Independent Review

HVDC Link Upgrade Programme

Transpower New Zealand Limited

4 September 2025

→ **The Power of Commitment**

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A	Final Report	Logan Peck	David Walker	*On iConnect*	David Walker	*On iConnect*	4 September 2025

GHD Limited NZBN 942 903 869 9856
Contact: David Walker, Market Lead – APAC Business Advisory | GHD
Level 4 BNZ Building, 1 Whitmore Street
Wellington, 6011, New Zealand
T +64 4 4955 800 | **www.ghd.com**

Executive summary

Programme Purpose and Strategic Role

Transpower's HVDC Link Upgrade Programme is an infrastructure investment initiative aimed at enabling long-term reliability and capacity for the inter-island electricity transmission system. The upgrade is triggered by the age of the existing submarine cable assets installed in 1991 and considers associated infrastructure spending to accommodate the cable replacement project. In addition, prepare the network for future energy demands and the integration of renewable generation sources.

The proposed programme encompasses:

- **Cable replacement:** replacement of existing submarine cables nearing end of life and installation of an additional cable to enhance capacity and improve redundancy.
- **Control system upgrades:** modernisation of control systems to improve operational efficiency and system stability.
- **Pole 2 overload capacity enhancement:** increasing pole 2's short-term transfer capacity.
- **Filter banks:** to reduce or remove unwanted and damaging harmonics produced by the DC to AC converters.
- **Cable termination stations:** replacement infrastructure to support the new cable configuration.
- **Cable storage facility:** establishment of a new facility to support maintenance and emergency response.
- **Cable removal:** removal of the existing cables.

Investment and Regulatory Alignment

The programme is being reviewed under the Major Capital Expenditure Proposal (MCP) framework, with oversight from the Commission. This Independent Expert Review (IER) by GHD and PSC Consulting aims to assess the level of alignment that Transpower's MCP has with Good Electricity Industry Practice (GEIP) and regulatory expectations.

Procurement and Planning

The HVDC Link Upgrade Programme is currently in its investigation phase, and procurement planning varies by component:

- **Cable Replacement:** Lead times for submarine cables can be up to 10 years due to high global demand and limited vessel availability. After a market review in 2024, Prysmian was selected via competitive tender for cable manufacturing and installation, with a reservation agreement for installation in 2031. A formal notice to proceed must be issued by 30 June 2026, enacting the full installation contract. Prysmian's scope includes all submarine and land-based cable design, supply, and installation, plus cable termination bushing commissioning. Other associated services will be procured through standard Transpower processes.
- **Cable Store:** Replacement is split in two: (1) Prysmian's subcontractor will design, manufacture, and install the cable carousel, to be added to the main cable contract for warranty reasons; (2) The building and foundation design/installation will be locally contracted using NZ providers. Demarcation and coordination processes will be put in place to ensure smooth information sharing.
- **Cable Termination Stations:** Conceptual design is finished. Detailed design and build will be separately contracted to enhance commercial and risk outcomes. Early contractor involvement is

planned, and a competitive tender through GETS will be used for construction, while HV electrical works will be directly contracted to approved providers.

– **HVDC Control Systems Replacement:** The supplier market is highly constrained. Only two providers were identified after a market-wide process. A period of upfront engineering will further define requirements before a formal Request for Proposal and Front-end Engineering and Design agreement. The outcome will determine if the contract is sole-sourced or competitive.
– **Filter Banks – Benmore / Pole 2 Overload Scheme:** Procurement plans for these projects are not yet developed.
– **Cable Removal:** The business case is in development and costs are being refined, currently based on the installation contractor's figures but will be tested with a wider market. If justified, international tendering is expected around 2028.

Overall, the approach combines early market engagement, competitive tendering, division of work packages for risk and commercial optimisation, and coordination between international and local contractors to ensure compliance and project success.

Economic Evaluation

Is there an investment need for cable replacement? If so, by when? Transpower states that by 2031 the existing cables will reach the end of their 40-year design life in 2031. Inspections and asset health data confirm that replacement will be necessary by 2032. Extending their operation beyond this date significantly raises the risk of failure, and therefore outages, placing the security of the New Zealand supply at risk. If feasible, repair would require a six-to-18-month response period should failure occur after 2031 although the risk the cables cannot be repaired grows as they age. Such an extended period with at least one cable offline is considered untenable given expected growth in energy demand.

Transpower provided an additional analysis of the likelihood and impact of a cable failure under a do-minimum option where Transpower would attempt to repair cables as they fail. The modelling suggests that in cumulative terms, there is a 37-50% chance that an individual cable will fail by 2035, and there is risk that more than one cable will fail by that time.

The total economic cost of cable unavailability is directly related to the number of cables down at any time, whether cables are repairable, and the state of hydro dam levels at the time of the outage. By 2031, the annual probability-adjusted economic cost of cable outage and repairs is estimated at $10 million to $170 million, dependent on whether cables are repairable. The optimal economic time to replace the cables based on the discounted cashflows of economic costs of outage and repair versus a replacement cost of $620 million (for three cables, like-for-like), was between 2025 and 2039.

Transpower has provided a credible explanation of the economic rationale for replacing the existing cables as well as an explanation for why the timeframe of the early 2030s is reasonable for risk avoidance and limiting economic costs.

Were options other than cable replacement considered? Transpower examined a long list of options that included non-transmission solutions, a do-nothing option where cables remain in use until failure, and multiple options for replacing the cables. Transpower dismissed non-transmission options in the early stages as the options were functionally equivalent to the do-nothing in terms of market response. The benefit estimation phase tested this assumption.

Has demand been modelled to identify appropriate capacity? Transpower presented four demand and generation scenarios incorporating different patterns of growth and supply. Scenarios were based on Electricity Demand and Generation Scenarios produced by MBIE. Modelling appears to have adequately considered large-scale existing generation, committed new generation and planned retirements. Analysis indicated that 1400MW delivered the highest net electricity market benefit, above that for replacing the existing cables like-for-like with 1200MW (see cost-benefit analysis below).

Was cost-benefit analysis completed on the short list? Transpower's approach to estimating the present value of benefits for each scenario option appears reasonable. Estimates included various costs required to complete each option within the wider programme e.g. cable removal and upgraded cable termination stations. Therefore, the analysis assumes the case for these components is valid. Analysis identified the 1400MW option as providing the greatest net economic benefit to the electricity market in accordance with the Commission's requirements. Several sensitivity tests accompanied the analysis; however, Transpower is undertaking Monte Carlo simulation testing to generate the P30/P70 cost band. The review recommends the Commission review the assumptions and model results.

Has the case been made for supporting works and timeframe? Costing of the preferred option (Option 3) includes additional works that assume the replacement of current cables with four cables providing 1400MW capacity. The review found a defensible case is mounted for additional works including replacement cable termination stations; a replacement control system; the filter bank upgrade; increased Pole 2 overload capacity; and a new cable storage facility.

The review recommends a separate application is made for the removal of existing cables. This would allow Transpower to proceed with the current process and provide additional time for a separate application investigating the case and evidence for the removal of cables. The Fast-track Approvals Act 2024 permits Transpower to consider the proportionality of benefits at a regional or national level in comparison to adverse effects. The legislation therefore allows Transpower to make a case for leaving existing cables in place by arguing that as the $122 million dollar cost of removal is to be directly borne by electricity consumers, the economic benefit of keeping the cables in place is of national significance.[1] We note that Transpower has had a legal opinion that raises the risk of the programme being denied fast track approval if the application is modified to exclude cable removal. Transpower is of the view that this could place the entire programme timeline in jeopardy.

Have long-list options for supporting works been appropriately narrowed down? The review finds Transpower appears to have reasonably considered the range of options for each component while noting the case for cable removal requires further investigation.

Do capital cost estimates appear credible? The review identified several elements of the cost-build up that pose potential risk. Overall, it found that headline cost estimates for each component appear reasonable, noting that only the cable replacement cost estimate is supported by a detailed proposal from a supplier. Additionally, the review found that pricing years in advance for a marine salvage job such as the recovery of decommissioned cables is challenging. The review notes that the modest allowance of approximately 13% inflation across the programme by 2031 may expose the project to upside risk given market-wide supply constraints for work of this type.

Transpower shoulders fuel cost, weather and metal cost risk, while civil and subcontracted works in New Zealand (30% of contract value) are provisional sums at this point.

Further to these cost risks, there is considerable price uncertainty at this early stage. Transpower has attempted to narrow the price range on each component. Using the current estimated range of potential pricing, costs for the project could range between $1 billion and more than $2 billion.

Have delivery risks been documented with plans to mitigate? Transpower provided a Risk Register outlining their approach to risk management. Outlined risk mitigations focus on the reduction of risk to Transpower (e.g. of being penalised for going over-budget) as opposed to managing risks to the electricity consumer, such as through hedging materials or exchange rate risks to minimise costs passed on to consumers.

Has a credible delivery governance structure been proposed? Transpower has provided an initial proposed governance structure, allowing for a direct link between the Board via CEO to the HVDC Link Upgrade Programme Governance Group; a Steering Committee that reports to the Governance Group; and a Project Team that draws on Business SMEs and works with stakeholders including iwi on a Working Group.

[1] Note, Transpower identified significant cost uncertainty of this component.

Technical Workstream Evaluation

Undersea Cable Supply and Installation (1400MW)

Transpower's proposed HVDC investments align with good industry practices to ensure a reliable and safe electricity system for New Zealand. The capacity required is justified based on future load growth and generation developments. The proposed programme is considered technically feasible and will be implemented in stages to mitigate outage risks. Stakeholder consultation is ongoing, and the programme approach will help manage complexities.

The procurement of long lead-time items is deemed necessary, and the project costs have a level of uncertainty, which is appropriate at this stage but should be considered in more detail. Transpower did clarify that they plan to perform detailed cable route surveys closer to the installation date. The results of these surveys could cause variations in the data relied upon by Prysmian, which may lead to a price and schedule variation.

Transpower plans to upgrade New Zealand's HVDC system by installing four new 500MW copper cables, increasing the link capacity from 1200MW to 1400MW. The project adheres to good electricity industry practices and includes a cable health model, electrical tests, and visual inspections to determine cable condition. The design life expectancy for the new cables is 40 years. Transpower will collaborate with Prysmian for cable design and installation and conduct DC load current rating calculations with a consultant. Voltage pole reversals (VPRs) will be managed to prevent cable life impacts. The project also includes a Capacity and Reservation agreement with Prysmian to ensure timely installation. Cost estimation and independent reviews validate the approach and decisions.

Cable Termination Station Replacement

Transpower proposes the replacement of the cable termination stations to allow construction offline, prior to the termination stations being live, consequently avoiding additional scheduled long network outages. Transpower's proposal would also improve resilience.

The existing cable termination stations (CTS) do not meet seismic requirements of Transpower policy and design code. An upgrade of existing structures to meet these requirements along with modification for new cable infrastructure includes lengthy outages to the network and is assessed as unfeasible. The proposed solution involves using site-specific seismic hazard assessments and geotechnical investigations, which show the design's technical feasibility. The planning phase includes resource consents, an HVDC planning strategy, and a communications plan, though building consent strategies are lacking. Independent evaluation of options from BECA support the prudence of new CTSs.

There are design and delivery risks and identified outages which influenced the options considered. The programme planning indicates timely completion, integrating connections and construction sequences with minimal disruption. The cost estimation was thorough, and procurement strategies are satisfactory.

Transpower's planning involves collaboration with Prysmian on CTS dimensions and weights, ensuring compliance with necessary electrical clearances. BECA's involvement as an independent engineering consultant in the solution study process is seen as a prudent approach.

HVDC Control System Replacement

HVDC control and protection systems typically require upgrades after eight years for IT components and after 15-20 years for other control system components due to hardware obsolescence. Aligning outage work for both cable and control system replacements is considered good practice. Transpower plans to replace the Real Time Digital Simulator (RTDS) and control system with the 2032 Pole 2 and

Pole 3 upgrade. The estimated cost of $202 million may be insufficient; we estimate the cost to be $250-300 million for the upgrade. Transpower is staging the proposal application for this work to be later than the main proposal and the removal of the decommissioned cables.

Benmore Filter Bank Upgrade

The strategy for implementing new filters is crucial to meet the harmonic limits set by the power quality provisions in the Electricity Industry Participation Code. The installation of a new filter bank, F8, is required for 1400MW operation and ensuring power quality at high transfer levels. Technical evaluations affirm that the filter is critical to maintaining compliance with network harmonic limits.

Pole 2 Overload Scheme

Transpower's HVDC link reliability is required for electricity transmission, requiring reserve generation or interruptible load to cover any shortfall if one pole fails. The Pole 2 840MW overload project is technically feasible and aims to reduce market costs. Detailed engineering design is required to confirm existing asset performance is not compromised. Transpower recognises the risk and acknowledges further work is required to determine overload capability.

Cable Storage Facility

Transpower has followed good practice in the options selection process for new cable storage, considering interdependencies and regulatory constraints, and scheduling the cable store completion prior to HVDC cable installation. Cost estimation was based on concept costing and design features and Transpower were able to provide procurement strategy details upon request. The programme outlines the interdependencies, but these are not to the same level of detail as those provided by Transpower for the CTSs, posing a higher risk of cost overruns. Attention to timing, regulatory constraints, and procurement approach is recommended to reduce risk.

Recovery of Decommissioned Cables

Transpower's approach to determining the need for removal / or not of decommissioned cables is considered aligned to GEIP. The costs need to be determined from salvage vendor estimates, and a comprehensive risk assessment, particularly for cables near shorelines, is necessary. Transpower has sought independent legal advice regarding the cable removal process. Transpower is staging the proposal application for this work to be later than the main proposal.

Overall review evaluation tables

Table 1 summarises the main points of our evaluation. **Appendix A** provides the details of our evaluation broken down by each section of the Terms of Reference.

Table 1: Overall summary review

Programme component	Our opinion
Undersea Cable Supply and Installation	– We consider Transpower's decision to invest in cable replacement is reasonable and consistent with its asset management policies (5.1). – We find the scope technically feasible and aligned with good asset management practice (5.2). – Transpower has appropriately staged the work to minimise outage impacts (5.3). We agree that the economic modelling indicates the 1400MW option has a better net benefit over the 1200MW option. – We find the procurement approach aligns with GEIP. While cost estimates are based on supplier proposals, they carry uncertainty due to market volatility (5.4, 5.5). – We believe environmental impacts have been adequately considered for this stage (5.6). – Transpower has applied mechanisms such as capacity reservation and intends to use P30/P70 cost bands (5.7). – We recommend the Commission focus on programme scheduling and risk management (5.8). – We received comprehensive information to support our review (5.9), and we do not identify any additional information requirements (5.10, 5.11).
Cable Termination Station Replacement	– We consider Transpower's proposal to build new CTSs appropriate due to natural hazard risks, insufficient scale of current buildings, and the benefits of avoiding outages. – We find the investment decision reasonable and consistent with asset management policies (5.1). – We find the scope technically feasible and aligned with good practice (5.2). Transpower has staged the work to minimise outages (5.3). – Costing was carried out by qualified professionals and is appropriate for this stage (5.4, 5.5). – We find environmental impacts and planning consents have been considered (5.6). – While no specific Capex IM mechanisms are noted, we recommend the Commission focus on cost estimation updates and delivery risks (5.7, 5.8). – We received the required information (5.9). – While we have not sighted net market benefits analysis of the like-for-like replacement versus new builds at a different location, our opinion is that a potential 6-12-month bipole outage to enable strengthening of the existing CTS or a downtime that equates to the build and commission timeframe of a like-for-like replacement is unfeasible (5.10, 5.11).
HVDC Control System Replacement	– We consider Transpower's proposal to replace the control systems slightly earlier than the 15/20-year timeline to be reasonable and consistent with asset management policies (5.1). – We find the scope technically feasible and aligned with good practice (5.2). – Transpower has staged the work to minimise outages (5.3). – We believe the cost estimate appears low compared to similar international projects and may require refinement (5.4, 5.5). – We find environmental impacts appropriate for this stage (5.6). – Transpower plans to use Capex IM mechanisms (5.7). – We recommend the Commission focus on capital costs and outage scheduling (5.8). – We received comprehensive information (5.9).

	– The Control System replacement works are both assumed in the 1,400MW net market benefit calculations and required for the HVDC Link upgrade. (5.10, 5.11).
Benmore Filter Bank Upgrade	– We consider the Benmore filter necessary to enable 1400MW operation. We find the investment decision reasonable and consistent with asset management policies (5.1). – We find the scope technically feasible and aligned with good practice (5.2). – Transpower has staged the work to minimise outages (5.3). – Cost estimates are indicative and require vendor confirmation (5.4, 5.5). – We find environmental impacts appropriate for this stage (5.6). – Transpower applies Capex IM mechanisms in its investment test (5.7). – We recommend the Commission focus on programme scheduling and risk assessment (5.8). – We received comprehensive information (5.9) – As the Filter bank is a necessary component of the HVDC Link upgrade to 1,400MW and is assumed in the net market benefit modelling, no further information is required on this component (5.10, 5.11).
Pole 2 Overload Scheme	– Transpower estimates that not completing this upgrade reduces the potential benefits of the programme by $42-48 million, implying a net reduction in benefits of around $35 million once the cost of the Pole 2 overload scheme is considered. – We find the scope technically feasible but requiring further engineering validation (5.2). – Transpower has staged the work to minimise outages (5.3). – Cost estimates are preliminary and subject to refinement (5.4, 5.5). – We find environmental impacts appropriate for this stage (5.6). – Transpower applies Capex IM mechanisms in its investment test (5.7). – We recommend the Commission focus on technical feasibility and cost accuracy (5.8). – Transpower has provided reporting demonstrating the potential net benefit of this component has been considered (5.1, 5.9, 5.10, 5.11).
Cable Storage Facility	– We consider Transpower has followed good practices in the options selection process for new cable storage. – We find the investment decision reasonable and consistent with asset management policies (5.1). – We find the scope technically feasible, and staging has been considered (5.2, 5.3). – Cost estimates are concept-level and pose higher risk of overruns (5.4, 5.5). – We find environmental impacts and planning constraints have been considered (5.6). – While no specific Capex IM mechanisms are noted, we recommend the Commission focus on cost estimation updates and procurement strategy (5.7, 5.8). – We received the required information (5.9). – The cable storage facility was assumed in the repair options for the modelled net market benefits. The Commission may wish to seek further information on the net benefits as part of its assessment of this stage (5.10, 5.11).
Recovery of Decommissioned Cables	– We acknowledge that the removal of existing cables may be required to meet consenting requirements and leave room for future replacements. However, we are not convinced there is an economic justification for their removal (5.1). – We find the scope technically feasible but environmental impacts have not been fully assessed (5.6). – Transpower proposes staging and separate procurement to allow for more accurate cost estimation (5.3, 5.4, 5.5).

[redacted]	– Capex IM mechanisms are applied in the investment test (5.7). – We recommend the Commission focus on cost estimation from salvage vendors and environmental risk assessment (5.8). – We note some information gaps remain regarding environmental justification (5.9, 5.10).

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Appendices

Part A

Introduction and background

1. Introduction

Transpower engaged GHD to perform the role of the Independent Expert Reviewer (IER) for the HVDC Link Upgrade Programme and its associated infrastructure. GHD engaged PSC Consulting as a sub-consultant to independently review the HVDC components of Transpower's project proposal.

1.1 Purpose of this report

This Independent Review evaluates whether Transpower's HVDC Link Upgrade Programme aligns with good industry practices, as required by the Commission for major capital expenditure proposals. The report presents our findings, to Transpower and the Commerce Commission (the Commission), based on the Evaluation criteria in the attached Terms of Reference (ToR) and will be provided to Transpower's Board to support their decision regarding the sign off of the MCP application. It will also be provided to the Commission to support its review of the MCP.

1.2 Scope and limitations

This report: has been prepared by GHD for Transpower New Zealand Limited and may only be used and relied on by Transpower New Zealand Limited for the purpose agreed between GHD and Transpower New Zealand Limited as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Transpower New Zealand Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.6 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.3 Independent Review

The Independent Review is an in-depth review of Transpower's HVDC Link Upgrade Programme and the processes and expenditure forecasts used to create the HVDC Link Upgrade Programme MCP. This Independent Review is an input to Transpower's formal submission to the Commission.

1.4 Terms of reference

The Terms of Reference are jointly agreed between Transpower and the Commission, and establish the overarching basis of our Independent Review that is to:

- engage independently with Transpower in accordance with these terms of reference,
- evaluate whether Transpower's HVDC MCP's capital expenditure (capex), operating expenditure (opex) (including the methods undertaken to prepare those costs), and key assumptions are consistent, and represent the actions of a prudent electricity transmission services supplier, having regard to Good Electricity Industry Practice (GEIP); and
- produce a report that meets the requirements in these terms of reference.[2]

Appendix B of this report includes a copy of the Terms of Reference.

[2] Terms of Reference (3).

Appendix C subsequently offers a mapping between the clauses in the ToR and the sections of this report to facilitate the Commission's review.

1.5 Overview of review approach

Our review of Transpower's HVDC Link upgrade consisted of five key stages:

- Project Inception
- Documentation review
- RFIs and Workshops
- Assessment of Processes and Decisions
- Independent Reviewer Report

1.5.1 Inception

Transpower organised a kick-off meeting on 27th May 2025, held between Transpower, the Commission, and key representatives of the project team to:

- Confirm the Terms of Reference, scope of work and the proposed review approach.
- Understand the status of Transpower's HVDC Link Upgrade Programme development progress, timetable, outstanding milestones and activities.
- Identify key focus areas or material issues of concern arising from previous work.[3]
- Overview the documents, processes, tools, and systems to be used in the independent review.
- Establish communication and information protocols to be followed by all parties.
- Agree on roles, reporting structure, style of deliverables and other administrative arrangements.

1.5.2 Documentation review

Our review of relevant Transpower documents and information was based on 65 documents provided by Transpower in June 2025. The documents provided by Transpower included:

- 18 Context Documents
- 3 Investment Test Documents
- 12 Governance Documents
- 9 HVDC Cables Documents
- 3 Cable Store Documents
- 7 Termination Station Documents
- 4 Control Systems Documents
- 2 Filter Banks Documents
- 4 Pole 2 Overload Documents
- 3 Cable Removals Documents

Transpower highlighted documents, or sections thereof, as either required or optional reading and uploaded all documents to a SharePoint site for us to begin our review as shown in Appendix D below.

All required reading was incorporated into the review. Optional reading was not incorporated, except as indicated by Transpower in relation to answering our RFIs or other queries.

[3] including RCP4

1.5.3 RFIs and Workshops

1.5.3.1 Requests for Information

The **Request for Information (RFI)** process was a critical component of the project, designed to provide us with the necessary information for our review. The list of RFIs is shown in **Appendix D.** The RFI process was as follows:

- Identification of Gaps: During the initial review of the documentation, the team identified any missing information, ambiguities, or areas requiring further clarification.
- Formulation of RFIs: The identified gaps were then formulated into specific questions or requests for additional information. Each RFI was clearly documented to ensure precision in the responses.
- Submission to Transpower: The RFIs were submitted to Transpower through the SharePoint platform.
- Tracking and Monitoring: Transpower established a tracking system to aid timely responses and follow-ups when necessary.
- Response and Resolution: Transpower reviewed the RFIs and provided the required information or clarifications. Any further questions arising from their responses were addressed in subsequent RFIs as needed.
- Integration into Review Process: The information gathered through the RFIs was integrated into the ongoing review and analysis, helping to inform the overall assessment and report preparation.

1.5.3.2 Workshops

The **workshop** process was an integral part of the project. Transpower facilitated the collaborative sessions and provided in-depth presentations and discussion to aid our understanding of the HVDC Link Upgrade Programme. The following workshops were conducted:

- Monday, 16 June 2025 – Cost Estimation and Risk Workshop
- Friday, 13 June 2025 – Control Systems Workshop
- Friday, 13 June 2025 – Economics Benefits Workshop
- Friday, 13 June 2025 – Cable Removals Workshop
- Thursday, 12 June 2025 – Pole2 Overload & Filter Bank Workshop
- Wednesday, 11 June 2025 – Cables Workshops
- Tuesday, 10 June 2025 – Cable Store Workshop

1.5.4 Assessment of Processes and Decisions

We undertook the analysis of the processes and inputs of the programme of works that constitutes the Transpower MCP Proposal at a document level and then at a workstream level. The evaluation approach is detailed in Section 3.

1.5.5 Review Report

The Review Report contains two main elements:

- The **economic evaluation** which covers the questions that would be raised as part of the Strategic Case and Economic Case within the five-case model for developing Business Cases. This evaluation uses both economics and the outputs of the technical workstream evaluation to inform the economic evaluation.

- The **technical workstream evaluation** which covers the terms of reference from the engineering perspective. Both Schedule C of the Capex IM and the numbered terms (5.1 to 5.11) were included as part of this review.

1.6 Assumptions Used in This Report

In the course of evaluating the Transpower HVDC Link Upgrade Programme, it is both prudent and necessary to make certain assumptions that guide our analysis, interpretation, and recommendations. These assumptions form the backbone of the review process, supporting both the depth and breadth of investigation into technical, economic, and regulatory aspects. This document outlines the principal assumptions adopted.

1.6.1 General Assumptions

Availability and Validity of Source Documentation

- We assume that all documents provided for review, including technical reports, economic models, and regulatory submissions, are current, accurate, and have undergone appropriate quality assurance processes. Any references, data, or figures cited from these sources are presumed to be reflective of real-world conditions and operations at the time of their creation.

Representativeness of Workshop Inputs

- The findings and discussions from the Pole2 Overload & Filter Bank Workshop, the Cables Workshops, and the Cable Store Workshop have been considered a reliable and representative subset of stakeholder and expert opinions. We assume these sessions captured the core themes, concerns, and recommendations pertinent to the HVDC Link Upgrade Programme.

Regulatory Stability

- This review presumes that the regulatory frameworks set by the Commerce Commission and the Electricity Authority will remain largely stable for the duration of the upgrade programme's planning and execution. Any anticipated changes to regulations have been identified and incorporated only where specifically referenced in source materials.

No Material Change in Asset Ownership or Role

- Transpower's current role as owner and operator of the national transmission network is expected to remain unchanged for the purposes of this report. The scope strictly excludes scenarios in which Transpower would generate, own, or sell electricity.

Economic Parameters

- We assume standard inflationary pressures, interest rates, and economic growth rates as outlined in official forecasts, and that these remain reasonably consistent over the period assessed.

1.6.2 Technical Assumptions

Asset Performance and Lifespan

- The expected performance and operational lifespan of major assets such as transmission lines, HVDC cables, substations, and associated telecommunication infrastructure are taken as per Transpower's records. Assumptions about maintenance schedules, replacement intervals, and reliability statistics are based on industry norms unless stated otherwise.

Environmental and Site Conditions

- Site-specific environmental conditions (such as weather, seismic activity, and terrain) are assumed to be consistent with historical averages and reported data. Where projects are subject to environmental consents or resource management conditions, we assume these are either in place or attainable within proposed timeframes unless stated otherwise.

Supply Chain and Resource Availability

– The timely availability of materials, skilled labour, and logistical support necessary for project execution has been assumed, barring exceptional circumstances such as global supply chain disruptions, which are only factored in where they have been specifically identified as risks in the material reviewed.

1.6.3 Economic and Strategic Assumptions

Demand Growth and Electrification Trends

– Projections for national electricity demand, driven by decarbonisation and electrification trends, are based on Transpower forecasts. We assume these trends will continue as described, with no major reversal due to policy or technological change.

Cost Estimates and Contingencies

– All cost estimates include reasonable contingencies reflecting the current stage of project planning. It is assumed that no major unforeseen costs will arise outside those identified in the risk management sections of the reviewed documents.

Market Structure and Access

– The wholesale electricity market structure, rules, and access requirements as defined by the Electricity Authority are assumed to remain consistent, enabling Transpower's ongoing ability to act as the system operator.

Stakeholder Engagement

– Stakeholder views and feedback captured in workshops, consultations, and submissions are assumed to be broadly representative of national and regional perspectives. Any significant dissenting positions are presumed to have been captured or highlighted in the documentation reviewed.

1.6.4 Limitations and Boundaries of Assumptions

Scope of Review

– The assumptions outlined here are applicable only to Transpower's HVDC Link Upgrade Programme and the infrastructure proposed in the capital proposal. The findings and recommendations should not be extrapolated to unrelated business units or projects.

Temporal Validity

– These assumptions are valid as of the date of the review and are subject to change should material events, regulatory shifts, or technical advancements occur after the review period.

Data Integrity

– All conclusions drawn are dependent on the accuracy and completeness of data provided to the review team. While reasonable efforts have been made to verify information, residual uncertainties may remain where data quality was variable.

Uncertainty and Risk Management

– Assumptions regarding risk have been made in line with industry risk management practices, and all identified risks have been documented in the corresponding sections of this report. Unforeseen events outside these documented risks are not accounted for in the analysis.

2. Background

This section provides the relevant context for Transpower's HVDC Link Upgrade programme. The background covers Transpower's roles, regulatory context, proposed expenditure and current Transpower frameworks.

2.1 Transpower's roles

Transpower undertakes two essential roles of national significance in New Zealand:

– **Owner and operator of the national transmission network**, i.e., the high voltage (HV) electricity grid infrastructure. This physical infrastructure transports bulk electricity around New Zealand from where it is generated to where it will be finally consumed. It supplies the electricity either directly to major industrial users or to local Electricity Distribution Businesses that then finally delivers power to end consumers. This physical infrastructure is made up of approximately 11,000 km of transmission line, 3 subsea HVDC cables, 170 substations, 7,500 km of telecommunication fibre, 12 radio connections and various other supporting assets. Given the nature of this physical infrastructure, it is a natural monopoly and hence is economically regulated by the Commerce Commission.
– **System operator and responsible for managing the real-time power system and operating the wholesale electricity market**. Transpower is regulated by the Electricity Authority for undertaking this role in accordance with the rules and regulations that defines the market structure.

Transpower does not generate, own or sell electricity.

Like other jurisdictions, New Zealand's energy sector is rapidly transitioning to electrification due to decarbonisation drivers while society and its economy becomes increasingly reliant on electricity. Both Transpower's roles are important to enabling this transition to occur.

This report and its scope of work considers only Transpower's role as the owner and operator of the HVDC Link Upgrade Programme and associated infrastructure.

2.2 Regulatory Context

Transpower New Zealand Limited is a state-owned enterprise responsible for the secure and reliable transmission and delivery of electrical energy from generating sites to distribution companies and large direct supply companies. The company operates under a robust regulatory framework designed to ensure quality and value for consumers.

The Commission reviews Transpower's proposed five-year work plan, setting spending allowances, quality targets, and determining allowable earnings on investments. Additionally, the Electricity Authority establishes how Transpower charges customers for services and sets standards for grid reliability. This framework incentivises Transpower to innovate, invest, and meet quality standards while limiting the return it can earn, ultimately benefiting consumers.

Transpower can submit additional proposals to the Commission for work that was uncertain or unknown at the time of the initial work plan. Major capital expenditure proposals, which are defined as projects costing over $30 million, require extensive consultation and must demonstrate net benefits to the electricity market or enhancements to grid reliability. Given the size and scope of the project, Transpower decided, in consultation with the Commission, that an independent expert review was appropriate.

Specifically, The MCP is subject to The Commission approval, and Transpower must demonstrate that the proposed investment aligns with Good Electricity Industry Practice (GEIP) and delivers efficient outcomes for the electricity market.

2.3 Strategic context, priorities and policy

Transpower works toward enabling a net-zero carbon economy in New Zealand. This is reflected in its adoption of the ‘accelerated electrification’ base case scenario, which anticipates rapid growth in electricity demand driven by decarbonisation of transport, process heat, and industrial sectors. This scenario is regularly benchmarked against international models such as AEMO’s Integrated System Plan to ensure relevance and robustness. The strategy is informed by the Whakamana i Te Mauri Hiko programme, which provides a pulse check on market movements and Transpower’s alignment with industry indicators like utility-scale renewables, electric vehicles, distributed energy resources, and affordability.

2.4 Overview of proposed Link Programme expenditure

The following provides an overview of Transpower’s Link proposal at the time of our independent review. We have highlighted the focus of Transpower proposal, summarised the expenditure categories at aggregated level and briefly explained the expenditure drivers in Link at a high level.

2.4.1 Focus of Transpower Major Capital Expenditure Proposal

Transpower’s HVDC MCP focuses on replacing ageing submarine electricity cables – originally installed in 1991 and nearing the end of their expected life in the early 2030s. Transpower proposes to replace these cables and to install an additional cable to increase transmission capacity and provide redundancy in case of outages. This upgrade is part of a broader suite of improvements, including upgrades to control systems, cable termination stations, Pole 2 overload capacity, filter banks, and cable storage. The recovery of decommissioned cables has also been considered.

2.4.2 Proposed Expenditure

The proposed expenditure in the HVDC Link Upgrade Programme consists of capex outlined in the figure below. These costs are taken from the short list and Transpower is updating the costs for the proposal.

Figure 1 proposed HVDC link upgrade programme costs

Project	Estimated cost ($m)	Expected completion
Undersea cables supply and install (1400 MW)	721.1	2031
Cable termination station upgrades	77.0	2030
HVDC control system replacement	202.0	2031
Benmore filter bank upgrade	16.8	2030
Pole 2 overload scheme	10.8	2030
Cable storage facility	11.4	2030
Recovery of decommissioned cables	121.5	2033
Project investigation costs	10.4	
Allowance for interest during construction and inflation	209.2	
Estimated total	**1,380.2**	

2.4.3 Link asset management strategy

The HVDC system is a crucial component of New Zealand's electricity transmission infrastructure, providing a high-capacity connection between the North and South Island grids. This system ensures access to the South Island's renewable generation and supports the North Island's thermal generation during dry periods. The HVDC link includes 570 km of overhead lines from Benmore HVDC converter station to Fighting Bay in the South Island, three 40 km submarine cables between Fighting Bay and Oteranga Bay, and 35 km of overhead lines from Oteranga Bay to Haywards converter station in the North Island.

The HVDC link comprises two poles, Pole 2 and Pole 3, each operating at 350 kV. These poles convert electrical power between AC and HVDC systems, connecting the North and South Island AC electricity grids through the HVDC system, forming New Zealand's transmission grid backbone. Pole 2 was built in the early 1990s, and Pole 3 was added in 2013. The HVDC link is vital for New Zealand's power system, especially given the dependence on hydro generation in the South Island and the growing intermittent wind and solar generation across the country. The north-south link is essential for supplying the North Island during winter peaks and the South Island during dry periods. Additionally, the system supports an efficient national electricity market, frequency-keeping services, and a national reserves market.

Maintaining a fit-for-purpose HVDC link is key to achieving New Zealand's goal of net zero carbon by 2050.The HVDC system establishes a high-capacity connection between the electricity transmission networks of the North and South Islands. This aids in maintaining cost-effective access to renewable energy generated in the South Island and thermal generation from the North Island during periods of low water availability.

As the landscape of HVDC changes, the HVDC link’s asset management strategy must account for a fundamental shift in its operational role. Historically facilitating predominantly northward transfers of South Island hydro generation, the link must begin to support increasingly dynamic bidirectional flows driven by variable wind and solar generation across both islands, potentially requiring multiple power direction changes each day.

2.4.3.1 HVDC Challenges

The HVDC Asset Class faces many challenges including:

- maintaining high availability
- managing planned and forced outages, and
- addressing risks such as major failures and third-party threats.

Transpower determines system availability against the international benchmarks reported to CIGRE. RCP4 determined an outage rate of 1.75% which is lower than the median international scheduled outage rates for thyristor-based HVDC systems of 2.37% excluding outages for Pole 2 refurbishment, Thyristor control unit (TCU) and human machine interface (HMI) software upgrade, and yearly maintenance.

Over the last 10 years the HVDC availability has been above 95%, except for 2020 when it was 88%.

2.4.3.2 HVDC Objectives

The Objectives for the HVDC Asset Class can be summarised as:

- zero fatalities or injuries,
- minimising environmental risks
- achieving high bi-pole capacity availability, and
- supporting the transition to more renewables.

2.4.3.3 Strategic Approaches

There are several strategic approaches taken by Transpower:

- **Safety**: Prioritise maintenance critical to safe operation, manage safety-related risks, and ensure trained and competent personnel.
- **Environment**: Implement leak management strategies, manage impacts in sensitive locations, and meet legislative requirements for minimizing harmonic distortion and noise complaints.
- **Performance**: Maintain high availability, manage obsolescence, and plan replacements and refurbishments to maximize asset utilisation.
- **Resilience**: Assess resilience and redundancy requirements, investigate control system replacement, and evaluate seismic compliance.
- **Lifecycle Delivery**: Undertake regular condition monitoring, inspections, and maintenance, and document failure modes and mitigation strategies.

[Plus, asset health models, criticality calculations, and long-term investment plans]

2.5 Procurement and Planning

The HVDC Link Upgrade Programme is still in the investigation stage, so some components have not commenced to the procurement stage. The procurement planning for each component is provided below.[4]

Cables Replacement: Procurement and installation lead times for submarine cables are long, up to 10 years, due to global demand and limited vessel availability. Following a market review in 2024, Transpower undertook a competitive tender process to reserve manufacturing and installation capacity for the replacement cables. Prysmian was selected, and a Capacity and Reservation Agreement was entered into with a contracted installation window in 2031. There is a contracted requirement to formally issue a notice to proceed (NTP) by 30 June 2026. The NTP enacts the Engineers, Procure, Installed Construct (EPCI) contract. The scope of works for Prysmian includes all submarine and land-based cable design, supply and installation, as well as the supply, installation and commissioning of the cable termination bushing in the Cable Termination Station building. All other services and materials outside the Prysmian works will be secured using Transpower's standard procurement processes.

Cable Store: The cable store replacement works are proposed to be divided into two separable portions: firstly, the design, manufacture and installation of the cable carousel by a Prysmian offshore subcontractor. The supply and installation of the cable carousel currently falls outside the scope of works for the cable contract but will be varied into this contract to take advantage of the warranty provisions. Secondly, the design and installation of the foundations and cable store building will be contracted by Transpower utilising New Zealand service providers using standard procurement processes. This strategy is proposed to manage the potential knowledge gaps of international suppliers in specific requirements of New Zealand's building code. Clear demarcation points will be agreed between the separate work packages. Processes will be developed to ensure coordinated information sharing between the parties (e.g. foundation capacity requirements, connection point details).

Cable Termination Stations: Conceptual design work has been completed and included in the Stage 2 Solution Study Report. It is proposed to undertake detailed design and build as separate contracted portions of work to optimise commercial opportunities and manage project risk. The detailed design will be scoped and tendered in accordance with procurement policies. Early contractor involvement is a critical part of the design process to ensure construction methodologies are incorporated into the design. The build contract will be open tendered through GETS as per Transpower's procurement requirements. HV electrical works within the buildings and connection of

[4] This information was provided to us by Transpower via an RFI. No further documentation has been sighted beyond the RFI response.

the equipment to Transpower's systems will be contracted directly to Transpower's approved service providers through a competitive tendering process. All other services will be secured using Transpower's standard procurement processes.

HVDC Control Systems Replacement: The HVDC controls systems supplier market is extremely constrained with demand for new and upgraded systems exceeding resourcing and supply capabilities. Suppliers are not willing to provide pricing for system upgrades until a moderate level of engineering and scoping has been completed. The Transpower HVDC link has several specific requirements that are not common in the market, e.g. different converter suppliers for each pole requiring bespoke interfaces, enhanced features such as round-power and frequency keeping, interfaces with regional controllers, etc. A market-wide RoI process was undertaken, following which only two HVDC control system providers were identified to take through to the Request for Proposal (RFP) stage.

The Transpower MCP has been staged to allow for a period in which a level of front-end engineering can be undertaken to better define the scope and cost of the control system replacement. The next steps are to complete an RFP stage (likely to be non-priced) followed by entering a Front-end Engineering and Design (FEED) agreement. The RFP will inform whether the FEED process is competitive or sole-sourced. Information gained from the FEED will inform the Stage 2 proposal to be submitted later.

Filter Banks – Benmore: A procurement plan is yet to be developed for this project.

Pole 2 Overload Scheme: A procurement plan is yet to be developed for this project.

Cable Removal: The Transpower MCP has been staged to enable the development of a robust business case detailing the need for removal. Costs are currently based on those provided by the cable installation contractor. Further refinement of costs will be undertaken, widening the market to other submarine services contractors. Refined costs will be used to inform the Stage 1A proposal should the business case justify the need. Procurement of the cable removal would likely be internationally tendered on the open market around 2028.

Part B

Link Programme Strategy and Evaluation Approach

3. Evaluation Approach

3.1 Economic Evaluation

Transpower's proposed investment is reviewed according to the criteria set out in Section 4. As per the Commission's statement in the inception meeting, a series of questions are posed which correspond to the typical questions that would be asked as part of the Strategic and Economic Cases of a business case.

The economic evaluation then uses these questions in conjunction with the results of the technical workstream evaluation to complete the analysis.

3.2 Technical Workstream Evaluation

To evaluate the Transpower MCP, we applied the criteria from the Terms of Reference directly. The three sections of the Capex IM constituted the criteria for the document-level analysis. We then aggregated this analysis into a workstream-level analysis using the numbered items from the Terms of Reference (5.1 through 5.11). Examples of our technical analyses are provided in **Appendix E Review techniques.**

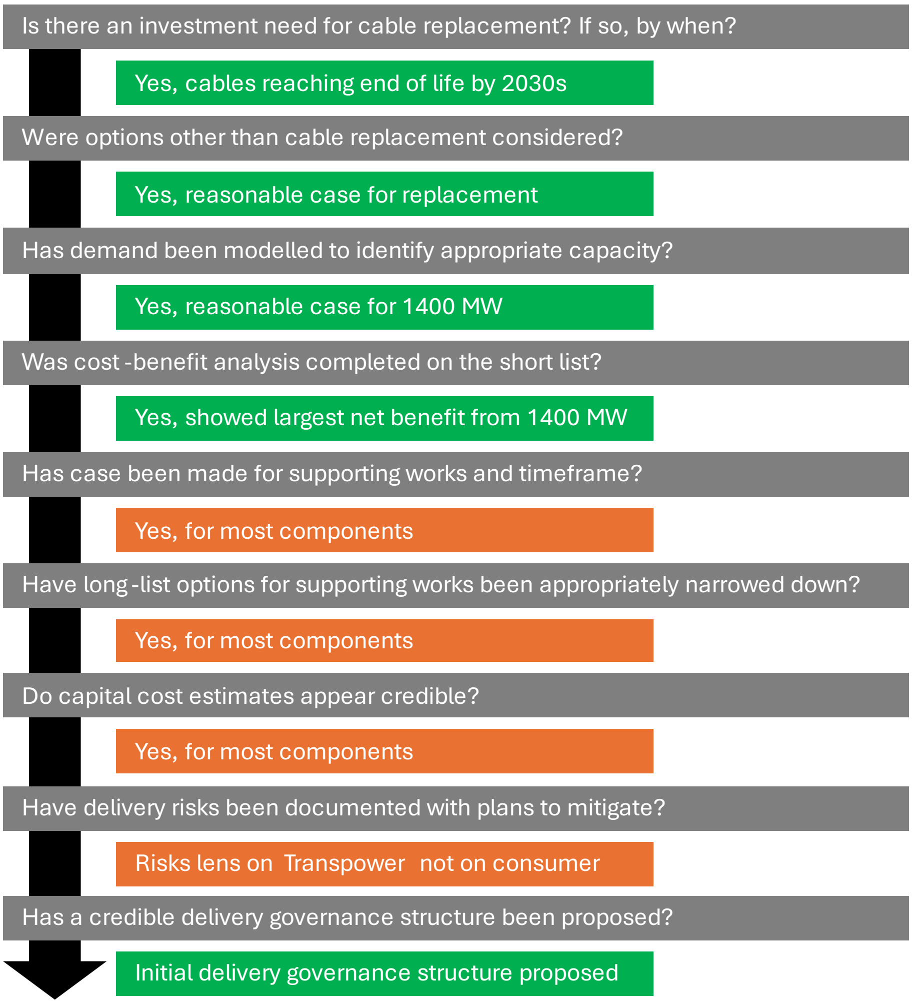
4. Economic Evaluation of Link Programme

The logic flow for the review of Transpower's argument of investment is set out below. A series of questions are posed, which correspond to the typical questions that need to be answered as part of the Strategic and Economic Cases of a business case.

We begin by examining whether Transpower has established that an intervention is needed at all, what options were considered and how the conclusion was arrived at that 1400MW cables are required.

We then examine how well the argument is made for supporting capital works, whether the options to achieve those outcomes have been evaluated reasonably, and whether the costings seem to have been credibly thought through.

Finally, we consider what attention has been given to operational costs, and how Transpower has identified and plans to manage delivery risks, as well as whether there is a planned delivery governance structure in place to ensure timely and successful delivery of the project.



4.1 Is there an investment need for cable replacement? If so, by when?

The argument for replacement of the existing cables presented by Transpower is defensible. The argument in broad terms is that: [5]

– The cables were installed in 1991.

– By 2031, the earliest Transpower could secure a cable replacement contractor, the cables will be 40 years old, reaching the end of their expected design life. Cables are expected to be at greater risk of failure beginning from 2032 according to modelling on asset health.[6]

[5] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Overview, p.8 (CON001).

[6] See Transpower. (2025). HVDC Link Upgrade Programme Major Capex Proposal short-list consultation Attachment 2: Cable Condition Assessment Report (CAB001).

- Repair of damaged cables should they fail beyond 2031 is expected to take six to 18 months, if repairable, which is an untenable period to have at least one of the cables out of action, given expected growth in demand over the years that follow.
- If this outage occurs during dry hydrological conditions in the South Island or North Island capacity shortages, security of supply challenges will arise with significant economic impacts.
- If the cable(s) cannot be repaired, the replacement timeframe is seven to 10 years based on current demand for cable replacement services. This claim is evidenced by the earliest window during which Transpower's preferred supplier for cable replacement could complete their work (2031).[7]
- Transpower provided an additional analysis of the likelihood and impact of a cable failure under a do-minimum option where Transpower would attempt to repair cables as they fail.[8]The analysis showed that the availability of the existing cables (W4, W5 and W6) would reduce over time and would potentially become unrepairable. The analysis used an asset health model for the 122 kilometres of cable, evaluated in one-kilometre sections, following a methodology used by the Office of Gas and Electricity Markets in the UK. The analysis only considers the possibility of single cable failures, excluding the possibility of multiple cable failures occurring simultaneously, so probably underestimates the risk and commensurate costs of not pre-emptively replacing cables.
- The modelling suggests that the **annual** likelihood of failure of an individual cable rises from 3-5% in 2025 to 5-9% by 2035. Acknowledging that these are individual cable failure estimates, the risk of one of the three cables failing in any given year would be higher than these estimates.
- In **cumulative** terms, the risks are much higher according to the modelling. There is a 37-50% chance that an individual cable will fail by 2035, and the risk will again be higher that one of the three cables will fail by that time.
- Transpower did model the possibility of more than one cable being unavailable at any time by using the average risk of an individual cable being down in any given year and then working out the risk of two cables or all three cables being out of action at the same time, and an assumed restoration period of one year per cable. They also evaluated a scenario where cables were unrepairable. If repairs are not possible, availability of all three cables drops to 15-30% by 2035. Even if repair is possible, availability of all three cables drops to around 74-83% in 2025 and then rapidly deteriorates through the forecast period.
- Transpower converts outage risk to economic cost by applying representative outage costs to the availability projections. These provide a counterfactual against the cost of replacing the cables. The total cost is directly related to the number of cables down at any time, whether cables are repairable, and the state of hydro dam levels at the time of the outage.
- Unsurprisingly, the modelling shows that if cables are unrepairable, the annual economic costs rise far more sharply than if they are repairable. Transpower makes the point that the older the cables get, the more likely the "unrepairable" scenario will be. By 2031, the **annual** probability-adjusted economic cost of cable outage and repairs is estimated at $10 million to $170 million, dependent on whether cables are repairable.
- Finally, Transpower assessed the optimal economic time to replace the cables based on the discounted cashflows of economic costs of outage and repair versus a replacement cost of $620 million (for three cables, like-for-like). This analysis suggested replacement dates of 2025 to 2039, depending on whether cables are repairable and the higher or lower estimates of the health of the cables.

Opinion

Transpower has provided a credible explanation of the economic rationale for replacing the existing cables as well as an explanation for why the timeframe of the early 2030s is reasonable for risk avoidance and limiting economic costs.

[7] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.1 (CON004).
[8] See Transpower. (Aug 2025). An economic assessment of HVDC cable failure and replacement scenarios.

4.2 Were options other than cable replacement considered?

The arguments set out above assume a cable solution is required. However, it is important to evaluate whether there is a non-transmission solution.

Transpower has examined within its long list of options the possibility of:

- Non-transmission solutions, which it defines as "load management or additional supply in both the North and South Island".[9]
- A do-nothing option, allowing the cables and associated equipment to run to failure without replacement.
- Options for replacing the cables like-for-like and for expanding capacity (see the discussion on capacity below).

Non-transmission solutions are dismissed as they "do not address the fundamental need for replacement cables. This option is not technically feasible, as it would not maintain the HVDC link." This seems a strange reason to dismiss non-transmission solutions as it presupposes that a cable link is required.

Opinion

Despite this being a seemingly early conclusion to jump to in the long-list evaluation, one can argue that this type of solution would result in similar outcomes to the "do nothing" option that allows the cables to run to end-of-life with no replacement plan. Signalling to the market that there is no plan to replace the cables at end of life would arguably generate the same market response from generators as actively signalling the need for each island to become electricity self-sufficient or manage loads in the absence of sufficient generation. It therefore seems plausible that Option 1 as modelled (the do-nothing option) could be an appropriate proxy for the non-transmission option although it would be good to have more clarity from Transpower on that scenario beyond what appears to be a very early dismissal in the short-listing process.

4.3 Has demand been modelled to identify appropriate capacity?

Having established the need to find a solution to the problem of inter-Island cables reaching end of life, if a cable replacement solution is to be proposed, the next question is to determine the appropriate capacity of the new cables.

4.3.1 Electricity demand modelling

Transpower presents four demand and generation scenarios that incorporate different patterns of growth and supply. These scenarios take account of:[10]

- future electricity demand, including assumptions regarding base demand, electric vehicle (EV) uptake, solar photo-voltaic (PV) uptake, and distributed energy storage
- existing, decommissioned and future new generation connected to the national grid
- capital expenditure and operating costs for both existing and future generation assets
- availability of fuel for generation
- fuel and carbon costs associated with generation
- grid-connected energy storage solutions.

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[9] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Attachment 3: Short-list of investment option, p.6 (CON003).
[10] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list consultation Attachment 1: Need for investment, demand and generation scenarios, p.10 (CON002).

The scenarios are based on Electricity Demand and Generation Scenarios (EDGS) produced by the Ministry of Business, Innovation and Employment (MBIE).[11] They account for different base levels of demand; step loads as new developments come on stream leading to step changes in demand; various rates of uptake of solar, EV and battery storage capacity; and the electrification of industrial heating processes.

Transpower uses the SDDP dispatch model to simulate the wholesale electricity market and OptGen to determine the location, timing, and technology of new generation to meet the growth in demand expected in each scenario.[12]

Opinion

Modelling appears to have adequately considered large-scale existing generation, committed new generation and planned retirements. Assumptions that have diverged from the Benefit-Based Charges (BBC) Assumptions Book v.2.0 are set out clearly.[13]

4.3.2 Implied benefits of larger capacity

Transpower sets out several defensible reasons for building greater capacity (1400MW rather than 1200MW).[14] These include:

– A significant share of growth in generation especially in the North Island is expected to be met by renewable energy sources, which tend to be more intermittent. Extra capacity would allow for more firming of supply in these periods.
– Four cables rather than three provides redundancy should one cable be damaged.
– Increasing the HVDC transfer capacity to 1400MW provides the option to increase the overload capacity for Pole 2, allowing it to absorb additional load for up to 15 minutes in the event of a Pole 3 trip, improving overall network stability and reducing costs by allowing the HVDC to cover a larger portion of its own reserve requirement.

To these we would add that the marginal cost of the greater capacity is likely to be a small share of total project cost for the risk mitigation it provides, a claim Transpower also makes elsewhere.[15]

4.4 Was cost-benefit analysis completed on the short list?

Assuming the do-nothing option (Option 1) is a reasonable proxy for the non-transmission solutions option, modelling this against like-for-like (Option 2) and expanded capacity (Option 3) cable replacements seem to be appropriate options to test.

Transpower has completed a benefits assessment on these three options that demonstrates that there are significant benefits of completing an expanded capacity cable replacement over the do-nothing option (or by extension, non-transmission solutions) and over the like-for-like replacement option.

The modelling is based on expected expansion of generation projects and generation dispatch simulations that seek to deliver electricity as efficiently as possible.[16]

Some of the key assumptions differentiating between options is that:

[11] Ibid.
[12] Ibid, p.21.
[13] Ibid, p.33-35.
[14] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Overview, p.9 (CON001).
[15] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.2 (CON004).
[16] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Attachment 4: Benefits modelling, p.4 (CON005).

– In Option 1, the HVDC link is assumed to be decommissioned in 2038 due to a failure of the control systems, which are a key component for the HVDC link to be able to operate, but with one cable failing in 2031, resulting in a transfer capacity of 1000 MW North rather than the current 1071 MW.
– All options assume installation of a STATCOM at Haywards in May 2027. From that point onward, allowing transfer capacity of 1200MW North and 950 MW South.
– Both Option 2 and Option 3 are assumed to be in place by 2031.
– Option 3 assumes increase in northwards transfer capacity to 1400MW from 2031.

We note that the analysis includes the additional infrastructure elements that will be necessary to maximise the value derived for Option 3, such as allowing for improved pole overload capability on Pole 2. The case for these additional components is discussed below in this assessment.

Further assumptions include:

– The value of unserved energy, estimated at $31,500 per MWh, in line with previous estimates we have seen
– Generation expansion plan modelling deficit cost tranches allowing for trigger points for stimulating extra generation
– Similar generation expansion plans for Option 2 and Option 3.

The modelling suggests that in all scenarios, Option 1 leads to more geothermal development. In all scenarios, more solar is generated in the North Island than the South Island, a pattern one would expect.

Consequently, Transpower estimates firstly the avoided cost of generation build from Option 2 and Option 3 relative to Option 1.[17] The results are replicated below.

Table 7: Electricity market capital benefits present value ($m 2024, 5% discount rate)

Scenario	Disruptive	Environmental	Growth	Reference
Option 1	0	0	0	0
Option 2	2,250	3,457	3,033	2,049
Option 3	2,250	3,457	3,033	2,049

Transpower estimates that Option 2 and Option 3 lead to lower generation build requirements worth billions of dollars in avoided costs by 2060 – between $2.0 billion and $3.5 billion in present value terms depending on the scenario.

As the table above shows, the avoided generation build costs are the same for Option 2 and Option 3, but Transpower estimates the operational benefits of Option 3 make it more attractive than Option 2. The analysis suggests that over time there are increasingly large electricity transfers in both directions – south and north. From 2030, transfers begin to be constrained by the limited 1200MW capacity.

To 2060, there are operational benefits to Option 3 over and above those from Option 2 that run between about $142 million and $225 million in present value terms depending on the scenario.

[17] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Attachment 4: Benefits modelling, p.21 (CON005).

Table 8: Operational benefits (2024 $m) present value (5% discount rate)

Scenario	Disruptive	Environmental	Growth	Reference
Option 1	-	-	-	-
Option 2	2,519	2,422	1,585	1,407
Option 3	2,683	2,647	1,727	1,650

Combining these results, Transpower concludes that the present value benefit of Option 3 scores highest. We would highlight that the Option with the highest net present value may not be the best value Option. The Benefit-Cost Ratio (BCR), which is calculated by dividing the benefits estimated here by the costs of each option, may be the best indicator of value.

Opinion

The approach taken to estimating the present value of the benefits of each option for each scenario seems reasonable. There appears to be defensible rigour in modelling how generation may respond to the loss of the HVDC connection or in the case of continued connection between Islands. Interrogating the modelling spreadsheets is outside the scope of this analysis but we have been able to reproduce the net present benefit values shown in the table below from the model outputs provided to us.[18]

[18] In the spreadsheet entitled CON006 Benefits_modelling_output_SLC.xlsx.

Table 10 Gross market benefits present value (2024 $m, 5% discount rate)

		Disruptive	Environmental	Growth	Reference
Option 1	Operating costs benefits	-	-	-	-
	Capital cost benefits	-	-	-	-
	Total benefits	-	-	-	-
Option 2	Operating costs benefits	2,519	2,422	1,585	1,407
	Capital cost benefits	2,250	3,457	3,033	2,049
	Total benefits	4,769	5,879	4,618	3,456
Option 3	Operating cost benefits	2,683	2,647	1,727	1,650
	Capital cost benefits	2,250	3,457	3,033	2,049
	Total	4,933	6,104	4,759	3,700

4.4.1 Comparing costs and benefits

Having assessed the benefits of the three Options, the Investment Test requires these benefits to be assessed against the costs associated with each option.

The benefits estimated under the four scenarios above are given an equal weighting such that an overall estimate of benefits can be calculated for each Option.[19]

Opinion

In the absence of stronger guidance on the likelihood of any scenario, this seems like an appropriate assumption.

The analysis period for the Investment Test is 30 years, noting that the cables have an expected life of 40 years. At the real discount rate of 5%, a 30-year period is likely to capture the vast bulk of the benefits. Instead, by annuitising the cost over the different lives of each asset over the calculation period, a result similar to estimating residual values was achieved.

Opinion

An alternative would be to use the 40-year analysis period and no residual value but 30 years with a residual value calculation is reasonable.

[19] See Transpower. (May 2025). HVDC Link Upgrade Programme Project Major Capex Proposal short-list consultation Attachment 5: Investment Test, p.6 (CON008).

The cost estimates presented in the Investment Test make no allowance for inflation or interest costs.[20] They do, however, include the various costs assumed to be required as part of the wider programme to complete each Option (such as cable removal, upgraded cable termination stations and so on), which are discussed in more detail below.

Opinion

We note that inflation and interest costs are included in other documents (around $210 million in the case of Option 3). While technically all costs and benefits should be in today's (real) dollars and therefore inflation should be excluded, interest costs should be included, as should any expected escalation over and above expected economy-wide levels of inflation.

The present value benefits and present value costs of the three Options are measured relative to Option 2.

Opinion

It is good practice to measure options relative to the Do-Minimum, which in this case is the Do-Nothing option. Measuring relative to Option 2 creates the impression that Option 1 has been dismissed outright. Nevertheless, it is clear from the analysis, that based on the assumptions used (not all of which we have access to), the largest net benefit will occur in Option 3.

We would note that The Commission requires Transpower to prioritise the project option with the best net electricity market economic benefit. From a value for money perspective, in good practice the project with the greatest BCR is often selected, as that implies maximum dollar return for every dollar invested, and accounts for the fact that often budgets are constrained.

Several sensitivity tests are provided, using different discount rates, assumptions about lower or higher benefits, and capital cost changes. All of these test results are presented as net present values.

Opinion

While there are risks to elements of the project where Transpower carries all the risk, such as currency risk, or commodity price risk (fuel, metals etc) may be worth running. We recommend the assumptions and model results be sighted by the Commission.

4.5 Has case been made for supporting works and timeframe?

The preferred option, Option 3, already allows in its costings for the assumed extra works needed to accommodate that cable solution (replacement of current cables with 1400MW capacity across four cables). However, it is worth considering the arguments for the additional components being required:

Replacement cable termination stations

The current termination stations are designed for three cables and not four, are exposed to the elements including coastal inundation, are seismically at risk, and within the tsunami inundation zone.[21] Transpower has provided additional reporting on modelling that estimates the risk-adjusted costs and benefits of building termination stations at higher elevations to avoid inundation risk.[22] Transpower documentation also suggests that strengthening the buildings to todays' seismic standards would require a bi-pole outage of six to 12 months and therefore new buildings would be more cost effective and would not require the same extended outages.[23]

[20] Ibid, p.8-9 (CON008).
[21] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.3 (CON004).
[22] See Transpower. (Aug 2025). Cable termination stations resilience benefits.
[23] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.3 (CON004).

Replacement control system

In the do-nothing modelling, Transpower assumes that one cable fails in 2031, but that the ultimate reason the cables stop operating is failure of the control systems by 2038, when the system would be 25 years old.[24] The expected life of the system was 20 years, which would mean replacement in 2033. Replacing the control system when commissioning the new cables avoids downtime for installation and testing of the control system at some future date.

Benmore filter bank upgrade

The economic modelling demonstrates the net benefit of Option 3 (1400MW) over Option 2 (1200MW).[25] To support this higher capacity, Transpower is required to manage harmonics and power quality as required by the Electricity Industry Participation Code.[26]

Increased Pole 2 overload capacity

There is currently a disparity between Pole 2 and Pole 3 short term transfer capacity. The goal is to increase Pole 2 overload capacity such that it is commensurate with Pole 3.[27] Transpower has estimated that "increasing the Pole 2 overload to 150% (840MW) will reduce the P2 – P3 restriction and Transpower estimates that this provides significant benefit (~$35m) in unlocking HVDC link transfer capacity when operating at high transfer levels."[28, 29] Transpower's modelling indicates that not increasing Pole 2 overload capacity would impose reduce the benefit of the preferred option by $42-48 million, while the estimated cost of the Pole 2 overload upgrade is around $11 million.

New cable storage facility

The documentation shows that, based on CIGRE reports and Transpower experience, a cable repair is expected once every 30 years per 100 km of cable installed. Consequently, with the four-cable system proposed, a large storage facility is required, with an estimated 10 km length of cable to be stored.[30] The current storage facility in Wellington has become unsuitable as the neighbouring wharf where cable would be loaded onto the cable-laying vessel has been condemned and there are increasing restrictions on docking vessels next to Wellington Airport.[31]

Recovery of decommissioned cables

Transpower has had a legal opinion provided on whether the existing cables will need to be removed as part of receiving fast track approval. The legal opinion states that this is likely, seemingly on the basis of Transpower's fast track application having already stated that it would remove the cables.[32] As the fast track proposal as submitted included an undertaking to remove the decommissioned cables, the legal opinion raises the risk of the programme being denied fast track approval if it is proposed without the cable decommissioning. Transpower is of the view that this could place the entire programme timeline in jeopardy.

[24] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Attachment 4: Benefits modelling, p.9 (CON005).
[25] See Transpower. (May 2025). HVDC Link Upgrade Programme Project Major Capex Proposal short-list consultation Attachment 5: Investment Test, p.13 (CON008).
[26] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.3 (CON004).
[27] Ibid, p.4 (CON004).
[28] See Transpower. (May 2025). HVDC Link Upgrade Programme Major Capex Proposal short-list Consultation Attachment 4: Benefits modelling, p.32 (CON005).
[29] See Transpower. (Aug 2025). Economic benefit of pole 2 overload – summary.
[30] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.2 (CON004).
[31] Ibid, p.2 (CON004).
[32] See Dentons. (20 Feb 2025). Advice on removing the HVDC Cables (letter to Transpower (CABR001).

Opinion / recommendation

The documentation shows that by the time the existing cables reach 40 years of age; they are unlikely to be reliable back-up or emergency cables.[33] Transpower's asset health modelling forecasts the year for earliest intervention is 2032 to 2035 for the existing cables.[34]

It is unclear what environmental basis there is for removing the cables, and therefore what basis there was for Transpower to include removal of existing cables in its fast-track application. Given the considerable cost of this element (an estimated $122 million plus inflation and interest costs), the environmental case needs to be made that the cables will result in significant adverse effects.

Fast track legislation also allows for consideration of the proportionality of benefits at a regional or national level against potential adverse effects. As the $122 million will be a cost directly borne by electricity consumers, the economic benefit of not needing to remove the cables could be argued as being of national significance, and the fast-track process would therefore allow for a case to be made for leaving the cables in place.

We recommend that the removal of the cables be dealt with under a separate application, allowing Transpower to proceed with the current process, and allowing more time to investigate the case and evidence for removing the cables under a separate MCA.

4.6 Have long-list options for supporting works been appropriately narrowed down?

This evaluation of the strategic and economic case has already demonstrated that Transpower has mounted a case for 1400MW cables over 1200MW cable replacement and over taking no action at all.

The next question is whether a range of alternatives have been considered for the other components requiring work to ensure maximum economic benefit is derived from the 1400MW cables. The argument for taking action has been made previously, particularly in the case of the cable store, cable termination station, control systems and filter bank upgrades. The question at hand is whether adequate consideration of alternatives has been undertaken.

Replacement cable termination stations

Transpower has had an external consultant complete a review of alternatives for cable termination stations including for upgrades to the existing facilities to make them meet modern seismic standards.[35] The study sets out the key challenges with existing sites and considers engineering solutions to overcome those challenges. It also provides examples of new-build stations that could overcome the challenges and minimise outages.
The report concludes that new-build options (a GX-4 four cable long/narrow building at both the North Island and South Island sites) is preferable.[36]

Opinion

Transpower appears to have reasonably considered the range of options for cable termination, including improving the resilience of existing stations. The conclusion that a new building in each location will deliver the modern seismic standards improvements needed at lower cost than trying to make the existing sites more robust seems defensible, assuming the credibility of the cost estimates provided for each option.

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[33] See Transpower. (2025). HVDC Kick-off Meeting Presentation, Slide 35.
[34] See Transpower. (2025). HVDC Link Upgrade Programme Major Capex Proposal short-list consultation Attachment 2: Cable Condition Assessment Report (CAB001).
[35] See Beca.13 March 2025). HVDC Cable Replacement Project CTS - Combined Concept Stage Report SSR1, p.21 (TER002).
[36] Ibid, p.6-7.

Replacement control system

The documentation shows that the control system needs to be bespoke to meet New Zealand's unique two-island power system requirements, including Round Power and Reactive Power Control functions.[37]

Opinion

The control and protection system for Pole 2 and Pole 3 must be designed, manufactured, installed and tested to interface with the existing converter station equipment at the sites. These control and protection systems are not available as "off the shelf" systems. Transpower will produce a technical specification for the replacement Pole 2 and Pole 3 control systems and will contact the major European based HVDC manufacturers to discuss their interest in the replacement project. Control system replacement projects recently have required a preferred supplier and capacity reservation approach due to the HVDC market demand and long lead times.

Benmore filter bank upgrade

The documentation shows that the filter bank upgrade is necessary to facilitate an increase in transfer and maintain capacity to 1400MW.[38]

Opinion

HVDC link 1400MW transfer capacity requires additional filters to be installed to ensure network harmonics limits are met as per the Electricity Industry Participation Code. Filter installations are considered standard practice to ensure power quality standards are met.

Increased Pole 2 overload capacity

Transpower has modelled options with and without increased overload capacity and has estimated that there are net benefits of $35 million from expanding Pole 2 overload capacity, consisting of additional benefits of $42-48 million and the additional cost of the upgrade of around $11 million.[39]

Opinion

Currently P2 is constrained to 500MW by the single cable. Installation of a 4th cable will shift the constraint to the P2 converter rating. (700MW). Increasing P2 overload to 150% (840MW) is considered the most practical option to minimise market costs until P2 converter equipment is replaced around 2042.

New cable storage facility

Transpower has had an external consultant complete a review of alternatives for cable storage locations including the existing cable store in Wellington.[40] A long list of 12 was whittled down to five in part based on whether proposals were received or whether suitable sites were available.

The short list was assessed for suitability based on:

- vessel berthage capacity
- distance from site store to vessel
- double or single turntable optionality
- site hazards including natural hazards
- other factors such as nearest service provider, site ground type and heavy vehicle access.

The report concludes that Auckland or Timaru would be the best sites.

[37] See Transpower. (2025). HVDC Kick-off Meeting Presentation, Slide 27.
[38] See Transpower. (May 2025). Benmore filter bank F8 – Rationale for inclusion in the HVDC Cable MCP, p.2 (CABF001).
[39] See Transpower. (Aug 2025). Economic benefit of pole 2 overload – summary.
[40] See Amplitude Consultants. (20 May 2025). HVDC Spare Cable Store Investigation: Evaluation of Cable Store Location Options (CABS002).

Opinion

The consultant report appears credible and thorough in considering the range of possible sites and narrowing the list to two sites.

Recovery of decommissioned cables

An assumption has been made that the cables will need to be removed to receive consent for the new cables, and to keep Transpower's social license to operate.[41]

Opinion

The case needs to be made for the significance of environmental adverse effects of leaving the cables in place. There are previously laid cables, no longer used, that may help in demonstrating whether the adverse effects of leaving cables in place is significant. Alternatively, what evidence is there internationally to demonstrate the scale of the negative or positive impacts of leaving cables in place.

Perhaps most notably, under the fast-track legislation, an explicit hierarchical weighting is introduced for evaluating the proportionality of adverse effects to the national benefits of an infrastructure project.

We recommend that the removal of the cables be dealt with under a separate application, allowing Transpower to proceed with the current process, and allowing more time to investigate the case and evidence for removing the cables under a separate application.

4.7 Do capital cost estimates appear credible?[42]

We consider the capital costs under several sub-headings:

– Headline estimates of costs for the preferred 1400MW option by component
– Allowances for escalation and interest
– Buyer and supplier cost risk sharing
– Overall cost risk

4.7.1 Headline estimates of costs

We have considered the cost estimates provided for each of the seven elements:

– **Replacement cables:** It is our understanding that proposals were received from two providers out of three approached, and that the Prysmian offer was preferred. As this estimate is based on a market response, it has been market tested.
– **Replacement cable termination stations**: We believe that the basis of the costs outlined was reasonable and that the costing was carried out by suitably qualified specialists.
– **Replacement control system**: we suggest the cost of replacing the control system may be more in the $250-300 million range. We note this is within the -35% to +65% cost range currently assumed for this component but is toward the upper end.[43]
– **Benmore filter bank upgrade**: Costs appear to be in the right order of magnitude for the current climate but do not have any supporting evidence.
– **Increased Pole 2 overload capacity**: Costs appear to be in the right order of magnitude for the current climate but do not have any supporting evidence.
– **New cable storage facility**: We note that pricing has been carried out by cost estimation engineer, but that the level of detail does not match that provided **for cable termination stations**, and there is consequently a higher risk of exceeding cost estimates.

[41] See Transpower. (Date unknown). HVDC Upgrade Programme High-level Context, p.4 (CON004).
[42] We note that cost estimates presented in this document are consistent with those present in the Short List or provided to us in June 2025. We understand that Transpower's MCP application will refine cost estimates.
[43] See Transpower. (2025). Cost estimation approach – HVDC IR Presentation, Slide 3.

– **Recovery of decommissioned cables**: As a marine salvage job, this work is harder to lock down years in advance than cable supply and install. It is unlikely Transpower will have a better idea of the cost until it is closer to project delivery.

4.7.1.1 Allowances for escalation and interest

The cost estimate of $1.38 billion provided includes $209.2 million for inflation and interest costs, or a 17.9% mark-up on current day P50 estimated costs.[44] A subsequent Request for Information revealed that this figure includes $153 million for inflation (13% escalation over today's estimate) and $56 million for interest costs.[45]

We note that it is six years until the cable laying process would begin, with some elements of the wider project to begin only in 2033. With high demand for cable laying services, costs may well rise by more than 13%, with costs of in-demand electricity network infrastructure likely to rise faster. As RFI028 acknowledges, "recent market pressures have led to prices of some equipment and materials increasing at a faster rate than CPI". We consider that there is a material risk that the costs will rise faster than this allowance.

4.7.2 Buyer and supplier cost risk sharing

According to Transpower, the terms of the agreement with Prysmian place significant cost risks on Transpower, notably:[46]

– Fuel cost risk
– Weather risk
– Metal cost risk.

Further, civil and subcontracted works in New Zealand (30% of contract value) are provisional sums at this point.

Transpower shouldering a large share of the project risk means there is significant upside risk to pricing on the largest element of the project.

4.7.3 Overall cost risk

There is considerable price uncertainty at this short-list stage of the project, even with the costs that have been priced and putting aside risks that contracting will require Transpower to take on. Transpower is currently working to narrow the price range on each component to support the cost estimates to inform the proposal.

Transpower provided estimated cost ranges for each item except Inflation and Interest. Inflation and interest ranges were calculated by using a 30% reduction in both inflation and interest costs for "Low" and 4% inflation with a 30% increase in interest costs for "High". Using the current estimated range of potential pricing, and the stated assumptions for inflation and interest costs leads to a wide cost range. Costs for the project could range between $1 billion and more than $2 billion using these assumptions, with significant risk skewing toward the upper end of the range.

4.7.4 Have delivery risks been documented with plans to mitigate?

Transpower initially provided a Risk Register with a targeted subset of 20 key risks, providing visibility into their approach to risk management.[45] This was later augmented by a more comprehensive risk register.[46] For each risk, their likelihood, consequence and unmitigated risk rating was provided. This was followed by preventative and mitigative controls and a consequent mitigated risk rating. Risks

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[44] See Transpower. (2025). HVDC Kick-off Meeting Presentation, Slide 11.
[45] See Transpower RFI029.
[46] Ibid, p.16.

were categorised into four groups – commencement, measurement, construction and "other" risk, with most of the risks being in the construction category. However, as is appropriate, the register does point to several commencement risks related to consenting or in many cases, delays due to additional costs of the project being identified.

Opinion

The approach taken is typical of risk registers and the proposed actions to prevent and mitigate risks seem reasonable.

However, it is important to note that there is a difference between a risk register seen from the perspective of Transpower and a risk register seen from the perspective of the New Zealand electricity consumer. The risk register takes the former approach. For example, instance Risk CR009, which deals with the risk of materials costs for the manufacture of the cables increasing in excess of the highest bound contained in the submission, is focused on whether Transpower will be penalised by the Commission for going over budget. The proposed mitigation is to have uncontrollable lift in metals prices sit outside the penalizable price envelope. This would reduce risk for Transpower but would not reduce risk for the consumer in the way that direct purchase of materials or other practical mitigations may.

4.8 Has a credible delivery governance structure been proposed?

Transpower has provided an initial proposed governance structure.[47] Naturally, this early in the process a lot more work will be done in refining the proposed governance structure. However, the current proposal allows for:

– A direct link between the Board via CEO to the HVDC Link Upgrade Programme Governance Group, implying a senior reporting role direct to the CEO for management of risks, commercials and oversight

– A Steering Committee that reports to the Governance Group, with a focus on operational issues and coordinating internal resources

– A Project Team that draws on Business SMEs and works with stakeholders including iwi on a Working Group.

Opinion

With direct line of sight from the CEO to the project Governance Group, and from the Board to the Governance Group via the CEO, there is likely to be sufficient senior oversight over a project this scale. Details on who makes up the Governance Group, Steering Committee and Project Team will be key to ensure that the right mix of technical, financial, project management and risk management skills are included.

4.9 Conclusion

Is there an investment need for cable replacement? If so, by when? Transpower stated that by 2031 the existing cables will have been in use for 40 years. Additionally, repair of the cables is considered infeasible. If repair proved possible, a six-to-18-month repair period is estimated should failure occur after 2031. Such an extended period with at least one cable offline is considered untenable given expected growth in demand.

Transpower's additional modelling suggests that in cumulative terms, there is a 37-50% chance that an individual cable will fail by 2035, and there is risk that more than one cable will fail by that time. Transpower has provided a credible explanation of the economic rationale for replacing the existing

[47] See RFI034 and attached Supporting Document

cables as well as an explanation for why the timeframe of the early 2030s is reasonable for risk avoidance and limiting economic costs.

Were options other than cable replacement considered? Transpower examined a long list of options that included non-transmission solutions, a do-nothing option where cables remain in use until failure, and multiple options for replacing the cables. Transpower dismissed non-transmission options in the early stages as the options were functionally equivalent to the do-nothing in terms of market response. The benefit estimation phase tested this assumption.

Has demand been modelled to identify appropriate capacity? Transpower presented five demand and generation scenarios incorporating different patterns of growth and supply. Scenarios were based on Electricity Demand and Generation Scenarios produced by MBIE. Modelling appears to have adequately considered large-scale existing generation, committed new generation and planned retirements. Analysis concluded the 1400MW option best met demand requirements (see cost-benefit analysis below).

Was cost-benefit analysis completed on the short list? Transpower's approach to estimating present value of benefits for each scenario option appears reasonable. Estimates included various costs required to complete each option within the wider programme i.e. cable removal and upgraded cable termination stations. Therefore, the analysis assumes the case for these components is valid. Analysis identified the 1400MW Option as providing the greatest net economic benefit to the electricity market in accordance with The Commission requirements. Several sensitivity tests accompanied the analysis. The review recommends the Commission review the assumptions and model results.

Has the case been made for supporting works and timeframe? Costing of the preferred option (Option 3) includes additional works that assume the replacement of current cables with four cables providing 1400MW capacity. The review found a defensible case is mounted for additional works including replacement cable termination stations; a replacement control system; the filter bank upgrade; increased Pole 2 overload capacity; and a new cable storage facility.

This review recommends a separate application is made for the removal of existing cables. This would allow Transpower to proceed with the current process and provide additional time for a separate application investigating the case and evidence for the removal of cables. The Fast-track Approvals Act 2024 permits Transpower to consider the proportionality of benefits at a regional or national level in comparison to adverse effects. The legislation therefore allows Transpower to make a case for leaving existing cables in place by arguing that as the $122 million dollar cost of removal is to be directly borne by electricity consumers, the economic benefit of keeping the cables in place is of national significance.[48] We note that Transpower has had a legal opinion that raises the risk of the programme being denied fast track approval if the application is modified to exclude cable removal. Transpower is of the view that this could place the entire programme timeline in jeopardy.

Have long-list options for supporting works been appropriately narrowed down? The review finds Transpower appears to have reasonably considered the range of options for each component while noting the case for removal requires further investigation.

Do capital cost estimates appear credible? The review identified several elements of the cost-build up that pose potential risk. Overall, it found that headline cost estimates for each component appear reasonable noting that only the cable replacement is supported by a detailed proposal from a supplier. Additionally, the review found that pricing years in advance for a marine salvage job such as the recovery of decommissioned cables is challenging. The review notes that the modest allowance of approximately 13% inflation by 2031 may expose the project to upside risk given market-wide supply constraints for work of this type.

Transpower shoulders fuel cost, weather and metal cost risk, while civil and subcontracted works in New Zealand (30% of contract value) are provisional sums at this point. The review recommends

[48] Note, Transpower identified significant cost uncertainty of this component.

Transpower undertakes further sensitivity testing during the Monte Carlo analysis to develop an application that reasonably accounts for these potential risks.

Disregarding these cost risks there is considerable price uncertainty at this early stage. Transpower has attempted to narrow the price range on each component. Using the current estimated range of potential pricing, costs for the project could range between $1 billion and more than $2 billion.

Do capital cost estimates appear credible? The review identified several elements of the cost-build up that pose potential risk. Overall, it found that headline cost estimates for each component appear reasonable noting that only the cable replacement is supported by a detailed proposal from a supplier. Additionally, the review found that pricing years in advance for a marine salvage job such as the recovery of decommissioned cables is challenging. The review notes that the modest allowance of approximately 13% inflation by 2031 may expose the project to upside risk given market-wide supply constraints for work of this type.

Transpower also shoulders fuel cost, weather and metal cost risk, while civil and subcontracted works in New Zealand (30% of contract value) are provisional sums at this point.

Using the current estimated range of potential pricing, costs for the project could range between $1 billion and more than $2 billion.

Have delivery risks been documented with plans to mitigate? Transpower provided a Risk Register outlining their approach to risk management. Outlined risk mitigations focus on the reduction of risk to Transpower (e.g. of being penalised for going over-budget) as opposed to managing risks to the electricity consumer, such as through hedging materials or exchange rate risks to minimise costs passed on to consumers.

Has a credible delivery governance structure been proposed? Transpower has provided an initial proposed governance structure, allowing for a direct link between the Board via CEO to the HVDC Link Upgrade Programme Governance Group; a Steering Committee that reports to the Governance Group; and a Project Team that draws on Business SMEs and works with stakeholders including iwi on a Working Group.

5. Technical Workstream Evaluation

We evaluated each of the seven workstreams in accordance with the approach laid out in **Section 3**. It then aggregated the results of the analysis to seven categories for Transpower and the Commission's review. The economic analysis of each workstream was done separately and is contained in Section 4 above. These technical evaluations should be read in conjunction with the economic analysis for a complete picture of our recommendations.

5.1 Undersea Cable Supply and Installation (1400MW)

5.1.1 Strategy Development and Implementation

Transpower's Cable Supply and Installation solution involves an upgrade or replacement of the existing HVDC system already operating in the New Zealand's power system and electricity market. This existing HVDC link comprises of 2 poles, Pole 2 and Pole 3 both operating at 350 KV, consisting of three 500MW, 1,400mm^2 copper HVDC cables cable. The proposed solution is to install four 500MW, 1,400mm^2 copper HVDC cables which will allow the link capacity upgrade from 1200MW to 1400MW.

5.1.2 Asset health and risk modelling

Transpower has developed a cable health model based on an internationally recognised framework Common Network Asset Indices Methodology (CNAIM) that tracks cable condition and ageing indicators across the full length of the New Zealand HVDC cables. Input data is applied to the model by Transpower based on the outcomes of electrical tests and visual ROV and dive survey inspections that are performed annually.

5.1.2.1 Condition Assessment

The condition assessment follows good electricity industry practice to determine the condition of the cables. The section of the report regarding the existing operation of the cables, the cable stations and the submarine cable failure rates is considered to follow prudent asset management practice. International projects such as Konti-Skan 1 and 2 (Sweden to Denmark) [**Konti-Skan Connect | Svenska kraftnät**] are following a similar plan to Transpower to replace their circa 1988 HVDC submarine cables.[49] The manufacturer design and high voltage type testing determines the design life of the cable that is installed, operated and maintained according to the manufacturer's guidelines. The Transpower cables were designed and type tested to demonstrate a 40-year life., Cable Asset Health Index (AHI) modelling indicates a trend towards an earlier predicted year for cable intervention with each update of the model. The trend towards earlier replacement has been primarily influenced by discovery of additional defects and changes to the seabed, combined with increasing cable age. The AHI trends show that even if the poorer sections were replaced first, the next poorest sections would need to be replaced between 2032 and 2037

5.1.2.2 Risk Assessment and Mitigation

There is a high-level risk assessment and mitigation controls expected to support the outage programme.

Transpower did clarify that they plan to perform detailed cable route surveys closer to the installation date. The results of these surveys could cause variations in the data relied upon by Prysmian, which may lead to a price and schedule variation. All projects with high voltage cables will face this same

[49] Konti-Skan Connect | Svenska kraftnät

challenge due to the volume of orders through 2035, and the requirement to reserve capacity nearly 10 years in advance. Transpower has used best efforts to estimate the cable route conditions for initial pricing by Prysmian. Transpower will perform the onshore and offshore cable route surveys to provide data that Prysmian will use to fine tune the design of the cables and installation. This process will minimize the risk that cable route conditions will cause an impact on the cable rating or installation.

Transpower has a plan to reduce the risk of freespans in the submarine cable routes. The plan is to use the information from the cable route survey to design the route to avoid areas that are at risk of freespans and make final adjustments from data gathered during the pre-lay survey that will be conducted approximately three months before the submarine cable installation.

Transpower did not specify DC load current ratings in their Employers Requirements – Technical Specification (SUP-16670). Transpower confirmed that Prysmian will have the responsibility to calculate the DC load current rating based on the cable route survey data and the size of the conductor. Transpower will engage a specialist high voltage cable design consultant to review Prysmian's cable design and rating reports. Part of the Prysmian design review should include coordination of the Prysmian DC load current rating with the converter station OEM to confirm the converter station DC load current will not exceed the Prysmian DC load current rating. The converter station OEMs typically add 3% to account for typical control system errors.

Voltage pole reversals (VPS) can impact cable life and have been specified by Transpower as 3,650 VPRs per year over the 40-year life of the cable, while Prysmian has offered a 2,000 VPRs per year over the 40-year life of the cable. There are no long-term historic trends in the data showing increasing or decreasing polarity reversals, rather there is some volatility over the years. It appears that the volatility in the number of polarity reversals align with hydrological inflows, with fewer polarity reversals experienced when there are low hydro inflows in the North Island.

The addition of significant intermittent wind and solar generation will require the South Island hydro generators to become a more responsive cover. This will in turn lead to an increase in the number of daily polarity reversals over the 40-year design life of the new cables.

Transpower and Prysmian will need to coordinate on the number of VPRs that will be in the design basis. Prysmian has clarified their 2,000 VPR requirement is associated with fast VPR events associated with transient events, and that slow VPR events associated with power reversals will need to be considered in the design basis. Transpower plans to work with their high voltage cable consultant and Prysmian to specify the amount of fast and slow VPRs. Transpower will also work with both parties to determine any type tests that should be required due to the fast and slow VPR specifications.

5.1.3 Service levels

The documentation addresses the need to ensure a resilient HVDC link of 1400MW capacity is available to enable the economy transition to renewable energy.[50] The Asset Class Strategy sets out the challenges, objectives and strategic approaches specific to the management of the HVDC assets throughout their lifecycle.

5.1.4 Interdependencies

The planning and approval requirements have been somewhat presented; however, more detailed information is required. It is understood that the risk assessment and mitigation controls are:

- A Capacity and Reservation agreement has been entered into with Prysmian for installation in 2031 (the next window they had available).
- The mechanism for not penalising the deposit payable as part of the CRA was supported by the Commission in the RCP4 determination.

[50] CAB002_HVDC Cable Options

– Transpower is negotiating the EPC contract in parallel to the Major Capex Proposal (MCP) The Commission approval process.

5.1.5 Cost Estimation

The costing has been carried out and reviewed by costing specialists.[51]

5.1.6 Deliverability

The EPC contract delivery is based on contractors' international experience and views, and the procurement plan for the HVDC Cable Project has been prepared according to good utility practice.[52]

A Cable procurement plan that includes a Capacity Reserve Agreement has been implemented to ensure cable design, supply and installation to meet key milestones. The preferred cable cross-sectional area (CSA) for both cables has been determined by Prysmian (PPL) and is based upon continuous and overload rating information provided by Transpower (TPNZ). Following the award of the EPC contract Prysmian will complete a full cable design and ampacity study to confirm the proposed cable ratings and CSA. For completeness, Transpower proposes to engage an independent peer review of the PPL cable design and ampacity study.[53]

Evidence provides details that prudent AM policy and procedures have been implemented to determine, monitor and predict cable asset health index (AHI).[54]

We believe that Transpower made the correct decision to replace cables 4, 5 and 6 with four (4) new cables. This decision avoids multiple mobilisations of European based, HVDC submarine cable vendors and installers. The HVDC submarine cable market appears to be very strong through 2035 and there is limited availability of manufacturing and installation periods.[55]

5.1.7 Technical Opinion

As per an independent report by Amplitude Consultants. Our independent review agrees Transpower is using the best-available information sourced from annual tests and inspections completed over the lifetime of the cables to determine a date for their planned replacement. The tests and inspections performed by Transpower are in line with good electricity industry practice and appropriate for the installation and environmental conditions of the cables. Not replacing the submarine cables as per the proposed timeline is considered placing a high risk on the performance of the New Zealand electricity system.

5.2 Cable Termination Station Upgrades

5.2.1 Strategy development and implementation

The options outlined reflect good industry practice. The options and concept designs have been developed in reference to the Transpower requirements for seismic design as detailed in TP.GG.61.02 Seismic Policy and the accompanying TP.DS.61.03 Seismic Design Code. The design demonstrates the early consideration emerging information on seismicity in the use of SSSHA (site specific seismic hazard assessment) to determine seismic design criteria and the presence of the Geotechnical Investigation & interpretive report. Both have been incorporated into in the presented concept designs.[56] The documentation demonstrates that the steps taken in concept design to test technical feasibility are satisfactory.[57]

[51] CAB003_HVDC Cable replacement - Procurement Plan
[52] CAB002_HVDC Cable Options
[53] RFI026
[54] CAB001_Attachment 2-Cable Condition Assessment Report and RFI No. 001 Cables AHI
[55] CAB001_Attachment 2-Cable Condition Assessment Report and RFI No. 001 Cables AHI
[56] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report
[57] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report

Planning and required resource consents are allowed for in programme. A strategy for HVDC planning inputs has been developed as well as a communications and engagement plan.[58]

Strategy for building consent application or exemptions is missing from the documentation; however, building consent applications are mentioned in the report and indicative timeframes have been given.[59] Information provided in workshops indicates that consenting planning supports the works being exempt from a building consent.

Independent concept options provided by BECA show that new CTSs at both OTB and FTB are considered prudent and efficient based on a 4-cable solution.[60]

5.2.2 Asset health and risk modelling

There is a standard design and delivery risk on this project as design is currently at concept stage and further information, and detail is to be included in later delivery stages.[61]

Outages are identified for each option, and several options were discarded due to the high number of required outages.[62]

5.2.3 Interdependencies

Programme planning information[63] shows a credible design and construction time frames. The programme indicates the completion of cable termination station ahead of the cable installation. Cable replacement documentation includes and onshore connection point to reduce risks associated with cable termination stations completing after the commencement of cable placement.

Connections, construction sequence and outages for each option have been identified with a view to integration into the system and market operations.[64] This information is used to inform reduce the long list of recommendations.

5.2.4 Service Levels

5.2.4.1 Existing Cable Termination Stations

The existing cable termination stations (CTS) do not meet required policy and standards for resilience, as set out in TP.GG.61.02 and the accompanying design standard TP.DS.61.03. These documents include the requirements for resilience for seismic design of new Transpower infrastructure and upgrading of existing infrastructure. The existing sites have been assessed as difficult to upgrade to meet policy and design code requirements or to accommodate a 4-cable termination arrangement.

Seismic improvement is required at the existing cable termination sites. Significant adjustments to existing infrastructure at a site, as initiated by new cables, additional cable, new bushings and support elements proposed at each termination station, initiate the requirement to upgrade the existing structures to meet the current Transpower design standards.

In the event of no upgrade works being carried out at the termination stations, the stations are required to be upgraded to 75% of the IL4 SSHA and 100% where practicable.

A concept design has been carried out for the strengthening of each cable termination station to achieve the 75% requirement. These options (one at each site) have been identified as unfeasible due to the extended periods of network shutdown required as part of the works.

[58] RFI009
[59] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report
[60] TER002 HVDC CTS report
[61] Ibid.
[62] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report
[63] RFI028
[64] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report

5.2.4.2 New Cable Termination Stations

The concept design of options for new cable termination stations have been created with reference to the required Transpower policy and design code (TP.GG.61.02 & TP.DS.61.03). The cable termination station options demonstrate compliance with TP.DS.61.30 in the use of site-specific seismic hazard assessment and implementation of relevant return periods. This rigour at early stages of the design process supports the design's technical feasibility.

5.2.4.3 Tsunami Resilience of Cable Termination Stations

Transpower policies and design standards do not specifically mention design for resilience when considering tsunami inundation.

Independent studies have been conducted to determine Tsunami risk to the two cable termination sites. These have been conducted by suitably qualified professionals and utilise return period and risk levels aligned with the Transpower Seismic resilience and design criteria.

Tsunami events have been considered in the evaluation of options. Where feasible, options have incorporated design to minimise tsunami inundation.

5.2.5 Cost Estimation

Costing information has been provided for a single option, replacement of cable termination stations with incorporated design for tsunami resilience. The basis of the costs for the recommended option are clearly outlined, and the costing was carried out by a suitably qualified specialist. Procurement strategy and timeframes outlined in report to our satisfaction.[65]

Costing information has not been provided for the balance of the options in the long list of works to the cable termination stations.

5.2.6 Deliverability

Planning and associated consents are outlined as a one-year process. The basis of this time frame is not given and no preliminary assessment of resource of building consents strategies is given.[66]

We agree with Transpower’s plans to site the transition joint bays (TJB) to allow the submarine cable to be pulled onto the land, so the installation vessel is free to move on. The short distance between the cable termination station (CTS) and the TJB should not be a problem for installation of the HVDC underground or land cables.[67]

At the time of writing, Transpower reported it has held meetings with Prysmian to review the dimensions of the CTS building, and Prysmian has provided diagrams to document the required dimensions. This coordination with Prysmian will confirm the weight and dimensions of the cable terminations will be considered in Transpower’s CTS design, including the electrical clearances in the vicinity of the cable termination for steady state, transient and test set voltages. The CTS procurement process includes engagement of BECA as independent engineering services consultant to produce Solution Study Reports. We observe this as a prudent staged concept design approach.[68]

5.2.7 Technical Opinion

Independent evaluation of options from BECA support the prudence of new CTSs.

[65] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report
[66] TER002 HVDC CTS report and TER003 - Geotechnical Interpretive Report
[67] TER002 HVDC CTS report and RFI No. 007 Termination Station On-Shore Connection Point
[68] TER002 HVDC CTS report

5.3 HVDC Control System Replacement

5.3.1 Strategy development and implementation

HVDC control and protection systems are typically upgraded after 8 years of service for the typical HMI or IT components (servers, LAN switches, routers, firewalls, PCs, monitors, keyboards, etc.) and after 15-20 years for the remaining control system components. International standards such as CIGRE Technical Brochure 649 and IEC TR 62978-2017 reference a life of 7 years for the HMI and 12-15 years for the digital control system. These upgrades are required due to the obsolescence of hardware components where spare parts are no longer available and repairs at the component level are not possible. This upgrade cycle is typical for the major HVDC manufacturers as they all will use similar hardware components that will become obsolete.

Examples of International projects that have completed control and protection system upgrades are provided in **Table 2** below.

Table 2 International Control Systems Project Examples

Project	Size	Location	COD	Upgraded
Basslink	500 MW	Australia	2006 COD	planned 2030 upgrade
Directlink	3 x 60 MW	Australia	2000 COD	Upgraded 2019
Murraylink	220 MW	Australia	2002 COD	Upgraded 2020
Skagerrak 3	440 MW	Norway-Denmark	1993 COD	Upgraded 2014
Baltic Cable	600 MW	Sweden	1994 COD	Upgraded 2019
Kontek	600 MW	Denmark-Germany	1995 COD	Upgraded 2016
Swepol Link	600 MW	Sweden-Poland	2000 COD	Upgraded 2024
Moyle Interconnector	2 x 250 MW	UK	2001 COD	Upgraded 2022
Quebec – New England	2,000 MW multi-terminal	Canada - USA	1992 COD	Upgraded 2016

The hardware items such as computer processor chips are typically the first items to be obsolete as technology advances and requires new devices. The HVDC manufacturers will not be able to use the new computer processor chips in an HVDC control and protection circuit board that has a 20-year-old design. As the HVDC control and protection system ages, there will be a greater number of hardware devices that are obsolete. Good electric industry practice for HVDC control systems is to maintain sufficient spare parts to maintain the system until the next upgrade at 15-20 years.

Software from various vendors is used in the HVDC control and protection system, and this software is also exposed to obsolescence when the vendors no longer have a market for a 15–20-year-old product that is not compatible with new hardware or cyber security requirements. Patch management of software to maintain performance and security from cyber threats is not possible with obsolete software. Good electric industry practice for HVDC control systems is to coordinate with the HVDC manufacturer to receive regular software patches to maintain performance and cyber security.

The plans proposed to replace the control and protection system in alignment with the cable system replacement outage are technically feasible with Siemens or Hitachi Energy as the vendors. Both these HVDC vendors have experience installing control systems in HVDC converters supplied by other vendors.

5.3.2 Asset health and risk modelling

Transpower confirmed they will replace the RTDS simulator and the replica control system with the 2032 Pole 2 and Pole 3 control system upgrade.

The specification of the control and protection system replacement in 2031 will need to be done looking forward to replacing the Pole 2 converters in 2042. The main issue in 2042 will be the VBE (valve-based electronics) which interface between the HVDC controls and each thyristor position.

5.3.3 Interdependencies

The plan to align the outage work for both the cable replacement and the control system replacement is considered good electricity industry practice.

5.3.4 Service Levels

The existing Pole 2 and Pole 3, HVDC control and protection systems were installed in 2013 and would be due for replacement in 2028 to 2033. The HVDC manufacturer, Siemens Energy, has notified Transpower in Oct 2023 that the HVDC control platform will be phased out starting in Oct 2025. Transpower noted that it has sufficient spare parts to maintain the control and protection system until it is replaced in 2031.

5.3.5 Cost Estimation

It is unclear whether Transpower estimated cost of $202 million (2024) will be sufficient for a turnkey contract to replace the HVDC control and protection system, the RTDS simulator and the replica control system. Based on project team experience from upgrade planning in 2024-2025 on other HVDC projects in North America, we estimate this cost to be in the range of $250-300 million (2025) for a turnkey solution delivered in New Zealand.

5.3.6 Deliverability

Transpower will be meeting with HVDC vendors and conducting an RFP process in 2025 with vendor selection by May 2026. HVDC vendors will be offering control and protection system upgrades according to Transpower’s bespoke technical needs for the HVDC transmission functional and performance requirements. This will confirm that design, manufacturing, delivery, installation and site commissioning will be complete by June 2031. Transpower will need to work with the HVDC vendors to determine the detailed site work plans including the scheduled outages to remove the existing control system and install the new control system.

5.3.7 Technical Opinion

Our independent review agrees Transpower’s plans to replace the Pole 2 and Pole 3 control system to coincide with the replacement of the HVDC submarine cables is technically feasible and allows the four new HVDC cables to be integrated into the new control system, which prevents the risk of revising the existing control system in 2031 and then replacing it in 2033.

5.4 Benmore Filter Bank Upgrade

5.4.1 Strategy development and implementation

Filters are used to reduce or remove unwanted and damaging harmonics produced by the DC to AC converters. Transpower LCC converters are inherently more electrically noisy than modern VSC types. Harmonic limits are a requirement of the power quality provisions in the Electricity Industry Participation Code and as such, Transpower has an obligation to meet these limits. At higher transfer levels all filters are required to be in service. The addition of F8 also provides an increased level of filter redundancy.

The need for the new filter bank (F8) is satisfactorily outlined. Pole 3 was delivered by Siemens as a stage 2 (1200MW) and 3 (1400MW) programme. Stage 3 required a fourth cable, a second STATCOM and additional filter bank at Haywards. Filter bank 8 is considered a prudent augmentation to ensure the 1400MW operation can be achieved and will meet power quality requirements at high link transfer limits.

5.4.2 Asset health and risk modelling

Asset health and network risk are managed as per the Asset Class Strategy. Transpower continues to mature its asset health and network risk (AHNR) modelling and has leveraged its maturing tools, data and AHNR knowledge to identify appropriate levels of expenditure to maintain asset health and avoid any appreciable deterioration of network risk.

Power System Modelling supports the additional F8 filter installation to ensure Transpower can meet power quality obligations.

5.4.3 Interdependencies

The plan to align the outage work for both the cable replacement and the Filter installation is considered good electricity industry practice.

5.4.4 Service Levels

The Filter installation provides operational benefits compared to the counterfactual (do nothing). The additional filter will ensure the HVDC Link can met customer power quality performance metrics during periods of high-power transfer.

5.4.5 Cost Estimation

Cost estimation is to be the vendor’s estimate against comparable installations. Firm pricing will be sourced on completion of detailed design.

5.4.6 Deliverability

The Benmore filter bank upgrade will need to be added to the control and protection system, so adding the Benmore filter at the same time as the control system upgrade will save cost and outage time. Power System studies to verify the harmonic performance will be done in conjunction with the control and protection system replacement project. These studies will be an incremental cost to the HVDC manufacturers scope for the control system upgrade. Performing these studies as a separate project would be more costly.

5.4.7 Technical Opinion

Based on the information provided the filter is considered an essential part of the fourth cable installation to ensure network harmonics limits are met as per the Electricity Industry Participation Code.

Filter installations are considered standard practice to ensure power quality standards are met.

5.5 Pole 2 Overload Scheme

5.5.1 Strategy development and implementation

The core system operation requires sufficient reserve in the grid to cover the risk of a single failure of grid equipment or connected generation.

The HVDC Bipole is operated at N-1 security level meaning network performance standards must be maintained for the loss of one pole. This is achieved by allowing the remaining pole to ramp up automatically to maintain dispatch bipole transfer level if the other pole has tripped. If the pole cannot ramp up high enough to maintain the dispatch bipole level, the deficit MW (shortfall) must be provided by reserve generation or interruptible load in the receiving island**.**

Currently P2 is constrained to 500MW by the single cable. Installation of a 4th cable will shift the constraint to the P2 converter rating. (700MW**).** Implementing P2 840MW overload also helps reduce the need to purchase instantaneous reserve (IR) from the market.

There is a good engineering feasibility study backing the Pole 2 overload project. The Independent ABB report is highly technical and presents the HVDC Pole 2 overload enhancement capability study and details of the asset enhancement required.[69] The report notes that to reduce the spinning reserve need Pole 2 needs to pick up temporary overload for 15mins.[70]

The main circuit equipment of most concern regarding overload is the smoothing reactors, the converter transformers and the valves. Due to large thermal time constants and design margins of the smoothing reactors they have sufficient capability for 15-minute overloads.[71] Due to the short time constants of the thyristors, even 60 seconds is the thyristor limit.[72]

Suitable evidence is provided that the enhancement option is good engineering practice, and the outage provides the opportunity to implement this effectively.[73] However, the OEM raises concerns with overload stress on aged assets. While the concept might be ok there needs to be further engineering done detailed design and risks to provide the certainty to proceed.

This work is technically feasible, but an independent engineering review of the solution and risks is recommended.[74]

5.5.2 Asset health and risk modelling

Asset health and network risk is managed as per the Asset Class Strategy. Transpower continues to mature its asset health and network risk (AHNR) modelling and has leveraged its maturing tools, data and AHNR knowledge to identify appropriate levels of expenditure to maintain asset health and avoid any appreciable deterioration of network risk.

5.5.3 Interdependencies

The plan to align the outage work for both the cable replacement and the Pole 2 upgrade is considered good electricity industry practice.

[69] OVL001 Feasibility study - Overload Study
[70] Ibid.
[71] OVL001 Feasibility study - Overload Study.
[72] Ibid.
[73] Ibid.
[74] Ibid.

5.5.4 Service Levels

Provides operational benefits compared to the counterfactual (do nothing). Ensures availability of instantaneous market reserves and therefore minimises costs to energy consumers.

5.5.5 Cost Estimation

Cost estimations are based on vendor advice and are subject to detailed design. We recommend that these are revisited when more detail is available.

5.5.6 Deliverability

Combining the P2 overload scheme with the control and protection replacement will minimise costs related to control system integration and testing. If the commissioning were undertaken independently, the costs would be significantly higher.

The replacement of the P2 converter is scheduled for 2042 or later (after 50 years of service), which will provide the next opportunity to increase P2 capacity to match P3. By commissioning Pole 2 in conjunction with the controls replacement, economic benefits can be realised earlier. However, this approach is not without risk. Initial technical reports have indicated that achieving this integration should be feasible, but further investigation into the transformer and thermal chain limitations is necessary.

Detailed engineering design is required to confirm that the existing asset performance will not be compromised. Transpower recognises the risk and acknowledges that further work is required to determine overload capability. Demonstrating good engineering practice, Transpower aims to reduce risks by implement the scheme with limits when ambient or transformer steady state temperatures require lower overload capability.

5.5.7 Technical Opinion

Increasing P2 overload to 150% (840MW) is considered the most practical option to minimise market costs until P2 converter equipment is replaced around 2042.

5.6 Cable Storage Facility

5.6.1 Strategy development and implementation

Transpower has followed good practice in the options selection process as evidenced by the evaluation of multiple sites for new cable storage, and the work itself is technically feasible.[75] The planning assessment supplied by Transpower indicates that planning requirements for both shortlisted sites have been determined and recorded. Further, the space cable storage investigation process and report follow good electricity industry practice.[76] We recommend further attention to the timing, regulatory constraints and procurement approach to reduce risk.[77]

5.6.2 Asset health and risk modelling

The existing cable store asset has been assessed as being unable to store the recommended quantities of the repair cable and has severely restricted access and loading capabilities. Consequently, either significant upgrade works, or capacity increase are required.

The risks associated with each of the proposed sites have been subject to a qualitative assessment.

[75] CABS002 HVDC Spare Cable Store Investigation
[76] Ibid.
[77] Ibid.

5.6.3 Interdependencies

Programme planning[78] shows that the interdependence of the commissioning of the cable store facility has been considered. The cable store is scheduled for completion prior to the installation of the HVDC cable.

5.6.4 Service Levels

The current storage facility in Wellington has become unsuitable as the neighbouring wharf where cable would be loaded onto the cable-laying vessel has been condemned and there are increasing restrictions on docking vessels next to Wellington Airport due to the height of the berthing vessel.

5.6.5 Cost Estimation

A cost estimation engineer carried out the pricing of the cable storage facility and RFI006 provided the basis of the concept costing, along with an outline description of the design features.

The originally supplied documents did not contain the procurement strategy for the turntable, foundations and enclosure; however, the supplied RFI006 response includes the basis for this costing along with the outline design features report. The programme provided in RFI 28 response outlines the interdependencies and shows the cable store being delivered prior to the new cable installation. The level of detail does not match that provided for CTS structures and consequently has a higher risk of exceeding cost estimates.[79]

5.6.6 Deliverability

Regulatory constraints have been identified in the planning assessment provide. Further to this the required timing in included in the overarching programme (RFI 006, RFI 026, BECA Planning Assessment).

5.6.7 Technical Opinion

We recommend further attention to the timing, regulatory constraints and procurement approach to reduce risk. Independent evaluation of the presented options supports the development of a new cable storage facility.

5.7 Recovery of Decommissioned Cables

5.7.1 Strategy development and implementation

Transpower's proposed approach to determine the need for cable recovery is considered prudent. The proposal is consistent with the HVDC Asset Class Strategy that sets out the challenges, objectives and strategic approach specific to the current fleet of HVDC assets throughout their lifecycle. Given the technical challenges and costs, we consider Transpower is following good practice by seeking independent advice regarding the approach and pathways to determine the need or not to remove the cables.

5.7.2 Service Levels Cost Estimation

Capital cost must be determined from salvage vendor estimates (expected later in the project) and a detailed risk assessment is required, particularly for cable near the shoreline.

[78] RFI028
[79] CABS003 XXX Cable Store - Concept

5.7.3 Deliverability

Transpower has sourced independent advice that outlines due process and pathways to guide the need or not for cable removal.[49]

5.7.4 Technical Opinion

The decommissioned cables have no further HVDC link operational need. Subject to environmental considerations there is no technical reason associated with the HVDC link to remove the decommissioned cables.

Appendix A

Acronyms

A-1 Abbreviations

Table B.1 Abbreviations used in this report

Abbreviation	Meaning
AC	Alternating Current
AHI	Asset Health Index
AHNR	Asset Health and Network Risk
BBC	Benefit-Based Charges
Capex IM	Capital Expenditure Input Methodology
CBA	Cost-Benefit Analysis
CNAIM	Common Network Asset Indices Methodology
COD	Commercial Operation Date
CRA	Capacity and Reservation Agreement
CTS	Cable Termination Station
DC	Direct Current
EPCI	Engineer, Procure, Construct and Install
FEED	Front-end Engineering and Design
FTAA	Fast-track Approvals Act
GEIP	Good Electricity Industry Practice
GETS	Government Electronic Tender Service
HILP	High Impact Low Probability
HMI	Human Machine Interface
HV	High Voltage
HVDC	High Voltage Direct Current
IER	Independent Expert Review
IM	Input Methodology
IR	Instantaneous Reserve
IT	Information Technology
kV	Kilovolt

LCC	Line Commutated Converter
MBIE	Ministry of Business, Innovation and Employment
MCP	Major Capital Expenditure Proposal
MW	Megawatt
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
P2 / P3	Pole 2 / Pole 3 (HVDC link components)
P30/P50/P70	Probability-based cost bands (30^{th}, 50th and 70th percentile)
PV	Photovoltaic
RCP4	Regulatory Control Period 4
RFI	Request for Information
RoI	Registration of Interest
RTDS	Real Time Digital Simulator
SE&C	Safety, Environment & Compliance
SLC	Short List Consultation
SSSHA	Site Specific Seismic Hazard Assessment
STATCOM	Static Synchronous Compensator
ToR	Terms of Reference
TJB	Transition Joint Bay
VBE	Valve-Based Electronics
VPR	Voltage Pole Reversal
VSC	Voltage Source Converter

Appendix B

Terms of Reference (ToR)

B-1 Terms of reference for review for Independent Expert Review of Transpower's HVDC Link Upgrade Programme

The terms of reference for the Independent Expert Review of Transpower's HVDC Link Upgrade Programme were agreed by Transpower and the Commission. These are shown below.

Terms of reference for Independent Expert Review of Transpower's HVDC Link Upgrade programme

Purpose of this document

1. This document outlines the terms for carrying out an independent review of Transpower's HVDC Link Upgrade Major Capex Proposal (MCP) (**HVDC Proposal**) to the Commerce Commission.

2. These terms of reference have been prepared based on the Transpower Capital Expenditure Input Methodology Determination 2012 (Principal Determination), as consolidated on the 13 December 2023 (**Capex IM**) and the Transpower Input Methodologies Determination 2010, as consolidated on 13 December 2023 (**Transpower IMs**).[1]

The Reviewer's role and obligations

3. At a high level, the Reviewer's role and obligations will be:

   3.1 engaging independently with Transpower in accordance with these terms of reference;

   3.2 evaluating whether Transpower's HVDC MCP's capex, opex (including the methods undertaken to prepare those costs), and key assumptions are consistent, and represent the actions of a prudent electricity transmission services supplier, having regard to Good Electricity Industry Practice (**GEIP**);[2] and

   3.3 producing a report that meets the requirements in these terms of reference.

Scope of the review and content of report

4. Included in the scope of the review will be the following components of the HVDC Link Upgrade programme:

   4.1 HVDC 350kV submarine and land-based cables

   4.2 Civil and building works for new termination stations

   4.3 HVDC control system

   4.4 Removal of existing 350kV cables

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1 The current Transpower IMs and Capex IM are available at Commerce Commission – Transpower input methodologies (comcom.govt.nz).

2 'Good electricity industry practice' is defined in Part 1 of the Electricity Industry Participation Code 2010 as: **good electricity industry practice** in relation to transmission, means the exercise of that degree of skill, diligence, prudence, foresight and economic management, as determined by reference to good international practice, which would reasonably be expected from a skilled and experienced **asset** owner engaged in the management of a transmission network under conditions comparable to those applicable to the **grid** consistent with applicable law, safety and environmental protection.

4.5 Construction of a new cable storage facility

5. In the report, the Reviewer will:

5.1 provide an opinion on whether Transpower's decision to invest in replacement and/or enhancement of assets associated with the HVDC Link is reasonable and whether the decisions made in developing the scope of the work are consistent with Transpower's asset management policies;[3, 4]

5.2 provide an opinion on the extent to which Transpower's proposed scope of work (i.e., bundling and timing of different elements) is consistent with good asset management practice, and is technically feasible;

5.3 provide an opinion on whether Transpower has appropriately considered options in its delivery of the various components of the HVDC Link Upgrade programme of work. This includes how it has considered staging its work to minimise the impact of outages on the market and its service quality measures;

5.4 provide an opinion on the extent to which Transpower's approach to costing the proposed work is reasonable in the current (and forecast) supply chain environment, and both aligns with Transpower's asset management frameworks and provides an appropriate level of cost accuracy for the timelines required;

5.5 assess whether the proposed costs have been created through appropriate procurement and cost estimation methods], at an acceptable level of accuracy.

5.6 provide an opinion on whether Transpower has adequately considered the environmental impacts of the projects insofar as they impact the costings and timing of the delivery programme.

5.7 provide an opinion on whether Transpower has chosen to use appropriate mechanisms (e.g. P30/P70 deadband, exempt capex, and/ or grid output amendments) available in the Capex IM to allocate risks arising from our approach to costing;

5.8 provide a list of the key issues and areas that it considers the Commission should focus on when the Commission evaluates Transpower's HVDC MCP;

5.9 provide an opinion on whether Transpower provided the Reviewer with the type and depth of information it needed to provide its review report; and

5.10 identify any other information not included in the HVDC MCP that the Reviewer reasonably believes would:

[3] This includes considering the appropriateness of the inputs that Transpower has used in its net electricity market benefit modelling and the use of the outputs of that model to inform Transpower's preferred investment option. However, the Reviewer does not need to assess Transpower application of the Investment Test nor its market modelling.

[4] This include considering any relevant feedback from stakeholders.

5.10.1 be available to Transpower; and

5.10.2 assist the Commission's evaluation of Transpower's HVDC MCP.

5.11 The Reviewer is not expected to undertake a review of Transpower's application of the Capex IM Investment Test nor its market modelling.

Key process matters

6. Transpower will provide the Reviewer with available information on its HVDC Link Upgrade proposal at the start of the review. As soon as reasonably practicable after the engagement of the Reviewer, Transpower and the Reviewer will agree a timeline for the review process. This will set out what information Transpower will provide to the Reviewer and when.

7. The review process will run parallel to the finalisation of the application, starting after the shortlist consultation, with information provided on an agreed timeline.

8. The Reviewer will also meet with the Commerce Commission (with Transpower present) to understand the questions that the Commission would like the Reviewer to directly address.

9. The Reviewer will engage with Transpower on an ongoing basis.

10. The Reviewer will nominate a primary point of contact, who will be ideally based in Wellington.

11. The Reviewer will prepare a draft report for Transpower to review and comment on, with Transpower incorporating feedback into the HVDC MCP proposal.

12. The Reviewer may update its draft report to take account of any responses or further information provided by Transpower or any changes Transpower may make to its HVDC proposal.

13. The Reviewer will provide Transpower with its final review report so that Transpower can submit it to the Commission concurrently with Transpower's HVDC proposal and make it publicly available.

14. Transpower will highlight any matters in its HVDC proposal where it maintains a different view from that of the Reviewer.

15. It is anticipated that the Commission will meet with and/or ask questions of the Reviewer after Transpower submits its HVDC proposal to confirm the Commission's understanding of the review report and to inform the Commission's plan for its evaluation of Transpower's HVDC proposal.

16. The Reviewer's report will also be used to help inform Transpower Management and Board on its approval decision for submission of the MCP to the Commerce Commission.

17. It is anticipated that the Reviewer’s findings will help inform a draft decision paper that the Commission will publish to invite stakeholder comment on Transpower’s HVDC proposal. As part of this paper the Commission anticipates consulting on the extent to which it should rely on the Reviewer’s findings in its evaluation of the HVDC proposal.

18. For the avoidance of doubt, the Reviewer is not required to audit or assure the quantitative information in Transpower’s HVDC proposal. The Reviewer is expected to ascertain and conclude on the effectiveness of the process used to assemble the quantitative information that informs the HVDC proposal.

19. The Reviewer and Transpower will directly agree on the communication protocols regarding the sourcing and use of information from Transpower by the Reviewer.

Attachment A: Evaluation criteria to be applied in the review

Purpose

This attachment provides more detail on the evaluation criteria that the Reviewer is to apply in undertaking the review.

The evaluation criteria for the Major Capex Proposal reflects the evaluation criteria in Schedule C of the Capex IM, which the Commission must apply when assessing Transpower's major capex proposal. We have replicated the key sections the Reviewer should have regard to below.

In applying these evaluation criteria, the Reviewer should exercise its professional judgement about the relative consideration to give to each criterion.

C2 **General evaluation of major capex proposal**

The **Commission** must have regard to at least one of the following factors when evaluating a **major** capex proposal:

(a) whether the **proposed investment** and **investment options**:

(i) reflect **good electricity industry practice**;

(ii) are technically feasible;

(iii) are able to be implemented in terms of the statutory planning process under the Resource Management Act 1991, other regulatory consents, and obtaining property and access rights; and

(iv) can be integrated into system and market operations;

(b) whether the estimated time required for construction, consultation, meeting statutory planning and other regulatory requirements, and obtaining property and access rights prior to a proposed **commissioning date** or **completion date** is reasonable;

(c) whether the key assumptions around outage planning are reasonable;

(d) the extent to which, in complying with clause 3.3.1(9) with respect to the consultation programme or the approach for consideration of **non- transmission solutions**, **Transpower** has had regard to the views of interested persons; and

(e) the impact of the **sensitivity analysis** on **electricity market benefit or cost elements** of the **proposed investment** and **investment options**.

C3 **Evaluation of major capex allowance and maximum recoverable costs**

The **Commission** must have regard to at least one of the following factors when evaluating the **major capex allowance** and **maximum recoverable costs** for the **major capex project** or **staging project** that **Transpower** submits for approval in its **major capex proposal**:

(a) how **major capex project outputs**, key drivers, key assumptions, and cost modelling were used to determine the **P50** and **major capex allowance** or **maximum recoverable costs**;

(b) the capital costing methodology and formulation, including unit rate sources, the method used to test the efficiency of unit rates and the level of contingencies included;

(c) the impact of forecast costs on other costs of **Transpower**, including the relationship with operating expenditure;

(d) mechanisms for controlling actual capital expenditure with respect to the **major capex allowance** or **maximum recoverable costs**; and

(e) the efficiency of the proposed approach to procurement of goods and services.

C5 **Evaluation of major capex project outputs**

The **Commission** must have regard to at least one of the following factors when evaluating proposed **major capex project outputs**:

(a) the extent to which the **major capex project outputs** reflect the nature, quantum and functional capability of the **transmission investment** assets to be **commissioned**;

(b) the extent to which the **major capex project outputs** reflect the change in the functional capability of the **grid** as a result of undertaking the proposed **major capex project** or **staging project**;

(c) the extent to which the **major capex project outputs** are consistent with key assumptions used in determining the **major capex allowance** or **maximum recoverable costs**;

(d) the nature of the **electricity market benefit or cost elements** directly related to the **supply** of **electricity transmission services** taken into account in applying the **investment test**; and

(e) in the case of a **non-transmission solution**-

(i) the extent to which the **major capex project outputs** reflect the nature and quantum of any product or service provided to **Transpower**; and

(ii) the extent to which the **major capex project outputs** reflect the change in the functional capability of the **grid** resulting from the product or service provided to **Transpower**.

Appendix C

Mapping of report content to ToR requirements

C-1 Mapping of report content to the ToR

Terms of Reference	Section in this Report
The Commission must have regard to at least one of the following factors when evaluating a major capex proposal: **(a) whether the proposed investment and investment options:** **(i) reflect good electricity industry practice;** **(ii) are technically feasible;** **(iii) are able to be implemented in terms of the statutory planning process under the Resource Management Act 1991, other regulatory consents, and obtaining property and access rights; and** **(iv) can be integrated into system and market operations;** **(b) whether the estimated time required for construction, consultation, meeting statutory planning and other regulatory requirements, and obtaining property and access rights prior to a proposed commissioning date or completion date is reasonable;** **(c) whether the key assumptions around outage planning are reasonable;** **(d) the extent to which, in complying with clause 3.3.1(9) with respect to the consultation programme or the approach for consideration of non- transmission solutions, Transpower has had regard to the views of interested persons; and** **(e) the impact of the sensitivity analysis on electricity market benefit or cost elements of the proposed investment and investment options.**	Section 5

The Commission must have regard to at least one of the following factors when evaluating the major capex allowance and maximum recoverable costs for the major capex project or staging project that Transpower submits for approval in its major capex proposal: **(a) how major capex project outputs, key drivers, key assumptions, and cost modelling were used to determine the P50 and major capex allowance or maximum recoverable costs;** **(b) the capital costing methodology and formulation, including unit rate sources, the method used to test the efficiency of unit rates and the level of contingencies included;** **(c) the impact of forecast costs on other costs of Transpower, including the relationship with operating expenditure;** **(d) mechanisms for controlling actual capital expenditure with respect to the major capex allowance or maximum recoverable costs; and** **(e) the efficiency of the proposed approach to procurement of goods and services.**	Sections 4 and 5
The Commission must have regard to at least one of the following factors when evaluating proposed major capex project outputs: **(a) the extent to which the major capex project outputs reflect the nature, quantum and functional capability of the transmission investment assets to be commissioned;** **(b) the extent to which the major capex project outputs reflect the change in the functional capability of the grid as a result of undertaking the proposed major capex project or staging project;** **(c) the extent to which the major capex project outputs are consistent with key assumptions used in determining the major capex allowance or maximum recoverable costs;** **(d) the nature of the electricity market benefit or cost elements directly related to the supply of electricity transmission services taken into account in applying the investment test; and** **(e) in the case of a non-transmission solution-** **(i) the extent to which the major capex project outputs reflect the nature and quantum of any product or service provided to Transpower; and** **(ii) the extent to which the major capex project outputs reflect the change in the functional capability of the grid resulting from the product or service provided to Transpower.**	Sections 4 and 5

5.1 provide an opinion on whether Transpower's decision to invest in replacement and/or enhancement of assets associated with the HVDC Link is reasonable and whether the decisions made in developing the scope of the work are consistent with Transpower's asset management policies; **This includes considering the appropriateness of the inputs that Transpower has used in its net electricity market benefit modelling and the use of the outputs of that model to inform Transpower's preferred investment option. However, the Reviewer does not need to assess Transpower application of the Investment Test nor its market modelling.** **This includes considering any relevant feedback from stakeholders.** **5.2 provide an opinion on the extent to which Transpower's proposed scope of work (i.e., bundling and timing of different elements) is consistent with good asset management practice, and is technically feasible;** **5.3 provide an opinion on whether Transpower has appropriately considered options in its delivery of the various components of the HVDC Link Upgrade programme of work. This includes how it has considered staging its work to minimise the impact of outages on the market and its service quality measures;** **5.4 provide an opinion on the extent to which Transpower's approach to costing the proposed work is reasonable in the current (and forecast) supply chain environment, and both aligns with Transpower's asset management frameworks and provides an appropriate level of cost accuracy for the timelines required;** **5.5 assess whether the proposed costs have been created through appropriate procurement and cost estimation methods], at an acceptable level of accuracy.** **5.6 provide an opinion on whether Transpower has adequately considered the environmental impacts of the projects insofar as they impact the costings and timing of the delivery programme.** **5.7 provide an opinion on whether Transpower has chosen to use appropriate mechanisms (e.g. P30/P70 deadband, exempt capex, and/ or grid output amendments) available in the Capex IM to allocate risks arising from our approach to costing;** **5.8 provide a list of the key issues and areas that it considers the Commission should focus on when the Commission evaluates Transpower's HVDC MCP;** **5.9 provide an opinion on whether Transpower provided the Reviewer with the type and depth of information it needed to provide its review report; and** **5.10 identify any other information not included in the HVDC MCP that the Reviewer reasonably believes would:**	Sections 4 and 5

5.10.1 be available to Transpower; and **5.10.2 assist the Commission's evaluation of Transpower's HVDC MCP.**	
5.11 The Reviewer is not expected to undertake a review of Transpower's application of the Capex IM Investment Test nor its market modelling.	N/A

Appendix D

Documents sighted

D-1 Documents sighted in IV review

The following table lists the documents that have been sighted as part of our review of the Transpower HVDC Cable Project proposal.

In total there were 65 documents, plus 35 Requests for Information.

Table 3 List of Required and Optional Reading Specified by Transpower

Document	Required Reading For IER	Optional Reading for IER
CON001_Short List Consultation Main Document	pg. 3-17	
CON002_Attachment 1-Need, Demand and Generation Scenario	pg. 3-17	
CON003_Attachment 3-Short list of investment options	pg. 4-14	pg. 12-36
CON004_ Needs case for each element- Internal	Whole document	
CON005_Attachment 4-Benefits modelling	pg. 9-33	pg. 34-42
CON006 Benefit modelling output	Tab: Benefit modelling output	Tab: Other tabs
CON007_Asset Strategy Document	Refer to section tabs	Refer to section tabs
CON008_Attachment 5-Investment Test		As needed
CON009_Investment Test-HVDC FINAL_SLC		As needed
CON010_HVDC- Attachment 6-Indicative pricing allocations		As needed
CON011_HVDC options costing-shortlist		As needed
CON0012_HVDC MCA_SLC		As needed
CON013_HVDC Submarine Cable Replacement and Enhancement Paper		As needed
CON014_HVDC Cable Replacement and Enhancement Investigation_Summary of submissions		As needed
CON015_HVDC White Paper-Summary of submission		As needed
CON016_Discussion Paper-Examining the purpose and future role of our HVDC link-March2024		As needed
CON017 HVDC Cable Replacement - Shortlist Estimate Summary Sheet .xlsx		As needed
CON018 HVDC Cable Replacement - Basis of Estimate - Shortlist.docx		As needed

Document	Required Reading For IER	Optional Reading for IER
CON019 HVDC Cable Replace - Cost Estimation Plan – Shortlist Stage.docx		As needed
CON020 HVDC Cable Replace - Cost Estimation Plan - Submission Stage.docx.		As needed
CON021 O&M Maintenance Requirements		As needed
GOV001 HVDC Governance arrangements memo		As needed
GOV002 Board paper- HVDC undersea cable- May 25		As needed
GOV003 HVDC Risk register		As needed
GOV004 HVDC board paper Dec 23		As needed
GOV005 CEO Report - HVDC Cable Feb 24		As needed
GOV006 HVDC board paper Mar 24		As needed
GOV007 HVDC Cables Update Post trip briefing Mar 24		As needed
GOV008 CEO Report - Ministerial briefing - Apr 24		As needed
GOV009 Board paper HVDC Cable Replacement Update Aug 24		As needed
GOV010 Board paper- HVDC Undersea Cable Replacement Nov 24		As needed
GOV011 HVDC Committee- HVDC Undersea Cable Replacement - Diligent Book Dec 2024		As needed
GOV012 Governance document - Investment option decision		
CAB001_Attachment 2-Cable Condition Assessment Report	Refer to section tabs	Refer to section tabs
CAB002_HVDC Cable Options	Refer to section tabs	
CAB003_HVDC Cable replacement - Procurement Plan	Whole document	
CAB004_HVDC cables Supply and Install	Refer to section tabs	Refer to section tabs
CAB005_Capacity Reservation Agreement	Refer to section tabs	Refer to section tabs
CAB006_HVDC outage costs	Refer to section tabs	Refer to section tabs
CAB007_ RFP Price stage - Cable Replacement		As needed
CAB008_SSR2		

Document	Required Reading For IER	Optional Reading for IER
CAB009_ Cable review of condition report		
CABS001_ Procurement approval Cable store	Refer to section tabs	
CABS002 HVDC Spare Cable Store Investigation	Refer to section tabs	Refer to section tabs
CABS003 XXX Cable Store - Concept	Refer to section tabs	Refer to section tabs
TER001 Termination stations Transpower design standards		Refer to section tabs
TER002 HVDC CTS report	Refer to section tabs	
TER003 - Geotechnical Interpretive Report	Refer to section tabs	
TER004 Procurement Plan_HVDC CTS	Whole document	
TER005 FTB CTS Buildings - Concept - HVDC Cable Replacement	Estimate summary tab	Other tabs
TER006 OTB CTS Buildings - Concept - HVDC Cable Replacement	Estimate summary tab	Other tabs
TER007 SSR2 is for CTS		
CNSY001 Seimans service	Refer to section tabs	
CNSY002 HVDC Control System Procurement Plan	Whole document	
CNSY003 ROI Request of Interest-Control Systems	Refer to section tabs	
CNSY004 Memo on needs case for control system upgrade acceleration	Whole document	
CABF001 Technical requirements for filterbank memo	Whole document	
CABF002 Filter bank cost estimation	Estimation summary tab	Remaining tabs
OVL001 Feasibility study - Overload Study	Whole document	
OVL002 Feasibility study - Cooler upgrade analysis	Whole document	
OVL003 Implementation and options analysis		
OVL004 Filterbank cost estimate	Estimate summary	Estimate source
CABR001 HVDC Cable Removal advice		
CABR002 Procurement approach cable removal		
CABR003 Cost estimation cable removal		

D-2 Requests for Information

In total, 35 RFIs were submitted to Transpower in support of our Independent Review.

Table 4 List of RFIs submitted to Transpower

RFI	Subject	Document	Reason
1	Cables - Asset Health modelling	CAB001 RFI relates to Cable Condition Report	More clarification around the Asset Health modelling and outcomes
2	Control System Docs	CON007 / Asset Strategy Document	Provide clarification on the support of the control and protection system through 2032, the replacement of the RTDS and the control replacement in 2042.
3	Hydro Inflows	CON005 HVDC - Attachment 4 - Benefits modelling	Understanding water values/simulation of hydro inflows
4	Natural Hazard and Resilience	CON007 Asset Strategy Documents	Understanding natural hazards and resilience for structures
5	Cable Store Soil Classes VI and V11	CABS002 HVDC Spare Cable Store Investigation	Understanding soil classes
6	Cable Storage Component Costs	CABS003 XXX Cable Store – Concept (Excel)	Understanding the basis for component costing.
7	HVDC Connection points	TER002 HVDC CTS report	Understanding connection points for HVDC Cables
8	Cable Termination Station (CTS)s	TER004 CTS Engineering procurement plan	Clarify if this procurement process has been implemented
9	Cable Termination Station (CTS)s	TER002 CTS Stakeholder engagement and planning approvals	Clarify if these activities have been included in the concept stage
10	Cable Termination Station (CTS)s	TER002 CTS Prysmian Involvement	Clarify inputs from Prysmian on the concept designs
11	Cable Termination Stations	CON007 Asset Strategy Document	Understand decisions leading to the location of the termination stations.

12	Cable Docs - determination of 10 km of spare HVDC submarine cable	CON004 / HVDC Programme High-Level Context	Provide clarification on the determination of 10 km of spare HVDC submarine cable.
13	Cable Docs_ clarification on the plan to leave the circa 1964 cables abandoned in place.	CON004 / HVDC Programme High-Level Context	Provide clarification on the plan to leave the circa 1964 cables abandoned in place.
14	Cable Docs_ cable repair timeframe.	CAB001 / Transpower Attachment 2: Cable Condition Assessment Report	Provide clarification on cable repair timeframe.
15	Cable Docs_ plan to reduce the risk of freespans	CAB001 / Transpower Attachment 2: Cable Condition Assessment Report	Provide clarification on plan to reduce the risk of freespans when the (4) new cables are installed.
16	Cable Docs_ clarification on Prysmian prices	CAB004 / Transpower Cable Replacement supply and cost estimate	Provide clarification on Prysmian prices.
17	Cable Docs_DC operating voltage and load current	CAB005 / Prysmian Capacity Reservation Agreement	Provide clarification on DC operating voltage and load current.
18	Cables Condition Analysis Trends	CAB001 / Attachment 2 - Cable Condition Assessment Report	More information on International or Australian MI cable condition analysis trends to support the modelling outcome.
19	Cables Hybrid Replacement Option	CAB001 / Attachment 2 - Cable Condition Assessment Report	More information on hybrid option details.
20	Cables outage planning	CAB002 / HVDC Cable Options	More information about outage planning stages, risk assessments and mitigations.
21	Cables planning approvals	CAB002 / HVDC Cable Options	More information on project planning approval and milestones.
22	Cables VPR Operations	CAB001 / Attachment 2 - Cable Condition Assessment Report	More information on VPR operations.
23	Cable_ annual VPRs	CAB007 / RFP Price Stage – Cable Replacement	Provide clarification on annual VPRs (voltage polarity reversal).
24	Cable_ clarification on onshore and offshore site conditions	CAB007 / RFP Price Stage – Cable Replacement	Provide clarification on onshore and offshore site conditions.

25	Cable_ external protection for the submarine cable	CAB001 / Attachment 2 - Cable Condition Assessment Report	Provide clarification on external protection for the submarine cable from gravel and boulder movement.
26	Cable_ scope of responsibility for cable ampacity and cable design	CAB005 / Capacity Reservation Agreement	Provide clarification on scope of responsibility for cable ampacity and cable design
27	Durability and Maintenance	TER002 / HVDC CTS report	Please include the steps taken or proposed in the new design to improve durability and maintenance requirements at the termination stations.
28	Programme risk	CON007 / Asset Strategy Document CAB002 / HVDC Cable Options TER002 / HVDC CTS report	Please provide a consolidated project risk register and overarching programme.
29	Split of $209.2 million for inflation and interest costs	From various context documents	The preferred option makes an allowance of $209.2 million for interest during construction and inflation. It is unclear what the split is. In a CBA, interest costs should be included, general inflation should not, except if there is expected to be higher cost escalation than simply inflation, a distinct possibility in this project. We would therefore like to understand the role of inflation and interest costs in the $209.2 million allowed.
30	Risk Register	Follow up from Cost Estimation/Risk Workshop	To understand the risks that have been captured and how they have been handled.
31	Transpower Overall Programme Schedule	20250619 Cable Replacement High Level Phasing - Landscape	Provide clarification on the programme schedule.
32	Risk/Cost Tradeoff Per Commerce Commission Comment	NA	To understand the analysis on risk/cost tradeoff of increased cable failures due to asset age and condition and the impact on the market vs capex deferral.
33	HILP resilience analysis per Commerce Commission Comment	NA	To understand the HILP resilience analysis that exists.

34	Governance Structure	NA	To understand the Governance Structure as it stands and as it is proposed for the delivery stage.
35	Procurement Planning	NA	Understand the extent of procurement planning at this early stage.

Appendix E

Review techniques

E-1 Review techniques

The following table provides the summary review that was used for the Project review. This matrix was used against each document and against each entire workstream.

Table 5 Detailed Review by Terms of Reference Section

	Undersea Cable Supply and Installation (1400MW)	Cable Termination Station Upgrades	HVDC Control System Replacement	Benmore Filter Bank Upgrade	Pole 2 Overload Scheme	Cable Storage Facility	Recovery of Decommissioned Cables
5.1 provide an opinion on whether Transpower's decision to invest in replacement and/or enhancement of assets associated with the HVDC Link is reasonable and whether the decisions made in developing the scope of the work are consistent with Transpower's asset management policies;	Transpower's proposed HVDC investments are aligned with GEIP Assets Management policies and practices to ensure a reliable and safe electricity system for New Zealand. In line with GEIP the approach is considered both prudent and efficient. The proposal is consistent with the HVDC Asset Class Strategy that sets out the challenges, objectives and strategic approach specific to the current fleet of HVDC assets throughout their lifecycle. A review of future scenario HVDC capacity requirements has been performed against load growth, generation development and retirement of North Island thermal (fossil fuel) generation. The capacity required is justified	Transpower's decision to invest in replacement of the existing cable termination stations is consistent with their Asset management policies. It demonstrates consideration of the requirements for enhances network resilience and continuity of network delivery during construction works.	Transpower's proposed HVDC investments are aligned with GEIP Assets Management policies and practices to ensure a reliable and safe electricity system for New Zealand. In line with GEIP the approach is considered both prudent and efficient. The proposal is consistent with the HVDC Asset Class Strategy that sets out the challenges, objectives and strategic approach specific to the current fleet of HVDC assets throughout their lifecycle.	Technically feasible and justified to deliver the link capacity upgrade HVDC link 1400MW transfer capacity requires additional filters to be installed to ensure network harmonics limits are met as per the Electricity Industry Participation Code. Filter installations are considered standard practice to ensure power quality standards are met.	Technically feasible and justified to deliver instantaneous market reserve requirements Currently P2 is constrained to 500MW by the single cable. Installation of a 4th cable will shift the constraint to the P2 converter rating. (700MW). Increasing P2 overload to 150% (840MW) is considered the most practical option to minimise market costs until P2 converter equipment is replaced around 2042	Transpower's decision to invest in an upgrade to the cable store facility is reasonable as the existing cable store no longer meets the requirements for the length of repair cable to be stored as well as the ability to deliver the cable to repair vessels. Transpower has demonstrated their asset management policies and requirements for network resilience in the evaluation of proposed cable store locations.	Transpower's proposed HVDC investments are aligned with GEIP Assets Management policies and practices to ensure a reliable and safe electricity system for New Zealand. In line with GEIP the approach is considered both prudent and efficient.
5.1.1 This includes considering the appropriateness of the inputs that Transpower has used in its net electricity market benefit modelling and the use of the outputs of that model to inform Transpower's preferred investment option. However, the Reviewer does not need to assess Transpower application	Modelling by Transpower included: Costs side: Transpower provided cost estimates for each of the major components assumed to be needed in three scenarios. As discussed previously and below, the level of certainty on each component varies, from a contracted estimate in the case of the replacement cable provision with a supplier, to relatively uncertain estimates on elements that will need to be contracted in the future. Benefits side: Transpower provided four scenarios of energy demand growth based on MBIE models. Market benefit estimate: Transpower provided an estimate of the net market benefit for each of the three scenarios, concluding that the net market benefit of the preferred option (a 1400MW capacity set of four cables with supporting infrastructure) provides the best net result. The appropriateness of each component of the proposed programme of works is considered in the relevant sections of the Executive Summary and the remainder of this table.						

	Undersea Cable Supply and Installation (1400MW)	Cable Termination Station Upgrades	HVDC Control System Replacement	Benmore Filter Bank Upgrade	Pole 2 Overload Scheme	Cable Storage Facility	Recovery of Decommissioned Cables
of the Investment Test nor its market modelling.							
5.1.2 This includes considering any relevant feedback from stakeholders.	Documents present evidence for good industry practice with respect to SE&C. MPC consultation has occurred with Stakeholders and Customers in relation to the future of the HVDC link and the proposed upgrade program Further Project Short List consultation with interested parties is currently underway	N/A	Documents present evidence for good industry practice with respect to SE&C. MPC consultation has occurred with Stakeholders and Customers in relation to the future of the HVDC link and the proposed upgrade program Further Project Short List consultation with interested parties is currently underway	Documents present evidence for good industry practice with respect to SE&C. MPC consultation has occurred with Stakeholders and Customers in relation to the future of the HVDC link and the proposed upgrade program Further Project Short List consultation with interested parties is currently underway	Documents present evidence for good industry practice with respect to SE&C. MPC consultation has occurred with Stakeholders and Customers in relation to the future of the HVDC link and the proposed upgrade program Further Project Short List consultation with interested parties is currently underway	N/A	Documents present evidence for good industry practice with respect to SE&C. MPC consultation has occurred with Stakeholders and Customers in relation to the future of the HVDC link and the proposed upgrade program Further Project Short List consultation with interested parties is currently underway
5.2 provide an opinion on the extent to which Transpower's proposed scope of work (i.e., bundling and timing of different elements) is consistent with good asset management practice, and is technically feasible;	The proposed program of work is considered technically feasible. The solution is a replacement and upgrade of an existing HVDC system and Transpower would deliver the works under the necessary legislation and regulatory requirements. The portfolio of projects has many design interfaces, and a program approach is considered good industry practice that will help manage these complexities. Maximising program delivery efficiency through a well-planned focus on outages for cable installation and accommodating other upgrade works e.g. Control Systems during this outage time	The options outlines in TER002 reflect good industry practice. This is demonstrated in the use of SSSHA to determine seismic design criteria, Geotechnical Investigation & interpretive report used in concept design	Replacing the Pole 2, Pole 3 and bipole control systems with the same HVDC supplier is considered technically feasible and good asset management practice. This will ensure that the control system can be completely designed, factory tested, installed, commissioned and supported by the same HVDC supplier. Training, spare parts and future upgrades will be handled by a single HVDC supplier. Transpower has used RFIs to screen the HVDC suppliers to those that have demonstrated experience to install a control system in a converter station built by another supplier.	The proposed program of work is considered technically feasible. The solution is a replacement and upgrade of an existing HVDC system and Transpower would deliver the works under the necessary legislation and regulatory requirements. The portfolio of projects has many design interfaces, and a program approach is considered good industry practice that will help manage these complexities. Maximising program delivery efficiency through a well-planned focus on outages for cable installation and accommodating other upgrade works e.g. Control Systems during this outage time	The proposed program of work is considered technically feasible. The solution is a replacement and upgrade of an existing HVDC system and Transpower would deliver the works under the necessary legislation and regulatory requirements. The portfolio of projects has many design interfaces, and a program approach is considered good industry practice that will help manage these complexities. Maximising program delivery efficiency through a well-planned focus on outages for cable installation and accommodating other upgrade works e.g. Control Systems during this outage time.	Yes - good practise to have functional Cable store in place prior to cable install	The proposed program of work is considered technically feasible. The solution is a replacement and upgrade of an existing HVDC system and Transpower would deliver the works under the necessary legislation and regulatory requirements. The portfolio of projects has many design interfaces, and a program approach is considered good industry practice that will help manage these complexities. Maximising program delivery efficiency through a well-planned focus on outages for cable installation and accommodating other upgrade works e.g. Control Systems during this outage time
5.3 provide an opinion on whether Transpower has appropriately considered options in its delivery of the various components of the	Transpower has planned to stage the work to mitigate the risk of outages. The final development of the staged work and outage plan will	Connections, construction sequence and outages for each option identified	Transpower has planned to stage the work to mitigate the risk of outages. The final development of the staged work and outage plan will	Transpower has planned to stage the work to mitigate the risk of outages. The final development of the staged work and outage plan will	Transpower has planned to stage the work to mitigate the risk of outages. The final development of the staged work and outage plan will	Yes - good practice to evaluate multiple sites for new cable storage	Transpower has planned to stage the work to mitigate the risk of outages.

	Undersea Cable Supply and Installation (1400MW)	Cable Termination Station Upgrades	HVDC Control System Replacement	Benmore Filter Bank Upgrade	Pole 2 Overload Scheme	Cable Storage Facility	Recovery of Decommissioned Cables
HVDC Link Upgrade programme of work. This includes how it has considered staging its work to minimise the impact of outages on the market and its service quality measures;	require input from the HVDC cable and converter suppliers.		require input from the HVDC cable and converter suppliers.	require input from the HVDC cable and converter suppliers.	require input from the HVDC cable and converter suppliers.		
5.4 provide an opinion on the extent to which Transpower's approach to costing the proposed work is reasonable in the current (and forecast) supply chain environment, and both aligns with Transpower's asset management frameworks and provides an appropriate level of cost accuracy for the timelines required;	Given the stage of the project planning and considering the market demand for long lead items such as subsea cable and HVDC control systems, the capacity reserve procurement approach is considered prudent and necessary. Vendor costs estimates and past project cost references will have a level of uncertainty	Costing carried out by suitably qualified professional	Transpower has developed internal estimates for the control system replacement that they plan to revise after discussions with the HVDC suppliers later in 2025.	Given the stage of the project planning and considering the market demand for long lead items such as subsea cable and HVDC control systems the capacity reserve procurement approach is considered prudent and necessary. Vendor costs estimates and past project cost references will have a level of uncertainty	Given the stage of the project planning and considering the market demand for long lead items such as subsea cable and HVDC control systems the capacity reserve procurement approach is considered prudent and necessary. Vendor costs estimates and past project cost references will have a level of uncertainty.	Costing relevant to current stage in procurement and timeframes	Transpower has developed internal estimates for the cable removal that they plan to revise after discussions with salvage vendors closer to removal date
5.5 assess whether the proposed costs have been created through appropriate procurement and cost estimation methods, at an acceptable level of accuracy.	As above - a reasonable approach for this stage of the project but has uncertainty risk	Costing carried out by suitably qualified professional.	Transpower will have more accurate capital estimates for the control and protection system when the HVDC suppliers respond later in 2025.	As above - a reasonable approach for this stage of the project but has uncertainty risk	As above - a reasonable approach for this stage of the project but has uncertainty risk	Costing relevant to current stage in procurement and timeframes. Note - review later stages for updates in cost estimation methods	Transpower will have more accurate capital estimates for the removal from vendors later in project
5.6 provide an opinion on whether Transpower has adequately considered the environmental impacts of the projects insofar as they impact the costings and timing of the delivery programme.	Considered appropriate for this stage of the project	Planning assessment and engagement plan carried out	Considered appropriate for this stage of the project	Considered appropriate for this stage of the project	Considered appropriate for this stage of the project	All sites under consideration located in ports, limitations of sites considered in assessment but no formal planning assessment for recommended sites	Transpower considers that there may be environmental impacts of leaving the existing cables in place and has therefore recommended removing them in its FTAA application. However, no environmental reports showing the impact of leaving the cables in place have been provided.
5.7 provide an opinion on whether Transpower has chosen to use appropriate mechanisms (e.g. P30/P70 deadband, exempt capex, and/ or	Investment test applies the costs and benefits specified by the Commerce Commission in TPs capital expenditure input methodology	N/A	Investment test applies the costs and benefits specified by the Commerce Commission in TPs capital expenditure input methodology	Investment test applies the costs and benefits specified by the Commerce Commission in TPs capital expenditure input methodology	Investment test applies the costs and benefits specified by the Commerce Commission in TPs capital expenditure input methodology	N/A	Investment test applies the costs and benefits specified by the Commerce Commission in TPs capital expenditure input methodology

	Undersea Cable Supply and Installation (1400MW)	Cable Termination Station Upgrades	HVDC Control System Replacement	Benmore Filter Bank Upgrade	Pole 2 Overload Scheme	Cable Storage Facility	Recovery of Decommissioned Cables
grid output amendments) available in the Capex IM to allocate risks arising from our approach to costing;							
5.8 provide a list of the key issues and areas that it considers the Commission should focus on when the Commission evaluates Transpower's HVDC MCP;	Project program schedule resourcing plan Project risk assessment plan	N/A	Capital costs from the HVDC suppliers. Schedule of Pole 2, Pole 3 and bipole outages that will be required for installation and commissioning.	Project program schedule resourcing plan Project risk assessment plan	Project program schedule resourcing plan Project risk assessment plan	Transpower to demonstrate how capital cost estimates will be updated as design and delivery progresses	Capital cost must be determined from salvage vendor estimates Detailed risk assessment required particularly near shoreline
5.9 provide an opinion on whether Transpower provided the Reviewer with the type and depth of information it needed to provide its review report; and	Comprehensive information was provided through project documents, interactive workshops and RFI's	Yes, required information supplied in original documents and following RFI responses	Comprehensive information was provided through project documents, interactive workshops and RFI's	Comprehensive information was provided through project documents, interactive workshops and RFI's	We have not been able to confirm the Transpower claim that improving Pole 2 overload capacity would generate $25 million in benefits.	Yes, required information was provided in initial documents and RFI responses	Transpower has not yet completed the environmental assessments that would be necessary to conclude that removing the cables is necessary.
5.10 identify any other information not included in the HVDC MCP that the Reviewer reasonably believes would:	NA	NA	NA	NA	NA	NA	NA
5.10.1 be available to Transpower; and	NA	NA	NA	NA	NA	NA	NA
5.10.2 assist the Commission's evaluation of Transpower's HVDC MCP.	NA	NA	NA	NA	NA	NA	NA
5.11 The Reviewer is not expected to undertake a review of Transpower's application of the Capex IM Investment Test nor its market modelling.	NA						