Submission
No 33

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

Organisation: Energy Grid Alliance

Date Received: 10 July 2023

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07 July 2023

Parliament of NSW
Legislative Council
Standing Committee on State Development
Via online submission

RE: **Inquiry into the feasibility of undergrounding the transmission infrastructure for renewable energy projects**

Dear Sir/Madan

The Inquiry into the feasibility of undergrounding the transmission infrastructure for renewable energy projects was established on 22 June 2023 to inquire into and report on the feasibility of undergrounding the transmission infrastructure for renewable energy projects.

The Terms of Reference indicate that the Standing Committee on State Development inquire into and report on the feasibility of undergrounding the transmission infrastructure for renewable energy projects, with particular reference to:

a) the costs and benefits of undergrounding,
b) existing case studies and current projects regarding similar undergrounding of transmission lines in both domestic and international contexts,
c) any impact on delivery timeframes of undergrounding, and
d) any environmental impacts of undergrounding.

To this end, Energy Grid Alliance (EGA) is pleased to make a submission to this inquiry. The attached paper (*EGA - Feasibility of undergrounding transmission infrastructure.pdf*) addresses the terms of reference as much as practical. It is important to note that EGA's submission focusses primarily on the benefits of underground HVDC, not underground HVAC. This is due to the superior benefits of using HVDC technology.

It is important throughout the Inquiry, that distinction and comparison be made between underground HVAC and underground HVDC as the outcomes can be notably different with respect to environmental impacts, costs, and system resilience. Underground HVDC provides a superior transmission solution that minimises degradation of the broader environment by mitigating the likelihood, extent and/or duration of potential effects and increases system resilience to climate and extreme weather events.

It is also important to note, with respect to costs, that there is no on-size-fits-all solution. Studies (often based on assumptions) have shown that the cost of undergrounding can be between 3 to 20 times more expensive than an overhead HVAC solution. Once reason these figures have varied so considerably is that the distinction between HVAC and HVDC has not been made during the assessment. Other reasons costs can vary per project are due to topography, geography, and overall route selection. Costs vary widely depending on the specifics of the project (such as power rating, circuit length, overhead vs. cabled route, land costs, site seismology, and AC network improvements required at either terminal). A detailed comparison of DC vs. AC transmission costs may be required in situations where there is no clear technical advantage to DC, and economical reasoning alone drives the selection.

To realise the true net benefit of underground HVDC over the life of a project, a Triple Bottom Line (TBL) analysis is required for each transmission project to consider profit, people, and the planet.

In addition to the attached paper, EGA has also submitted the following appendices for consideration. EGA consider the focus of the Terms of Reference to be too narrow to truly appreciate the benefits of underground transmission.

These appendices represent submission that EGA has made to previous consultation processes. While some have a Victorian focus, the observations and recommendations are applicable to all Australian states.

The following appendices have been hyperlinked for ease of access.

1. **Understanding External Costs of Overhead Electricity Transmission**
External costs should be considered in transmission planning to rebalance the true benefits, this will lead to greater market efficiency and environmental sustainability. The evaluation of the external costs could be of great help during the cost-benefit analysis, allowing the negative impacts to be considered in the process to identify the optimal transmission development path. This could be achieved through new planning tools, such as a Strategic Land Use Assessment (SLUA), Multi-Criteria Analysis (MCA) and Economic Impact Assessment (EIA) some of which are currently being proposed by the Victorian government under its proposed Victorian Transmission Investment Framework (VTIF).

2. **Review of AusNet Services WVTNP Underground Construction Summary Report**
While AusNet Services findings are preliminary and are still subject to peer review, their investigation finds that undergrounding the HVAC transmission line along their proposed routes would cost approximately 16 times more. As a result, AusNet Services dismissed undergrounding and have recommend overhead construction. However, the absence of design and cost detail for both the underground HVAC and HVDC options referenced make it difficult to verify and substantiate the conclusion. Misconceptions may have inadvertently led to overhead HVAC construction being recommended as the preferred solution by the investigation and underground solutions prematurely dismissed.

3. **Response to the Built Environment Climate Change Adaptation Action Plan 2022-2026**
Increasing frequency of dangerous fire weather poses a threat to most assets, with a particularly high operational risk to transmission lines due to heat and smoke. It is also an important consideration in transmission line route selection and design. Routing critical transmission infrastructure away from bushfire prone areas or underground, would enable our energy networks to better withstand extreme weather events and build increased network resilience. In countries like Australia that are prone to bushfires, underground HVDC Transmission Interconnectors or Transmission lines solve at least two problems for NEM Transmission and Distribution Participants in

the event of bushfires and in planning the Risk Management of their Assets during bushfires. Underground HVDC as opposed to Overhead HVAC or HVDC Interconnectors or Transmission lines are not at risk of starting bushfires. Underground HVDC Interconnectors or Transmission Lines do not need to be turned off if they are in the path, or in the vicinity of a Bushfire.

4. Response to the Building a Better Understanding of Bushfire Risk Consultation Paper

According to the Australian Energy Market Operator (AEMO), "good engineering design will ensure that any new infrastructure does not lead to unsustainable deterioration in grid resilience. Building additional transmission lines along a bushfire prone transmission corridor would be an example of resilience deterioration". To help defend Australia's communities, economy and the environment against extreme weather events and future-proof critical energy infrastructure, the Government, network planners, and operators need to adopt best planning practices and design resilience into the grid by avoiding or undergrounding bushfire prone regions and heavily forested corridors. Routing critical transmission infrastructure away from bushfire prone areas or underground, would enable our energy networks to better withstand extreme weather events and build increased network resilience.

Engineering Resilience

Climate change is resulting in rising global temperatures, erratic patterns of precipitation, sea level rise and more frequent or intense extreme weather events. This has significant implications for electricity security. For generation, the impacts of climate change can reduce the efficiency and alter the availability and generation potential of power plants, including both thermal and renewable facilities. Climate change impacts on transmission and distribution networks can result in higher losses, changes in transfer capacity and particular physical damage. It is also expected to increase electricity demand for cooling in many countries, which will become a driving factor for generation capacity additions.

Studies suggest that the benefits of resilient electricity systems are much greater than the costs in most of the scenarios considering the growing impacts of climate change. It is estimated that for every dollar invested in climate-resilient infrastructure, six dollars can be saved. According to the World Bank, if the actions needed for resilience are delayed by ten years, the cost will almost double.

Underground transmission, which require a higher upfront outlay than above-ground systems, can significantly reduce potential damage from climate impacts and save recovery costs. Transmission lines above ground tend to be more vulnerable to climate hazards such as high-speed winds, wildfires, floods, and landslides, than underground systems.

There are clear gaps in current regulatory framework that prevent prioritisation of resilience. When impacts of extreme weather events interrupt electricity supply and lead to large socio-economic costs, network operators are only expected to bear a fraction of the repair and social costs, with most of the costs often being passed through to energy consumers. Lack of competition and the presence of monopolistic market conditions also discourage network operators from investing in climate resilience measures for enhanced quality of electricity services.

Policy makers need to fulfil a critical role in building resilient electricity systems by adopting effective policy measures that can prevent a potential 'market failure'. Investing in resilience is demonstrated to deliver significant improvements in both resilience and reliability, resulting in beneficial cost and performance outcomes for customers using cost-effective and efficient network investment approaches.

Increasingly, energy system vulnerabilities to heightened climate impacts, particularly extreme weather, are recognised as material risks to individual assets, the integrated energy system, and society. Routing critical transmission lines underground, would enable our energy networks to better withstand such extreme weather events and build increased resilience. Increasingly, utilities in other countries are routing power underground, despite the added expense. Denmark was among the first to mandate it in 2008, requiring most new AC and HVDC transmission to be routed underground. In 2015, Germany mandated underground transmission for HVDC systems.

There will always be debate around the cost versus benefit and justifying the additional project cost of undergrounding to improve resilience to future climate effects. Considering the long terms economic and social costs, caused by these extreme weather events, the risk in building overhead transmission infrastructure is that investments will not be optimally designed for the needs for resilience to future climate change. This inherent limitation may not be fully appreciated until the future climate is experienced. And by then it will be too late.

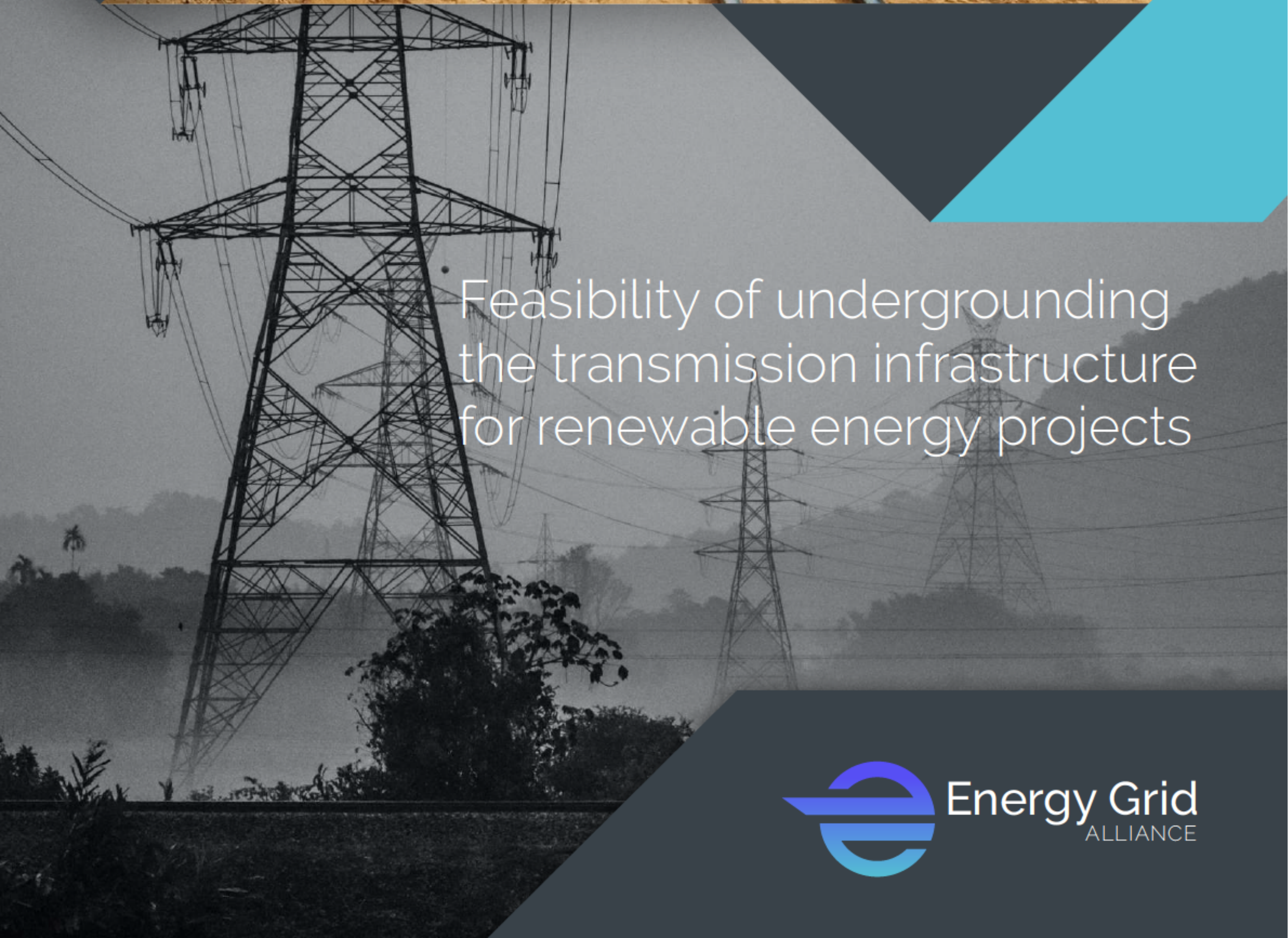
Australia’s electricity system is transforming at a rapid rate. We need a reliable and resilient power system that keeps the lights on around the clock, especially during extreme weather events when Australians need it most. Investing in transmission networks that are reliable, resilient, secure, and efficient will support the connection of new wind, solar and hydro generation and smart storage solutions that are waiting to be commissioned.

Where there is a need for new transmission, underground options should be considered, using existing rights-of-way where technically feasible. This will eliminate risks to the infrastructure from extreme weather and bushfire related events and significantly reduce socioeconomic and environmental impact.

I would like to thank you for the opportunity to contribute this Inquiry and welcome further discussion should you have any questions regarding this submission.

Sincerely

Darren Edwards
Director



Feasibility of undergrounding the transmission infrastructure for renewable energy projects

Energy Grid
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The transition to renewable energy generation must be harmonised with broader environmental goals to enable the exploitation of co-benefits and minimise negative socioeconomic and environmental impacts.

Contents

We must strive to achieve decarbonisation targets whilst maintaining environmental standards.

Background

The transition from coal-based to renewable energy is one of the key challenges of the 21st century. Conversion of the energy supply system must, however, be designed to minimise the impact on the environment and landscape and take account of human needs. The strong incentive mechanisms over recent years have led to a dynamic expansion in renewable energies and in order to harmonise climate change objectives with the conservation of biodiversity, the interests of nature conservation and landscape management must be fully considered.

This raises the question of what consequences will arise for the environment and society if Australia's renewable energies are gradually expanded until the Australian Government's Net Zero climate goals are reached?

Economic models and financial mechanisms should be developed to provide transparency around environmental, social, and economic trade-offs. This will ensure that the full impacts of decarbonisation are recognised, and the societal and environmental benefits are maximised.

HVDC has experienced a dramatic global expansion in use over recent years, as well as putting cables underground rather than stringing lines overhead. Historically, the higher cost of HVDC and undergrounding was a significant deterrent to its use. However, with lower cost production methods, improved technologies and increased reliability, the cost differential between underground HVDC cables and overhead lines is rapidly narrowing.

Globally, transmission network developers are more frequently turning to underground HVDC as an economically viable and environmentally sensitive way of providing redundancy, resilience and reliability in transmission networks.

Leadership is required to address the interdependencies between achieving decarbonisation and non-climate related environmental degradation and harmonise environmental policies with decarbonisation strategies, with respective bodies working together at state, national and international levels.

Governments, businesses and individuals and investors have an obligation to reduce greenhouse gas emissions and prepare Australia for the impacts of climate change. We must strive to achieve decarbonisation targets whilst maintaining environmental standards. Undergrounding transmission, where feasible, can help achieve this.

The Transition to Renewable Energy

The transition to renewable energy is great news for the climate and some regional communities welcome the transition for the many benefits it provides our climate, agriculture and environment.

Renewable Energy Zone (REZ) development across our nation will involve significant investment in transmission network infrastructure to transport electricity from the source of generation to electricity consumers.

This infrastructure will in most cases be routed through regional areas and communities that often have limited capacity to absorb this new infrastructure. It is critical that communities are recognised as key stakeholders in this transition and are involved from project inception.

It is important that best practice planning, setback distances, constraints and resilience policies be investigated, considered and applied during initial investment tests, rather than a project proponent having to deal with the consequences of ill-conceived corridor selection, resulting in community backlash, cost blowouts and material project delays.

It is important to recognise that transmission line projects of this scale have not been built for close to four decades. As such, there is limited knowledge of best practices and a notable lack of planning policy and framework supporting new transmission. There is limited consideration of externalities beyond the poles and wires.

Our research has shown that existing planning policy and resilience framework relates to activities around existing infrastructure, not new. This results in reactive planning and mitigation measures rather than a proactive approach. When routing transmission lines, it is crucial that the path of least-regret is taken, and the most resilient approach engineered.

Australia's electricity system is transforming at a rapid rate. We need a reliable power system that keeps the lights on around the clock, especially during extreme weather events when Australians need it most.

Investing in transmission networks that are reliable, resilient, secure and efficient will support the connection of new wind, solar and hydro generation and smart storage solutions that are waiting to be commissioned.

Where there is a need for new transmission, underground options should be considered, using existing rights-of-way where technically feasible. This will eliminate risks to the infrastructure from extreme weather and bushfire related events and significantly reduce socioeconomic and environmental impact.

According to analysis by world-leading transmission cable manufacturers, **ABB**[1]**,** by optimising design solutions that minimise the number of overhead transmission links needed and undergrounding HVDC, it is possible to cut hundreds of millions of tonnes of carbon emissions by reducing the volume of construction materials required.

By working together, with smart thinking and technology, we can engineer resilience, safeguard reliability, reduce carbon emissions, encourage renewable generation investment, create new and exciting jobs, and avoid unnecessary impacts on our economy and environment.

Feasible Transmission Alternatives

Route selection should try to avoid, minimise, or offset impacts on important environmental, social, cultural, landscape values and strategic land use conflict by utilising existing rights-of-way as a priority.

Replacing overhead High Voltage Active Current (HVAC) with High Voltage Direct Current (HVDC) on existing infrastructure and deployment of underground HVDC technology should be considered as preferred transmission options to avoid community and environmental impacts.

While HVDC solutions may increase initial project cost due to the need for converter stations, they would deliver greater lifetime benefits, including increased electricity throughput, less energy losses, improved reliability, less exposure to weather events, increased bushfire resilience, lower operating costs, less environmental impact and considerably less opposition.

This is illustrated in the following table.

What are the feasible alternatives?

1. Leveraging existing transmission corridors
2. Converting existing transmission infrastructure to HVDC
3. Underground HVDC transmission

Comparative Analysis Ranking

🟩 Superior Outcome
🟧 Moderate Outcome
🟥 Inferior Outcome

Project Considerations	Overhead HVAC Proposed Corridor C2 *Greenfield*[1]	Overhead HVAC Existing Corridor B3 *Greenfield & Brownfield*[2]	Overhead HVAC Existing Corridor B4 *Brownfield*	Converting Existing Assets to HVDC *Brownfield*	Underground HVDC *Green & Brownfield*
Capital cost	🟧	🟩	🟩	🟧	🟥
Ongoing operating cost	🟧	🟧	🟧	🟩	🟩
Lifetime Project Costs (30 years)[3]	🟧	🟧	🟧	🟧	🟧
Triple bottom line[4]	🟥	🟧	🟧	🟩	🟩
Fault finding/maintenance	🟩	🟩	🟩	🟩	🟩
Electricity throughput constraints	🟧	🟧	🟧	🟩	🟩
Transmission losses	🟧	🟧	🟧	🟩	🟩
Reliability and Security	🟧	🟧	🟧	🟧	🟧
Resilience to climate change[5]	🟧	🟧	🟧	🟩	🟩
Environmental impact	🟥	🟩	🟩	🟩	🟩
Biodiversity impact	🟥	🟩	🟩	🟩	🟩
Visual amenity impact	🟥	🟧	🟧	🟧	🟩
Cultural impact	🟧	🟩	🟩	🟩	🟩
Land use conflict[6]	🟧	🟧	🟧	🟩	🟩
Social impact	🟥	🟧	🟧	🟩	🟩
Community opposition	🟥	🟧	🟧	🟩	🟩

1. *Greenfield Site: Previously undeveloped sites for commercial development or exploitation.*
2. *Brownfield Site: Sites that have had previous development on them.*
3. *Lifetime Project Costs: Includes construction, ongoing operation, maintenance, economic impact due to power outages.*
4. *Triple bottom line: The triple bottom line is a sustainability based accounting method that focuses on people (social), profit (economic) and planet (environment).*
5. *Resilience to climate change: Resilience from bushfire to communities and infrastructure, resilience to increased extreme weather events.*
6. *Land use conflict: Strategic agricultural land, urban growth, significant landscape, materially populated towns.*

Permitted Activities - Overhead vs Underground

Both farming and agriculture can be affected by overhead and underground transmission, by the elimination of cropland, the temporary loss of crop production due to construction, and the incompatibility of certain crops and agricultural and/or farming activities with transmission facilities. Transportation can be affected by the placement of transmission lines and towers near airports, roads, and waterways.

To better understand the impacts, it is important to conduct a side by side comparison. The table below outlines the potential impacts of both overhead HVAC transmission (AusNet Services)[2] and underground HVDC transmission (Marinul Link)[3]. It is relevant to note that undergrounding can provide superior outcomes by utilising existing rights of way and avoiding traversing private land where possible.

According to the Victorian Farmers Federation (VFF)[4], aside from general disruption to farming operations, the VFF is concerned about the following issues caused by overhead transmission lines traversing agriculture and farm land:

- decreased land value and loss of productive capacity;
- Requirement for permits to use tractors and machinery under powerlines;
- inability to irrigate under powerlines;
- inability to utilize emerging technologies such as drones and autonomous vehicles;
- failure to inform owners of changed policy on the easements;
- refusal to give notice or inform landholders what chemicals have been used on site causing issues with vendor declarations;
- spread of weeds;
- failure to close gates;
- damage to crops;
- materials left on site causing damage to machinery.

Comparative Analysis Ranking

🟩 Superior Outcome 🟧 Inferior Outcome

Activity	**Overhead HVAC** (AusNet Services)	**Underground HVDC** (Marinus Link Victoria)
Cropping	🟧 Permitted to a depth of 300mm from the original ground profile. Permitted within 5m of the tower steelwork provided access for maintenance works is maintained.	🟩 Ploughing/tilling to a depth of 500mm) is permitted. Ploughing/tilling to a depth of 700mm) is conditional. Ploughing/tilling to a depth greater than 700mm) is prohibited.
Grazing of livestock	🟩 Permitted	🟩 Permitted
Irrigation	🟧 Centre pivot and lateral moving irrigators permitted to a height of 8.6m. Headers with augers extended is permitted to a height of 5m. Rain gun irrigators are prohibited.	🟩 Permitted. Fixed centre pivot irrigation infrastructure is conditional.
Dams	🟧 Building a dam is prohibited within easement area. Dams cannot be located within a 30m radius of any tower centre.	🟩 Building a dam is prohibited within easement area.
Vegetation	🟧 Mature tree and shrub growth of up to 3m in height is permitted. Planting trees and shrubs should be scattered or clumped with no more than 10% density of cover over the easement area.	🟧 Planting a garden is permitted (access may be required in the unlikely event of a cable fault). Planting deep rooted trees (greater than 0.5 metres) is prohibited.
Vehicles	🟧 Permitted to travel under the lines and operate vehicles up to 5m in height.	🟩 Permitted without restrictions.
Construction and earth moving	🟧 Construction including earth moving and excavation is subject to height restrictions and requires prior approval and a permit.	🟧 Building minor, temporary or light structures is permitted subject to depth limitations. Excavation or earthworks is conditional. Reducing or increasing ground level is prohibited. Constructing houses or substantial structures is prohibited.
Fencing	🟧 All fixed metallic parts must be earthed and are subject to prior approval.	🟧 Using electric fences is subject to prior approval.
Aerial crop spraying manned aircraft (e.g. light plans and helicopters) and unmanned aerial vehicles (e.g. drones)	🟧 Manned aircraft and unmanned aerial vehicles are prohibited.	🟩 Permitted.

Global Rise of HVDC Transmission

Historically, comparisons of high-voltage alternating current (HVAC) with high-voltage direct current (HVDC) transmission as a means of providing grid connections have tended to opt for the HVAC option.

However, around the world, the installation of HVDC systems is now increasing at a rapid pace. Examples include Europe, North and South America, and China etc., and the trend is accelerating. *(see Figure 1)*.

Australia appears to be lagging behind the world trend but is now catching up. HVDC has historically been viewed as a last resort under special conditions, such as frequency conversion, interconnectors or subsea transmission, however, a number of HVDC projects are now under development to facilitate the long-distance transmission of renewable energy sources.

Another factor behind the global rise in popularity of HVDC, in addition to increases in renewable energy capacity, growth of cross-regional electricity trading, and rising demand for a more reliable electricity supply, is the economic justification for using HVDC to strengthen grid connections. This has been demonstrated by numerous HVDC projects, as well as cost-benefit analysis (CBA) conducted by the European Network for Transmission System Operators - Electricity (ENTSO-E)[5].

Figure 1 | Construction of VSC HVDC Europe

VSC: voltage source converter HVDC: high-voltage direct current

Map Source: Hitachi Review Vol. 69, No. 4 462 463

Rapid technical progress in voltage source converter HVDC (VSC HVDC) has also contributed significantly to this outcome. VSC technology is a recent advancement, with the first commercial systems commissioned in the late 1990s. VSC technology uses the switching of Insulated Gate Bipolar Transistors (IGBTs) in a Convertor Station to create an AC voltage waveform to cause both active power and reactive power to flow, in either direction. The same IGBTs are used to create a DC voltage to allow active power to flow to or from another Converter Station. The maturing of VSC HVDC technology offers a variety of benefits to power grids that have made HVDC an effective option for strengthening grid connections.

In the past, HVDC connections tended to be used to connect different AC power grids, in many cases by subsea cables, however, a notable development in recent years has been that there is growing number of cases where HVDC is installed within a single synchronous grid—where the AC option was usually chosen in the past—or where HVDC systems have been built to operate in parallel with existing AC grids as high capacity shunts or 'bypass' connections.

This indicates that HVDC can solve a variety of electricity grid challenges and in a growing number of cases HVDC has a competitive edge over AC options.

Globally, rather than only being used for a limited range of applications, where special conditions apply, HVDC has become a widely used option for a diverse range of situations.

Some key observations on international trends in HVDC projects include:

- An increased preference for VSC technology
- Increasing power capacity requirements for VSC projects
- Increased instances of multi-terminal VSC HVDC systems
- More HVDC projects with long-distance underground land cables being developed and installed
- More VSC HVDC systems using long distance HVDC overhead transmission lines
- Increased interest in the conversion of existing HVAC transmission lines to HVDC.

The increased rate of HVDC use is a result of how rapidly VSC HVDC technology has advanced over the past 20 years.

VSC HVDC can now provide capacities up to 3 or 4 GW and typically use voltages between 100kV and 800kV. Technological progress is also reducing the required land area for transmission and the electrical losses of AC-to-DC Converter Stations, thereby improving the overall economics of HVDC. This means the technology can meet most application needs.

VSC HVDC has a major role to play in increasing the penetration of renewable energy around the world while also helping to improve grid stability.

Technical Considerations

High-Voltage direct current (HVDC) transmission uses direct current (DC) for the bulk transmission of electricity, in contrast to the more common high-voltage alternating current (HVAC) systems. The reason HVAC systems are more common than HVDC is historical. National Grids have been evolving for over 100 years. Solid-state power electronics for cost effective HVDC Systems did not become available until the early 1970's.

Technical Advantages of HVDC vs HVAC

- An HVDC line has lower power losses than an HVAC line of the same capacity in practically all cases, which means more power is reaching its destination
- For long-distance transmission, HVDC systems are less expensive and have lower electrical losses
- HVDC avoids the heavy currents required for AC to charge and discharge the cable capacitance each cycle when placed underwater or underground, this allows cables to be buried rather than suspended on towers
- For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be justified, due to other benefits of direct current links
- Underground cables will have higher reliability and lower failure rates than overhead lines.

HVDC has experienced a dramatic global expansion in use over recent years due to the following benefits:

- Undersea-cable transmission schemes between land masses and from offshore renewable energy generation
- Point-to-point long-haul bulk power transmission without intermediate 'taps,' usually to connect a remote generating plant to the main grid
- Increasing the capacity of an existing power grid in situations where additional lines are difficult or expensive to install
- Power transmission and stabilisation between unsynchronised AC networks. An example being the ability to transfer power between countries that use AC at different frequencies. Power transfer can occur in either direction, which increases the stability of both networks by allowing them to draw on each other in emergencies and failures
- VSC HVDC systems can relax operational constraints imposed on AC grids by voltage stability considerations and can be used for damping control to suppress power swings that might occur on the AC grid
- VSC HVDC can contribute to the transient stability of existing AC grids through supply of reactive current during a grid fault to minimise the voltage drop and the suppression or damping of power swings after the fault is cleared
- VSC HVDC can be utilised to support restoration after blackouts.

Technical Disadvantages of HVDC vs HVAC

Some disadvantages of HVDC may be in conversion, switching, control, availability, and maintenance.

- Because of the additional conversion equipment HVDC is statistically less reliable and has lower availability than alternating current (AC) systems
- Converter Stations are expensive to build
- At smaller transmission distances, power losses in the Converter Stations may be greater than in an AC transmission line (which does not require a Convertor Station) for the same distance
- For shorter distances, cost of Converters may not be offset by reductions in line construction cost and lower line loss
- Operating an HVDC system requires many spare parts to be kept, often exclusively for one system, as HVDC systems are less standardized than HVAC systems and technology changes faster
- In contrast to AC systems, realising multi-terminal systems is complex, as is expanding existing systems to multi-terminal systems.

Table 1 - Pros and Cons of VSC HVDC and HVAC **Technology**[6]

Parameter	HVAC	VSC HVDC
Controllability	No	High
Losses Substation/Converters	Lower	Higher
Losses Lines/Cables	Higher	Lower
Inherent Voltage Support Capability	Not Available	Available
Inherent Damping Control Capability	Not Available	Available
Overhead Line	Larger Conductors, More Conductors, Larger Towers	Smaller Conductors, Fewer Conductors, Smaller Towers
Underground Cable Capability	At a distance >50km and at higher voltage, requires substantial reactive compensation	No Practical Limit on Distance, Fewer Cables
Tap Off Points Along Route	Unlimited, relatively low cost	Limited to a few, preferably known in advance, high cost
Substation/Converter Station Footprint	Smaller	Larger
Easement Width for Overhead Lines	Larger	Smaller
Trench Width for Underground Lines	Larger (up to 45m)	Smaller (2 4m)
Visual Impact of Overhead Lines	Greater	Lesser
Visual Impact of Underground Lines	Greater	Negligible

Socioeconomic Considerations

VSC HVDC transmission has several technical advantages over HVAC transmission, including controllability, lower losses on the transmission lines, voltage support and damping control capability. Conversely, HVAC transmission has lower losses in the terminals (substations) than a HVDC Convertor Station.

For the same power transfer level, the VSC HVDC transmission can be superior in terms of environmental impact and aesthetics where the use of underground cables becomes more viable.

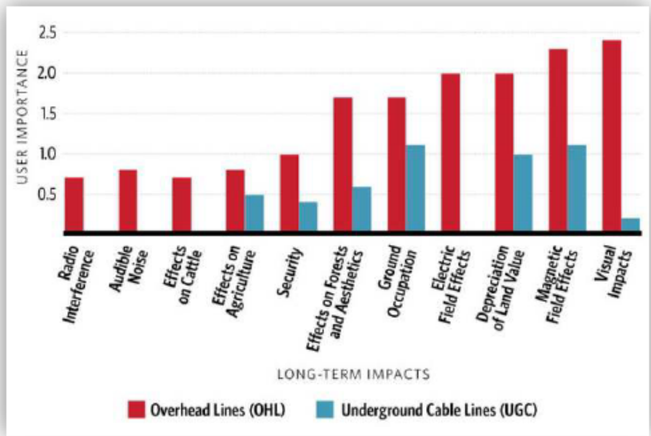
Historically, the higher cost of underground HVDC was a significant detractor for its use. However, with lower cost production methods, improved technologies and increased reliability, the cost differential between underground cables and overhead lines is rapidly narrowing.

Transmission project developers are more frequently turning to underground HVDC as an economically viable and environmentally sensitive way of providing redundancy, resilience and reliability in transmission networks.

To realise the true net benefit of underground HVDC over the life of a project, a Triple Bottom Line (TBL) analysis is required to consider profit, people and the planet. Not just profit.

The International Council on Large Electrical Systems (CIGRÉ), compared the impacts of greatest environmental concern for overhead lines (OHL) and underground cable lines (UGC)[7]. (*See Figure 2*)

Figure 2 | User Importance of Long-term Impacts



Compared to overhead HVAC, underground HVDC transmission provides significant socioeconomic benefits:

- Little to no risk of underground cables causing fire or being affected by severe weather events
- Infrastructure resilience to extreme weather-related events such as bushfires, storm damage, interruptions, costs of storm damage surveys and precautionary storm shutdowns
- Little to no impact to access e.g., for emergency services and aviation operations
- No avian or bat mortalities due to transmission line collisions
- No impact to Aboriginal cultural heritage and historic cultural heritage as areas can be avoided
- Minimal impact on private land or current land-use once construction is completed as easements can be designed to fit within an existing right-of-way
- Significantly reduced land-use conflict with easements typically ranging from 2-4m wide
- Protects agricultural values including irrigation infrastructure and avoids potential for loss of prime production agricultural land
- While a larger volume of soil excavation may be required, compared to an overhead line, vegetation is typically restored within a few years
- Minimises impact to endangered or threatened and protected species, biodiversity and native vegetation
- Protects landscape values and visual amenity
- Equivalent or reduced visual and land-use impact from Converter Stations as they would be expected to occupy a similar area as a typical HVAC terminal station with much of the equipment being housed indoors
- No audible noise
- Little to no electromagnetic field impacts
- Lower maintenance costs than overhead lines
- Opportunity costs from lengthy planning delays are reduced and the expense and complexity of public legal battles are minimised
- Less impacted by planning zones, overlays, and buffers.

Environment Considerations

The transition from coal-based to renewable energy is one of the key challenges of the 21st century. Conversion of the energy supply system must, however, be designed to minimise the impact on the environment and landscape and take account of human needs. The strong incentive mechanisms over recent years have led to a dynamic expansion in renewable energies. To achieve a harmonisation of the climate change objectives with those of conserving biodiversity, the interests of nature conservation and landscape management must be fully considered.

While the output of renewable energy generation thus far has only met a relatively minor proportion of the total energy requirement in Australia, in places this has come at the cost of significant changes to the landscape and impacts on the natural environment. This raises the question of what consequences will arise for nature, landscape and society if renewable energies are gradually expanded until the Australian Government's Net Zero by 205 is reached?

According to Victoria's Climate Change Act 2017[8], everyone — State Government, local government, businesses, individuals — has a role to play in reducing greenhouse gas emissions and preparing Australia for the impacts of climate change. This means considering the benefits to the environment of emission reduction strategies. Whilst ambition for rapid decarbonisation is commendable it is recognised that it risks a wide range of unintended negative environmental consequences, both locally and across the world. We must strive to achieve decarbonisation targets whilst maintaining environmental standards.

Decarbonisation must be harmonised with broader environmental goals to enable the exploitation of co-benefits and minimise negative impacts. This coupled approach was demonstrated at COP26 where efforts to reduce fossil fuel use were set alongside the Glasgow Leaders' Declaration on Forests and Land Use[9], with 141 countries agreeing to halt and reverse forest loss and land degradation by 2030.

Economic models and financial mechanisms should be developed and deployed to provide transparency around environmental, social, and economic trade-offs. This will ensure that the full impacts of decarbonisation are recognised, and the societal and environmental benefits are maximised. Underground transmission answers many of the requirements that stakeholders now expect.

The construction and operation of overhead transmission infrastructure can lead to significant land use changes in the transmission right-of-way and on the grounds of associated facilities. The priority when planning transmission lines routes should be to avoid environment and land use conflict in the first place.

The impact of new overhead transmission infrastructure on an area may depend on the topography, land cover, and existing land uses. In forested areas for example, the entire right-of-way width is cleared and maintained free of tall-growing trees for the life of the transmission line. The result is a permanent change to the land cover resulting in habitat fragmentation.

Agriculture can be affected, by the elimination of cropland, the temporary loss of crop production due to construction, and the incompatibility of certain crops and agricultural activities with transmission facilities. Transportation can be affected by the placement of transmission lines and towers near airports, roads, and waterways.

Where transmission lines are routed through areas that are valued for their scenic qualities, or close to materially populated towns, the visual impacts of the line may extend well beyond the right-of-way.

Underground HVDC provides a superior transmission solution that minimises degradation of the broader environment by mitigating the likelihood, extent and/or duration of potential effects. Transmission network planners must apply the following mitigation hierarchy in order to maximise environmental benefits.

- **1. Avoidance**: measures taken to avoid creating adverse effects on the environment from the outset, such as careful spatial or temporal placement of infrastructure or disturbance, e.g., undergrounding
- **2. Minimisation**: measures taken to reduce the duration, intensity and extent of impacts that cannot be avoided
- **3. Rehabilitation/restoration**: measures taken to improve a degraded environment following exposure to impacts that cannot be completely avoided or minimised
- **4. Offsets**: measures taken to compensate for any residual, adverse impacts after full implementation of the previous three steps of the mitigation hierarchy

HVDC Transmission Superhighways

Although the location of generation sources is becoming more diverse, system demand remains relatively localised, and power still needs to get to the same locations. The NEM Renewable Energy Zones (REZ) are maturing, incentivising generation to cluster where fuel resource is favourable and in locations where high-capacity network augmentation between the REZ and the bulk transmission system could be economic. This is not without its challenges though, as the bulk transmission system can then become the bottleneck, requiring extensive and costly augmentation with long lead times and considerable regulatory uncertainty.

Injecting REZ generation capacity directly into major demand centres seems a sensible option to explore, providing a bypass of existing and emerging bottlenecks in the transmission where management of future congestion risk is of major concern or in other words, creating a high-capacity parallel path to "shunt" power and offload the parallel transmission network.

HVDC can make this possible

Other countries are exploring and implementing the conversion of AC transmission lines to HVDC systems to benefit from the higher power transfers possible without installing new transmission towers[10]. One HVDC transmission system deployed overhead can prove to be more reliable than a double circuit AC transmission line[11].

The implementation of such "transmission superhighways" could allow the bulk of the generation to get to the major load centres directly with lower losses, while leaving the parallel AC transmission network with less congestion to allow generation and loads to "tap in" along the way.

This solution can be visualised as a highway bypass, allowing the bulk of traffic to bypass the area while still keeping the roads in and within the bypassed area available for local traffic to enter and leave with less congestion.

Underground Transmission a Priority in Germany

The Federal Government has put the policies in place for expanding the grid more quickly and gaining public acceptance for it. Following the agreement within the governing coalition in July 2015, the cabinet gave the go-ahead in October 2015 for an increased use of underground DC cables (in German). On 3 December 2015, the Bundestag adopted the draft legislation, as amended by the coalition party groups, and the bill passed the Bundesrat on 18 December 2015. The new rules entered into force at the turn of the year 2015/2016[12].

In Germany, priority will now be given to building the new electricity highways (the HVDC transmission lines) as underground rather than overhead powerlines. This applies in particular to the large transmission lines running from north to south such as 'SuedLink' or 'SuedOstLink'. In general, overhead DC powerlines are to be prohibited in places where people live. They will only be used in exceptional cases, for example in areas where nature conservation interests are identified or where existing powerlines can be used without major impact to the environment.

The use of underground cables will result in higher costs. But it is also clear that, in macroeconomic terms, even if the grid is expanded using underground cables, this is still the cheapest route to a successful energy transition.

In macroeconomic terms, grid expansion which meets with local acceptance and takes place in actual fact will reduce the costs of the energy transition. At present, congestion management is causing high costs (combined costs for redispatch, feed-in management, reserve power stations). These annual costs exceeded 1 bn euros in 2015. Unless there is significant progress on grid expansion, these costs will continue to rise in the coming years.

Greater use of underground cables in Germany will cost an additional €3bn to €8 bn in investment costs (compared to the costs under the former legal situation). These are one-off investment costs which do not recur annually. These increased investment costs will be passed on in the form of grid charges.

It is very difficult to arrive at a precise cost estimate as there is no one-size-fits-all solution. The extent to which costs will increase due to the use of underground cables in the high voltage transmission grid will very much depend on local conditions (actual route, soil conditions, transverse infrastructure, actual cost of components, etc.).

Conversion of HVAC to HVDC Retrofitting Existing Lines

In general, HVAC transmission lines have an inherent design inefficiency whereby the conductor current carrying capability remains largely unused. With increasing system voltages and the consequential increase in conductor bundles; this design inefficiency worsens. When the same transmission line is converted to carry direct current, the full conductor current carrying capability can be fully employed. The net result is much higher power transfers, more economic utilization of existing assets and the removal of the need for new power line routes, rights of way and servitudes. HVDC also introduces many key technical and economic benefits such as lower power losses for bulk power transfers, creation of asynchronous power systems, advanced controllability of large power systems having both speed of response and intelligence of control[13].

An example of this application is ULTRANET[14] (*refer to Case Study 6*), a new HVDC link between North Rhine-Westphalia and Baden-Württemberg in Germany. When it is finished, this "electricity highway" will mainly transmit renewable electricity from the north of Germany to the center and south from 2026 onwards, thus further advancing the energy transition in Germany. This 340-kilometre-long line can transmit some 2,000 megawatts of electricity. When complete, ULTRANET, we will transmit direct and alternating current – both with a voltage of 380 kilovolts – over the same pylons. By using existing routes to do so, the project developers are increasing the capacity of the network in an efficient and resource-friendly way.

In addition, HVDC enables improved use of existing power lines through higher power density. This means that with the construction of HVDC lines, the need for new power lines in the AC grid will be reduced.

With HVDC direct current can also be transmitted in both directions (bidirectional). The advantage: not only the wind power can be routed from the coast to the south when there is a surplus of electricity from wind production - in times of strong sunshine it is possible, for example, to transport electricity from photovoltaics to the north.

Direct current reduces energy loss over long distances. In addition, direct current can be better controlled and regulated. This is important in order to be able to react quickly to large fluctuations in the amount of energy, which are primarily caused by wind power and photovoltaics.

When considering the Australian Energy Market Operators' Integrated System Plan, and its vision to connect Tasmania to Northern Queensland via a heavily loaded 500kV backbone, there is no apparent reason the same solution could not be deployed in Australia.

The benefits of ULTRANET include:

- Use of existing high-voltage lines - the construction of new lines can be largely avoided
- Joint routing of direct current and alternating current on the same masts - this reduces the space consumption
- High transmission capacities over long distances from point to point
- System security: Better control and regulation of direct current enables rapid reaction to fluctuations in the amount of energy, which are primarily caused by wind power and photovoltaics
- Transmission of large amounts of electricity in both directions
- Reduction of energy loss over long distances

Unqualified Assumptions for Undergrounding

According to AEMO 2023 Draft Transmission Expansion Options Report[15], In the absence of detailed designs, AEMO has made the following **assumptions** for considering undergrounding in areas where overhead transmission lines are not expected to be technically feasible or are not compliant with planning requirements or environmental legislation:

- HVAC underground cable is suited to lengths below approximately 50 km. Beyond 50 km length, AC cables at high voltage level will be subject to very large charging currents, requiring significant reactive compensation and design considerations.
- For HVDC options, longer lengths of underground cable are likely to improve commercial feasibility relative to overhead options.
- Direct burial of cables is cheaper than tunnel installation, but is only suitable in non-urban areas. Built up areas will typically require tunnel-installed cable to avoid existing infrastructure. Maintenance is easier on tunnel-installed cables due to simpler access of the cable.

AEMO's assumptions conclude that the costs of underground cables are approximately **4** to **20** times higher than overhead lines.

Star of the South, Australia's most advanced offshore wind project, has been developing a 2.2 GW capacity, high voltage, **underground** transmission system. Based on this experience and work with local landholders, communities, and other stakeholders, Star of the South offered the following inputs to the Options Report[16].

Reducing community, land use, environmental and visual impacts are typically the main drivers for choosing underground transmission. Underground transmission will have an increasing role in managing impacts and risks associated with the rapid and large-scale transition underway.

Different transmission technologies have varying advantages and disadvantages which need to be considered and balanced for each specific project. In addition to cost, consideration of community and visual impacts, land use and landholder impacts, soil disturbance, electrical system resilience, grid support, construction and maintenance are all important factors for sound decision making.

Social licence is a critical factor to enable the timely delivery of significant transmission required for Australia's energy transition. Star of the South welcomes an increased focus from AEMO on this need.

In its submission, Star of the South makes the following recommendations:

- That evaluation of transmission technology options includes multi-criteria analysis that includes environmental, social and land use considerations alongside cost and technical factors.
- The 'Tunnel installed cable' installation method is primarily applicable to urban areas, which may create the false perception that an underground cable solution is an order of magnitude more expensive than overhead transmission, particularly for rural projects. A more appropriate comparison would be to include unit costs for 'overhead lines', 'direct buried cables' and 'conduit buried cables'. This would reflect a more realistic unit multiplier for underground cables.
- The Options Report states that HVAC underground cables are suitable for lengths below approximately 50 km and beyond this distance, AC cables at high voltage levels will experience significant charging currents, necessitating reactive compensation and design considerations. The assumed transmission distance cut off in the costing tool for HVAC underground transmission should vary with the transmission voltage selected. For example, 20km for 500kV, 50km for 330kV and 75km for 275kV and 100km for 220kV.

Through our research, it has become clear to Energy Grid Alliance that many assumptions have been made by market participants with respect to undergrounding HVAC and HVDC that are either non-factual or misleading and require a great deal more clarification and technical detail.

In its own Underground Construction Summary Report (2021)[17] AusNet Services made similar assumptions and failed to make a clear distinction the costs and benefits between underground HVAC and underground HVDC. In many instances, 'undergrounding' was used as a broad term to cover both technical solutions. This resulted in undergrounding being dismissed for the Western Renewables Link as 16 times more expensive than an overhead solution.

AEMO's VNI West Project Assessment Draft Report (PADR) suggests that based on current cost assumptions, delivery of high-capacity HVAC 500 kV underground lines along the full length of the project is not economically justifiable under the RIT-T, with HVAC undergrounding costing in the order of at least **10-20** times more than overhead.

It is becoming abundantly clear there are too many assumptions being made and that underground transmission, specifically underground HVDC requires a great deal more attention.

Case Study

Underground HVDC Transmission

Capacity

525kV

Length

536km, underground

Underground Benefit

Avoids or minimises the typical impacts of overhead transmission line construction on sensitive environmental areas, including wetlands and forested areas.

1. SOO Green HVDC Link, USA

SOO Green is a first of its kind underground HVDC transmission line located primarily in the Canadian Pacific rail corridor between Iowa and Illinois in the US, that will connect the MISO and PJM regional energy markets, enabling the delivery of 2,100 MW of renewable energy from the upper Midwest to eastern markets. The innovative 350-mile project will use state-of-the-art 525KV class underground cable and Siemens' modern Voltage Sourced Converter (VSC) technology.

As the first link in a national clean energy grid, SOO Green's innovative underground rail co-location development model can be replicated to accelerate decarbonization and enhance grid reliability and resilience. Installing transmission cables safely underground within railroad rights-of-way protects landowners by avoiding using eminent domain to secure the project route. In addition, installing cables underground enables faster permitting by avoiding environmental and visual impacts associated with traditional overhead transmission lines.

The project will use two 5-inch diameter (about the size of a wine bottle), 525KV extruded cross link polyethylene (XLPE) insulated cables installed in a 2 ½' wide x 5' deep trench.

Underground rail co-location development

HVDC

Converter Station

The SOO Green HVDC Link will provide a number of significant benefits. Notably it will reinforce the transmission grid as an inter-regional 'backbone' transmission facility linking the transmission systems and increase the transfer capacity on the existing grid. The project will reduce viewshed and environmental impact through underground co-location within an existing pre-disturbed, privately owned railroad right-of-way, which not only avoids impacts to neighbouring landowners and the need for extensive use of eminent domain to secure real estate rights, but also avoids or minimises the typical impacts of overhead transmission line construction on sensitive environmental areas, including wetlands and forested areas.

The project represents an additional economic output in the state of Iowa of almost $1.0 billion, and over $1.1 billion the state of Illinois from transmission construction. The project will result in thousands of construction, operations and maintenance jobs, and additional economic activity throughout the Midwest.

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Case Study

Underground HVDC Transmission

Capacity

525kV

Length

750km, underground

Underground Benefit

Underground HVDC was selected mainly due to resistance from residents towards building overhead lines.

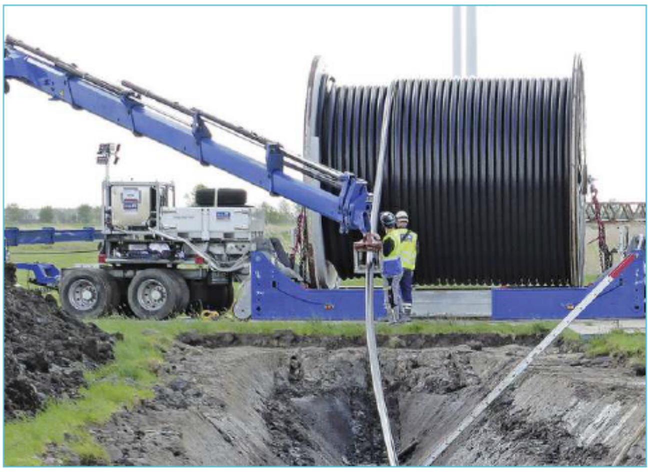
2. SuedLink, Germany

SuedLink was initially proposed as an overhead transmission line, however switched to HVDC underground cables following new legislation introduced by the German Government.

Under the new law, underground cables have been made the standard for new high voltage direct current (HVDC) projects while overhead lines will now become an exception. Further, overhead lines close to residential areas in general have been disallowed.

The project will deliver new underground cable connections to transport wind power from northern Germany to Bavaria and Baden-Württemberg.

There will be only manageable delays caused by the use of underground cables, compared to overhead cables.



Installation of underground HVDC cable

525kV HVDC cable trench

At a length of 750 kilometres, at 525kV and delivering 4000MW via two 2000MW circuits, SuedLink will be the largest transmission cable in the network and the longest underground power cable in the world .

SuedLink will help to better integrate renewable sources, such as wind and solar power, into Germany's electricity grid, and also link with interconnectors to provide cross-border energy resilience.

The project will be constructed using cable lengths of approximately 1200m. The number of trenches and the cable voltage is still to be optimised.

HVDC

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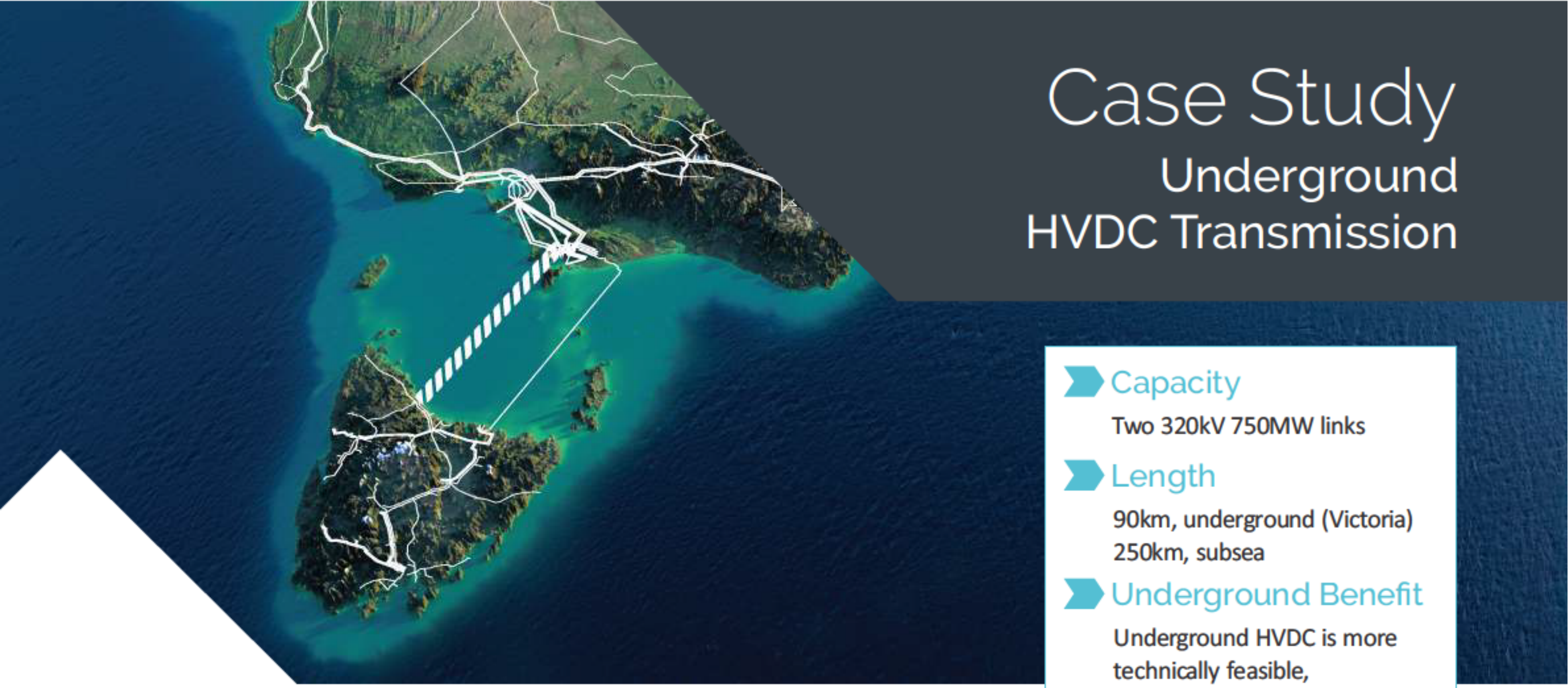


Case Study

Underground HVDC Transmission

Capacity

Two 320kV 750MW links

Length

90km, underground (Victoria)
250km, subsea

Underground Benefit

Underground HVDC is more technically feasible, economically viable, more efficient, and more beneficial to the project.

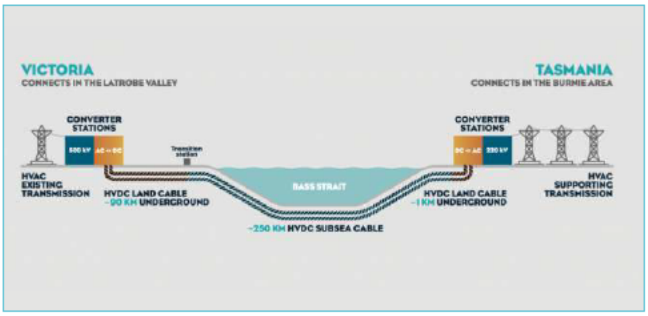
3. Marinus Link, Australia

Marinus Link involves laying approximately 250 km of subsea HVDC cables and approximately 90 km of underground HVDC cables to provide a second transmission connection between Tasmania and mainland Australia's electricity grid.

A set of HVDC cables between Heybridge in North West Tasmania and Hazelwood in the Latrobe Valley Victoria, with a converter station site at each end, has been identified as best suited to manage the energy transfer capacity of Marinus Link. It is proposed that the link is built in two 750 MW capacity stages, and that the land cables for each stage are located in a common easement.

The Marinus Link business case determined that, not only is underground HVDC technically feasible it was more economically viable, more efficient, and more beneficial to them; particularly so, when social licence, environmental and climate risks to overhead infrastructure were considered.

Map showing approximate land based underground cable route



Schematic indicating undregound, subsea and overhead transmission

Underground cables have been selected for the sea and Victorian land sections of Marinus Link due to a range of factors, including:

- HVDC uses fewer and more compact cables to transfer large volumes of energy over long distances of land and sea, compared to HVAC cables. HVDC cables therefore tend to be used to transport energy from 'point to point' at high volume over long distances.
- HVDC is the only viable technology for the approximately 250 km of subsea cable required for the Bass Strait crossing. It is viable to use on land as well, however a choice needs to be made as to where the converter stations connect it to the HVAC transmission network.
- It is more efficient to transport energy at HVDC from the Victorian coast right into the Latrobe Valley, and convert to HVAC there, as this represents the best balance between energy transfer, and connection of forecast new generation and load.
- For the Victorian HVDC land section, use of overhead HVDC transmission lines was considered, however would require more expensive VSC converter lightning protection schemes, and wider easements. Analysis therefore shows that underground HVDC cables, rather than overhead cable, is the preferred option for this section of the route.

HVDC

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Case Study

Underground HVDC Transmission

Capacity

150kV 220MW

Length

178km, underground

Underground Benefit

The Murraylink project earned several Australian state and national awards for both environmental and engineering excellence.

4. Murraylink, Australia

Murraylink is a 178km, 220 MW, 150 kV HVDC bipolar interconnector underground power transmission system, connecting the Riverland region in South Australia and Sunraysia region in Victoria through converter stations at Red Cliffs in Victoria and Berri in South Australia.

The controllable interconnection allows power to be traded in either direction between the two States and provides enough electricity to meet the needs of around 200,000 households. The HVDC transmission system comprises extruded cables buried in the ground and an HVDC converter station at each end of the link. Cables were laid and backfilled into the trench automatically using a Vermeer T755 Chain Trencher.

Network reliability is improved in terms of power supply and system voltage control, as the converter stations can both transmit power and support the AC voltage of surrounding networks, an important feature for the weak Berri network at the edge of the South Australian system.

Installation of underground HVDC cable

Underground co-location development using a Vermeer T755 Chain Trencher

From its near tri-state border site, Murraylink can deliver power from South Australia, Victoria, NSW and the Snowy River generation in either South Australia or Victoria, using existing corridors.

The Murraylink project earned several Australian state and national awards for both environmental and engineering excellence. The project won the 2002 Case EARTH Award for Environmental Excellence for best practice and innovation in the environmental management of civil construction projects.

These awards demonstrate that a high level of environmental sensitivity is possible in large scale transmission infrastructure projects when an underground HVDC solution is selected.

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Case Study
Underground HVDC Transmission

Capacity
80kV 180MW

Length
65km, underground

Underground Benefit
Underground installation on existing rights of way, easing permit processes and reducing environmental impacts.

5. Directlink (Terranora), Australia

Directlink interconnector (Also known as Terranora interconnector) is a 180 MW underground HVDC Light® transmission link connecting the New South Wales and Queensland electrical grids in Australia, allowing power to be traded between the two states.

The 65-km long link was built by TransÉnergie Australia, a subsidiary of the Canadian utility Hydro Québec and Country Energy. TransÉnergie US supplied its technical expertise for the construction and operation of the interconnection, as well as its expertise in marketing transmission services. The transmission system is now owned by Energy Infrastructure Investments consortium and operated by the APA Group. The Directlink interconnector comprises three HVDC Light® independent links of 60 MVA each operating at 80 kV. Three pairs of underground polymeric insulated HVDC Light® cables operate at ±80 kV and transmit 60 MW each, linking the regional electricity markets of New South Wales and Queensland.

Underground HVDC Trench

Underground HVDC Trench

The interconnection links the 132 kV AC grid in New South Wales with Queensland's 110 kV AC grid, and solves capacity shortage problem in southern Queensland, and a surplus capacity issue in New South Wales.

HVDC Light® technology provides numerous advantages for power market projects like this, including mostly underground installation on existing rights of way, easing permit processes and reducing environmental impacts; precisely defined and controlled power flow that matches power need and/or controls network voltage; support for weak power networks connected to the link; modularity, standardized design reducing construction and commissioning periods – the Directlink interconnector HVDC Light® link was delivered in 12 months. These features mean that HVDC Light® facilities can be installed quickly in response to competitive market signals.

HVDC

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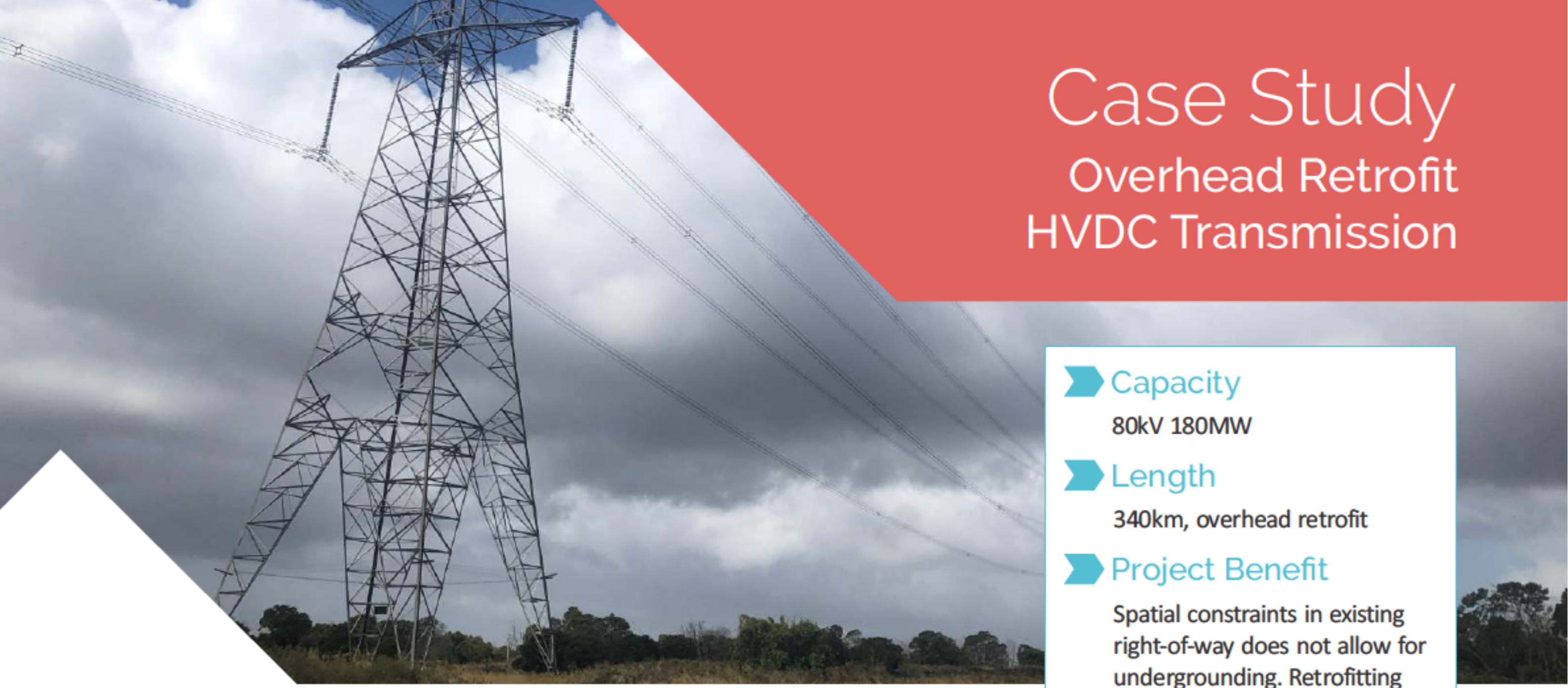


Case Study
Overhead Retrofit HVDC Transmission

Capacity
80kV 180MW

Length
340km, overhead retrofit

Project Benefit
Spatial constraints in existing right-of-way does not allow for undergrounding. Retrofitting existing infrastructure increases throughput and reduces further impact on the environment.

6. Ultranet, Germany

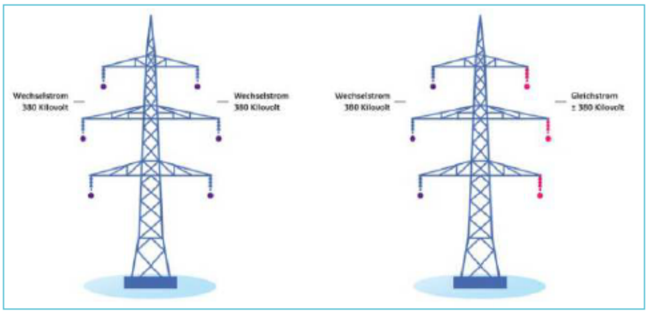
A project currently under construction in Germany is ULTRANET, a new DC link between North Rhine-Westphalia and Baden-Württemberg. The 340-kilometre-long line will transmit 2,000 megawatts of electricity and is due for commissioning in 2023.

The innovative hybrid approach will for the first time, transmit direct and alternating current – both with a voltage of 380 kilovolts – over the same pylons. By using existing routes to do so, Ultranet will increase the capacity of the network in an efficient, resource and environmentally friendly way.

The project contributes significantly to security of supply and grid stability through the widespread integration of renewable energies in northern (wind offshore and onshore) and southern Germany (wind onshore). In particular, the system flexibility is increased by the use of HVDC converter.

Figure 3 shows how Ultranet will utilise one of the two 380kV circuits on the existing transmission line to convert to a bipole with metallic return arrangement.

Figure 3 | Conversion of Existing HVAC circuit to HVDC



Installation of HVDC cable on existing HVAC overhead infrastructure

There is an increased interest in the conversion of existing HVAC transmission lines to HVDC. The benefits are clear – significant increase in power transmission capacity could be obtained without having to install any new transmission lines or cables. The work required to achieve this will include, as a minimum, the installation of the HVDC converter stations at each end and likely the replacement of the insulators on the existing AC transmission line.

There have been studies performed looking closely at various conversion scenarios, with some reports concluding that active power transmission capacity levels of between 50% and 150% may be possible, depending on the design of the existing AC transmission line to be converted.

Retrofitting existing HVAC infrastructure with HVDC increases throughput and reduces further impact on the environment.

HVDC

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Case Study
Underground HVAC Transmission

Capacity
2.2 GW of new capacity

Length
75km, mostly underground

Underground Benefit
The project proponent believes undergrounding provides benefits for the community, the landscape, and the environment.

6. Star of the South, Australia

Star of the South is Australia's first offshore wind project. The project includes a HVAC transmission network of undersea and underground cables and substations to connect the offshore wind farm to Hazelwood in the Latrobe Valley. The project will connect into one of the strongest grid connection points in the National Electricity Market, making use of existing infrastructure and skills in the region.

Star of the South is committed to using underground HVAC cables unless it's not technically feasible or where overhead lines would have lower impacts. While it's more costly to construct underground cables, the project proponent believes there are many other benefits for the community, the landscape, and the environment.

HVAC Transmission investigation area

Installation following Basslink – an existing, high voltage overhead transmission line

The 75 km land route passes through mostly agricultural and plantation land. Around 35 km of this route may follow Basslink – an existing, high voltage overhead transmission line, and where possible share some of the existing easement.

The scheme is planning for up to four power-load compensating sub-stations on the water, and another four along the 75km land route.

HVAC

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Case Study
Underground HVAC Transmission

Capacity

220kV

Length

87km, underground

Underground Benefit

Underground power was the preferred solution for the project as it has the least impact on landowners and people living and working in the area.

7. Aquasure - Desal Plant, Victoria

The Victorian Desalination Plant is powered by an underground 220kV High Voltage Alternating Current (HVAC) power cable. Interestingly, this project set the record at the time for the world's longest high voltage AC underground cable link.

Community consultation played an important part in developing the project. Underground power was the preferred solution for the project as it has the least impact on landowners and people living and working in the area. The power supply was placed underground, rather than overhead, at the request of communities and landowners.

The underground transmission route is 87-kilometres long and provides a dedicated supply for the desalination plant. The cables are located in the same easement as the pipeline (in separate trenches), sharing the same alignment except for a 9-kilometre section where it diverts at Clyde North to Cranbourne Terminal Station. Much of the transmission corridor was located along roadside easements where possible.

The HVAC design uses power-load compensating equipment, which is co-located with the pipeline booster pump station at Clyde North and at a point south of Lang Lang. Each of these installations occupies a small area and has landscaping to minimise visual impacts.

HVAC

Much of the transmission corridor located was along roadside easements where possible

Underground transmission, rather than overhead, at the request of communities and landowners.

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Energy Grid
ALLIANCE

Energy Grid Alliance was established with the purpose of engaging with energy transmission companies, industry regulators, market operators, relevant peak bodies, government and communities to establish best planning practices for new energy transmission infrastructure and to inform on the benefits of working with communities to acquire and maintain social license.

✉ info@energygridalliance.com.au
🌐 www.energygridalliance.com.au