Electricity transmission

Overhead and underground transmission options

Purpose

This booklet provides general information about overhead and underground transmission lines and associated infrastructure.

G-REZ

Gippsland Renewable Energy Zone project

Project highlights

$500m+ project

Enough clean energy to power **2 million** homes

Reducing **3.6 million** tonnes of CO_2 annually

Unlocking **3-4GW** of renewable energy

Improving **reliability** and **diversity** of Victoria's energy supply

Securing the future of Gippsland's **renewable energy** industry

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Overhead or underground?

Electricity transmission

What is electricity transmission?

Electricity transmission is the transfer of energy from one point to another within the electricity network through a conducting medium or material such as transmission line conductors or wires. Transmission lines vary in size, depending on how much energy they need to carry.

Some transmission lines provide a dedicated service to a single energy developer. Others such as network transmission lines, including those proposed as part of the Gippsland Renewable Energy Zone™ project (G-REZ™), are capable of providing shared services to multiple energy developers.

Given that multiple energy generators may be using a shared network transmission line, there is a much higher reliability and availability requirement placed on these lines, and therefore more constraints on land use around them.

How is a transmission route selected?

In identifying a preferred transmission route, AusNet considers:

- Geography and topography of the land including terrain and waterbodies
- Biodiversity and threatened habitat, including conservation and flora reserves
- Overall length of route and number of landowners impacted
- Existing and future land use and infrastructure requirements
- Places of cultural heritage significance
- Proximity to dwellings, schools, hospitals
- Incompatible land uses such as transport networks, airfields and airports
- Accessibility for renewable energy developers.

What is HVAC and HVDC transmission?

Overhead and underground transmission can be high voltage alternating current (HVAC) or high voltage direct current (HVDC). In Victoria, the transmission network is an AC network.

HVAC

In a HVAC transmission system, the generated AC power is stepped up to high voltages to transmit large volumes of energy from where it's made to where it's needed. It requires at least three line conductors for transmitting the three phase electrical power. The HVAC voltage transformation and transmission is simple and inexpensive however has higher loss of power compared to HVDC over longer distances. HVAC is best suited for multiple connections over shorter distances.

HVDC

In a HVDC transmission system, the generated AC power is converted into HVDC and then transmitted through the HVDC lines. At the load end it is again converted into AC. It requires a maximum of two cables, has lower loss of power compared with HVAC and is suited to transporting energy over long distances (hundreds of kilometres).

In Victoria, both **HVAC** and **HVDC** can be used for transmission. In determining which transmission infrastructure is most appropriate, HVAC or HVDC, a number of factors need to be considered including the length of transmission line and the nature of the network it's connecting into. DC connections are best suited for point-to-point connections over long distances (i.e. hundreds of kilometres), whereas AC is more suitable for multiple point connections over shorter distances. Given this, coupled with the fact that the Victorian transmission network is an AC network, G-REZ is being proposed to be developed as a HVAC transmission line. An AC transmission line also provides greater operational flexibility.

Overhead transmission

What is overhead transmission?

Overhead transmission lines transmit electric power across large distances. The lines (conductors) are suspended between 15 and 80 metres above the ground by towers or poles which vary in size depending on the size of the transmission lines and regulations.

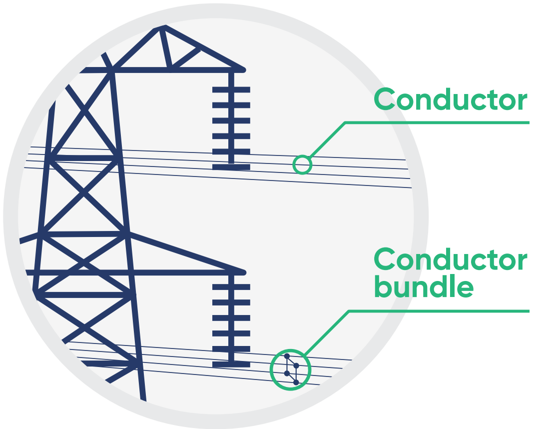
What are transmission towers?

Transmission towers are used to support overhead conductors (wires) at the required height above the ground to meet regulations and safety requirements.

What are conductors and conductor bundles?

Transmission conductors, commonly known as 'power lines' or 'wires', are the metal cables that carry high voltage electricity over long distances.

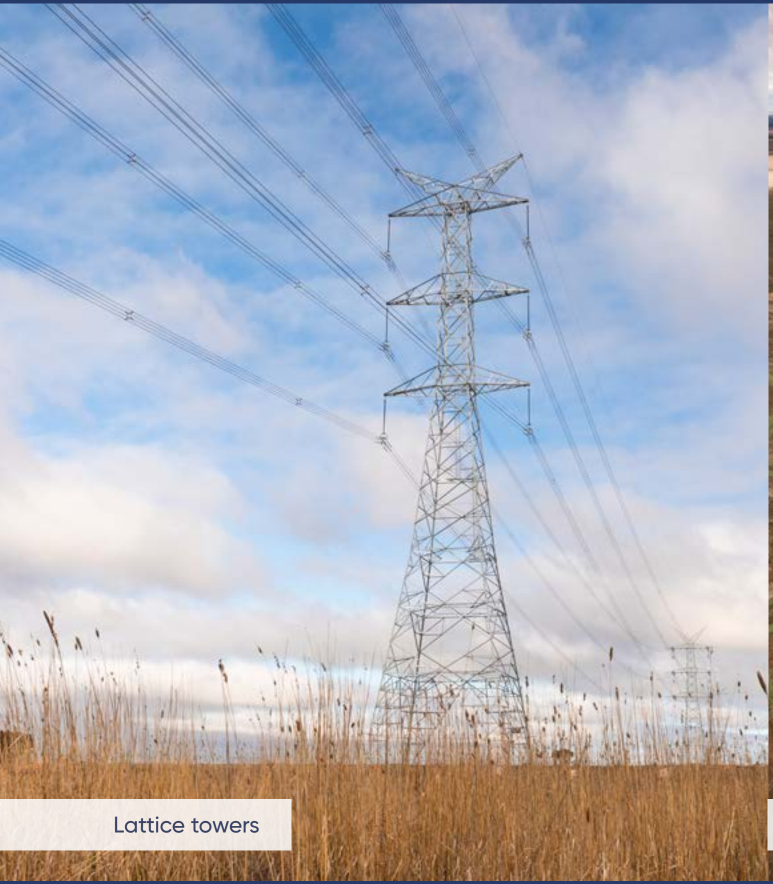
Conductor bundles refer to two or more conductors grouped together to efficiently increase power transmission for high voltage transmission lines. Conductor bundles are hung on each side of the tower crossarms.



What towers are proposed as part of G-REZ if developed overhead?

The towers proposed for the G-REZ project, if developed overhead, are double circuit steel lattice towers and will be between 60 and 80 metres high. They are called 'double circuit' towers because each tower supports two independent circuits, one on each side of the tower.

The steel lattice structure is a common tower type and is used extensively in Victoria and the national electricity network and is designed to environmental conditions. This type of structure is able to support the high voltage of the project (500kV) and the clearance required. The proposed transmission line would include both suspension and strain towers.



Lattice towers

Lattice and monopole towers

Monopole towers

Steel lattice tower types

The type of towers to be used for the G-REZ project, if overhead, will be decided following stakeholder consultation and relevant technical and environmental studies.

Suspension towers

Suspension towers are used where the transmission towers are in a straight line or have a very small deviation angle (up to 10 degrees). The insulators and wires are strung vertically from the crossarms. These towers have a smaller base and are lighter in weight relative to strain towers.

Strain towers

Strain towers are generally used where the transmission line changes direction beyond 10 degrees. These towers need to pull on the wires and are designed to take the tension load of the wires. Generally, strain towers are larger at the base and heavier compared to suspension towers. The insulators and wires are strung horizontally on the crossarms of strain towers with some hanging insulators to help hold the wires in place.

Monopoles

In some instances, monopole towers may also be used instead of lattice type towers. These consist of one pole anchored to the ground and generally have a smaller profile than lattice type towers. When used in place of suspension towers, only one pole is required, however when monopoles replace a strain tower, two poles are required.

Single circuit towers

In instances where height of the towers is an issue, two shorter single circuit towers can be used. These towers are 45-55 metres high, however two are required increasing the overall width of the easement in areas where this is utilised.

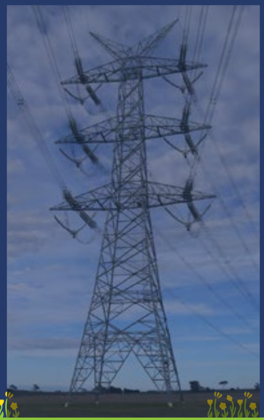
Suspension tower

Estimated average height range 60-80m

Approx. base dimensions: 20 x 20m

Strain tower

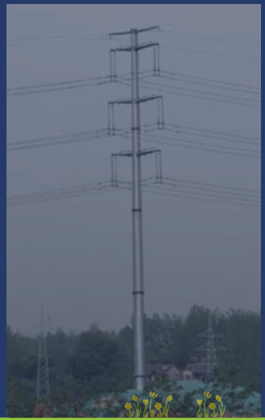
Estimated average height range 60-80m



Approx. base dimensions: 20 x 20m

Monopole

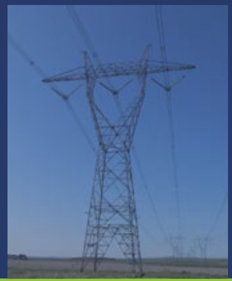
Estimated average height range 60-80m



Approx. base dimensions: 5m diameter

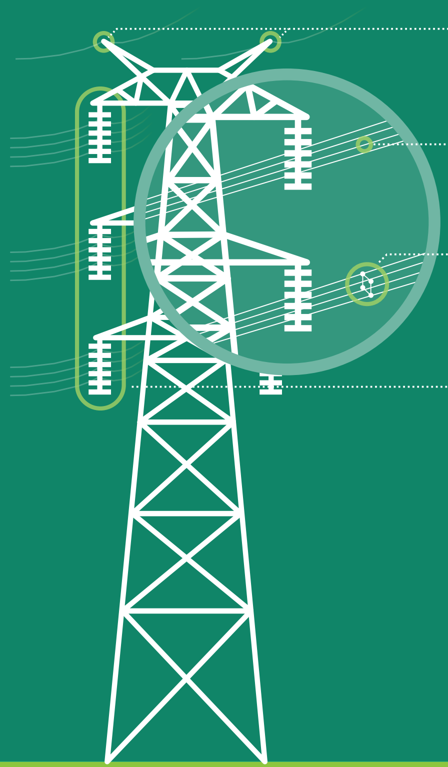
Single circuit tower

Estimated average height 45-55m



Approx. base dimensions: 20 x 20m

Numbers of wires



Ground wire x 2

+

Conductor/Wire x 4

+

Conductor bundle x 3 (Phase)

+

Circuit x 2

=

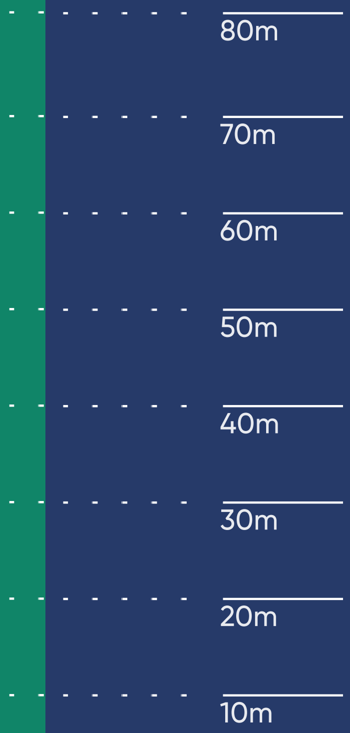
Total number of wires

26

Typical easement width

70–110m

Tower height



For 500kV overhead transmission, towers will be between 60 and 80 metres high.

The height of transmission towers is governed by the Electricity Safety (General) Regulations 2019, design and safety standards and the preferred location and route for the infrastructure. Regulations for transmission tower design and maintenance requirements have improved to respond to learnings from natural disasters, fire and other unplanned events.

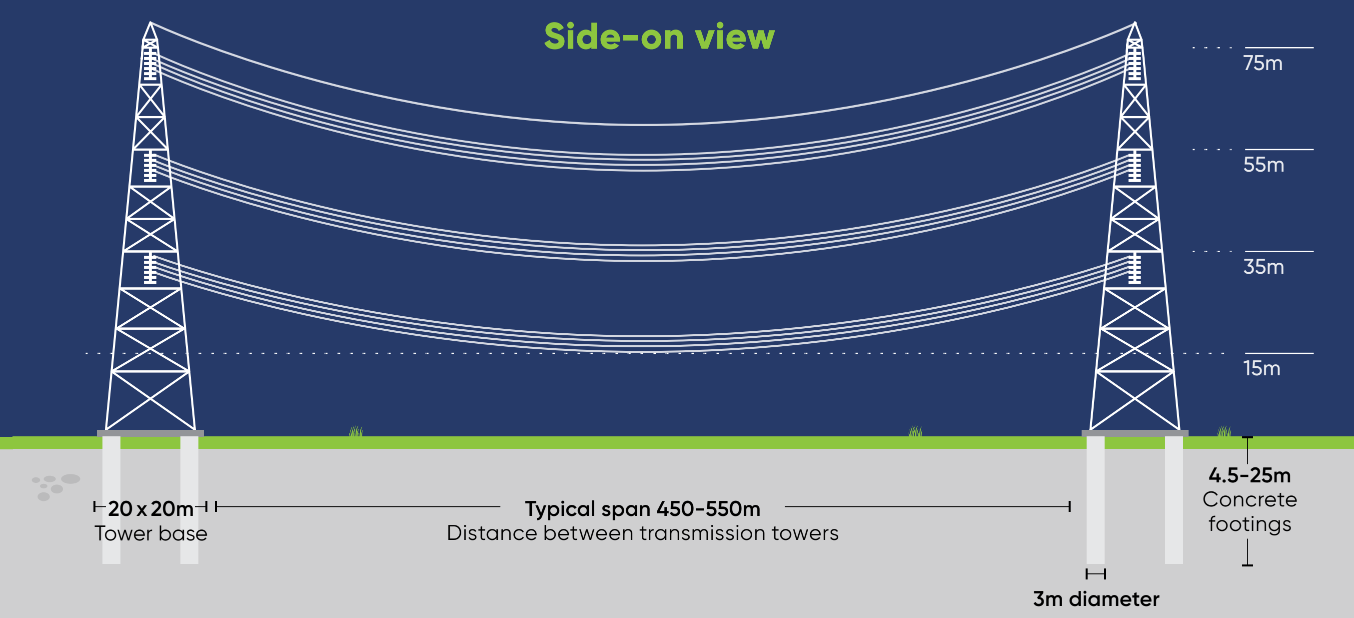
Transmission towers and their associated footings and wires are designed to meet the requirements of AS/NZS 7000:2016 Overhead Line Design, which outlines the engineering requirements for the structural integrity of the towers. The height of each tower is designed to ensure that minimum electrical safety distances are achieved between each wire, each wire and the ground, and each wire and any objects that may traverse the ground underneath. Further factors including agricultural land use and equipment heights, visual and landscape considerations, or biodiversity (fauna and flora) can also influence tower heights provided all minimum safety clearances are maintained.

Transmission towers are fitted with an approved anti-climbing device at approximately three metres above the ground, and safety signage is placed on all towers.

Easements associated with both underground and overhead transmission are generally not fenced, unless this is specifically requested by the landowner.

Conductor height

The typical minimum distances from the conductors to the ground for 500kV projects is 15m.



What are ground wires?

Ground wires are installed above the conductors (wires) to provide protection from faults and lightning. If lightning strikes the ground wire, the power in the strike is directed safely into the ground through the ground wire and towers. One or more of the ground wires may have a fibre optic core within the cable to provide communications between substations.

What size will the tower base and footings be?

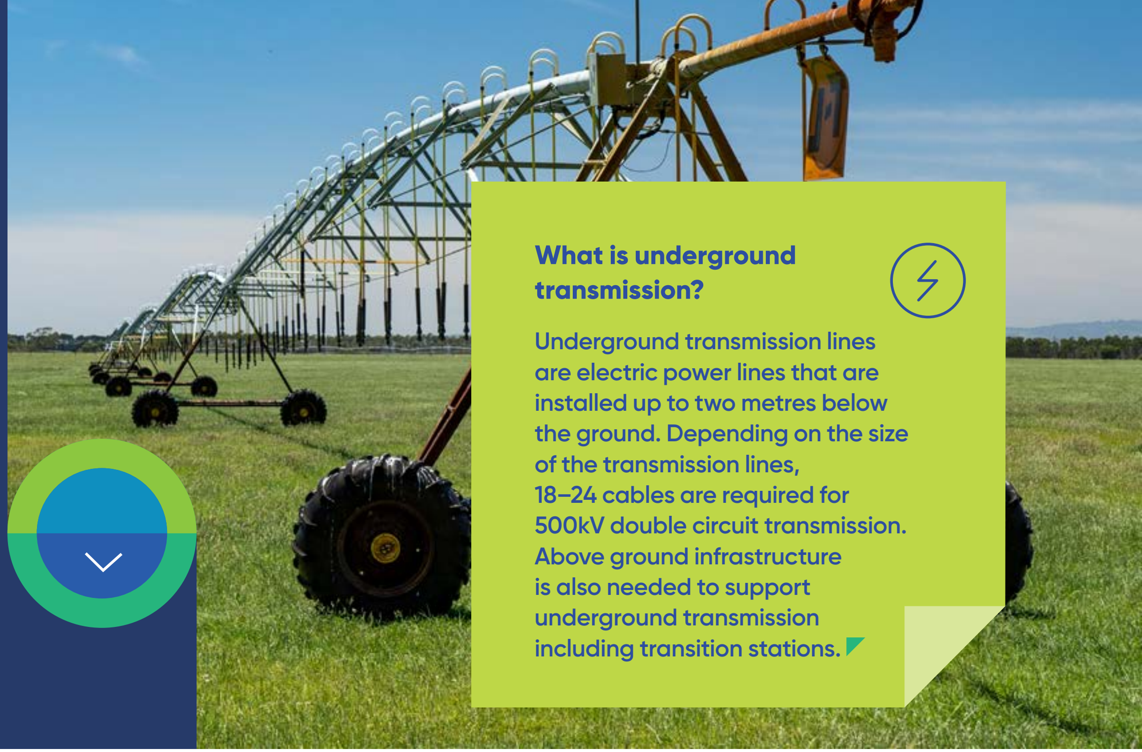
For a typical 500kV transmission line, the width of the base for a lattice tower is approximately 20 by 20m. Four concrete pile footings (or foundations) are required for each transmission tower, which will range from approximately 1.5–3m in diameter and from 4.5–25m deep (9m typical depth).

The tower base and footing size will vary for different tower locations and soil conditions.

How far apart will the towers be?

The spacing or span length between each transmission tower is determined by the minimum distance required between the ground and the wire. To account for this requirement, the typical span between towers is generally between 450 and 550m for 500kV transmission lines. Shorter or longer span distances are possible over sensitive areas or to avoid impacts. Longer spans require taller towers to achieve required ground clearances and wider easements to allow for sway of the transmission lines.

Underground transmission

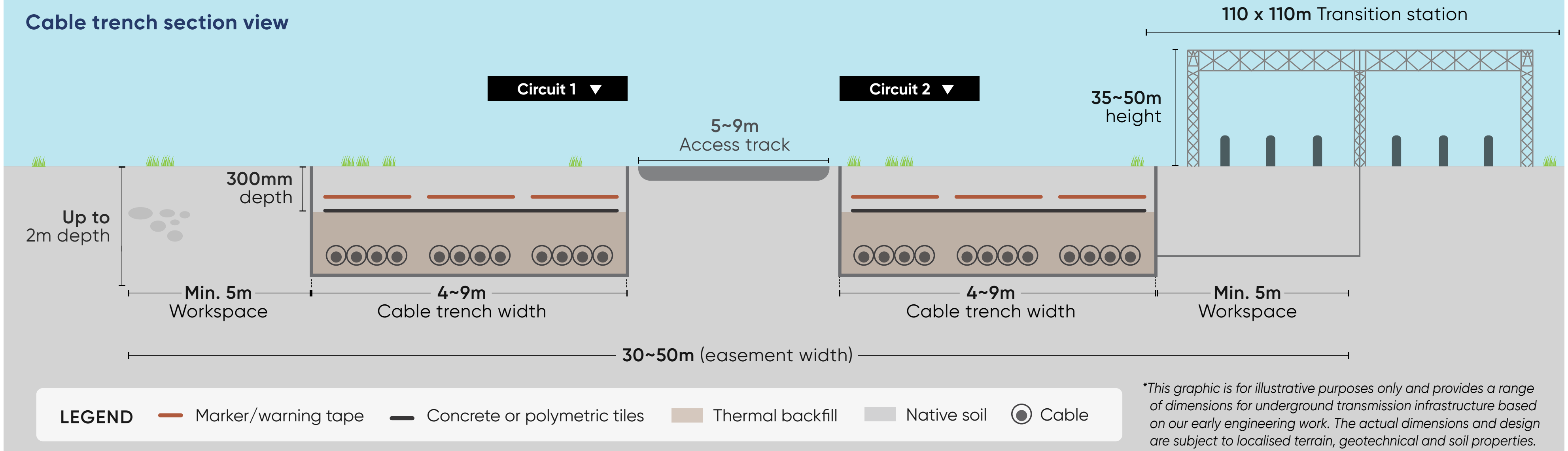


What is underground transmission?

Underground transmission lines are electric power lines that are installed up to two metres below the ground. Depending on the size of the transmission lines, 18–24 cables are required for 500kV double circuit transmission. Above ground infrastructure is also needed to support underground transmission including transition stations.

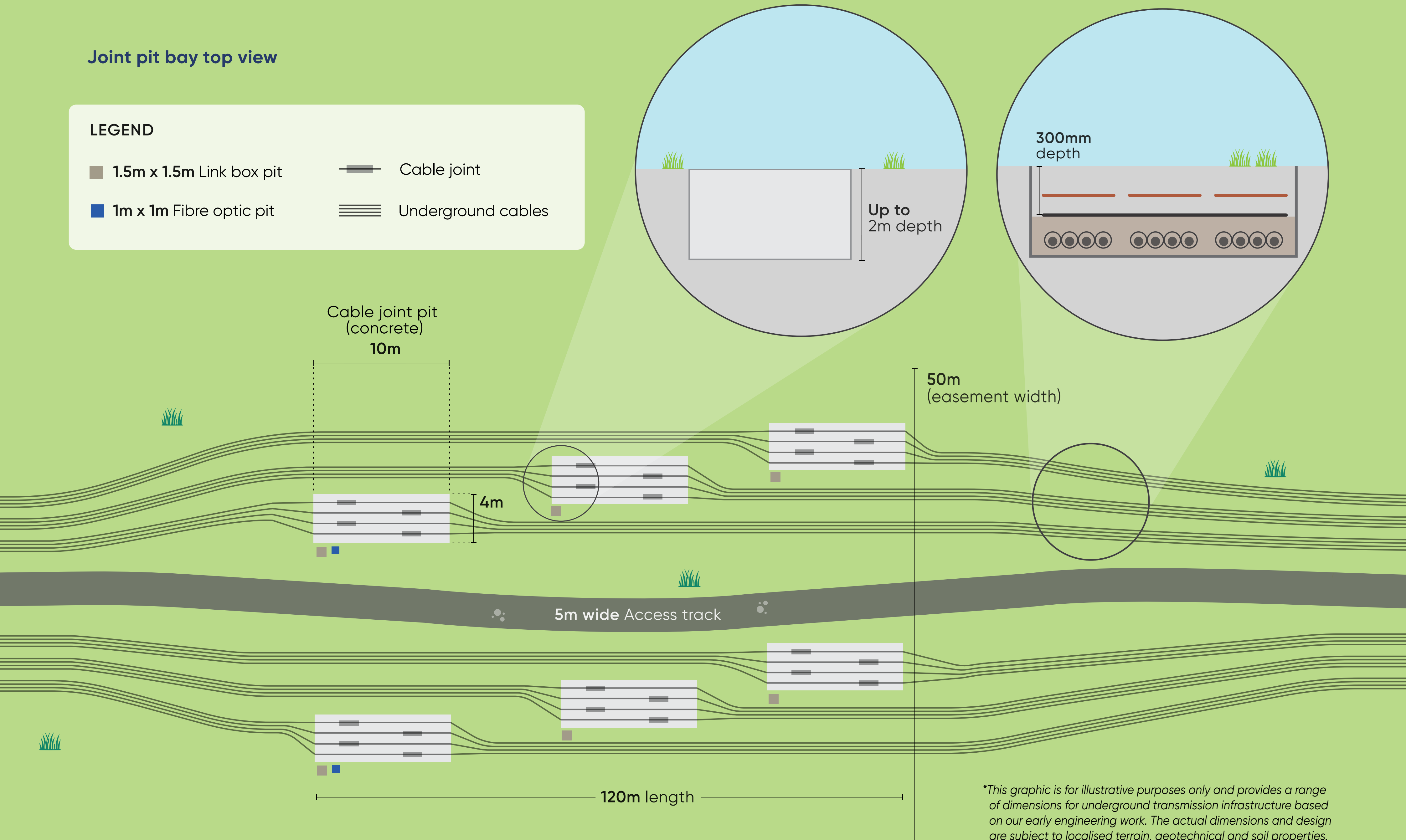
Underground option

Cable trench section view



This graphic is for illustrative purposes only and provides a range of dimensions for underground transmission infrastructure based on our early engineering work. The actual dimensions and design are subject to localised terrain, geotechnical and soil properties.

Joint pit bay top view



**This graphic is for illustrative purposes only and provides a range of dimensions for underground transmission infrastructure based on our early engineering work. The actual dimensions and design are subject to localised terrain, geotechnical and soil properties.*

What is involved in constructing underground transmission?

Term	UNDERGROUND
Trenches	Vegetation is cleared in the 30 to 50m wide construction zone and easement. Two or more open trenches at least 4m wide and 2m deep are dug along the length of the route to lay the cables. Trucks would transport most of the excavated soil away for disposal and thermal backfill material would be trucked in.
Transporting cables	Each 500 to 750m long cable comes on a cable drum weighing about 30 tonnes and requires a heavy vehicle to transport.
Laying cables	Underground cables for high voltage transmission circuits are buried up to 2m (assuming no underground obstacles) under the surface, typically within a conduit, covered with a layer of thermal backfill and a final layer of topsoil. Concrete or polymetric tiles (around 300mm deep) and marker tape are placed above the cables to alert people to their presence.
Cable joints	Underground cables are joined in concrete walled cable joint pits, every 500 to 750m. Cable joint pits are typically around 10m long by 4m wide and 2m deep. For the 18 to 24 cables needed for the G-REZ project, there would typically be six to eight pits in a joint pit bay area. Cable joint pits can come in precast sections or be poured in-situ. Cable joint pits also provide access to the cables along the route for maintenance, testing and repair. Concrete or polymetric tiles and marker tape are placed above the cables to alert people to their presence. Highly specialised jointing teams join the cables in cable joint bays. Joining a single cable takes on average six days per joint. For 24 cables this would equate to five months of work every 500m to 750m. Cable joints are the most likely part of a cable to fail - with more joints, the likelihood of the cable failing increases.

Term	UNDERGROUND
Construction areas	A construction workspace of approximately 30 to 50m wide is required for the length of the route, with larger areas required for construction of cable joint pits and where trenchless construction methods are used.
Above ground infrastructure	For a hybrid transmission solution comprising both overhead and underground infrastructure, transition stations requiring approximately 1-1.5ha are needed where the line transitions from overhead to underground and vice versa.
Trenchless construction	Trenchless underground construction methods, such as horizontal directional drilling (HDD), may be used if geotechnically feasible. Trenchless construction is typically used in short sections under roads, rail lines, major watercourses or in environmentally sensitive areas. As cable joint pits are still required, the maximum bore length is limited to 500 to 750m. Where horizontal directional drilling is used, a construction area of approximately 60m by 100m either end of the boring section may be required. Depending on geotechnical conditions and the separation required between cables, the easement may be up to 80m wide where trenchless construction is used to install the cables.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Key environmental differences between overhead and underground transmission infrastructure

The key differences in environmental impacts between overhead and underground transmission infrastructure construction mostly relate to visual impact and ground disturbance, and the ability to avoid impact through design.

Underground construction has less visual and landscape impact compared to an overhead transmission line, but ground disturbance and easement restrictions associated with underground transmission infrastructure impact on vegetation, biodiversity, Aboriginal cultural heritage, and agriculture and other land uses along the length of the transmission line.

For an overhead design, ground disturbance occurs at the tower locations every 450–550m. Towers can be positioned to avoid or span over sensitive areas. For underground construction, ground disturbance occurs along the length of the route to a width of approximately 30–50m. Clearing for access tracks is required for both overhead and underground construction.

The following table compares overhead and underground construction based on equivalent design parameters.

Consideration	OVERHEAD	UNDERGROUND
Aboriginal cultural heritage	Aboriginal cultural heritage sites can generally be avoided in design. Potential for visual impact on intangible cultural heritage associated with a place.	Aboriginal cultural heritage sites cannot easily be avoided in design. Lower potential for visual impact on intangible heritage with less overhead infrastructure.
Aviation	Overhead infrastructure presents a potential risk to aviation that in most cases can be managed.	Underground infrastructure presents no risk to aviation.
Biodiversity (vegetation management)	Biodiversity values can be fully or partially retained on an overhead transmission line easement. Vegetation up to 3m in height can be retained within the easement. Taller vegetation is permitted where the minimum clearance and fuel load densities are maintained, based on assessment. Native grasslands and associated habitat can be avoided in design. Trees outside the easement are maintained so that they are below the fall zone of the transmission line. Overhead transmission lines can be a hazard to some bird species. The partially cleared overhead transmission line easement can affect some native species by creating a barrier to movement between adjacent native vegetation.	Biodiversity values are not retained on an underground cable easement, except where trenchless construction methods have been used. All vegetation is cleared in the underground construction easement along the length of the route, except where trenchless construction methods are used. Less opportunity for trenches to avoid native grasslands and associated habitat. Only grass or shallow rooted vegetation is permitted to grow on the underground easement. Underground cables pose no risk to bird species. The cleared underground cable easement may affect some native species by creating a barrier to movement between adjacent native vegetation.

Consideration	OVERHEAD	UNDERGROUND
Bushfire and other natural disasters	There is no record of a bushfire being started by an overhead transmission line in Victoria. Safe operation of firefighting aircraft and ground based firefighting crews can occur within a certain distance of overhead transmission lines. Overhead transmission lines are exposed to extreme weather events which may exceed the design wind loads potentially resulting in damage.	Underground cables are not exposed to fire. There is no record of a bushfire being started by an underground transmission line in Victoria. Underground cables do not constrain aerial firefighting activities. Ground-based firefighting crews need to be aware of underground cables when bulldozing fire breaks. Storm damage to cables can occur due to soil erosion from flood events, tunnel erosion and landslips due to heavy rainfall.
Electric and magnetic fields (EMF)	Overhead transmission lines generate EMF. Transmission line ground clearance is designed to ensure electric and magnetic field strengths are below Australian and international EMF guidelines.	Underground cables generate EMF. Electric fields are screened by the metallic sheath built into the cable. Underground cable burial depth is designed to ensure electric and magnetic field strengths are below Australian and international EMF guidelines.

Consideration	OVERHEAD	UNDERGROUND
Historic heritage	Heritage sites and artefacts can be avoided in design by spanning over areas and micro-siting towers. Transmission lines can detract from the context of heritage places and sites.	Less opportunity for trenches to avoid heritage sites and artefacts compared to overhead transmission lines. Above ground infrastructure can detract from the context of heritage places and sites.
Landscape and visual	Potential for high visual impact in sensitive areas.	Reduced visual impact except where above ground facilities and easements through vegetation are required. Potential for high visual impact in sensitive areas where the following is required: • transition stations (partial undergrounding). • converter stations for HVDC/HVAC connections. • reactive compensation stations for HVAC.
Noise	Noise from transmission line conductors (wires) can be discharged under certain atmospheric conditions. Transformers in terminal stations emit noise.	Negligible audible noise from underground transmission lines except at associated above ground infrastructure.

Land use on transmission easements

(500kV double circuit line)

OVERHEAD

Permitted

- Traversing with heavy machinery, equipment and vehicles up to 5m high (up to 8.6m may be allowed with AusNet approval)*
- Working with heavy machinery within easement (AusNet permit required)
- Grazing
- Cropping, planting trees and shrubs with a mature growth height less than 3m. Preexisting taller trees can be retained based on AusNet assessment
- Centre-pivot and lateral irrigators permitted with AusNet Services' approval and where incorporated in design
- Installation of fences, low voltage power cables, stock water pipelines (with AusNet approval).

Not Permitted

- Gun irrigators
- Sheds and dwellings (small structures permitted with AusNet approval)
- Storage/handling of flammable materials
- Parking trucks and caravans.

UNDERGROUND

Permitted

- Operation of taller equipment and vehicles
- Gun, centre-pivot and lateral irrigators
- Grazing
- Installation of fences, low voltage power cables, stock water pipelines (with AusNet approval).

Not Permitted

- Restrictions on heavy machinery and equipment (AusNet approval needed)
- Sheds and dwellings
- Storage/handling of flammable materials
- Digging/excavation including cropping, cultivation, planting of deep/shallow rooted trees.

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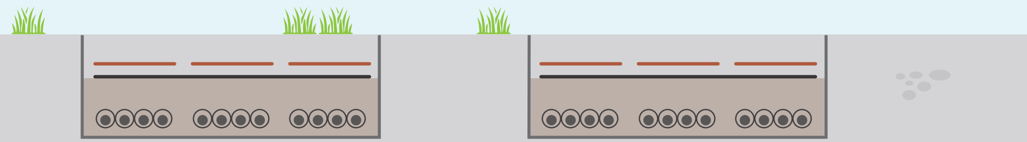

* Overhead transmission lines can be designed to provide greater ground clearance in some situations

Contact Us

For more information, or to speak to a member of our team, please visit:

grez.com.au

1300 360 795

info@grez.com.au

AusNet | Gippsland Renewable Energy Zone