Overhead and underground infrastructure explained

Community factsheet

This factsheet provides information to explain both overhead and underground transmission technologies.

Scan the QR code on the last page to find more information about decision-making for transmission projects in our *Community engagement in decision-making factsheet*, and about impacts in our *Social and environmental considerations for transmission projects factsheet.*

Overhead and underground transmission infrastructure both play a role in meeting our current and future energy needs. In Australia, with our large land area and dispersed communities, most transmission lines are overhead. This is because they are energy efficient over long distances, cost-effective and easy to maintain. Underground systems on the other hand can offer greater resilience to extreme weather events, such as bushfires and floods,[1] and reduce visual impact for residents and communities.

The decision between overhead and underground transmission lines is based on project and site-specific factors such as: the local community, topography, land use, the environment and cost. Choosing the suitable technology for each location is a key part of developing an efficient, reliable and resilient energy system.

Technology decisions

Worldwide, alternating current (AC) overhead transmission lines have been proven to be the lowest cost system for safe and reliable delivery of large amounts of energy over long distances.[2]

While many factors are considered as part of decision-making, price competitiveness is a key consideration in the Australian context, where keeping costs low for consumers is a key requirement. In Australia if an overhead transmission option is feasible, it is usually also cheaper than undergrounding (by far) and for this reason is often selected as the most appropriate option.

1 International Energy Agency, *Climate resilience – Power Systems in Transition – Analysis*
2 UQ and Curtin University, *Comparing High Voltage Overhead and Underground Transmission Infrastructure*

Transmission system technologies

Did you know?

Alternating current (AC) is the standard form of electricity used in Australian homes. High voltage alternating current (HVAC) can be efficiently moved over long distances, is easy to convert to different voltages and can be installed above ground or below ground.

HVDC or high voltage direct current (HVDC) is used for transferring bulk electricity point-to-point, over very long distances, between AC systems. It requires electrical stations called converter stations to convert power from DC to AC for in-home use.

An example of an underground (sub-sea) DC transmission line is the 370 km-long Basslink electricity interconnector, which links the electricity systems between Tasmania and Victoria.

Overhead transmission lines are designed to comply with State or Territory safety regulations and also the *AS/NZS 7000:2016 Overhead Line Design standard*, which ensures minimum electrical safety distances between each conductor, each conductor and the ground, the supporting tower or pole structure, on the ground infrastructure such as roads and rail lines and on-the ground land-uses, such as farming and other machinery, vehicles and equipment.

Features of both underground and overhead systems

Easements

Wherever there are transmission lines, there are also transmission line easements. These easements, also known as 'rights of way,' legally grant utility companies access to land for the construction, operation and maintenance of transmission infrastructure.

Easements provide a buffer zone in close proximity to the infrastructure within which some vegetation, structures and activities may be controlled or restricted to ensure the safe operation of the transmission line.

The creation of legal easements is associated with the payment of compensation, which is negotiated with the landowner. If a negotiated agreement cannot be reached, businesses with relevant government authority may use compulsory acquisition powers (which includes have measures for fair compensation).

Substations

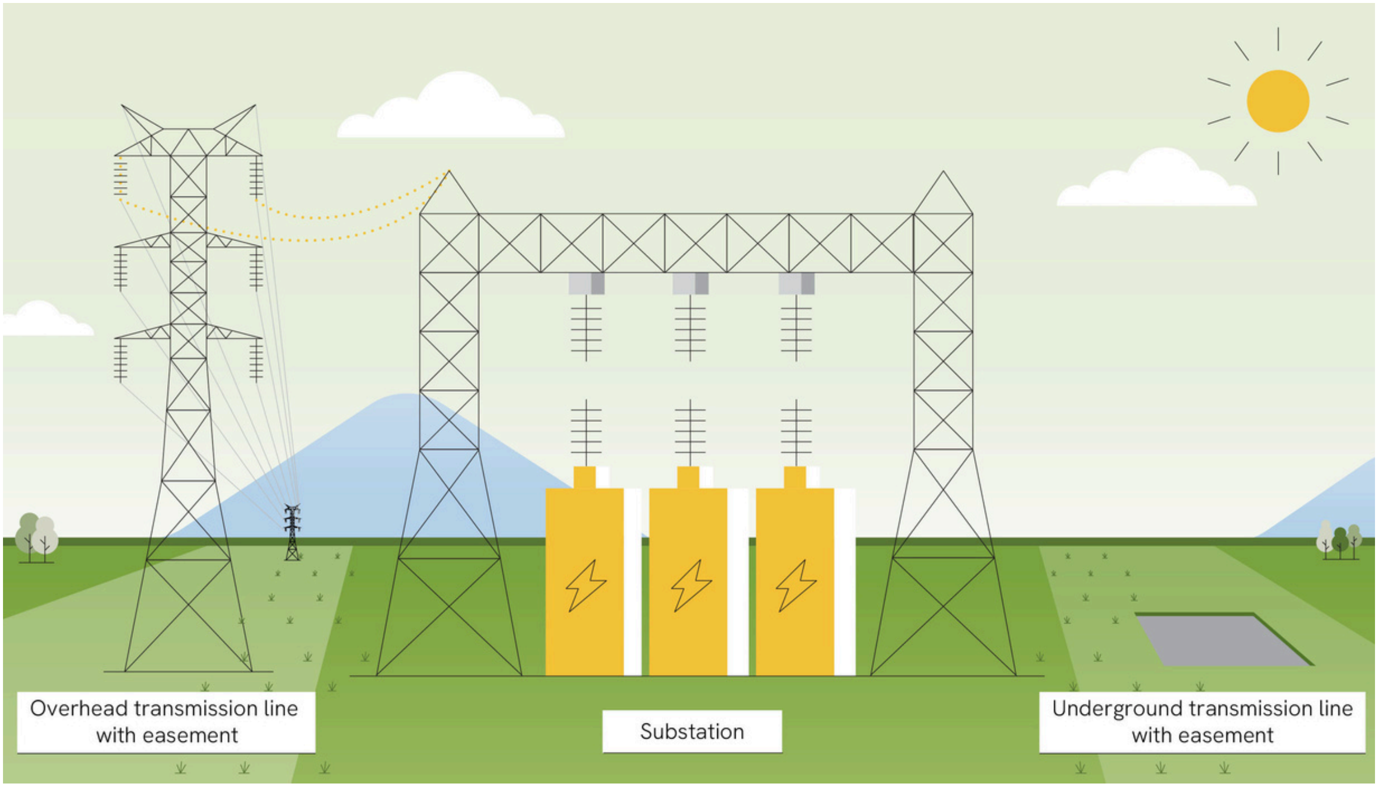
Both underground and overhead transmission lines provide electrical connections between electrical hubs, commonly known as substations - but also variously referred to as terminal stations, switching stations, converter stations and reactive power compensation stations.

These electrical hubs can be up to a few hundred kilometres apart and are critical components in the transmission system, containing a range of electrical equipment where electricity may be:

- Transformed to higher or lower voltages for transmission and distribution
- Switched from one transmission line to another
- Converted between technology types
- Or where reactive power is compensated to ensure power is transmitted.

Substations can be large (with examples up to 16 hectares) containing critical electrical infrastructure such as high-voltage transformers, circuit breakers and control equipment to regulate the flow of electricity, ensuring stable and reliable delivery across the system. They also play a key role in protecting the system by isolating faults and maintaining power quality.

Figure 1: Easements and substations across overhead and underground transmission technologies



Overhead transmission

Key features of overhead transmission infrastructure include:

Transmission structures
These large support structures come in a range of designs such as steel lattice towers or steel/concrete poles. The type of structure used is chosen for different locations based on the terrain, geology, conductor strain, as well as the voltage carried in the conductors.

Transmission structures range in size depending on voltage, design and terrain, with heights from 40 m to the largest being over 90 m. The average distance between each 500 kV (kiloVolt) transmission structure typically ranges from 300 - 600 m depending on terrain and ground conditions.

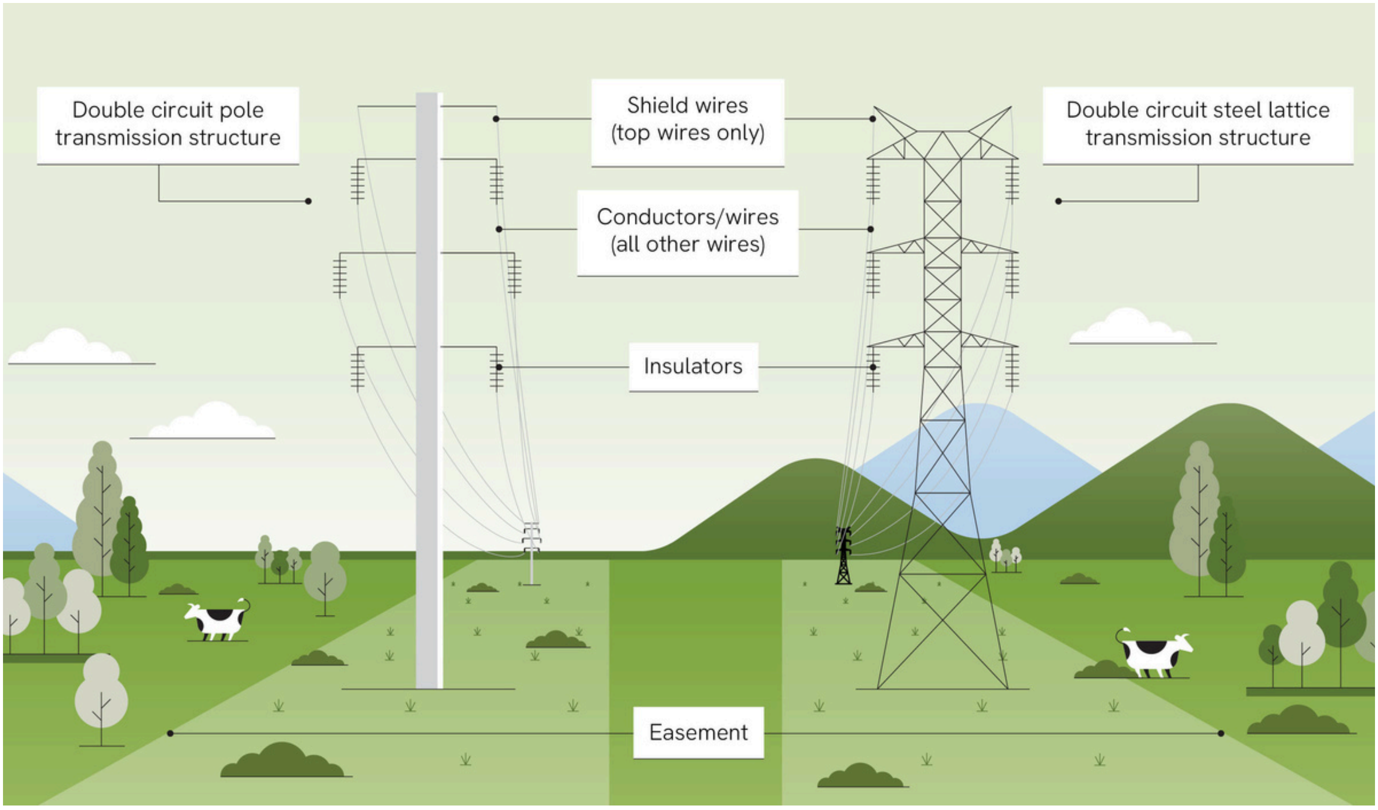
Transmission structures are designed to withstand various environmental conditions including high winds, ice loading and seismic activity.

Conductors
High voltage conductors (or wires) form the backbone of overhead transmission lines by carrying electrical current. They are typically made from aluminium or copper and are often reinforced with a steel core to enhance strength and reduce sagging. Cables – conductors wrapped in an insulation coating – are less common in overhead transmission lines due to the added weight and complexity of the technology.

Insulators
Strings of insulators support the conductors and create an insulated safe distance between the high voltage electricity and the structure. Insulators are generally made of porcelain, glass or polymer materials.

Shield wires and grounding systems
Shield wires are installed at the top of transmission structures to protect the lines from lightning strikes. They are connected to grounding systems that safely dissipate lightning energy into the earth, reducing the risk of damage and outages.

Figure 2: Overhead transmission infrastructure components



Underground infrastructure

Key features of underground transmission infrastructure include:

High voltage cables

Underground transmission lines use specially designed high voltage cables, typically made of copper or aluminium conductors wrapped in an insulation coating. The insulation surrounding underground cables is crucial for preventing electrical faults and maintaining the integrity of power flow. Advanced materials like 'cross-linked polymer' provide insulation and resistance to environmental stressors like moisture and temperature fluctuations.

Protective conduits

To safeguard cables from damage, underground transmission lines are often enclosed within protective conduits or ducts. These conduits, usually made of materials like PVC or steel, shield the cables from external forces, such as soil pressure, water ingress and construction activities.

Joint bays

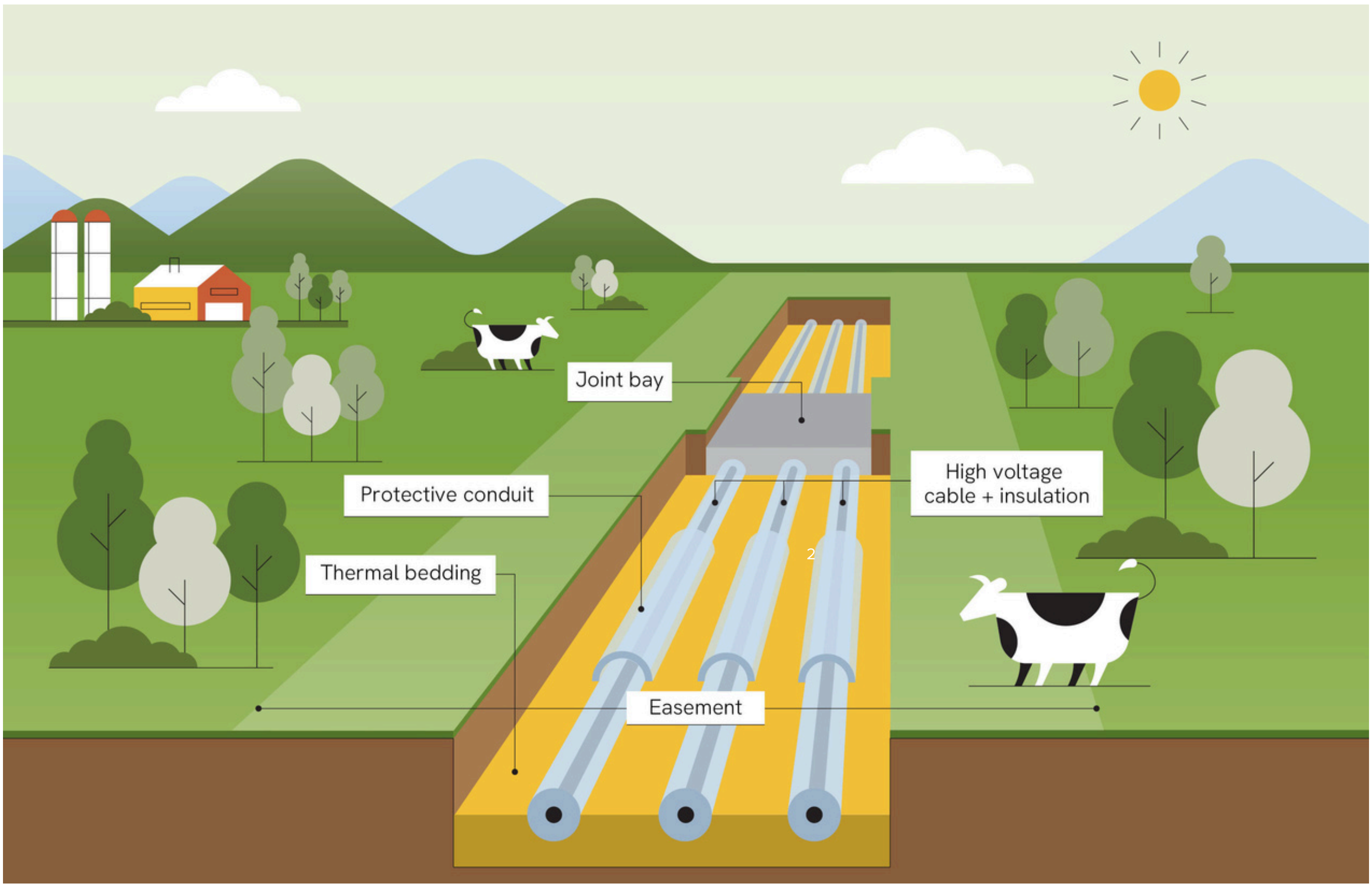
Joint bays are locations where lengths of underground cable are connected together (joined) along the route and also at locations to terminate underground cables at substations or other connection points.

The average distance between high voltage joint bays is typically between 500 m to 2 km, depending on the voltage level, length of the cable pieces and specific project requirements.

Joints must be carefully engineered to maintain the electrical and mechanical integrity of the cable system, preventing faults and ensuring long-term reliability, and must remain accessible during operation for inspection and maintenance activities.

Joint bays are commonly constructed and contained underground in a large concrete box, with a concrete lid allowing for access. However, above-ground joint bays may be required where conditions are not suitable for underground installation (e.g. in areas of hard rock).

Figure 3: Underground transmission infrastructure components (single circuit arrangement)



Construction process

Overhead transmission lines

Typically, construction timeframes may be approximately two years for a 100 km HVAC 500kV double circuit overhead transmission line. The construction phase of overhead infrastructure involves:

Foundation and Structure Installation

- **Ground works:** Vegetation is trimmed along the easement and groundworks undertaken such as at structure locations and for access tracks.
- **Foundations:** Strong foundations are built to support the structures, which typically involves digging and pouring of concrete.
- **Structure Erection:** Structures are assembled and erected on the foundations, using cranes or helicopters to access remote areas.

Stringing the Conductors

- **Pulling Lines:** Special equipment, including stringing blocks and pullers are used to pull the conductors from one structure to the next. In some cases, helicopters or drones are used to assist with stringing pilot wires and conductors when there is a need to reduce on the ground disturbances, or in situations where rapid response is needed like after natural disasters.
- **Tensioning:** The conductors are tensioned to the correct sag and secured to the structures.

Testing and Commissioning

- **Inspection:** The entire transmission line is inspected for any defects or issues.
- **Testing:** Electrical tests are conducted to ensure the line is ready for operation.

Underground transmission lines

It can typically take between four to six years to construct a 50 km HVAC 500kV double circuit underground transmission line. The construction phase of underground transmission projects includes:

Installation Trenching and Installation

- **Ground works:** Vegetation is removed and access tracks constructed along the length of the easement.
- **Trenching:** Trenches are dug along the selected route.
- **Cable Laying:** High voltage cables are laid in the trenches and are often placed in conduits or ducts for additional protection.
- **Backfilling:** The trenches are backfilled with specially prepared thermally stable material and the surface is restored as best as possible, to its original condition.

Jointing and Termination

- **Cable Splicing:** Cables are joined together using specialised techniques to ensure a secure and reliable connection.
- **Terminations:** At each end of the transmission line, cables are connected to substations or other infrastructure.

Testing and Commissioning

- **Inspection:** The entire system is inspected for any defects or issues.
- **Testing:** Electrical tests are conducted to ensure the system is ready for operation.

For more information about the impacts of transmission projects download our *Social and environmental considerations for transmission projects factsheet* via the QR code.

Maintenance requirements

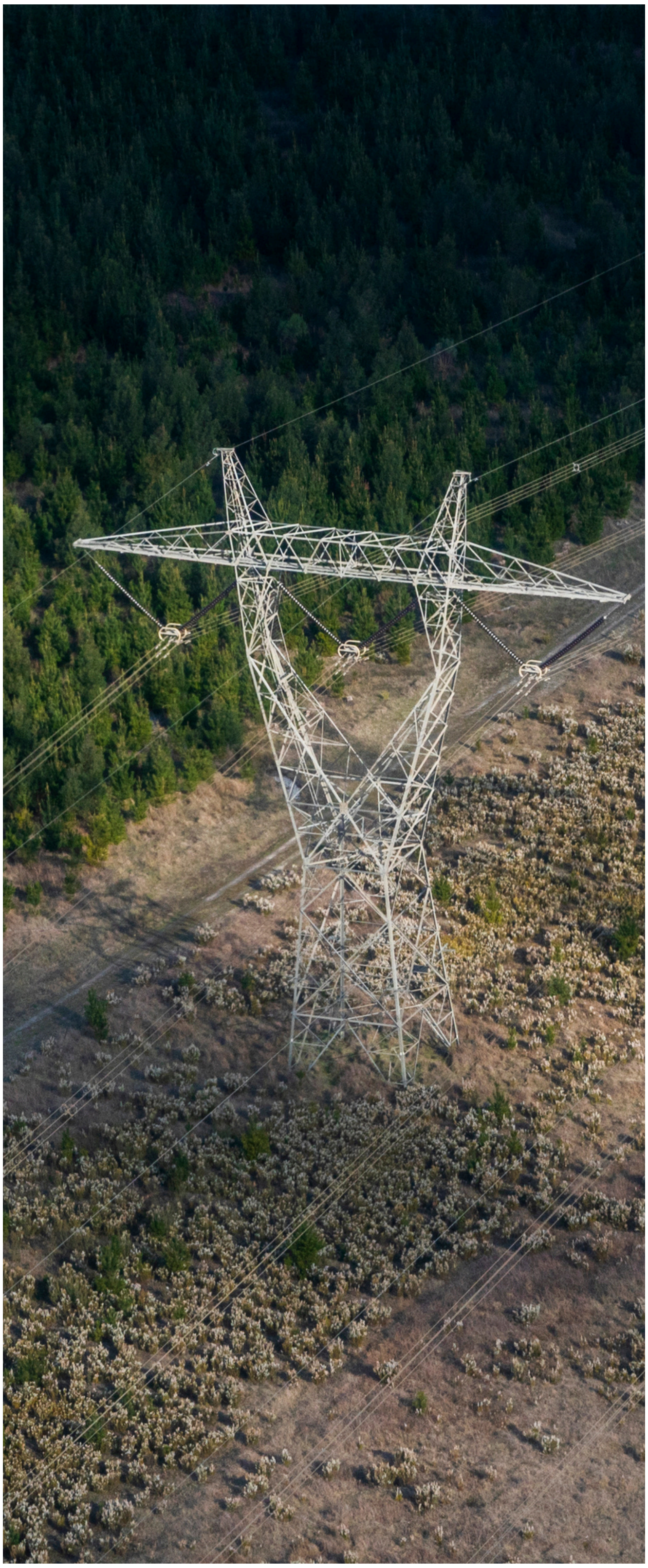
Routine inspections are generally undertaken annually on overhead and underground transmission infrastructure to assess for any damage or wear. If any maintenance issues are found during inspections, repairs will be planned by the transmission business and affected and nearby landholders will be consulted.

The time needed to undertake repairs on transmission infrastructure will vary depending on the work needed and whether it is overhead or underground. Maintenance and repairs on underground transmission infrastructure may require excavation works to access the cables or joint bays, making it potentially costly and longer to repair. It is estimated that repairs to underground infrastructure can take weeks or even months. Repairs to overhead infrastructure are often resolved within days or weeks due to the accessibility of above ground structures and lines.

Costs

Underground transmission infrastructure is more expensive than overhead transmission infrastructure. Independent reports[3] have found that is it is difficult to determine the capital costs of underground compared to overhead transmission infrastructure due to the lack of recent comparable projects, and current global and local economic factors including supply and demand risks and availability of skilled labour resources. Reports estimate that underground transmission can be anywhere between 3 to 20 times more expensive than overhead depending on construction type, route length and specific project factors. The biggest factors contributing to higher costs for underground transmission projects are due to the complexity and time-consuming nature of installation which requires specialised equipment and techniques to dig trenches, lay cables, and ensure proper insulation and cooling.

For more information about factors that are considered as part of transmission decision-making download our *Community in decision-making factsheet* via the QR code.



3 NSW Parliament, *Feasibility of Undergrounding the Transmission Infrastructure for Renewable Energy Projects*; and UQ and Curtin University, *Comparing High Voltage Overhead and Underground Transmission Infrastructure*

Easement compensation

Private landowners receive compensation for transmission easements on their property. In Australia, our States and Territories have separate Land Acquisition Acts that govern how transmission businesses can acquire private property for easements. These Acts do not provide a specific dollar rate or value for the compensation required to be paid. This means that the amount of compensation received is specific to each property.

To determine the amount of compensation for a particular landowner, transmission businesses use qualified valuers to value the impact of an easement on that property. Compensation is based on the market value of the land, and also makes provision for legal and valuation fees and other out-of-pocket expenses incurred as part of the process. In some cases, compensation may also include an amount for any unavoidable losses to productive land resulting from the easement, and for devaluation of the land.

Some States have introduced additional payments for impacted landholders. The principles of these additional benefit payments are typically an amount per-kilometre of easement paid each year for a set number of years.

Scan this QR code or visit www.understanding-australian-transmission-projects.com to find more factsheets and resources about Australian energy transmission projects.

Made in collaboration with: Community Power Agency, Energy & Water Ombudsman NSW, Farm Renewables Consulting, farmers for climate action, GCCN, Justice and Equity Centre, RE-ALLIANCE

Made in consultation with: Australian Government Australian Energy Infrastructure Commissioner

Proudly supported by the Energy Charter: a collaboration platform that brings together community and energy businesses to help put humans at the centre of the energy system.