AEMO Transmission Cost Database Report

MBB Group

Contents

Executive Summary

In recent years, the high voltage transmission industry has experienced issues with the accuracy of cost estimates for Integrated System Plan (ISP) projects and within the RIT-T process, resulting in re-work and loss of confidence by stakeholders. There have not been any large-scale transmission construction projects since Basslink in 2005 and it has become apparent that cost estimation processes previously used are no longer fit-for-purpose.

This report sets out a framework for the Australian Energy Market Operator (AEMO) to develop a new Transmission Cost Database. It aims to provide clarity on the work required and level of accuracy expected at each stage of the regulatory approvals process. It also recommends a process for AEMO to produce the initial Transmission Cost Database and update it yearly.

Through discussions with AEMO and Transmission Service Network Providers (TNSP) as well as experience on recent major infrastructure projects, a number of reasons have been identified for cost underestimation in the early stages of projects. The reasons with the greatest potential cost impact were:

- Lack of scope detail on brownfield work – understanding the full scope of works (e.g. equipment relocations) may not be apparent until significant design work has been undertaken
- Risk contingencies – past practice has not included risk contingencies in early cost estimates
- Little incentive to undertake detailed work at an early stage – site investigations, consultation on property acquisitions and design work can all have significant impacts on project cost however, TNSPs are unwilling to undertake this costly work until there is certainty that they will be able to recoup the investment

Cost Estimation Framework

The Cost Estimation Framework shown in Figure 1 has been developed to outline the work required at each stage of the regulatory process. This framework provides a high-level overview of the regulatory process, a description of the proposed scope of work for estimating costs and the target accuracy of cost forecasts at each stage. A Transmission Cost Database should also be developed to support more accurate estimation of project costs in the early stages of development.

Under this Cost Estimating Framework, the level of target cost certainty increases at each stage as additional planning, investigations and design works are completed.

In the identification of candidate Future ISP Projects, the Transmission Cost Database will be the primary source of cost information as only limited design work or investigations will have taken place. During the RIT-T process, TNSPs are responsible for further investigations, initial design and development of cost estimates, and the Transmission Cost Database will be used as a cross-check to confirm estimates are reasonable and have not omitted any material costs.

For a Contingent Project Application, costs will primarily reflect tendered contractor prices, supplemented by estimates from the TNSP.

Figure 1: Cost Estimation Framework

	Candidate ISP Projects	Preparatory Activities for Future Projects	Project Assessment Draft Report (PADR)	Project Assessment Conclusions Report (PACR)	Contingent Project Application (CPA) and ISP Feedback Loop
Description	• Identification of future projects to include in the ISP • High level assessment of potential costs / benefits to determine whether project has net benefits	• More detailed analysis of project options to determine provisional preferred option	• Comparison of credible options to determine the preferred option, taking into account submissions received on PSCR or ISP	• Final report on the comparison of credible options to determine the preferred option, taking into account submissions received on PADR	• Final application to AER for revenue adjustment to reflect costs of the project
Planning Works Undertaken	• Specify approximate route • High level line / substation specifications (eg voltage / capacity) • High level review of stakeholder / ecology / geotechnical issues • For brownfield projects: desktop scoping of required work, including Single Line Diagram for site and consultation with TNSP substation manager	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Procurement of construction contractor substantially progressed • Detailed geotechnical investigations substantially progressed • Procurement of options over easement commenced, initial consultation with landowners substantially complete • Alignment finalised apart from micrositing issues • Biodiversity offset liability determined and strategy finalised • Ecology / heritage studies substantially progressed • Planning approval commenced • Corporate cost budget finalised
Price Certainty	• Straightforward / small project: Class 4 Estimate (-30% to +50%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 2 Estimate (-15% to +20%)
	• Complex / large scale project: Class 5 Estimate (-50% to +100%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project: Class 3 Estimate (-20% to +30%)

Primary cost estimate from Transmission Cost Database

Primary cost estimate from TNSPs, cross check with Transmission Cost Database

Primary cost estimate from contractor proposals and TNSPs

Transmission Cost Database

AEMO will be responsible for the development of the Transmission Cost Database, through a combination of internal resources and external consultants, along with input from TNSPs, contractors and AER. The data will be updated at regular intervals to reflect recently completed projects - a feedback loop to revise adjustment factors using actual project outcomes.

The Transmission Cost Database will include cost data from completed projects, cost information from market engagement with contractors and data inputs from cost consultants. The database will calculate adjustment factors for different project attributes (e.g. location, geography and project complexity) to reflect the specifics of a particular project. The key outputs from the Transmission Cost Database will be:

- Overall project cost
- Cost / km of transmission line
- Substation costs
- Property acquisition costs
- Biodiversity offset costs

- TNSP corporate costs (site investigations / procurement / EIS / community and stakeholder engagement)
- Risk Allowance to reflect unexpected cost variations
- Contingency to reflect 'known unknowns'
- Adjustment factors used in the calculation

Two risk adjustments will be generated by the Transmission Cost Database:

- Contingency for known risks – based on a 'top-down' percentage of project cost based on class of estimate, unless risk identification work has been undertaken, in which case a probabilistic approach will be used
- Risk allowance for unexpected cost variations – a fixed amount added to cost that is based on the class of estimate

The indicative timeline for completion of the first version of the Transmission Cost Database is set out in the following table. The timeline below is subject to AEMO procurement approvals and appointment of a consultant by mid-November.

Scope	Timing
Develop Scope and RFP for Transmission Cost Database Consultant	Late October 2020
Tendering / Award of Contract	Early / Mid November 2020
TNSP / Supplier input	Late November 2020 to Late December 2020
Build database / final reporting	January 2021 to Early February 2021

A workshop was undertaken with TNSPs to obtain feedback on the draft Cost Estimation Framework. Key items of feedback were then incorporated into the final version of the framework.

Section 5 sets out the result of a benchmarking exercise to identify costing methodologies and project costs from other jurisdictions based on publicly available information.

1 Introduction

1.1. AEMO

AEMO's role is to manage the electricity and gas systems and markets across Australia, helping to ensure Australians have access to affordable, secure and reliable energy.

As part of this role AEMO provides detailed, independent planning, forecasting and modelling information and advice to drive effective and strategic decision-making, regulatory changes and investment. The network planning includes development of an Integrated System Plan ("ISP") that sets out future investment required in the electricity network in order to maintain reliability and security at least cost to consumers.

AEMO also provides inputs that are used in the Regulatory Investment Test – Transmission ("RIT-T") process for the regulatory assessment of proposed investments by the Australian Energy Regulator ("AER").

Key to development of the ISP is a cost estimation framework to allow identification of costs associated with network investment options, allowing net benefits of options to be determined.

1.2. Background

In recent years, the high voltage transmission industry has experienced issues with the accuracy of cost estimates for projects being included within the ISP and within the RIT-T process, resulting in re-work and loss of confidence by stakeholders. There have not been any large-scale transmission construction projects since Basslink in 2005, and it has become apparent that cost estimation processes that were previously used are no longer fit-for-purpose.

In addition, the AER has issued new Cost-Benefit Analysis (CBA) guidelines, which state:

- 'AEMO is required to check its cost estimates against recent contingent project applications, recent tender outcomes governing transmission network augmentations, and/or final project outcomes'
- 'We recommend AEMO consider the following discretionary guidance to promote accuracy of cost estimates:
    - work with the Transmission Network Service Providers (TNSPs) and/or non-network proponents to identify and value the classes of costs in clause 5.22.10(d) of the NER as accurately as possible'

This engagement is intended to set out a framework for AEMO to develop a new Transmission Cost Database and provide clarity on the work required and level of accuracy expected at each stage of the regulatory approvals process. It will also set out a recommended process that AEMO will follow in order to produce the initial database and update it yearly.

A separate report provides a framework to develop a portfolio approach to development of ISP projects to ensure greatest value for money is achieved through optimal staging of projects.

1.3. Objectives

The objectives of this project are to:

- Improve the accuracy of the transmission cost estimates used in the ISP
- Increase the level of detail of cost estimates available to AEMO and to stakeholders
- Provide clarity on the work required and level of accuracy expected at each stage of the regulatory approvals process
- Increase stakeholder acceptance of transmission costs used in future ISPs through a transparent cost estimation framework

The objective of this report is to document Phase 1 of the project, which provides strategic advice on scoping and set up of the project.

1.4. Contents of this report

The following table describes the contents of the remainder of this report.

Section	Description
Potential reasons for recent cost underestimation	A brief summary of identified reasons for why recent projects have seen significant cost increases since initial cost estimates
Framework for Cost Estimating	A framework for estimating costs of electricity transmission projects, including: • Overall framework • Implementation • Framework for a future guideline on the role of TNSPs in costing preparatory activities • Feedback from TNSPs on the framework
Transmission Cost Database	Details of the Transmission Cost Database that will underpin the cost estimation framework, including: • Key inputs • Data Sources • Key Outputs • Managing Confidential Information • Project Risks
International Benchmarking	A summary of pricing information obtained through a high-level review of publicly available information on transmission projects in other jurisdictions

2 Potential reasons for recent cost underestimation

Through discussions with AEMO and TNSPs and from experience on recent major projects, the following reasons have been identified for cost underestimation in the early stages of projects.

Reason	Description	Potential Impact
Lack of scope detail on brownfield work	Existing brownfield sites may require modifications which need consultation and input from asset owners to define site constraints and limits. Some constraints and limits include: - Requirements to relocate existing equipment or change the layout of substations to accommodate additional equipment, especially where the initial design of the substation did not allow for expansion. Limited capacity within existing substations may require additional land or expansion works to expand the footprint - Adjustments required to existing substation equipment may not become apparent until detailed design has been undertaken - Costs of installing and commissioning of primary plant and equipment within an operating environment - Upgrade or replacement costs of secondary systems and comms in situ - Practical considerations on getting lines in and out are not apparent	$$$
Risk contingencies	Typically, TNSPs and AER use a portfolio approach when determining risk contingencies on projects, whereby a P50 estimate is used, and it is expected that over time cost overruns / underspends will balance out over time However, on very large projects this approach exposes TNSPs to excessive risk: - There is not a large portfolio of similarly sized projects for the risks to balance out over time	$$$

Reason	Description	Potential Impact
	- On a single project, if downside risks were realised without a contingency in place, cashflows to the business could be severely impacted	
Little incentive to undertake detailed work at an early stage	TNSPs are only able to access a limited amount of funding for preparatory works. On very large projects, considerable work may be required in order to provide cost certainty, which may not be recoverable by TNSPs	$$$
Time pressures	Where a project has a timeline imposed on it by external parties (e.g. regulators / government) that does not match the natural time to deliver the project, additional costs will be incurred to accelerate the project through design and construction	$$
Biodiversity offset costs	Greenfield projects impact threatened species with high offset values (remote projects may be the first dealing with these species). There may be limited ability to offset liability credits with Biodiversity Stewardship Agreements due to availability of suitable land. These costs are not able to be fully understood until significant work is undertaken	$$
Negative community sentiment forcing late route alignment changes	If the community engagement has not been effective, this could harm the project's reputation, resulting in conflicting community demands and unrealistic community expectations. This could result in late changes to route alignment or alternative measures such as undergrounding	$$
Interface risk	Interface risks could include unrealistic project schedules due to conflicting activities with similar completion dates, numerous required interface agreements due to contractual obligations, not understanding approval times from asset owners (e.g. applications for relocation works, testing etc). In addition, interfacing parties (such as road, rail, utilities) may not have sufficient understanding of each other's standards, resulting in changes in scope late in project development	$$
Asymmetrical Risks	It is typical that on projects of this nature there are a significant number / value of risks that could increase cost, but a much lower	$$

Reason	Description	Potential Impact
	number / value of risks than can decrease cost. As risks are realised or more well understood over the development of the project from project identification to CPA submission, this naturally leads to the central cost estimate increasing over time	
Changes in Australian Standards	Australian Standards are regularly reviewed, and where the requirements of the standards are increased (e.g. spacing between conductors or bushfire resistant designs), additional costs are imposed on projects	$$
Internal costs – understanding of costs of managing large projects	As TNSPs do not regularly undertake projects of a similar size to the ISP projects, they do not have experience in the level of management and internal resources that are required. For these complex projects, they can be higher than for BAU projects and this may not become apparent until the project is well into its development	$$
Underestimation of land valuation or compensation	Negotiating margins for land valuations may not reflect future market conditions. Land use changes over time may improve the land value or increase the business compensation required Where there are limited alternative easements available, landowners will have a stronger negotiating position to extract higher prices for easements over their land	$$
Complexity of property acquisition	Larger projects can have larger impacts on the local communities that they pass through and affect multiple communities simultaneously. This can lead to higher requirements for stakeholder engagement as well as TNSPs requiring additional resources to manage negotiations with property owners and local communities	$
TNSP organisational maturity – contracting market may leverage more experience / sophisticated competitive advantage and strategic approach	With less experience in pricing infrastructure projects of larger scale (i.e. in excess of $1B) TNSP's may struggle with engaging the market, e.g. engaging Tier 2 contractors with projects that are estimated to be in excess of $1B, where Tier 1 contractors may be more appropriate. Also having a lack of understanding of negotiating and incentivising contractors on large projects may result in less optimal outcomes	$

Reason	Description	Potential Impact
Compulsory acquisitions – number or timing	Large projects require significant areas of land for transmission easements, access tracks and substations. This may involve numerous stakeholder engagements with local property owners that require more lead-time especially where compulsory acquisition is required. Often this additional time and cost is not factored into estimates	$
Union pressure on labour rates	It is common that when large projects are announced, unions will seek to agree additional terms with the contractor or the sponsor (TNSPs), e.g. higher hourly rates in return for no industrial action on the project. This can lead to higher costs than for BAU projects	$
Road improvements / Access Tracks – not considered in early stages	For large linear projects through regional areas, access tracks can be a significant cost. These may not be considered in the early stages of project development, with a focus on construction costs for towers / conductors. Furthermore, local stakeholders may require significant road improvements or remediation to compensate for heavy or high volume vehicles movements during construction	$
Early engagement – failure to effectively engage with stakeholders causing project delays	Not engaging key stakeholders could affect project development on future projects and not providing the community with enough detailed information could prevent them being able to make informed decisions	$

To address the reasons above, it is recommended that AEMO collaborate with TNSPs and AER to develop a common approach. A Framework for Cost Estimation detailing the level of work and cost items for each project stage could optimise the consistency of reported costs and improve the accuracy of pricing outcomes.

Further, sharing of information across TNSPs on a confidential basis through a Transmission Cost Database may also allow TNSPs to more accurately estimate project costs in future.

3 Framework for Cost Estimating

3.1. Regulatory pricing lifecycle

Under the National Electricity Rules, AEMO and TNSPs must follow a set process for identifying, evaluating and proposing transmission investments that are identified in the ISP. Figure 2 shows a high-level overview of this process, along with a description of the proposed scope of work for estimating costs and the target accuracy of cost forecasts at each stage.

The price certainty is based on the AACE International Cost Estimate Classification System[1], which is a widely used framework for cost estimating at different stages of development of a project. Figure 3 is a summary of the different stages (or cost estimate class) of projects as they progress through development.

Under this cost estimating framework, the level of target cost certainty increases at each stage, which requires additional planning and early works to achieve.

To identify candidate Future ISP Projects, it is proposed that the Transmission Cost Database will be the primary source of costing information, as only limited design work or investigations will have taken place. Over the RIT-T process (Preparatory Activities for Future Projects / PADR / PACR), TNSPs will be responsible for investigations, initial design and development of cost estimates, with the Transmission Cost Database being used as a cross-check to confirm estimates are reasonable and have not omitted any material costs.

For the Contingent Project Application, costs will primarily reflect tendered contractor prices, supplemented by estimates by the TNSP.

[1] https://web.aacei.org/docs/default-source/toc/toc_18r-97.pdf?sfvrsn=8#:~:text=As%20a%20recommended%20practice%20(RP,and%2For%20fund%20projects)

Figure 2: Framework for Cost Estimating

	Candidate ISP Projects	Preparatory Activities for Future Projects	Project Assessment Draft Report (PADR)	Project Assessment Conclusions Report (PACR)	Contingent Project Application (CPA) and ISP Feedback Loop
Description	• Identification of future projects to include in the ISP • High level assessment of potential costs / benefits to determine whether project has net benefits	• More detailed analysis of project options to determine provisional preferred option	• Comparison of credible options to determine the preferred option, taking into account submissions received on PSCR or ISP	• Final report on the comparison of credible options to determine the preferred option, taking into account submissions received on PADR	• Final application to AER for revenue adjustment to reflect costs of the project
Planning Works Undertaken	• Specify approximate route • High level line / substation specifications (eg voltage / capacity) • High level review of stakeholder / ecology / geotechnical issues • For brownfield projects: desktop scoping of required work, including Single Line Diagram for site and consultation with TNSP substation manager	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Market engagement completed with cost indications received • Desktop geotechnical / ecology / heritage study undertaken, and some fieldwork undertaken in identified high risk areas • Major landowners identified, including any high risk areas • Alignment developed based on Geotech / ecology / heritage / property ownership studies available • Biodiversity offset liability estimated based on ecology reports available • Corporate cost budget estimated at a high level	• Procurement of construction contractor substantially progressed • Detailed geotechnical investigations substantially progressed • Procurement of options over easement commenced, initial consultation with landowners substantially complete • Alignment finalised apart from micrositing issues • Biodiversity offset liability determined and strategy finalised • Ecology / heritage studies substantially progressed • Planning approval commenced • Corporate cost budget finalised
Price Certainty	• Straightforward / small project: Class 4 Estimate (-30% to +50%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 3 Estimate (-20% to +30%)	• Straightforward / small project: Class 2 Estimate (-15% to +20%)
	• Complex / large scale project: Class 5 Estimate (-50% to +100%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project : Class 4 Estimate (-30% to +50%)	• Complex / large scale project: Class 3 Estimate (-20% to +30%)

Primary cost estimate from Transmission Cost Database

Primary cost estimate from TNSPs, cross check with Transmission Cost Database

Primary cost estimate from contractor proposals and TNSPs

Figure 3: AACE Estimate Class

Estimate Class	Name	Purpose	Project Definition Level	Accuracy
Class 5	Order of Magnitude	Screening or feasibility	0% to 2%	L: -20% to -50% H: +30% to +100%
Class 4	Intermediate	Concept study or feasibility	1% to 15%	L: -15% to -30% H: +20% to +50%
Class 3	Preliminary	Budget, authorisation, or control	10% to 40%	L: -10% to -20% H: +10% to +30%
Class 2	Substantive	Control or bid / tender	30% to 70%	L: -5% to -15% H: +5% to +20%
Class 1	Definitive	Check estimate or bid / tender	50% to 100%	L: -3% to -10% H: +3% to +15%

Source: AACE International Recommended Practice and Estimate Classification

3.2. Implementation

Details of the Transmission Cost Database and how it will be used are set out in Section 4.

AEMO will be responsible for the development of the Transmission Cost Database, through a combination of internal resources and external consultants, along with input from TNSPs, contractors and AER.

3.2.1. Role of TNSPs

Where TNSPs identify a candidate project for the ISP, they are responsible for developing the initial cost estimate, however can use the publicly available Transmission Cost Database in doing this. Where the candidate project is identified by AEMO, it would develop the initial cost estimate, but may consult with the relevant TNSP in doing so.

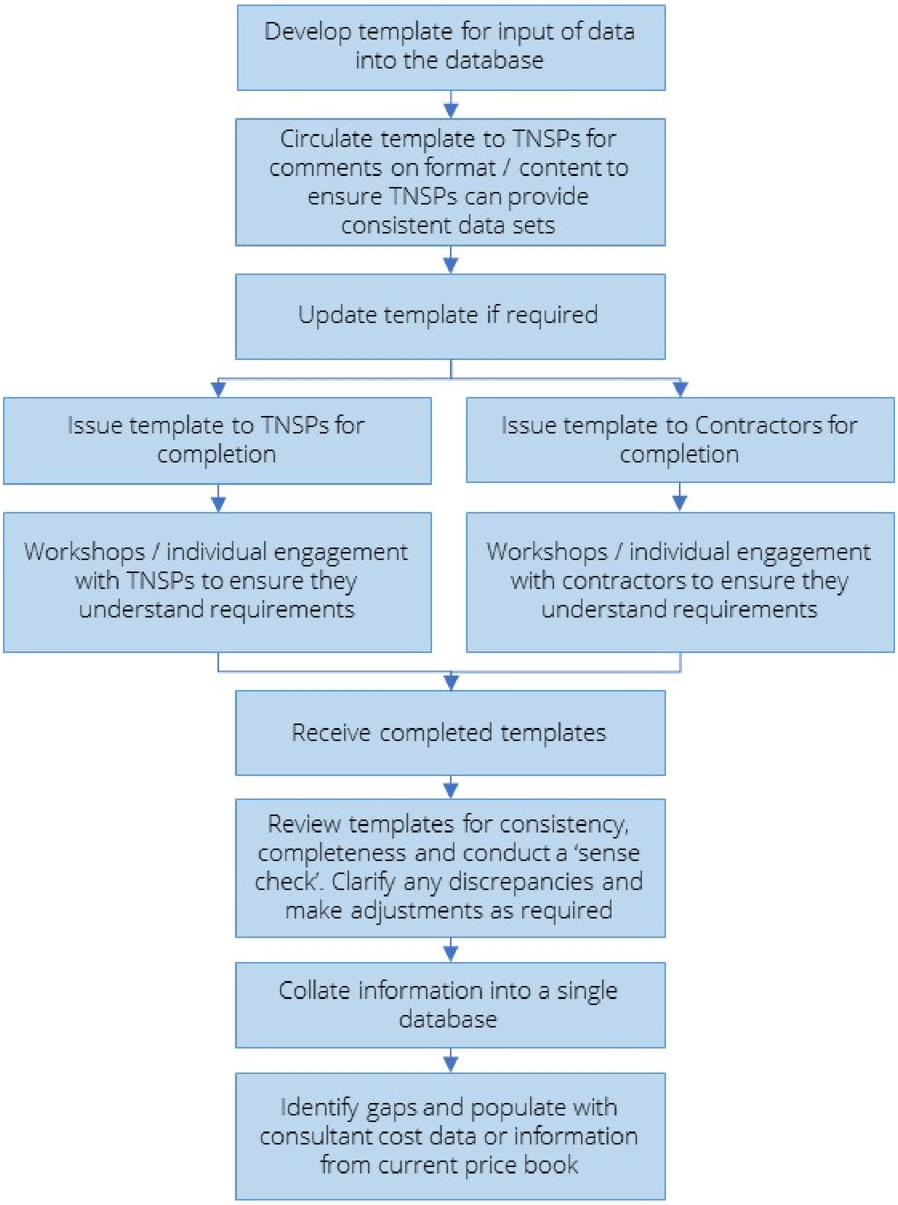
In addition, TNSPs would:

- Provide data for AEMO's Transmission Cost Database – through an initial data request and future updates
- Undertake preparatory activities prior to RIT-T and/or estimating works during the RIT-T process to achieve required costing accuracy
- Collaborate with AEMO on cost estimation for candidate Future ISP Projects
- Undertake procurement and final cost estimation

3.2.2. Transmission Cost Database Development

The process for developing the Transmission Cost Database is shown in Figure 4:

Figure 4: Transmission Cost Database Development Process



Once the complete collated database has been produced, the calculation sheet to calculate adjustment factors can be developed and the 'control panel' sheet can be developed for users to enter project attributes for a proposed project and calculate estimated costs.

The final step would be to input attributes that align with particular projects to confirm the outputs from the cost database calculation are reasonable. The calculations can be tuned through manual changes to the adjustment factors for project attributes.

The process for updating the Transmission Cost Database (at regular intervals) is as follows:

- Review the previous version of the database template and make any necessary adjustments (e.g. additional project attributes)
- Issue template to TNSPs and contractors to complete (noting that contractors are unlikely to be agreeable to undertaking this process more often than every 2/3 years unless they receive payment)
- Receive completed templates from TNSPs / contractors, review and incorporate into the cost database
- Where any gaps in information are identified, approach cost consultants for input, review costs provided by third parties and recommend a cost to be used in the database
- Review the costs within any recent Contingent Project Applications against initial estimates and determine reasons for any variances and any changes to the calculations in the cost database to improve cost estimation (e.g. adjustment factors for particular attributes)

3.2.3. Timeline

The indicative timeline for completion of the first version of the Transmission Cost Database is set out in the following table. This is subject to appointment of a contactor to undertake the work and relevant AEMO approvals for the engagement.

Scope	Timing
Develop Scope and RFP for Transmission Cost Database Consultant	Late October 2020
Tendering / Award of Contract	Early / Mid November 2020
TNSP / Supplier input	Late November 2020 to Late December 2020
Build database / final reporting	January 2021 to Early February 2021

3.3. Proposed framework for a Guideline to specify the role of TNSPs in costing Preparatory Activities

This proposed Guideline is under consideration for development with the TNSPs during 2021.

3.3.1. Objectives

The objective of the guideline is to set out the role of TNSPs in costing preparatory activities for ISP projects. This is to enable efficient collaboration and clarify the parties' (TNSP's / AEMO / other stakeholders) accountabilities in the process.

Preparatory Activities are undertaken in order to improve accuracy and level of detail of the inputs to the ISP and make more informed decisions about the potential benefits of investments.

3.3.2. Scope

The scope of the Preparatory Activities includes the following:

Option Identification

Identification and high-level analysis of options in order to identify a shortlist for more detailed evaluation, including:

- High level design
- Studies to assess transfer limits
- Studies to assess other impacts (system strength, etc)
- Provision of network information to perform load flow studies (ratings, impendences, etc)
- Provision of DLT and ST inputs (Transfer limits, REZ hosting capacity etc)
- Initial cost estimate – Class 4 (straightforward / small project), Class 5 (complex / large project)

Option Refinement

More detailed analysis on a limited number of potentially viable options to determine the preferred option, including:

- Actual plant / site layout
- Preliminary site selection
- Conductor / hardware selection, substation layout
- Geospatial routes / overlays and estimate of complexity – identify credible routes based on available easements, and heritage / culture / ecology overlays, and identify critical areas such as cut ins / line crossings
- Timelines for delivery (normal delivery, accelerated delivery)
- Staging of project
- Stakeholder engagement plan – parties that will need to be included and assessment of community / local council support or resistance
- Planning approval plan – identification of approvals required and assessment of any areas of complexity
- More detailed cost estimate – Class 3 (straightforward / small project), Class 4 (complex / large project)

3.3.3. Document Structure and Content

The document would be made up of the following sections:

Section	Description
Introduction	• Background to the ISP and RIT-T process and requirements of the framework for cost estimating
Future Projects	• List of future projects requiring Preparatory Activities
Design Scope	• Describe the design and other activities required to be carried out, project timelines and staging of the project
Costing Preparatory Activities	• Outline of the Preparatory Activities required as set out in the Scope section above • Timing of these activities • Define the level of accuracy to be achieved at each stage of the process, based on the class of estimate at each stage and the complexity / size of the project • Cost information to be provided, including: o Direct project costs (transmission line / substation) o Property acquisition o Site investigations (Geotech / environmental / heritage) o Biodiversity offsets o TNSP internal costs (project management / engineering design / procurement / EIS / insurance / stakeholder and community engagement) o Risk allowances (known / unknown) • Approach to costing risks
Preparatory Activities Responsibilities	• Allocation of responsibility for Preparatory Activities to the various parties (TNSP's / AEMO / other stakeholder) • Description of the process for TNSP's and AEMO to work together to develop design and costings
Cost estimating outputs	• Set out the format of the cost estimates, including document structure, tables of costs to be included and sensitivity analysis to be undertaken
Stakeholder Feedback	• Summary of feedback on the guideline by stakeholders and how the feedback has been incorporated

3.4. TNSP Feedback

MBB Group facilitated discussions with Transmission Network Service Providers (TNSP) including TasNetworks, Power Link, ElectraNet, TransGrid, AusNet Services and AEMO Victorian Planning to understand their views on the Transmission Cost Database framework and the availability of information to populate the database.

Key feedback is set out in the table below:

Topic	Comments
Reasons for Cost Underestimation	• Many of the sites are remote and incur significant mobilisation / demobilisation costs • Capacity constraints for contractors means that costs are increasing • Different contractors need to be used for large projects as many BAU contractors don't have the capacity
Cost Estimating Framework	• As well as forecasting total cost of projects, the s-curve also needs to be estimated • Project Definition influences level of accuracy. Design is usually not progressed enough until CPA stage or later for tower locations / numbers to be known – this drives property prices / environmental impacts / route alignment and so there is a limit to the accuracy that can be achieved in earlier stages • Once structure locations are known, community objections could force (for example) a switch to underground cables which is expensive • Scope definition is important to overcoming land owner challenges, as it is difficult to discuss until tower locations are known • Community engagement could influence costs, PADR and PACR stages need community consultation • Need to have a base cost, then factors to adjust the base cost such as regional / geographical factors • Need to define and distinguish between cost accuracy and cost contingency

Topic	Comments
	• Typically at PACR stage, well understood projects have a Class 3 estimate • Typically at PACR stage, less understood / complex projects have a Class 4 estimate • For Future ISP Project Identification, Class would be 1 level lower (i.e. Class 4/5) • In early stage estimation, scope should have a mixture of pessimism such as geographical and stakeholder factors • Risks are asymmetric (i.e. there are fewer risks that lead to lower costs) • Should include contingencies for risk events such as being required to underground cables
Data Sources	• Should be high level, not too much detail as they are early stage estimates • 2 major projects from SA available • 1 major project from Vic available, and another project currently in tender should be available
Data Review	• When updating the database in future, changes and the reasons behind them should be highlighted

This feedback has been reviewed and incorporated into the remainder of this document where appropriate.

4 Transmission Cost Database

4.1. Key Inputs

The structure and inputs to the Transmission Cost Database will be as follows:

Item	Description
Format	The Transmission Cost Database will be set up as a Microsoft Excel spreadsheet in order to facilitate use and updates by AEMO staff. The design of the spreadsheet will be finalised during phase 2 of this project, however the initial assumption is: • Separate sheets for input of costs and project attributes for transmission lines, substations and TNSP Costs • A calculation sheet that undertakes analysis of the data in the database to estimate the adjustment factors for each type of project attribute • A 'control panel' sheet where users can select project attributes and a cost estimate is generated based on user selections. This sheet will also allow manual override of the adjustment factors for project attributes (e.g. where the Transmission Cost Database doesn't have relevant data, or where more detailed information is available for a project which allows for a more accurate estimation of the adjustment factor required)
Inputs	Cost data from previous projects, contractors (through market engagement), pricing studies and existing pricing database. Cost data to include (where available): Transmission Lines • Cost / km (overall cost, all inclusive) • Cost / tower (across different tower load types, including foundations) • Conductor cost / km (including stringing / installation costs) • Cost / km for refurbishment of HVAC lines to HVDC lines • Civil construction costs • Site investigations • Design • Project management / mobilisation / accommodation • Clearing costs / km • Access tracks / km • Crossing of other transmission lines

Item	Description
	• Testing / Commissioning • Insurance / security bonds • Overhead, contractor's risk and profit Substations • Civil works • Cost for each type of equipment • Installation costs • Cost for line diversions / retrofit OPGM / Gantries / Cable Termination / Cable works within a terminal station / OHUG transition • Secondary systems / communications • AIS site area • GIS site area • GIS building • Secondary systems Building • Building services • Testing / commissioning • Design • Insurance / security bonds • Overhead and profit • Project management / mobilisation / accommodation • Site investigations TNSP Costs • Project management • Geotech / environmental / heritage investigations • Procurement • Property acquisition • EIS / environmental • Biodiversity offsets • Community / Stakeholder engagement • Risk / contingency
Project Attributes	Attributes will be allocated to each project from the following list. Using these attributes, adjustment factors will be calculated to be used on future cost estimates to allow for differences between the circumstances of each project: • Line technology (HVAC / HVDC) • Line type (Overhead / Underground / Submarine) • Line voltage (110 kV / 132 kV / 220 kV / 275 kV / 330 kV / 500 kV) • Circuit configuration (single circuit / double circuit / cable)

Item	Description
	• Line capacity (MVA) • Line Length (km) • Project Type (Greenfield Line / Line Upgrade) • Project complexity (Simple / Average / Complex) • Tower types (Self-supporting / Guyed / Lattice / Monopole / other) • Conductor Type (Mango / Orange / Paw Paw / other) • Substation voltage (110 kV / 132 kV / 220 kV / 275 kV / 330 kV / 500 kV) • Substation equipment (Transformers / Shunt Reactors / Capacitors / Static Var Compensator / Phase Shift Transformers / Synchronous Condensers – with / without flywheels. busbar, rack, CB (single bay / double bay / breaker and half bay), CVT, VT, CT, ES, ROI. Gas insulated or air insulated.) • Terrain (Desert / Scrub-Flat / Farmland / Forested / Rolling Hills (<8% slope) / Mountain (>8% slope) / Wetland / Suburban / Urban) • Procurement type (D&C / ECI / Construct Only / Free Issue) • Delivery timetable (Tight / Adequate / Long) • Market factors (Tight / Normal / Excess Capacity) • Whether bushfire resilience works are required • Whether climate change impacts need to be considered • Region-specific weather factors (high / low temperatures / high winds)

4.2. Data Sources

Input data for the database will be sourced from the following sources:

Source	Description
AEMO's existing price book	This database includes detailed pricing of individual cost components for transmission projects. It has been mostly sourced from cost consultants.
TNSPs	TNSPs have cost databases for historical projects, including direct construction costs as well as indirect costs (project management, investigations, property, risk / contingency). The majority of TNSP cost databases will be from smaller projects. These will be useful in determining 'base' project costs as well as the adjustment factor for costs on larger projects.

Source	Description
Contractors	Civil contractors, electrical engineering specialist contractors and substation equipment suppliers are able to provide high level cost estimates for various aspects of projects. Where more detailed information is required (e.g. requiring a level of design to be undertaken to determine costs), contractors may require payment for their services.
Engineering consultancies	Where there are gaps in information provided by other sources, engineering consultancies may be able to provide additional information from their own internal databases or bottom-up cost modelling. Engineering consultancies are likely to require payment for access to their proprietary information.

The data sourced through this exercise would then be aggregated within a spreadsheet. Against each project or cost estimate will be a series of attributes (as set out under 'Key Inputs'), describing the specific conditions for that project / cost estimate.

A regression analysis or other statistical calculation will be undertaken to determine the base cost as well as the values of adjustments for each of the attributes (e.g. base cost is increased by 15% where the project is in a mountainous area).

4.3. Key Outputs

Once the user enters the key attributes of the proposed project into the Transmission Cost Database, the key outputs would be:

- Overall project cost
- Cost / km of transmission line
- Substation Costs
- Property acquisition Costs
- Biodiversity offset costs
- TNSP Corporate Costs (site investigations / procurement / EIS / community and stakeholder engagement)
- Risk Allowance to reflect unexpected cost variations (See section 4.5)
- Contingency to reflect 'known unknowns' (See section 4.5)
- Adjustment factors used in the calculation

4.4. Managing Confidential Information

Some of the information being used in the database will be of a confidential nature (e.g. costs that have been bid by contractors or contract prices for construction of assets). It is intended that the cost database be publicly available and so in order to maintain confidentiality and to encourage disclosure of as much information as possible from database contributors, it is proposed that the information within the database be 'anonymised' so that it can not be traced back to an individual source or project.

Each project / cost estimate provided to AEMO will be provided with a unique identifier number that will be included in the database, but no other identifying information will be included within the database (such as project name / location / data source). AEMO will be able to use to identifier numbers to trace the source of information for the purposes of database management.

4.5. Project Risks

A major area where initial cost estimates have differed from RIT-T and CPA submissions is the inclusion of a project risk allowance. Typically, TNSPs and AER use a portfolio approach when determining risk contingencies on projects, whereby a P50 cost estimate is used, and it is expected that over time cost overruns / underspends will balance out over time. This manifests as TNSPs pulling pricing directly from their internal database for initial project estimates, without adding a risk component for large project risk or project specific risks.

However, on very large projects this approach exposes TNSPs to excessive risk:

- There is not a large portfolio of similarly sized projects for the risks to balance out over time
- On a single project, if downside risks were realised without a contingency in place, cashflows to the business could be severely impacted

This has meant that over time as project risks are identified and their quantum understood, additional risk contingencies have been added to the estimates to ensure that regulated rates of return are not impacted.

Project risks can be broken into 2 categories:

- Known risks (where risks are identified but the ultimate value of the risk is not known)
- Unknown risks (where the risk has not been identified but experience shows that in the course of major projects these can occur)

4.5.1. Known Risks

For known risks, for Class 4 or 5 estimates, the level of contingency would ordinarily be calculated using a 'top-down' percentage of project cost approach based on experience on previous similar projects. The percentage level of contingency would be greater for a Class 5 estimate than for a Class 4 estimate.

However, where projects have been developed in more detail, or where there have been large risks identified, a probabilistic approach should be used, with each identified risk being allocated a probability or probability distribution of different outcomes to determine an expected value of all identified risks across the project to be used as a contingency. The probability and outcomes should be based on mitigation measures being in place.

Examples of known risks include:

- Property acquisition costs
- Environmental impacts / biodiversity offsets / planning conditions
- Contamination
- Geotechnical conditions
- Discovery of ecology, heritage and precious metals
- Obtaining outages and managing works within outage periods
- Planning approvals timing
- Foreign Exchange / Commodity price risk
- Internal TNSP costs

4.5.2. Unknown Risks

For unknown risks, a risk allowance should be added to the price based on experience on previous similar projects. It is usually calculated as a percentage of the total cost of the project.

Examples of unknown risks include:

- Cost changes as design is developed
- Force majeure / extreme weather
- Political events in other countries causing supply change disruptions
- COVID-19

The risk allowance will be allocated based on the class of the estimate, as outlined in the US Government Accountability Office (GAO) 'cone of uncertainty approach'[2], and illustrated in Figure 5. The cost estimate baseline is expected to increase as estimates pass from one class to another, due to the majority of risks being asymmetrical (there are more risks that lead to increased costs compared to risks that lead to a reduction in costs). This is shown by the dark orange line in Figure 5.

The High Range and Low Range are based on the accuracy levels shown in Figure 3.

In order to adjust for this effect, a risk allowance should be added to the price estimates based on the class of estimate (reducing over time as the project progresses through the design stages). The adjusted estimate is shown by the light orange line in Figure 5.

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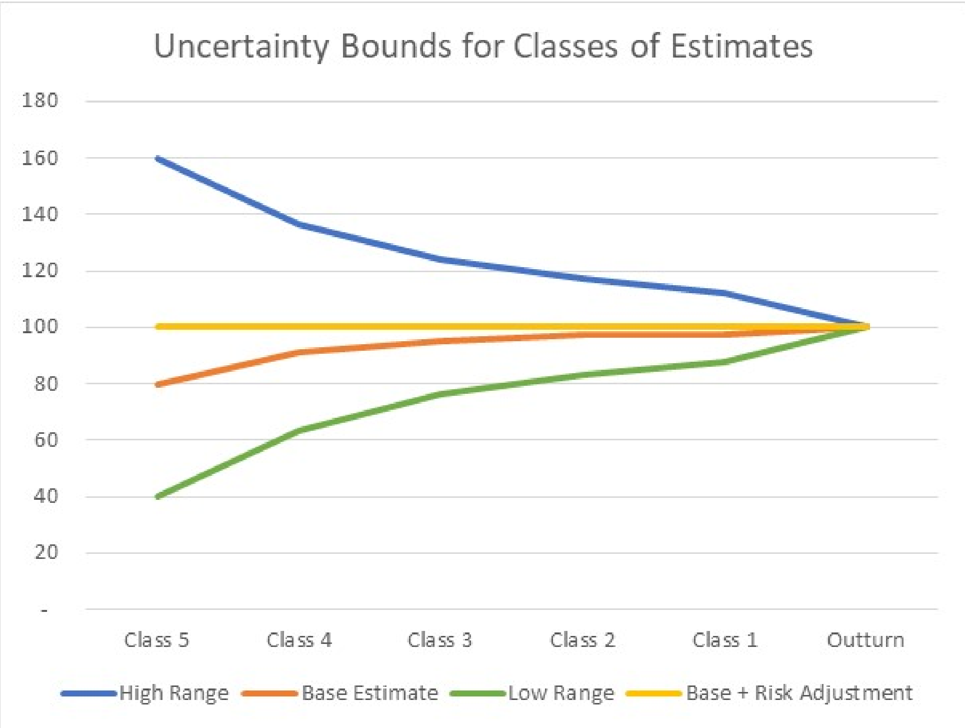
[2] https://www.gao.gov/new.items/d093sp.pdf, Figure 4

The adjustments at each class of estimate can be refined over time based on data from completed projects but initial estimates are shown below based on the AACE International accuracy levels shown in Figure 3. The pessimistic limits for the low range and the high range have been used and then the average of these points is the risk allowance.

Table 1: Unknown Risk Allowance

Estimate Class	Unknown Risk Allowance
Class 5	25%
Class 4	10%
Class 3	5%
Class 2	2.5%
Class 1	2.5%

Figure 5: Uncertainty Bounds for Classes of Estimates



4.6. Contractor Risk

When entering pricing information into the Transmission Cost Database and calculating risk contingencies / allowances for projects, care must be taken to ensure that there is no double counting of risk amounts.

This can occur under different contract models, where under certain contract models the contractor assumes a greater level of risk than under others. For example, a Design and Construct (D&C) contract transfers a substantial proportion of the risk to the contractor, whereas a Construct-Only model only transfers risks associated with construction of a defined scope of works.

If pricing is based on database inputs that used a D&C contract model, then the risk contingencies against that project should be lower, as many of the risks would have been priced within the contractor works.

5 International Benchmarking

MBB Group undertook a benchmarking exercise of other jurisdictions in order to identify costing methodologies and project costs from publicly available information.

The following sources were identified, with more details set out in the table following.

- OFGEM – Benchmarks for project management / risk allowances generated by different cost consultants
- Agency for the Cooperation of Energy Regulators (Europe) – Unit investment costs for electricity infrastructure – data collected from member states on unit costs for projects
- British Power International – Consultants report on Nemo Interconnector pricing (subsea)
- Atkins – Consultants report on NSL Interconnector (subsea)
- MISO (MidWest US) – Transmission Cost Estimation Guide – unit costs and methodology for cost estimation
- TransPower (NZ) – 110 kV transmission line cost report
- WECC (Western US) – Capital Costs for Transmission and Substations – Base unit costs and adjustment factors
- Individual project announcements – total cost / km length

Project	Document Source	Regulator	Location	Equipment	Cost in AUD	Cost/km in AUD	Terrain	kV/kW
Not Project Specific	Parsons Brinckerhoff (Jan/April 2012) – Electricity Transmission Costing Study	Ofgem	UK	AC O/H Line, AC U/G Cable Buried/Tunnel, AC U/G GI Cable Direct Buried, DC Subsea cable	Lowest Total Cost range was for 400 kV O/H lines costing $8.1m -$242.28m and the Highest Total Cost range was for 400 kV DC Subsea Cable costing $1,330.38m-$3,138.48m		Underground (Buried or Tunnel) and Subsea	400 kV
Not Project Specific	ACER – Report on Unit Investment Cost Indicators and Corresponding Reference Values for Electricity and Gas Infrastructure	Ofgem	UK	U/G 1 circuit, U/G 2 circuit, Subsea Cables (AC) and Subsea Cables(DC)		Lowest equipment cost was O/H 220-225 kV, 2 circuit costing $518,920.20/km and Highest equipment cost was U/G 380-400 kV, 2 circuit costing $8,830,225.80/km	Underground (Buried) and Subsea	Ranges from 150 kV to 400 kV

Project	Document Source	Regulator	Location	Equipment	Cost in AUD	Cost/km in AUD	Terrain	kV/kW
Gateway West	Individual Project Announcements	Rocky Mountain Power, Idaho Power	Salt Lake City, US	2 x 500 kV Overhead Transmission Lines, Steel Towers		$3,692,000/km	Mountainous, Dessert	750,000 kW
TransWest Express	Individual Project Announcements	TransWest Express LLC(Sponsor)	California, Nevada and Arizona US	2 x AC/DC Converter stations, a fibre optic network communications system and two ground electrode facilities		$4,260,000/km	Mountainous, Dessert	3,000,000 kW
SunZia	Individual Project Announcements	SunZia Transmission LLC(Sponsor)	New Mexico to Arizona, US	2 x AC/DC single circuit 500 kV Overhead Transmission Lines,		$2,130,000/km	Mountainous, Dessert	3,000,000 kW
Grain Belt Express	Individual Project Announcements	Invenergy Transmission LLC	Missouri and Kansas, US	HVDC Overhead transmission line		$3,266,000/km	Mountainous, Dessert	4,000,000 kW

Project	Document Source	Regulator	Location	Equipment	Cost in AUD	Cost/km in AUD	Terrain	kV/kW
SOO Green HVDC Link	Individual Project Announcements	Direct Connect	Iowa and Illinois US	HVDC Underground 525 kV transmission line		$3,550,000/km	Underground	2,100,000 kW
New England Clean Energy	Individual Project Announcements	Central Maine Power, AvanGrid	Maine, US	345 kV Substation, HVDC 345 kV Overhead transmission line		$1,704,000/km	Forestland	1,200,000 kW
Champlain Hudson Power Express	Individual Project Announcements	Transmission Developers	New York, US	2 x HVDC transmission lines		$3,124,000/km	Underground (Buried) and Subsea	1,000,000 kW
SuedLink HVDC Power Transmission	Individual Project Announcements	TenneT, TransnetBW	Bavaria, Germany	2 x HVDC transmission lines, Converter stations		$22,885,714.29/km	Underground (Buried)	525 kV
Woodville-Mangamaire-Masterton A 110 kV	Woodville-Mangamaire-Masterton A 110 kV Transmission	Transpower NZ	Wellington, NZ	220 kV transmission line		Lowest cost was to dismantling transmission line and substation which cost		177,000 kW

Project	Document Source	Regulator	Location	Equipment	Cost in AUD	Cost/km in AUD	Terrain	kV/kW
Transmission Line	Line Technical Cost Report					$58,091.26/km and Highest cost was upgrade replacement of conductors costing $168,224.65/km		
Not Project Specific	MISO Transmission Cost Estimation Guide	MISO	Texas, US	Single transmission line ranging from 69 kV to 500 kV, Double transmission line ranging from 69 kV to 500 kV		Lowest cost was a single circuit transmission line (69 kV) which costs $1,331,250/km and the highest cost was double circuit 500 kV transmission line	50% level ground with light vegetation, 30% Forested and 20% Wetland	69k V – 500 kV

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