in Route Selection Criteria Table (Appendix B) in Underground Report.	LB	High	4/3/2025	No change proposed. Community concerns are intrinsically linked with the environment, social and cultural heritage values explictly referenced in the route selection critieria. The route selection criteria implicitly consider community/social values. For example: - The agricultural industry is a key source of employment and economic activity in the region. Therefore, route selection criteria such as avoiding diagonal crossing of paddocks and reducing potential for sterilising agricultural land were developed and adopted. - The community in some areas of the Project highly value the landscape and amenity of the rural environment and informed the Project that they specifically moved to their the area for its landscape and amenity. Therefore, route selection criteria of maximising separation distances to houses, utilising topography to minimise visual impacts and avoiding significant landscape overlays to minimise impacts on scenic values were developed and adopted. - The local community value the region's natural features and landscapes. Route selection criteria relating to landscape and biodiversity values such as avoiding parks and reserves and land use zones as public conservation and recreation reflect these values.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025

16	SECTION 5.2	Draft	Financial	CLOSED	LB	None	1/29/2025	**Risk:** Objective 2 states that the project aims to create opportunities for NEM strategic development. The conceptual underground project focuses on a single option: a 100% underground, point-to-point DC link. However, other DC options could be considered. The report further states that due to cost, time, land requirements, and difficulty in establishing efficient connections for generators, the DC proposal does not meet the objectives. This statement may be interpreted as non-scientific. **Comment:** The report states: "The underground project would not meet the project objectives or the National Electricity Rules and is therefore not a feasible alternative. This is further discussed in Section 5. … A conceptual underground project would be a point-to-point HVDC connection from Bulgana to Sydenham and would not easily facilitate connection for electricity generators along the route." This statement is an opinion, as it does not consider a multi-terminal station, which can facilitate future renewable generators and is available from reputable vendors in Australia. Modern topologies include LCC-HVDC and VSC-HVDC, which can operate under different control characteristics and have been studied for offshore wind use in Europe. However, it is noted that multi-terminal systems can suffer from transient overvoltage, which must be studied in further detail during a detailed analysis. The statement further claims that "it would be difficult for generators to establish efficient connections to HVDC cables," without providing scientific justification. This depends on the size and location of future generation projects. In fact, it is widely accepted in the industry that transmitting high energy over long distances is best serviced by HVDC links, with multiple reference projects in Western Europe and Brazil supporting this. **References:** *https://ieeexplore.ieee.org/document/9474603/ *https://ieeexplore.ieee.org/document/8571582/ *https://ieeexplore.ieee.org/document/7125495/ *https://ieeexplore.ieee.org/document/8602314/ *https://ieeexplore.ieee.org/document/8994513/	LB	Medium	4/3/2025	No change proposed. The purpose of the report is to assess the feasibility of an underground 500kV transmission line as an alternative to the proposed overhead transmission line, specifically a full (point to point) underground project, to respond to stakeholder and community interest as to why such a project is not feasible for WRL. The scope of the report does not include consideration of other DC options or multi terminal systems. It is not the role of AusNet to develop alternate projects. The National Electricity Rules under the National Electricity Law govern the operation of the NEM. The Regulatory Investment Test for Transmission (RIT-T) and following Victorian Government Order issued under the National Electricity (Victoria) Act 2005 identify the credible option (the proposed overhead transmission line) that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. No other options were determined to be preferred options by the RIT-T and therefore would not be supported by the National Electricity Rules. Statement in full is that "Due to cost, time and land required for convertor stations, it would be difficult for generators to establish cost efficient connection to a HVDC transmission line". Cost comparisons are discussed earlier in the report in section 3.3 and timing in section 3.4 which provide the justification for the statement.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
17	V3_1-001-ANS-0000-EAP-RP-0001_0.16_Underground Report	Draft	General	CLOSED	MH	None	4/24/2025	**Risk**: Incorrect revision dates **Comment:** The document revision does not fall in the sequence. Also, the date on the title page does not match the revision date. When referring to the document, incorrect document details will lead to incorrect information.	MH	None	4/3/2025	Accepted. The year for V0.16 has been corrected from 2022 to 2024 in the revision table. V0.17 date on the title page matches date in revision table.	Proponent	4/14/2025	Updated. Closed	MH	None	4/24/2025
18	V3_1-001-ANS-0000-EAP-RP-0001_0.16_Underground Report	Draft	General	CLOSED	MH	None	4/17/2025	**Risk:** Document number is missing the version of the document. **Comment:** Missing version number of the document. Including the accurate or current version number in the document control will avoid referring to older versions.	MH	None	4/3/2025	No change proposed. AusNet uses Aconex for document control which has a document number separate to a revision number. Both the document number and revision number are included in the file name. Aconex is a well accepted document control system.	Proponent	4/14/2025	Accepted, Closed	MH	None	4/17/2025
19	SECTION 6	Draft	General	CLOSED	MH	None	4/17/2025	**Seek Clarification:** The Underground Report concludes that undergrounding is not a viable option considering objectives 2 and 3 stated in Section 5. However, BV notes that there are other projects in Australia that plan to implement undergrounding as a preferred option (See references below [2] and [3]). BV seeks clarification on whether the option analysis (Overhead vs Undergrounding) was assessed using any commonly advocated framework such as multi-criteria analysis and triple bottom line [1], etc. **References:** [1] https://www.aemc.gov.au/sites/default/files/documents/energy_grid_alliance.pdf (Section 1.3) [2] Murraylink: 220MW, 150kV, 176 km [Ref: "Murraylink APA." Hitachi. [Online]] – A directly buried cable with a similar length to the Western Renewables Link project. [3] The estimated cost for the Murraylink DC link extension (200 km) was $191M in 2012 [Ref: "Murraylink Transmission Company Pty Ltd Contingent Project Proposal." [Online]].	MH	Seek Clarification	4/3/2025	No change proposed. The report concludes that undergrounding is not a viable option as (1) it is not supported by the National Electricity Rules, and (2) does not meet some of the Project objectives. The Project objectives as provided in section 2.1 are specific to this project, Western Renewables Link, and not other projects in Australia. The purpose of the Undergrounding Report is to provide further explanation to stakeholders and the community as to why a fully underground project is not feasible as it is a key area of interest for them. The purpose of the report is not to provide a detailed or technical options analysis for overhead vs underground. It is not the role of AusNet to develop alternate projects. The National Electricity Rules under the National Electricity Law govern the operation of the NEM. The Regulatory Investment Test for Transmission (RIT-T) and following Victorian Government Order issued under the National Electricity (Victoria) Act 2005 identify the credible option (the proposed overhead transmission line) that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. No other options were determined to be preferred options by the RIT-T or Order under the National Electricity (Victoria) Act and therefore would not be supported by the National Electricity Rules.	Proponent	4/14/2025	Accepted, Closed	MH	None	4/17/2025
20	SECTION 3.3.3	Draft	General	CLOSED	MH	None	4/24/2025	**Risk:** In Section 3.3.3, Paragraph 2, the WVTNP project is mentioned, however is not included in the Key Terms (Page 6) **Comment:** In BV's opinion, WVTNP should have included in the Key Terms section so that readers understand the project name.	MH	None	4/3/2025	Accepted. Acronym expanded in full on first mention (now section 3.3.2) and added to key terms table as suggested.	Proponent	4/14/2025	Updated. Closed	MH	None	4/24/2025
21	SECTION 4	Draft	General	CLOSED	MH	None	4/24/2025	**Risk:** In Section 4.1.1, there are some minor numbering inconsistencies (This should be Section 4.1). **Comment:** In BV's opinion, numbering should be consistent throughout the document structure.	MH	None	4/3/2025	Accepted. Level 3 headings in Section 4.1 have been corrected to level 2 headings. Numbering is now consistent throughout the document.	Proponent	4/14/2025	Updated. Closed	MH	None	4/24/2025
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22	Section 3	Final	Financial	CLOSED	MH/SH	None	4/17/2025	**Risk:** The scope of services and design documentation referred to in Attachment B has not been provided for BV's review, creating a gap in the available information needed for assessment. **Comment:** BV recommends Proponent to provide the Attachment B and any other referenced attachments for BV's review	MH/SH	Seek Clarification	4/3/2025	No change proposed. The RLB cost estimate report was provided to BV for reference to assist in the peer review of the Undergrounding Report. The concept design has also been provided to BV for consideration and was discussed at a meeting with DTP IAU, Councils, Bureau Veritas, Amplitude and Mott MacDonald. The purpose of the Undergrounding Report is to respond to community interest by providing further explanation as to why a fully underground project is not feasible. The Proponent considers the cost estimates provided in the Undergrounding Report are sufficient in summarising the general industry understanding of the difference between overhead transmission lines and underground cables which is the purpose of section 3.3. Cost estimates for HVAC overhead transmission lines and comparison to underground transmission lines is not solely reliant on the RLB cost estimate. The report references a range of other case studies including the PADR (2018), Amplitude (2021), Parsons Brinkerhoff (2012), Transgrid (2022) and VicGrid (2024) that provides multiple lines of evidence that the cost of underground is materially higher compared to overhead transmission lines.	Proponent	4/14/2025	Accepted, Closed	MH/SH	None	4/17/2025
23	Section 1.3	Final	Financial	CLOSED	MH/SH	None	4/17/2025	**Risk:** The report acknowledges that "drawings and information used to estimate are considered to be of a conceptual nature only and therefore the estimates would currently range from Class 4 to Class 5 under the Victorian State Project Cost Estimation Manual estimate classification system," but it is unclear whether the Proponent adequately address the implications of this classification for project planning and risk management. **Comment:** Cost estimates based on conceptual designs have a high degree of uncertainty and therefore risk. BV recommends including a note states that "Given the conceptual nature of the designs, there will be opportunities to optimize and potentially reduce costs as designs are further developed."	MH/SH	None	4/3/2025	No change proposed. Note paragraph 3 in section 1.3 which already states - "*Once a preferred option is selected and the design matures, the next set of estimates are expected to be a Class 2 to Class 3 classification, which is technically 'business case' ready and suitable as a 'budget baseline'. At this stage it is expected that design will be well defined (and accordingly) the risk allowances and sensitivities can be reduced* ."	Proponent	4/14/2025	Accepted, Closed	MH/SH	None	4/17/2025
24	Section 4.7	Final	Financial	CLOSED	MH/SH	None	4/17/2025	**Risk:** The report excludes costs related to environmental permits and approvals, creating a gap in the overall project budget estimation. **Comment:** Environmental and regulatory issues can lead to significant delays and cost overruns for large infrastructure projects. In BV's opinion, it would be beneficial to include contingency for environmental mitigation measures as a separate line item in Section 4.7 in RLB report.	MH/SH	Low	4/3/2025	No change proposed. As acknowledged in the RLB report (s1.3) the design information used for the estimate is conceptual in nature and therefore the estimate aligns with this level of detail (Class 4 to Class 5 estimate). Class 5 estimates are suitable for initial project scoping and broad cost estimates, and Class 4 is suitable for preliminary project planning and feasibility studies. The purpose of the Undergrounding Report is to respond to community interest by providing further explanation as to why a fully underground project is not feasible. It is not within the scope of the report to present a technical options analysis of overhead vs underground. It is acknowledged that there may be additional costs associated with the project that are not included in the RLB estimate such as environmental and planning approvals and environmental mitigation measures, land acquisition and compensation etc. Attachment II explicitly qualifies that "*The cost estimate does not include the project development and impact assessment and approvals re-work that would be required to progress a full underground concept for the Project* ." Regardless of the above, the cost of the environmental and planning approval process would be similar for both the overhead and underground options as they would be subject to the same regulatory approval processes and require equivalent level of environmental assessment (EES). The cost of mitigation measures is highly dependent on the Project design, site-specific conditions and impact assessment which is not available for the underground option and not commensurate with the conceptual design and Class 4/5 level cost estimate.	Proponent	4/14/2025	Accepted, Closed	MH/SH	None	4/17/2025
25	Title Page	Final	General	CLOSED	MH/SH	None	4/17/2025	**Risk:** The RLB report (published 28 August 2023) and the underground report (published 9 December 2024) have a time gap between their publication dates, potentially affecting the accuracy and relevance of cost estimates. **Comments:** The undergrounding report 1-001-ANS-0000-EAP-RP-0001 potentially identified new risks or cost-saving opportunities with DC link options that were not known in year 2023. BV recommends the Proponent to review (update the RLB report base on undergounding report) to determine whether newly identified risk control measures may incur additional project expenditures, or if the opportunities identified could optimise the design concept and thereby reduce the project cost.	LB	Low	4/3/2025	No change proposed. No new information has been incorporated into Attachment II since August 2023 that would influence the Class 4/5 level cost estimate prepared by RLB which is based on a conceptual design. The RLB cost estimate is one of many cost estimates / case studies referenced in Attachment II including the Western Victoria Renewable Integration RIT-T PADR (AEMO, 2018), Amplitude Consultants (2021), Parsons Brinkerhoff (2012), Transgrid (2022), (NSW Parliament Legislative Council, March 2024), and VicGrid (2024) that provides multiple lines of evidence that the cost of underground is materially higher compared to overhead transmission lines. The purpose of the Undergrounding Report is to respond to community interest by providing further explanation as to why a fully underground project is not feasible. The Proponent considers the cost estimates provided in the Undergrounding Report are sufficient in summarising the general industry understanding of the difference between overhead transmission lines and underground cables which is the purpose of section 3.3.	Proponent	4/14/2025	Accepted, Closed	MH/SH	None	4/17/2025

26	Section 1.1	Final	General	CLOSED	PG/LB/SH	None	4/17/2025	**Risk:** The report lacks specific details regarding specialist supplier engagement and country of manufacture for critical components, creating uncertainty about supply chain reliability and cost accuracy. **Comment:** There has been significant change in the global supplier landscape for HVDC links in recent years. BV observes that while the methodology and overarching assumptions mention "supplier estimates" for DC Converter Stations as being "turnkey for an Engineer Equipment Package (EEP)" and "liaising with other Specialist Suppliers to obtain pricing for bespoke items," the report does not provide details on the number of suppliers contacted, selection criteria, countries of manufacture, or whether competitive or indicative pricing was obtained. BV recommends documenting the supplier engagement process and explaining how the final EEP costs were determined and validated.	PG/LB/SH	Low	4/3/2025	No change proposed. AusNet/RLB have not gone through a tender for the equipment so the definitive costs sought by BV are not available. The proposed documenting of how final EEP costs are determined and validated are considered unlikely to add much value and disproportionate to the Class4/5 cost estimate and concept level design. The RLB cost estimate is one of many cost estimates / case studies referenced in Attachment II including the Western Victoria Renewable Integration RIT-T PADR (AEMO, 2018), Amplitude Consultants (2021), Parsons Brinkerhoff (2012), Transgrid (2022), (NSW Parliament Legislative Council, March 2024), and VicGrid (2024) that provides multiple lines of evidence that the cost of underground is materially higher compared to overhead transmission lines. The Proponent considers the cost estimates provided in the Undergrounding Report are sufficient in summarising the general industry understanding of the difference between overhead transmission lines and underground cables which is the purpose of section 3.3.	Proponent	4/14/2025	Accepted, Closed	PG/LB/SH	None	4/17/2025
27	Section 1.2	Final	Electrical	CLOSED	LB/SH	None	4/17/2025	**Risk:** The Options Analysis presented in Section 1.2 appears to be misaligned with the Undergrounding Report, potentially impact the accuracy of cost estimates and future decision-making. **Comments:** The options analysis in Section 1.2 may not be compatible with the undergrounding report 1-001-ANS-0000-EAP-RP-0001. In BV's opinion, Option 1A appears to be discounted as it is not mentioned in the Undergrounding Report. Additionally, the description of Option 2B in Table 1 is unclear regarding whether the quoted 1500MW capacity refers to total system capacity or per-circuit capacity. BV recommends reconciling these discrepancies to establish a reliable basis for accurate cost estimation and technical assessment.	LB/SH	Low	4/3/2025	No change proposed. V0.16 of the undergrounding report (Attachment II) reviewed by BV does refer to Option 1A in section 3.3.2 and Table 3-2. Regardless, V0.17 of the undergrounding report no longer refers to Option 1A and instead presents the cost estimate for Option 2B only (not explicitly titled Option 2B but the design/components are described). The description of Option 2B is consistent across the two reports with no discrepancy. The quoted 1500MW refers to per circuit, with a total capacity of 3000MW provided by two circuits.	Proponent	4/14/2025	Accepted, Closed	LB/SH	None	4/17/2025
28	Section 1.3	Final	Financial	CLOSED	LB	None	4/17/2025	**Risk:** The report follows the Victorian State Project Cost Estimate manual; however, the specific reference details for this document are not provided, potentially impacting the validity and accuracy of the cost estimation methodology. **Comments:** The absence of a specific reference to the Victorian State Project Cost Estimate manual raises concerns about which version or edition was applied. BV notes that the Victorian government offers multiple guidelines for public works and infrastructure projects, and other relevant standards (AS, ISO, NOR) also provide valuable guidance. Alternative industry-standard cost estimation models such as CART or PERT have not been considered. Additionally, ISO 15663:2021, which provides specific guidance for petroleum and natural gas sectors with emphasis on lifecycle cost analysis, could serve as a useful reference for large power projects. BV recommends clearly documenting the specific standards and guidelines applied to ensure transparency and consistency in cost estimation methodologies.	LB	Medium	4/3/2025	No change proposed. The report only refers to the classification system of the Victorian State Project Cost Estimation Manual i.e., the reference to Class 4 and Class 5 estimates. Refer s1.3 - *At this stage the drawings and information used to estimate are considered to be of a conceptual nature only and therefore the estimates would currently range from Class 4 to Class 5 under the Victorian State Project Cost Estimation Manual estimate classification system. This Class 4 and 5 classification aligns with information which is suited to developing concept and feasibility estimates and the selection of preferred options.* The Proponent considers sufficient information is provided about what level of cost estimate has been produced.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025
29	Section 3.3	Final		CLOSED	PG	None	4/17/2025	**Risk:** The report does not address known and potential cost impacts from current and future manufacturing and supply chain constraints or global market conditions, creating significant uncertainty in the budget forecasts. **Comment:** BV recommends to include how current global supply chain issues and market conditions for HVDC equipment might affect the cost estimates and delivery timelines going forward. This assessment should consider factors such as material availability, manufacturing capacity constraints, international shipping challenges, and currency fluctuations that could significantly impact project costs.	PG	Low	4/3/2025	No change proposed. As acknowledged in the RLB report (s1.3) the design information used for the estimate is conceptual in nature and therefore the estimate aligns with this level of detail (Class 4 to Class 5 estimate). Class 5 estimates are suitable for initial project scoping and broad cost estimates, and Class 4 is suitable for preliminary project planning and feasibility studies. The RLB cost estimate is one of many cost estimates / case studies referenced in Attachment II including the Western Victoria Renewable Integration RIT-T PADR (AEMO, 2018), Amplitude Consultants (2021), Parsons Brinkerhoff (2012), Transgrid (2022), (NSW Parliament Legislative Council, March 2024), and VicGrid (2024) that provides multiple lines of evidence that the cost of underground is materially higher compared to overhead transmission lines. The Proponent considers the cost estimates provided in the Undergrounding Report are sufficient in summarising the general industry understanding of the difference between overhead transmission lines and underground cables which is the purpose of section 3.3.	Proponent	4/14/2025	Accepted, Closed	PG	None	4/17/2025
30	Section 4.7	Final	Financial	CLOSED	LB	None	4/17/2025	**Risk:** The RLB Report does not consider the Life Cycle Cost (LCC) including CAPEX and OPEX. **Comment:** The project's financial assessment should adopt a high-level systematic approach that considers the life cycle cost (LCC) beyond initial capital expenditure. The current analysis fails to account for mid- to long-term operational expenses, which may impact the project's financial feasibility and the Proponent's operational budget. BV recommends considering a high-level Life Cycle Cost (LCC) analysis in the RLB Report to ensure a more complete financial evaluation. **Reference:** *Comparing high voltage overhead and underground transmission infrastructure (up to 500 kV) report by Curtin University, it is assumed that 1.5% (HVAC Overhead) and 0.15% (HVAC Underground) of the total capital cost per annum are the typical O&M costs for transmission line projects. *O&M Cost - In 2018, ABB won a $30 million order to upgrade two critical Australian HVDC links to the ABB Ability MACH control system, and APA Group experienced DC cable faults with rectification costs that are likely to be significant.	LB	High	4/3/2025	No change proposed. Life cycle costs were not included in the RLB cost estimate as there is no detailed design to be able to calculate the cost of losses. The Undergrounding Report refers to Parsons Brinkerhoff (2012) which includes lifetime costs (capital and O&M) and Transgrid (2022) which has published estimate O&M costs for the proposed HumeLink Project. The study by Madigan et al (2023) explains that costs of underground cables are approximately four to 20 times higher than overhead lines depending on the type of installation. HVDC options in this study only considered subsea cables of 2 different AC/DC converter technologies. Land based HVDC lines were not considered in their study. The report states that maintenance requirements for overhead and underground line components of HVDC are expected to be similar of HVAC overhead and underground. They do note also that the additional maintenance requirements associated with AC/DC converter stations would be significant resulting in overall higher lifetime maintenance requirements. There is no data source provided for the basis of the assumed 1.5% (HVAC Overhead) and 0.15% (HVAC Underground) of the total capital cost per annum are the typical O&M costs for transmission line projects used by Teegla and Singal (2015). The author has also assumed that maintenance requirements for overhead and underground line components of HVDC are expected to be similar of HVAC overhead and underground. However, the additional maintenance requirements associated with AC/DC converter stations would be significant resulting in overall higher lifetime maintenance requirements. Without being able to verify the source of the data which could vary considerably based on project location and technical parameters that is the basis of the assumed % cost of maintenance it can not be referenced or relied upon for costing. The costs quoted are also noted that they are only for general comparison purposes between overhead and underground technologies and should not be applied to specific projects. **Reference:** September 2023. 4. Cost and Economic Aspects. Comparing high voltage overhead and underground transmission infrastructure (up to 500 kV)https://s37430.pcdn.co/ciet/wp-content/uploads/sites/16/2023/11/04_Cost_Economics_Aspects.pdf S. K. Teegala and S. K. Singal, "Economic analysis of power transmission lines using interval mathematics," J. Electr. Eng. Technol., vol. 10, no. 4, pp. 1471–1479, Jul. 2015, doi: 10.5370/JEET.2015.10.4.1471.	Proponent	4/14/2025	Accepted, Closed	LB	None	4/17/2025

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