Meeting Date: 26 October 2022

Transmission: planning, management and Security

Security and Reliability Council

This paper introduces presentations by the grid owner: - updating on their asset management planning for new capacity and electrification, grid security and resilience, design standards and fault response.

Note: This paper has been prepared for the purpose of the Security and Reliability Council (SRC). Content should not be interpreted as representing the views or policy of the Electricity Authority.

1. Introduction

1.1.1. This paper introduces the main theme for the SRC's October meeting – transmission.

1.1.2. The secretariat has arranged for a suite of papers and presentations from the grid owner, the scope of which the SRC had input into at its August meeting.

1.1.3. Members are encouraged to read the overview paper first, as that gives context for the other papers and presentations.

1.1.4. Members may also wish to review the gird owner's June presentation on grid asset management, as the papers for October build and update on that. The June grid owner paper is available here.

1.1.5. This section briefly explains transmission grid security concepts and notes three horizons relevant to grid security and system operation. System operation is included because the system operator facilitates asset outage coordination.

1.1.6. The following table provides a guide to terminology used in this report, and how it maps to terms in the Electricity Industry Participation Code (Code).

Table 1: Guide to terminology used in this paper

Terms	Usage in this Report	Terms used in the Code
Security and *grid security*	A key reliability strategy for the grid owner. Refers to providing redundancy in the transmission system so that supply to a point of service is resilient to failure of any single transmission asset or circuit.	N-1 criterion Secure state at GXP
Stability and *system stability*	Principal obligation of the system operator. Refers to operating the power system within required parameters to preserve power quality and avoid cascade failure.	System security Satisfactory state Principal performance obligations

1.1.7. The Code also uses the term security of supply to refer to the system operator's functions (in Part 9) in monitoring and forecasting generation fuel and generation capacity adequacy.

1.1.8. The grid owner is accountable for the capability and availability of the grid, while the system operator is accountable for the stability of the power system. The system operator works with the grid (and generation) assets made available at any time to ensure generation and load remain in balance.

1.1.9. The following table summarises key horizons over which grid security considerations play out for each party, noting that the system operator section focusses on roles relevant to grid outage management only.

Table 2: Grid security horizons

	Horizon	Description	Comments
Grid owner	Strategic planning	Long-term planning of the capacity, configuration and other performance characteristics of the transmission system.	Planning standards (including grid reliability standard) and investment frameworks are relevant here.
	Work design and scheduling	Design of projects (or programmes of work) to alter, repair or inspect grid assets, and scheduling an overall grid works programme.	Includes determining project build methodologies and coordinating required outages.
	Execution	Carrying out work on the grid.	Includes de-energising and re-energising parts of the grid.
System operator	Forecasting and coordination	Scanning ahead to identify situations where planned outages could impact stability.	Facilitative role – forecasting, assessment and information provision.
	Operational planning	Putting measures in place in advance to mitigate risks.	Grid owner and grid users can also mitigate risks.
	Real-time operation	Monitoring in real-time and acting if needed to preserve stability.	Includes emergency management measures.

1.1.10. Transpower works with its grid customers to plan changes in grid capability and configuration well in advance. This includes:

a) external drivers – forecasting when grid connections, regional networks or backbone will become more stressed or slack due to demand or generation changes and identifying how to optimise grid capability

b) internal drivers – identifying whether planned asset renewal or alteration works present opportunities to optimise grid capability.

1.1.11. Transmission grids are designed to achieve very high levels of reliability, including by:

a) using robust, highly reliable assets and maintaining them in good condition (including by replacing them before they fail)

b) enhancing capacity ahead of growth, and

c) duplicating assets to provide redundancy.

1.1.12. Building too far ahead of growth and providing full redundancy everywhere are both expensive, so the amount of built redundancy varies across the grid and over time. As assets are taken out of service for maintenance, replacement or to support upgrades, the level of redundancy is temporarily reduced.

1.1.13. The grid owner has posed a set of three key challenges and related questions, as set out in part 9 of Appendix D to this paper. Members are asked to consider the challenges for discussion at this meeting enabling direct feedback for the grid owner to potentially include in its future planning.

1.1.14. The grid owner will attend and present to the SRC and be available for questions relating to these papers, or other aspects impacting the capability and availability of the grid.

2. Questions for the SRC to consider

2.1.1 The SRC may wish to consider the following questions.

Q1. What further information, if any, does the SRC wish to have provided to it by the secretariat?

Q2. What changes, if any, does the SRC consider should be made to its risk radar, in the light of these papers and presentations?

Q3. What advice does the SRC have for the Authority

Appendix A: Grid owner overview paper

Appendix B: Grid owner paper – asset management and resilience

Appendix C: Grid owner presentation – asset management and resilience

Appendix D: Grid owner paper – Transmission planning and net zero grid pathways

Appendix E: Grid owner presentation – Transmission planning and net zero grid pathways

Grid Owners Asset Management and Transmission Planning Approach

Date: 26th October 2022

To: Electricity Authority, Security & Reliability Committee

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From: John Clarke, Grid Development, Transpower

1. Purpose

This short paper is an overview of the two Grid Owner papers, Asset Management and Transmission Planning. They both build on the Grid Owners presentation and discussion at the June SRC. The June slides and narrative are a useful refresher for SRC members. The two narrative documents here are intended to support a discussion on the key points at the meeting will be supported by the PowerPoint slides that follow each paper. Both papers include a final section on a number of challenges that could form the basis for further discussion at the meeting.

2. Asset Management and Resilience

This paper briefly discusses the regulatory context for Grid asset management and sets out our asset management journey over the last 12 years, from the end of the big build phase and into the future towards 2030.

It describes our asset management framework. The strategies, performance objectives, how we now account for Network Risk as well in our decision making. It also notes the challenges of maintaining current grid reliability with more grid connections for decarbonisation.

It notes we are improving the accessibility of our Asset Management Plan which is the key insight for our customers and regulators into how we maintain the performance and reliability of the grid.

The paper then specifically addresses resilience as an emerging area. It lists the natural hazards, including from climate change, that can give rise to unexpected long duration and wide area grid failures. How we distinguish reliability from resilience. How we are already taking a more proactive stance in addressing resilience with additional spares and recovery plans. That our growing maturity and analysis capability has enabled us to identify a funding envelope of specific resilience investments that will form part of our next five year regulatory submission to the Commerce Commission.

The paper then explains our emerging work on resilience in the context of the four "R"s risk reduction, readiness, recovery and response. We provide short case studies of events and issues and how they inform our work under each of these areas including design standards, spares. We cover the important lessons from our response to some recent events that have further informed our approach.

We set out three resilience and reliability challenges that the SRC may wish to discuss further.

3. Transmission Planning and Net Zero Grid Pathways

This paper draws on Transpower's view of the future, outlined in *Whakamana i Te Mauri Hiko– Empowering our Energy Future* as the context for our purpose and how it guides our long-term grid planning strategy out to 2050. That our *Electrification Roadmap* highlights the critical role the grid plays in enabling decarbonisation. This is also referenced in other publications and studies into how New Zealand can meet its climate change goals. That our response to the longer-term challenge is our Net Zero Grid Pathways programme

The paper then describes the role of our annual Transmission Planning report and the four strategic goals that support our approach to grid planning. Service and cost performance as well as customers and stakeholders and asset management capability.

The regulatory construct for how grid planning needs are assessed and funded is briefly covered. It then considers a range of influences in the external environment and how this is influencing major drivers of new grid investment. Namely:

- The number of new connection enquiries, investigations and connection commitments
- An upward step change in the forecasts for electricity from our connected customers

The paper then discusses in some detail our two-stage approach to demand forecasting, to establish both future energy demand and peak electricity demand. How our approach to demand forecasting has changed with new technologies such as embedded generation. Also, how we use a "prudent" forecast to manage uncertainties in assess the timing more immediate investment needs.

The role of the standard grid investment test scenarios, developed by MBIE are discussed and how we have consulted with industry to update these for proposed forthcoming grid investment to be submitted later this year.

The outputs of the annual Transmission Planning report are described and how they are progressed into grid investments. A list of our current envisaged and proposed Major Capital investments out to 2030 are listed.

Our Envision tool to aid the ability of our customers to easily understand the TPR and where they can connect new generation is highlighted.

The paper then returns to our longer-term enabling programme Net Zero Grid Pathways, and the two phases of that key programme.

- Phase 1 to 2035, to extract capacity from the existing grid backbone on a least regrets approach to ensure the grid is an enabler in the face of a range of uncertainties
- Phase 2 to 2050 to ensure we have a reliable and resilient grid to support an economy heavily reliant on electricity.

The work underway on Phase 1 is described as is our plans to engage in 2023 on Phase 2. Phase 2 will likely involve new grid connections to support regional growth, Renewable Energy Zones (REZ) and provide a resilient backbone to match the criticality of electricity supply.

The potential for renewable energy zones is set out along with what we see as the next stage in identifying how this concept would work in New Zealand. In addition, the challenges of regional growth and how this fits with our Net Zero Grid Pathways work is referenced.

Finally, the paper sets out a number of challenges that may require refinements to the existing regulated context for investment in the grid and what we are currently doing within our remit of Grid Planner to address them. They can be discussed further at the meeting.

TRANSPOWER

Asset Management and Resilience Planning at Transpower

Security and Risk Committee Update

John Clarke, Julian Morton and Malcolm Cleland

Who we are

- Owner and operator of the national grid for power transmission
- Regulated SOE with a five yearly reset
- Depreciated asset base – 60% of conductors were installed between 1950’s the and 1980’s
- Lifeline utility with special post disaster function
- Interdependencies with other lifelines such as roads, rail, gas, water, fuels, telco etc

The takeaways

- Significant improvements in grid reliability in recent years due to sound AM practices
- Decarbonisation = more reliance on electricity for transport and process heat
- Climate change = more intense flood events and storms
- Social risk appetite for resilience will change
- Resilience has mostly been managed operationally and by building back better
- Our preparedness has improved with the mobile substation and reviewing spares holding
- We have identified the need to develop proactive resilience programmes

Where we fit in

We own and operate New Zealand's national electricity transmission network and run the electricity market system

1 Generation
Generation companies generate power from wind, thermal, hydro and geothermal. They sell the power they generate on the electricity market. Emerging distributed generation includes electric vehicles, batteries and solar photovoltaic.

2 New Grid Connects
As New Zealand moves to electrify its economy, Transpower is receiving more requests to connect to the grid. This includes new generation such as solar and wind, as well as new industrial demand.

3 Transmission
Transpower transports high voltage electricity from where it is generated to distribution companies and some large directly connected customers.

4 Industrial Customers
A few major industrial companies receive their power directly from Transpower.

5 Substations
Substations reduce the voltage at the point where electricity is delivered to distribution companies – our customers.

6 Systems Operations
Operates the wholesale electricity market and manages system security.

7 Distribution
The lower voltage electricity is transported by distribution companies to homes and businesses throughout New Zealand.

8 Commercial
Some commercial customers that consume large quantities of energy purchase power directly from the wholesale electricity market.

9 Retail
Retailers buy power on the electricity market, package it together with other costs of delivering power (transmission and distribution), and on-sell it to customers.

10 Domestic and Business Users
Domestic and business users receive their electricity directly from retail companies, which deliver power to homes, businesses and commercial operations using distribution companies' lines.

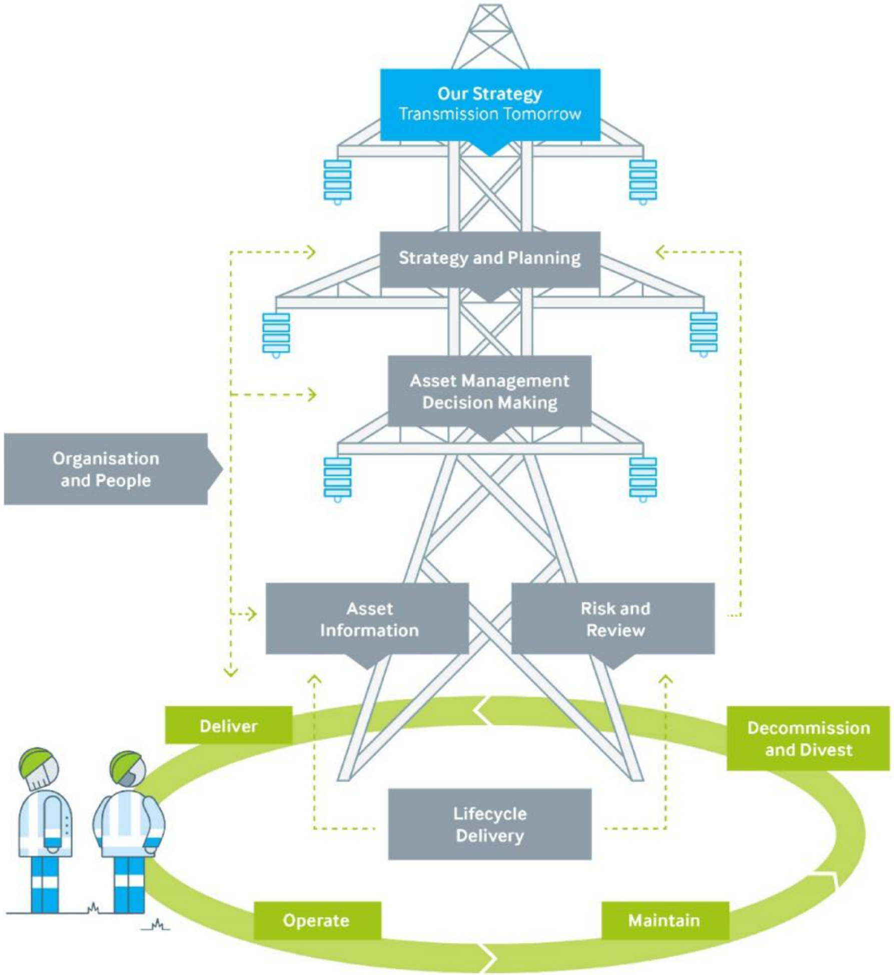
Maturity

RCP1 2012-14	RCP2 2015-19	RCP3 2020-24	Improvements	RCP4 2025-29
1. Restart Investment Supported the end of the glide path.	**5. Lift AM competence** Significant uplift in asset management capability was delivered, including a new grid operating model.	9. Asset stewardship Long term benefits for customers to deliver a safe and reliable network.	13. Asset Health and Network Risk Continue to improve our maturity for asset planning.	17. Electrification Supporting the energy transition to decarbonise New Zealand.
2. Economic Projects Supported Pole 3 and Wairakei Ring investments.	6. **Services Focus** Strong focus on reducing interruptions. Performance improved in RCP2.	10. Agility Growing importance for Transpower.	14. Cost Estimation Improving our cost tracking, data tools, feedback loops and project cost estimates.	18. Resilience Deliver a Safe and Reliable network and the emerging need for greater resilience.
3. Economic Return WACC set and ratchetted down.	7. Lift Efficiency Efficiency workstreams in the Transformation programs delivered benefits.	11. External challenge Being prepared for external stakeholder influence the submission (e.g. Gentailers).	15. Customer Engagement Early engagement that is targeted, informed, transparent, and full circle.	19. Environmental and Sustainable Climate change, environmental stewardship, and communities.
4. Limited Service Measures Limited incentives & quality targets. No points of service categories	8. Customer facing Service Measures Ambitious targets caused investigations, yet overall service improved.	12. Full Review of Service Measures Improved PoS categories. Incentivise asset health rather than deliverables.	16. Targeted Review Engaging our customers on what is working and what isn't working for RCP4 Service Measures.	20. Deliverability and Workforce Planning Early planning to inform the submission and ensure we deliver on our objectives.

Transpower's
Grid Asset Management

Our Grid Asset Management framework ensures line of sight from our strategy, Transmission Tomorrow, through to how we plan, design, build and maintain the Grid Assets to deliver services and customer value.

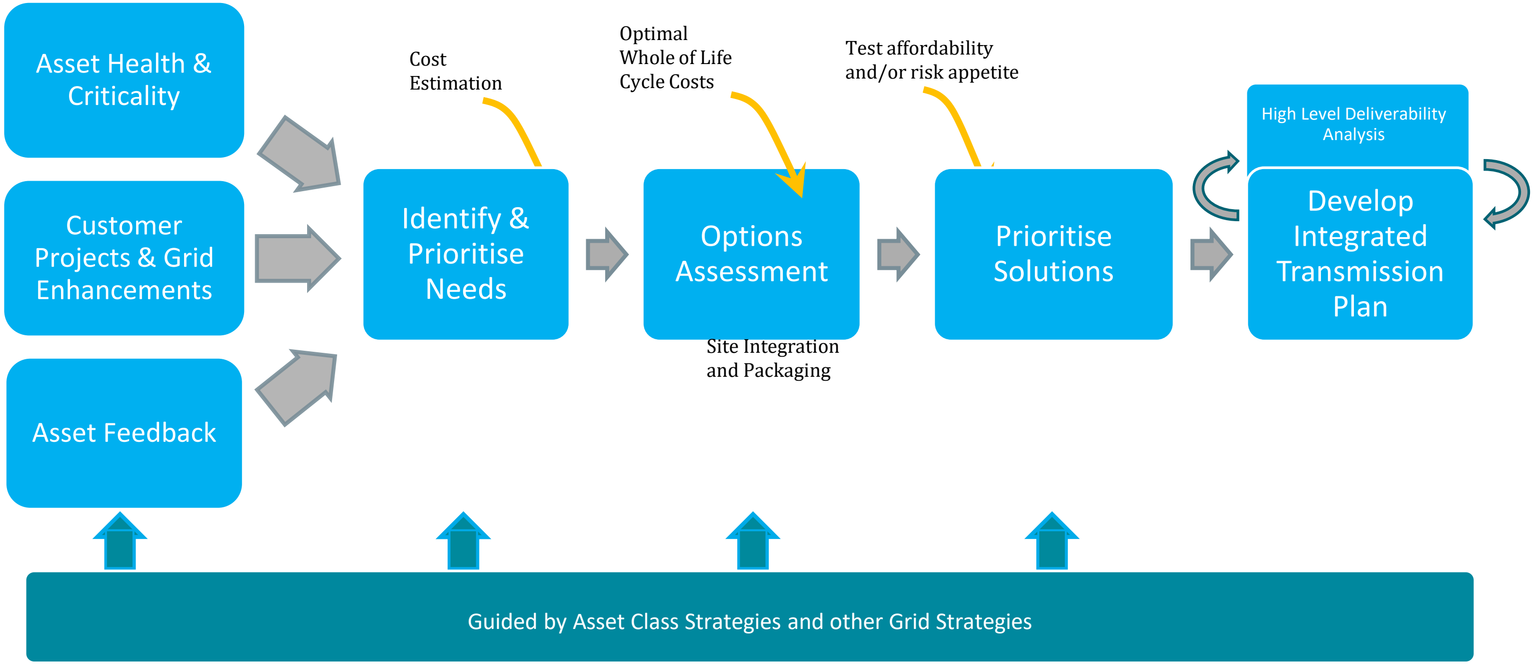
Our asset management system aligns with ISO 55001, and sound asset management helps us achieve good electricity industry practice (GEIP) in line with our peers. This provides confidence to the independent verifier and the Commerce Commission that we are managing performance, risks and costs.



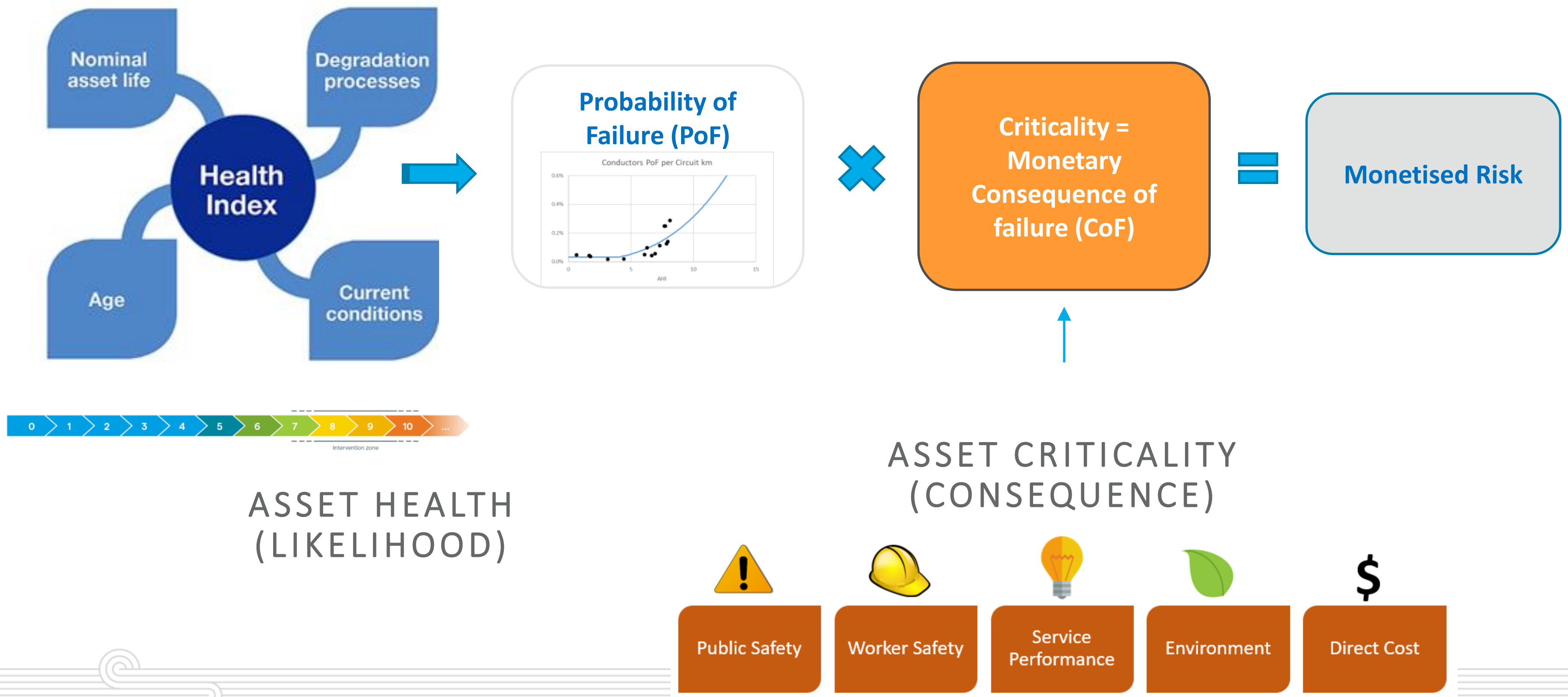
Asset planning decision framework

The decision framework, within the Asset Management decision making stage of our Grid Asset Management Framework provides a consistent, repeatable risk-based approach for asset planning decisions. The key drivers for investment are safety, network performance, future demand, risk of asset failure, and cost performance. The framework principles apply to all grid capital and relevant grid operating expenditure.

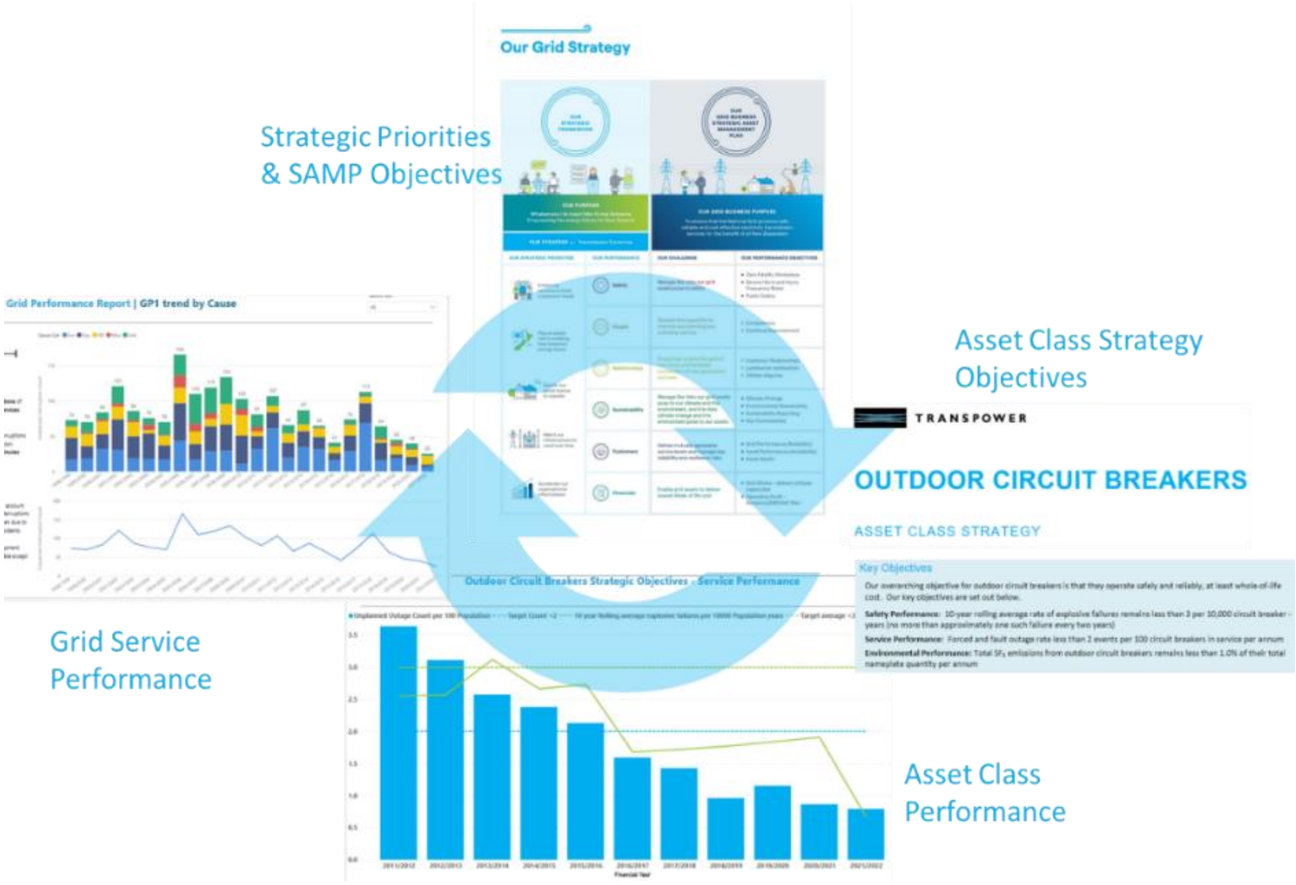
High level view



Asset health and condition based risk

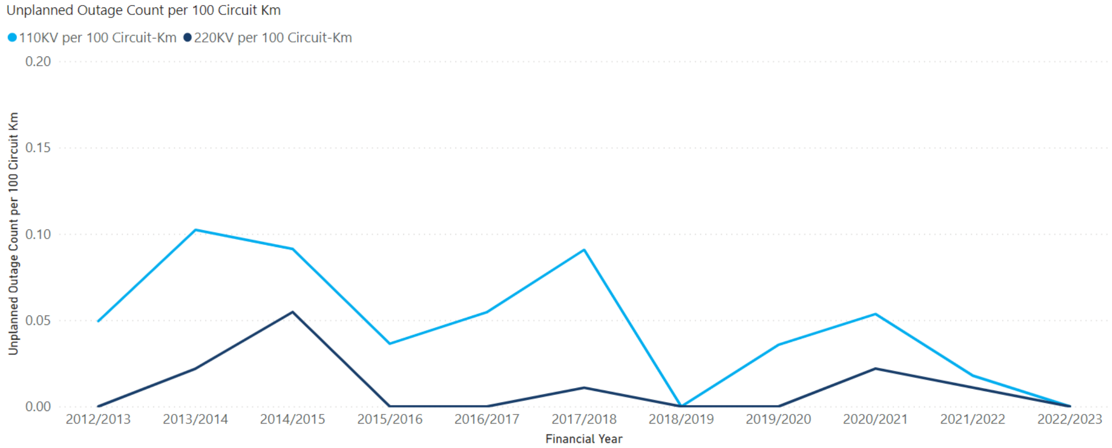


Performance

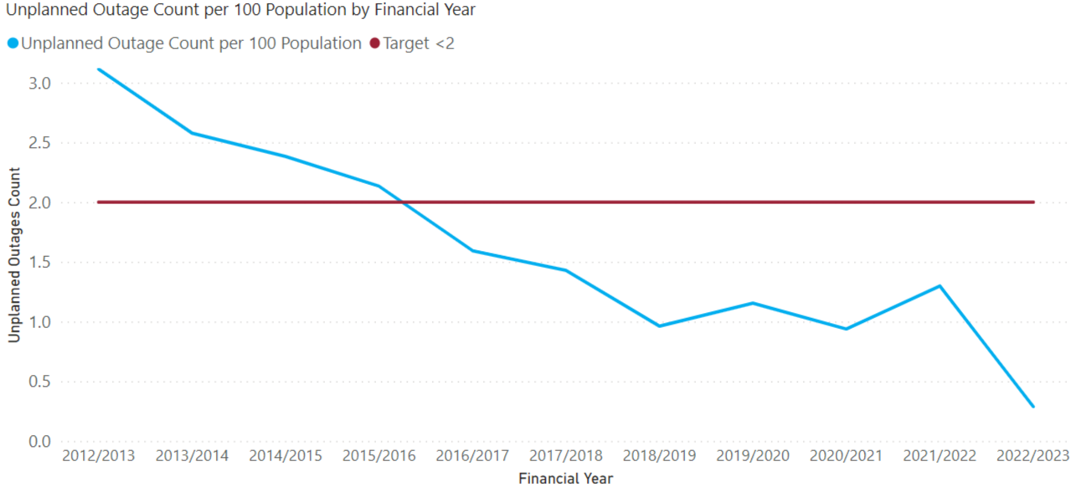


Tracking asset class performance

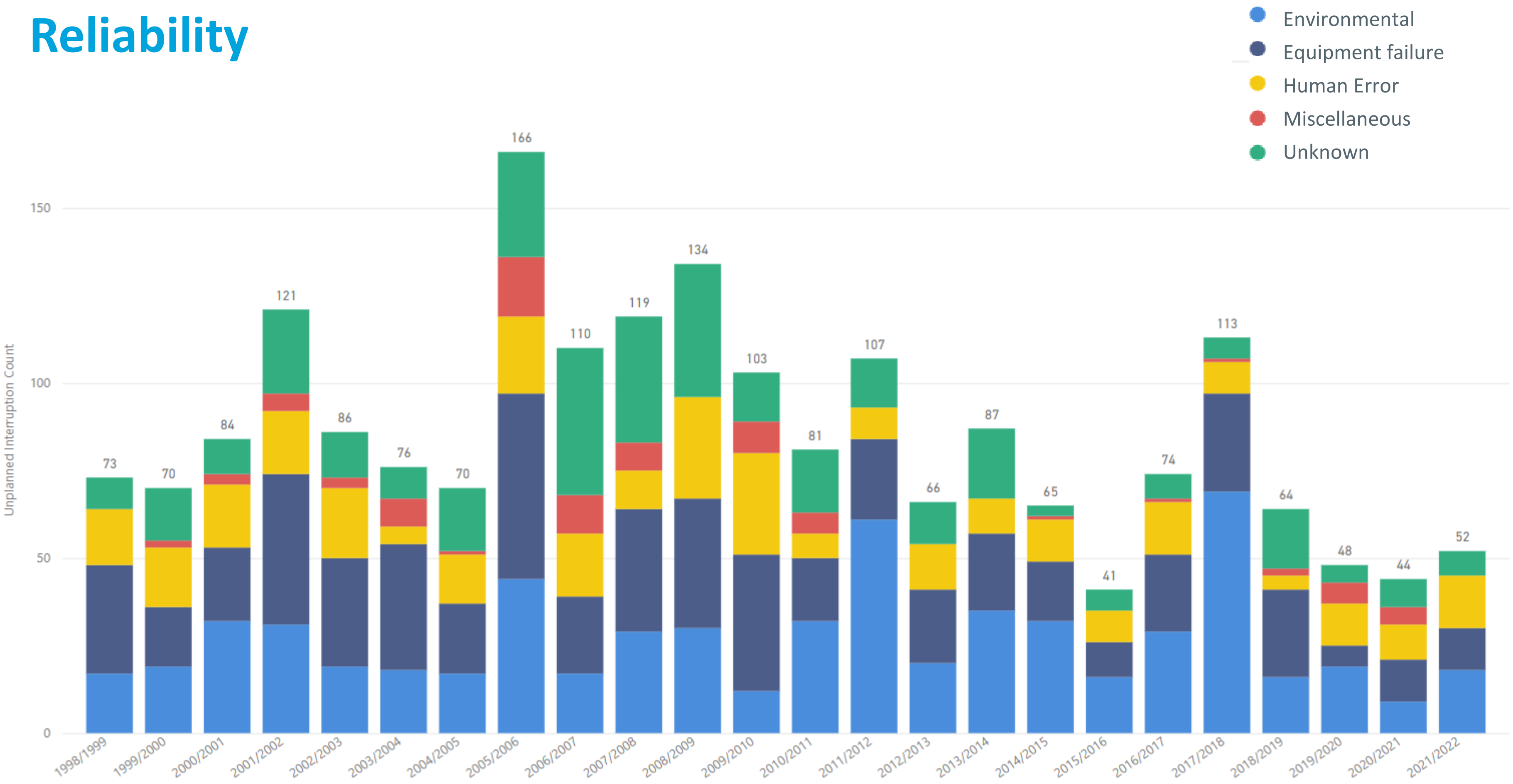
Outdoor Circuit Breakers



Conductors



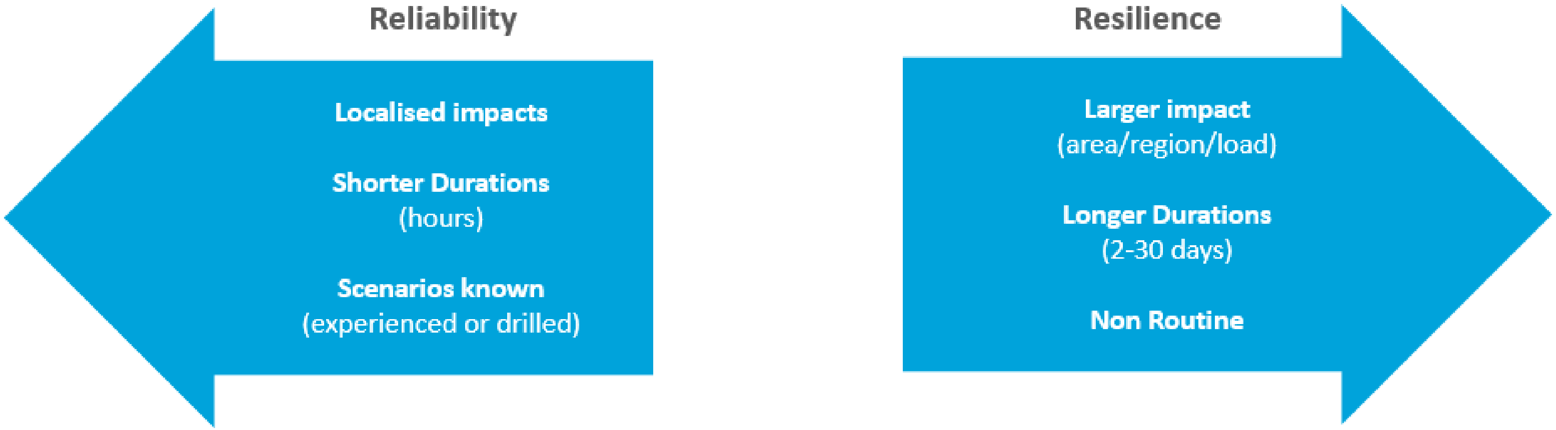
Reliability



Resilience and Reliability

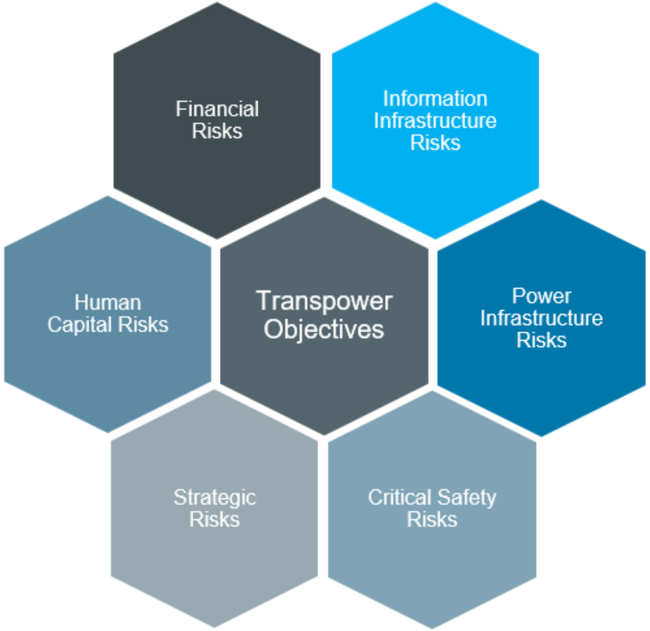
Resilience: The state of being able to avoid utility supply outages, or maintain or quickly restore service delivery, when high impact events occur.

Resilience and Reliability are intertwined.

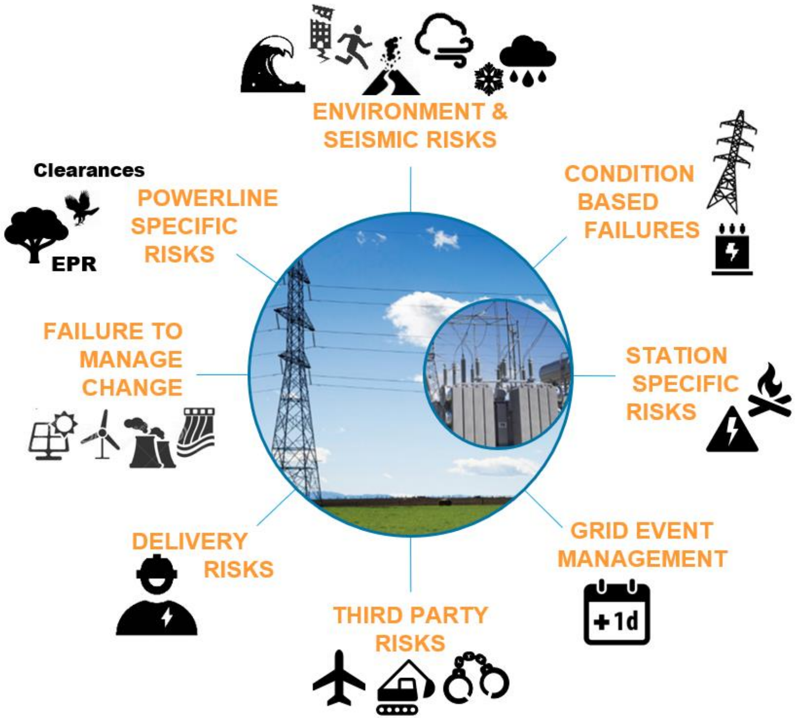


Critical risks

TRANSPOWER CRITICAL RISKS



POWER INFRASTRUCTURE CRITICAL RISKS



Risk consequences include Service Performance, Public Safety, Worker Safety, Environment and Direct Cost.

Grid Major Hazards

Most NZ infrastructure providers have low maturity:

- no national picture of infrastructure resilience investment
- no understanding of societal risk tolerance for different hazards
- most utilities do not have specific resilience investment categories
- resilience projects (without other drivers) fail to pass benefit-cost tests under existing funding models.

Transpower has been working on understanding major hazards for many years.

We have good resilience data sets, a draft resilience strategy, and have developing a resilience program for RCP4 of a series of proactive investments ~$100M.

		THREATS	GRID MAJOR HAZARDS
NATURAL HAZARDS		Seismic	Substation buildings, equipment, and bus structures Transmission lines and cables Communications
NATURAL HAZARDS		Volcanic	Insulator flash over from ash and line loading damage Disruption to electronics / AC systems Lahar impacting sites/lines
NATURAL HAZARDS		Tsunami	Risk to towers/poles Risk to substations Risk to subsea cables and cable stations
NATURAL HAZARDS		Space weather	Geomagnetic induced currents Transformer damage, voltage control and protection issues No voice communications and no satellite communications
NATURAL HAZARDS		Land stability	Risk to towers poles Risk to access tracks Landslides damaging buildings and structures
NATURAL HAZARDS	WEATHER RELATED	Flooding	Risk from braided rivers (and other rivers) to towers/poles Risk to substation control equipment and cables Risk to ICT optic-fiber routes
NATURAL HAZARDS	WEATHER RELATED	Severe wind and tornados	Tower and pole collapse Increased bushfire risk Conductor failures increase
NATURAL HAZARDS	WEATHER RELATED	Snow	Snow ice loadings on lines Snow loading on buildings
NATURAL HAZARDS	WEATHER RELATED	Increased temperatures	Conductor derating Peak Loads move into Summer Insufficient cooling of control equipment at substations
NATURAL HAZARDS	WEATHER RELATED	Bush fire	Bushfire encroaching assets Transpower starting bush fire Flashover on lines due to flames
ASSET RISKS		Common mode failure	Asset failure causes widespread long duration outage Critical towers understrength Cascade failures and substation design
ASSET RISKS		Vandalism, sabotage, terrorism	Physical damage of assets and theft Interference with network operations and with market Denial of service, corruption of our data
ASSET RISKS		Asset fires	Substation building fire risk Transformer cascade fire risk Cable fire risk and other equipment fire risk

High Impact Events

Floods

Canterbury 2021
Rangitata 2019
Pauatahanui 2016
Stoke 2011
Manawatu (2x) 2004
Melling 1998

High Impact Events

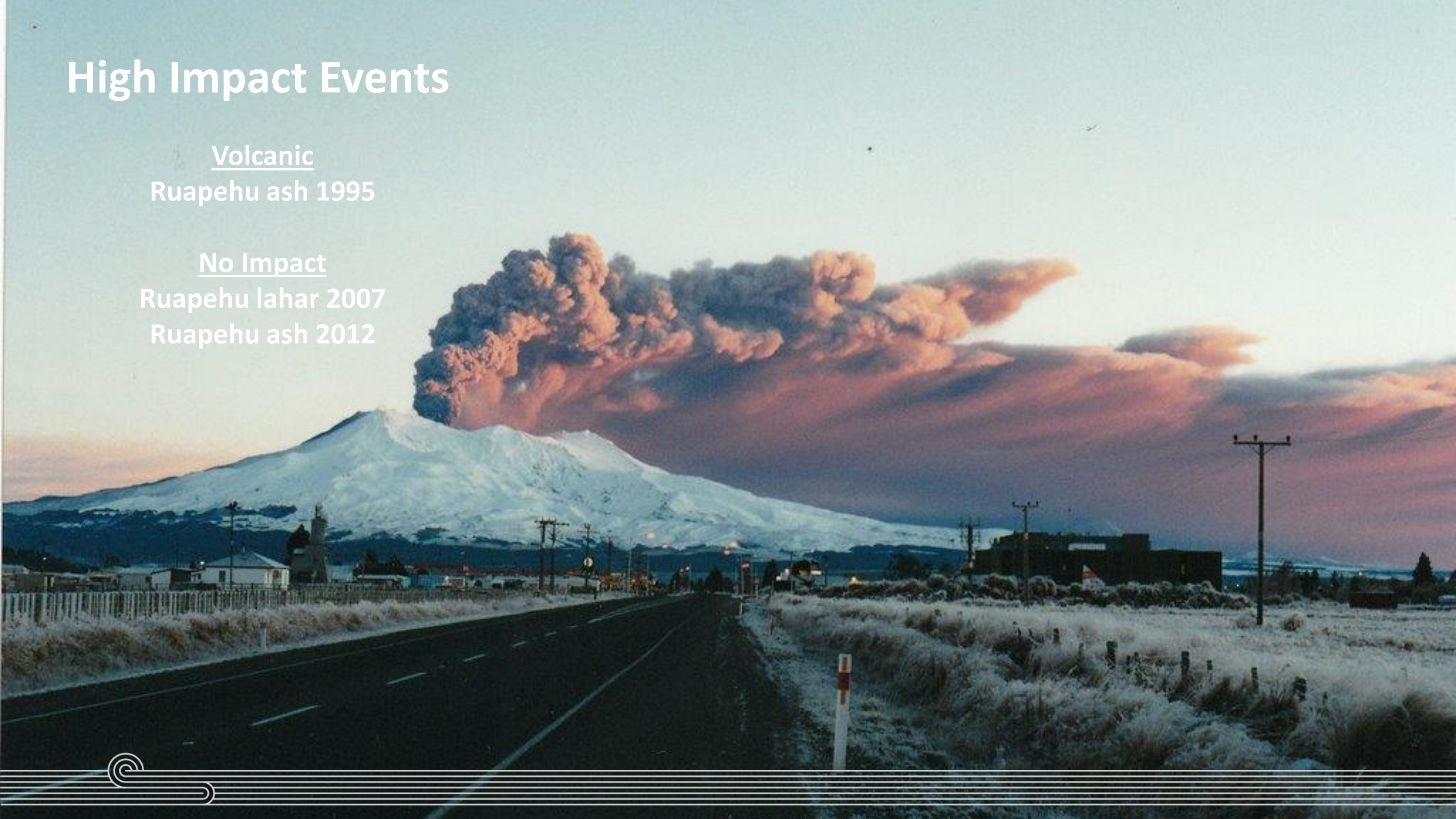
Earthquake
Kaikoura 2016
Christchurch 2011

Slope stability
Floods/Seismic

High Impact Events

<u>Volcanic</u>
Ruapehu ash 1995

<u>No Impact</u>
Ruapehu lahar 2007
Ruapehu ash 2012

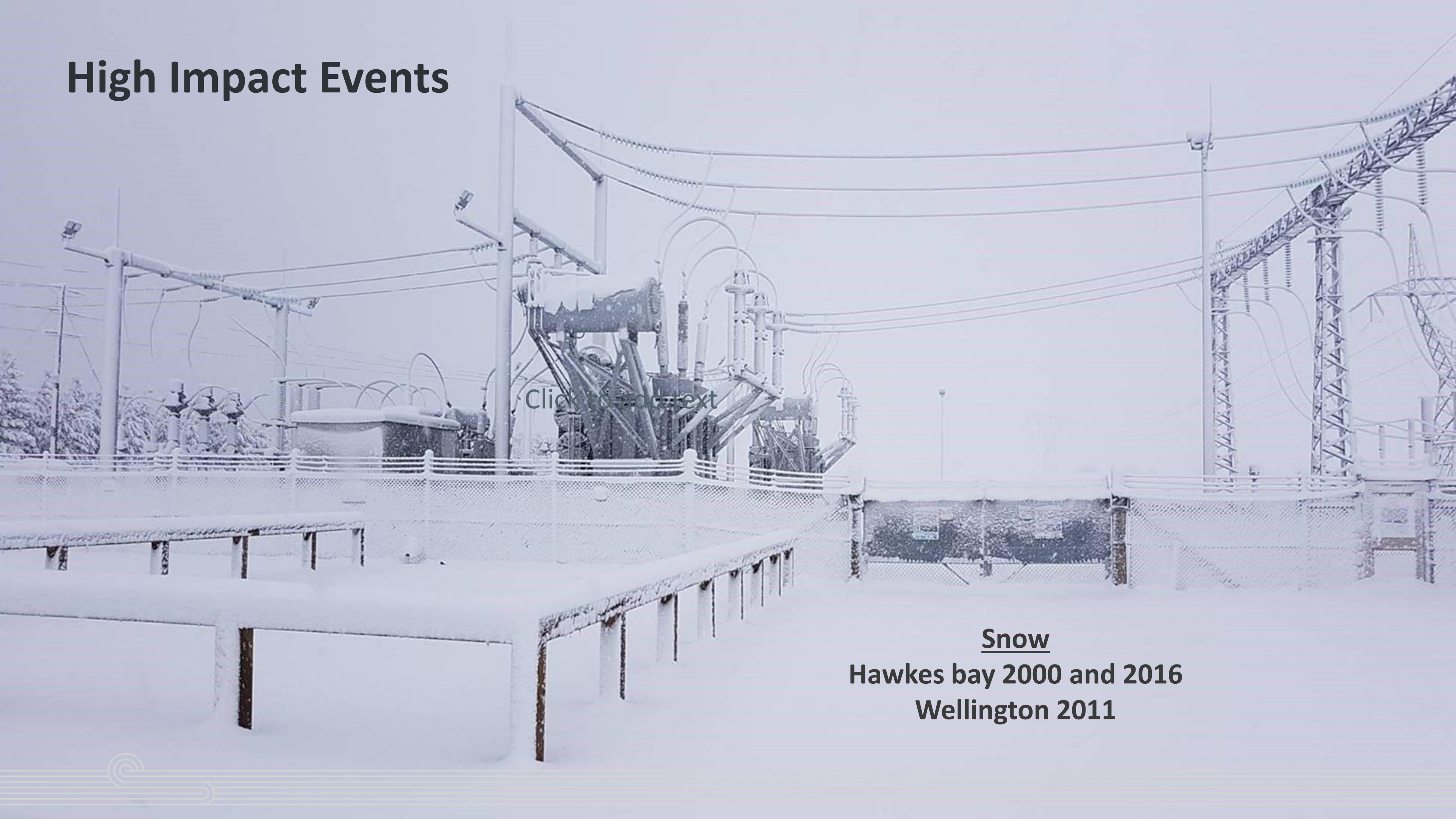


High Impact Events

<u>Ex Tropical Cyclones</u>
Gita 2018
Cook 2017

<u>Tornados</u>
Edgecumbe tower failure 2007

High Impact Events



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<u>Snow</u>

Hawkes bay 2000 and 2016

Wellington 2011

High Impact Events

<u>Common mode failure</u>

Otahuhu earthwire 2006

Port Hills Fire 2017

Vector cable fire at Penrose 2012

<u>Space Weather</u>

Halfway Bush transformer failure 2001

High Impact Events

Aircraft

7 crashes in the last 20 years

Third Party

Irrigators

Cranes

Container lift

Our Resilience Approach

Our resilience approach is consistent with the industry and national lifelines approach.

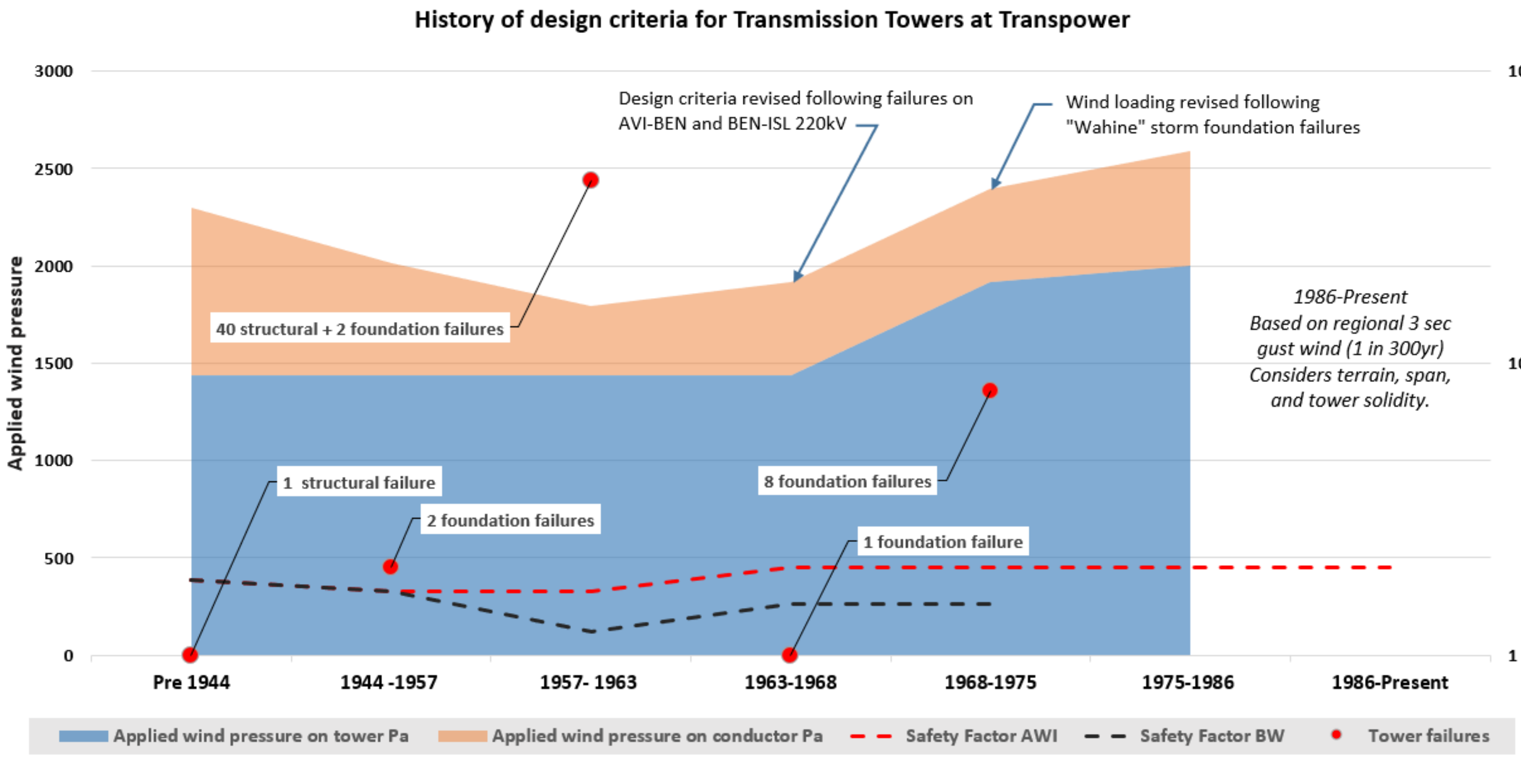
In RCP4 we intend to take a modestly proactive approach where we can balance risk reduction and readiness investment with our ability to recover from disasters. The risk reduction involved is the cost-effective strengthening of those assets that are vulnerable and critical to the system where service impact is most significant.

Resilience Criteria

- An appropriate balance between providing resilience through strengthening existing assets with what we would do if we were building new. This ensures we set reasonable thresholds for vulnerability.
- Our decision making looks at what bis critical for service to our customers, and is prioritised using other dimensions including future changes and cost benefit.
- We will continue to develop our resilience criteria for other hazards and widen the criteria to include restoration.

Hazards	Climate Change related	New build design standard	Resilience criteria	Currently vulnerable and critical
Substation flooding	Yes	450-year RP	250-year RP	12
Transmission Tower Flooding	Yes	50-year RP	20-year RP	14
Wind event tower (excl. HVAC)	Yes	300-year RP	150-year RP	>400 HVDC
Slope stability of towers and poles	Yes	30-year RP	30-year RP	52
Seismic IL4	No	2500-year RP	2500-year RP	30
Tsunami	No	2500-year RP	2500-year RP	5
Volcanic tephra (ash)	No	50-year RP	25-year RP	~150
Space weather	No	300-year RP	100-year RP	14

Legacy standard versus new build



Resilience Programme

Resilience Programme	Estimated RCP4 Deliverables
Strengthening critical buildings to meet seismic policy requirements for life safety and to maintain essential service	85 buildings
Pre-enabling works to allow a spare transformer to be easily connected at Wilton for contingency planning	1 site
Eliminate overhead station earthwire which is a common mode failure that can cause extended loss of supply	6 sites
Fire upgrades to fire stopping and fire detection for critical substation buildings that have fire risks	3-6 substations
Hardening transmission lines to be more resistant to a volcanic ash event in the central North Island using pollution resistant insulators	65 towers
Slope stability mitigation work for towers and poles to prevent slips that will result in critical transmission circuits being removed from service	18-69 structures
Resilience for bridges and access tracks (washouts, slips, scour) so we can access our assets and repair them in a flood event	12 sites
Procurement of a mobile switch room to manage a contingency where a switchboard or building has been damaged	1 new
Emergency exercise for tower restoration (physical deployment)	5 drills
Development of new capabilities in response to the changing cybersecurity threats, technology and business environments. Our cybersecurity investment to replace existing regional-based firewalls associated with the TransGO Refresh will also build resilience in our network. This investment is incorporated in the reliable and safe grid outcome area.	Across all sites and services
Improve information to enable decision making and improve visibility and awareness of high impact events than can affect the Transmission System in order to react and restore faster and avoid utility supply outages	Tools to support Operations

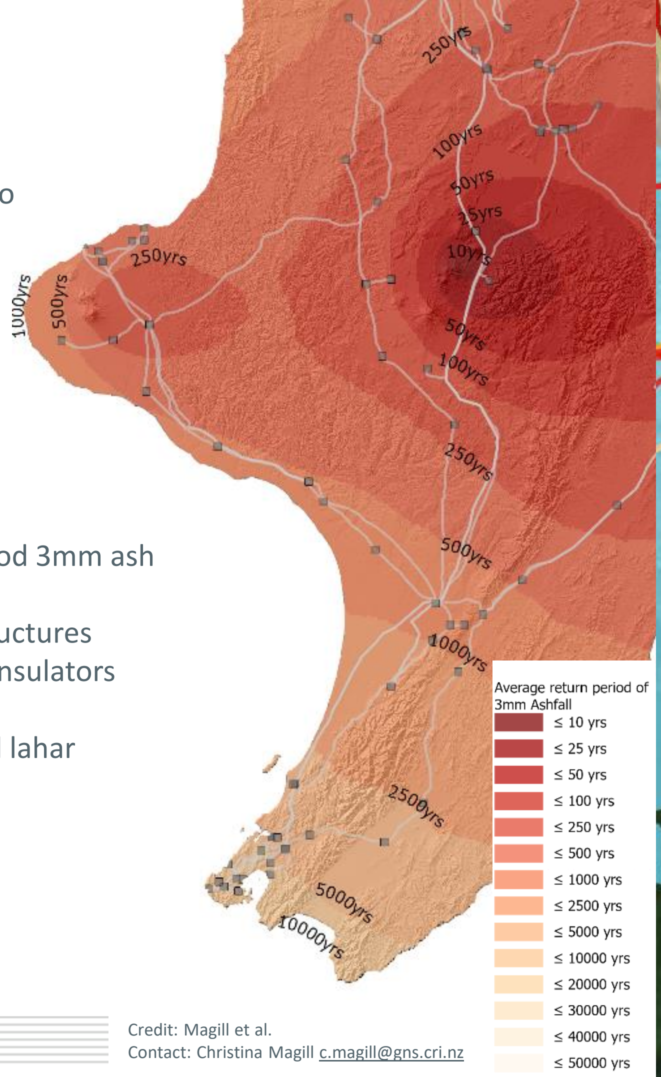
Volcanic

Working with researchers to understand the risk

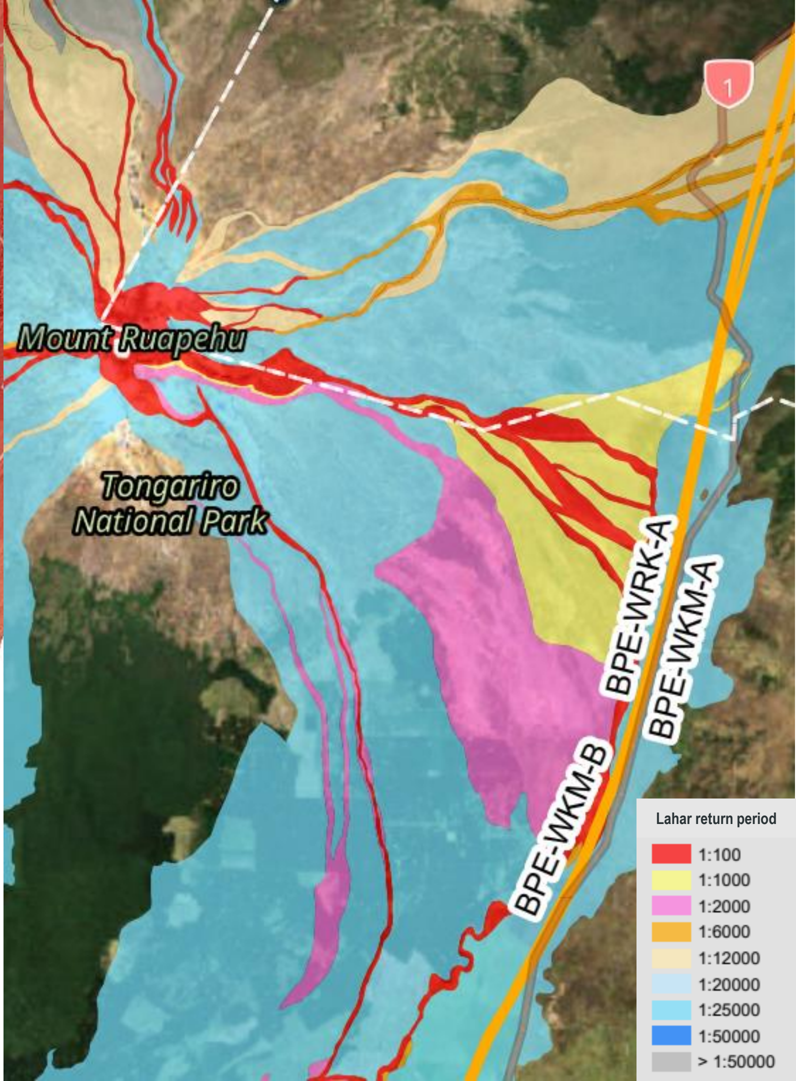
Testing scenarios and developing options

Ruapehu

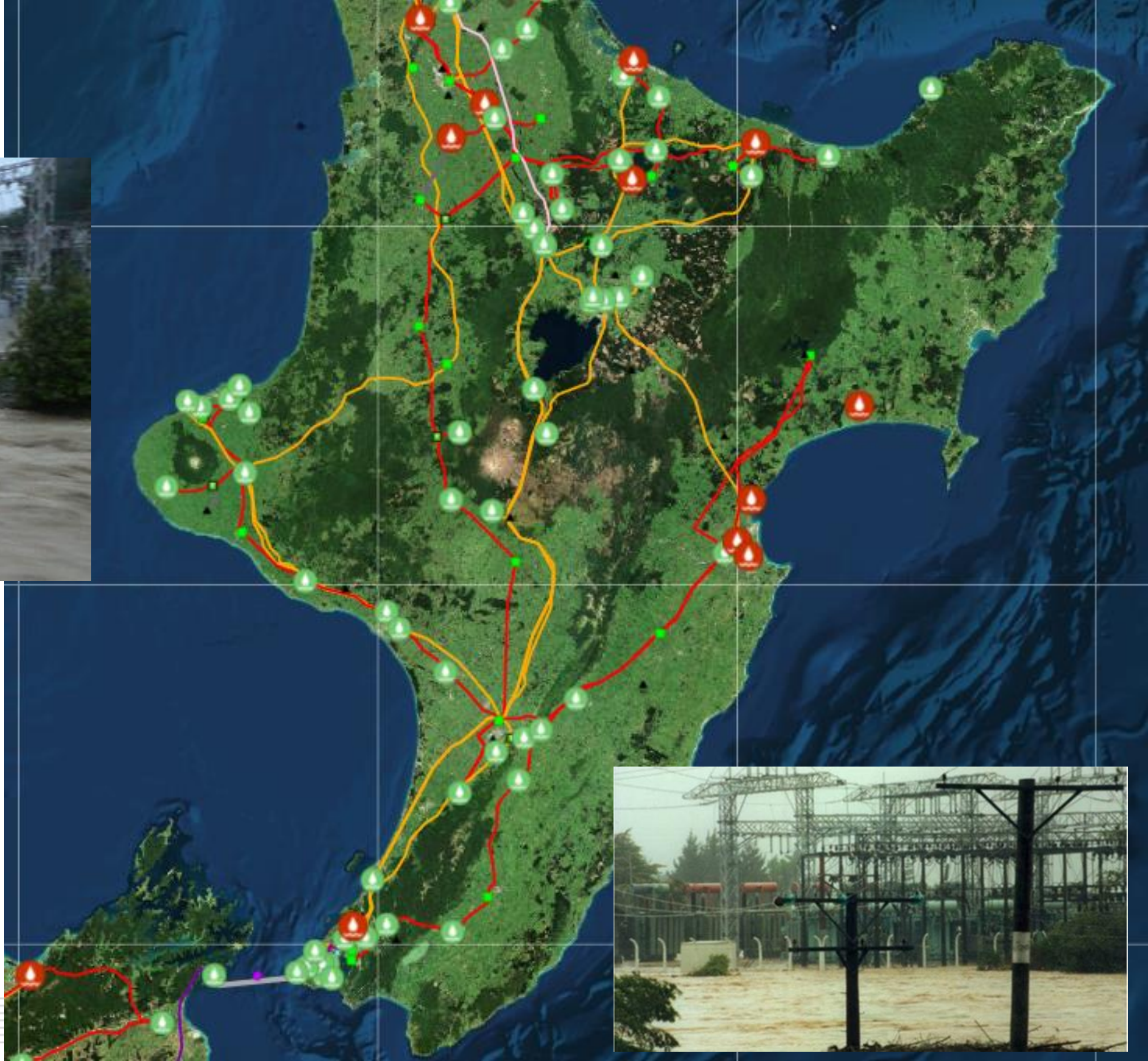
- 10-25 year return period 3mm ash
- Insulator flashovers
- 3 circuits and 500+ structures
- Use of anti-corrosion insulators
- Harden one circuit
- 100 year return period lahar



Credit: Magill et al.
Contact: Christina Magill c.magill@gns.cri.nz



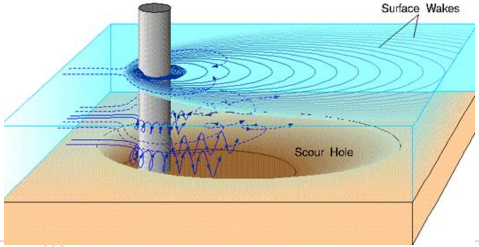
Station Flooding



Desktop estimates of Return Periods
Estimates for climate change scenario
Based on 300mm above control room floor
Develop funding for programme

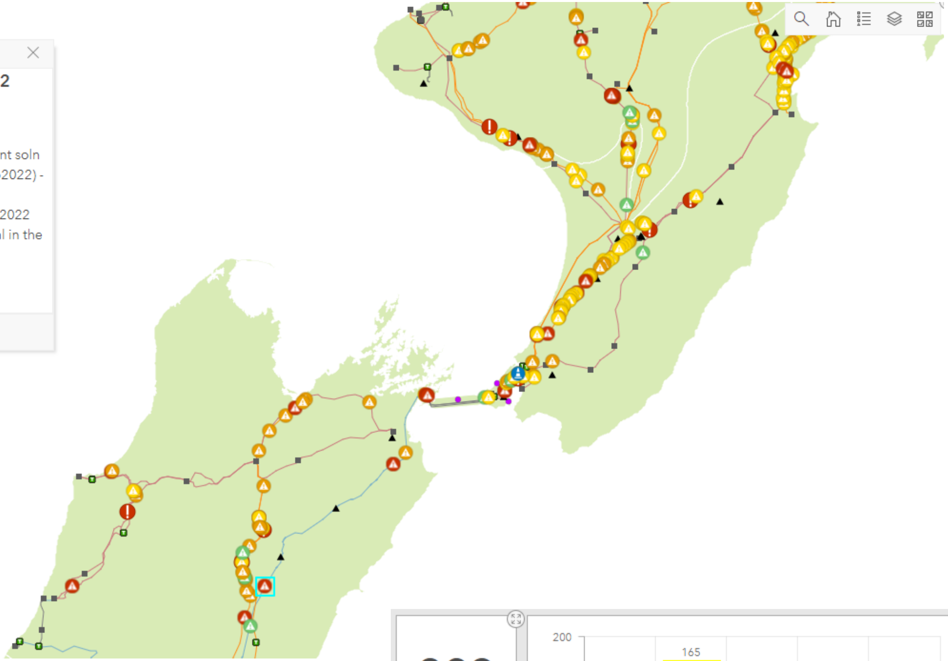
Flooding is the biggest climate change risk for Transpower

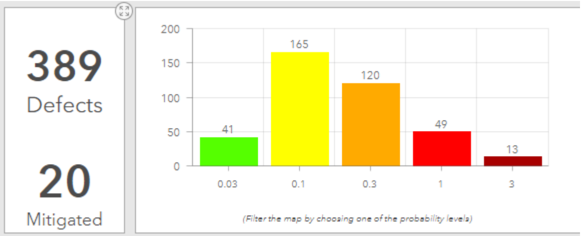
Towers in Braided Rivers



Desktop to understand which towers are critical and vulnerable
Survey and modelling to further develop risk understanding and options

National Slip register





National register GIS map of 389 slips actively monitored
Active program to manage structures and access roads

Seismic

Equipment design standards and testing

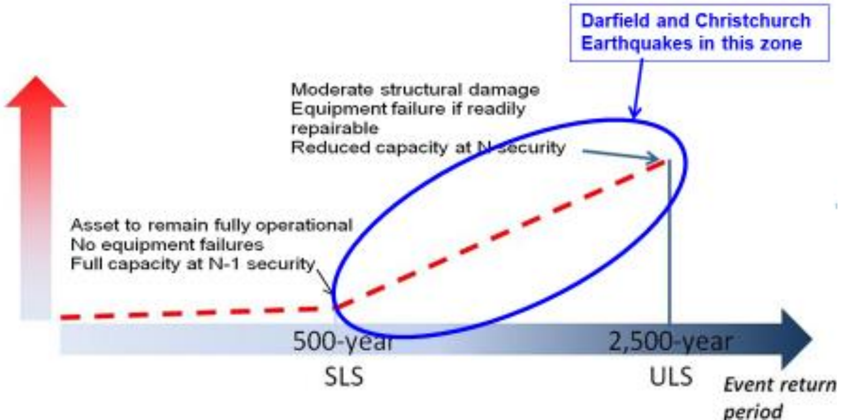
Spares where standard is not met such as bushings.

Building seismic program continues

Regulatory requirements

Transpower’s seismic policy

New National Seismic Hazard Model



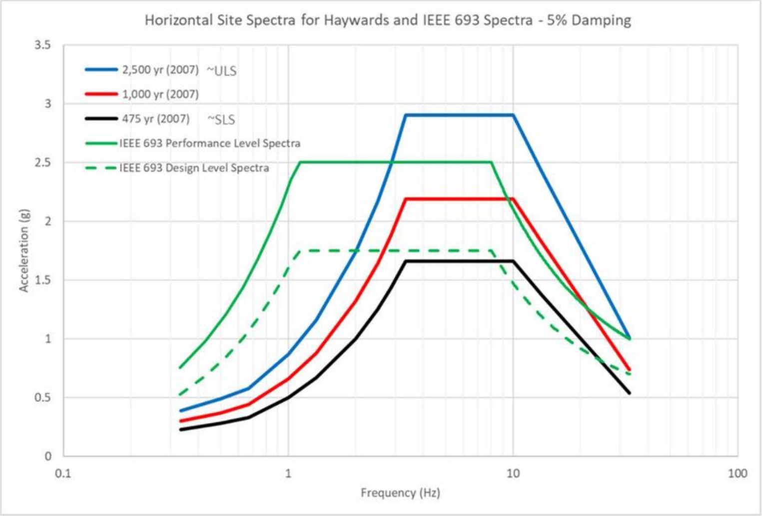


Figure 1 : A comparison between the Haywards spectra and the IEEE standard


BILE SUBSTATION
MS2
TRANSPOWER

Readiness and Response

Funding for second mobile switch room

Undertaking emergency drills

CIMS systems and training

Contingency planning and spares

Information readily available

Use of geospatial software during incidents

Funding and Decision Making

- Resilience criteria would not be justification alone for any preventative or mitigative action, but it will provide focus on vulnerable assets that are below the criteria - to review their mitigation options and ensure future site development considers the risk. Example below:

Flooding Hazard	New build design standard	Proposed Resilience criteria
Substation flooding	450 year RP	250 year RP
Flooding tower	50 year RP	50 year RP

- Common traps in using cost benefit analysis for resilience:
  - how to account for the uncertainty of likelihood and impacts
  - accounting for the ability to meet the future level of service - changes in consumer expectations
  - accounting for future growth and expansion, and changes as well as future likelihoods
  - often not positive due to the low probability for a single risk, but can be positive when combined with other risks and/or other drivers
  - not assessing trade off between investing in contingency planning and spares to hardening infrastructure
  - needs to consider other non-transmission solutions
  - option analysis needs to be fit for purpose and commensurate with the investment and business drivers

Still maturing

A combination of factors are driving the need for our maturity to improve for resilience planning:

- Asset Health and Network Risk roadmap
- Increasing number of weather events
- Electrification of the energy sector
- Impact of climate change

We are well positioned to develop in this area:

- Reliability of the grid in check
- Supportive culture with asset planners working with delivery managers

What next?

- Consult with customers on their appetite
- Propose funding for resilience
- Treat resilience as a portfolio that needs a management plan

Challenges for discussion

Development of National and international resilience standards for Transmission

- The need for resilience funding is an emerging area for asset managers of critical infrastructure.
- Increasing pressures such as the National Adaptation plan require rapid maturity progression.
- Regulators in New Zealand will also be facing increasing pressure to modernise existing codes, standards and regulations to provide the support and guidance to deliver resilience.

Transpower Planned Resilience Programme in RCP4

- Our RCP4 proposal is exploring the use of uncertainty mechanisms for resilience programs
- We have suggested changes to support investment in Resilience in the Capex IM review

Probabilistic vs Deterministic decision making

- The disconnect between probabilistic risk-based decision making and deterministic requirements.
- The deterministic n-1 circuit security requirements are an example.
- In other cases, Transpower has set its own standards on what we consider as economic e.g. towers to withstand a 300-year return period 3 sec gust wind speed.

Questions

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TRANSPOWER

Asset Management and Resilience

Electricity Authority Security and Reliability Council

Date: 26 October 2022

Contents

1. Purpose

The purpose of the paper is to summarise Transpower's Asset Management approach and how it is developing resilience planning for the grid.

2. Regulatory Context

Transpower own and operate the transmission network as well as provide the System Operator service and run the market system. Our customers are upstream and downstream within the electricity system as outlined below in figure 1. The two main regulators for Transpower are the Electricity Authority and the Commerce Commission.

The Commerce Commission reviews grid investments every 5 years through a regulatory control period process. Major capex projects (>$20M) to replace assets or enhance the grid are submitted to the Commission separately. The Commerce Commission requires Transpower to report on its asset management plans and the forecasted grid capabilities over time[1]. They provide price-quality regulation that incentivises service measures (currently +/- $10M per year) and uses quality standards, that if breached can result in enforcement action if Good Electricity Industry Practice cannot be demonstrated.

Our asset management plan is published annually and is a key foundation document that summarises our approach to asset management and the forecast investment plan and is supported by a wide range of supporting documents and frameworks across the business. Our asset management plan covers Grid, Business Support and ICT assets.

The Electricity Authority contracts Transpower to provide the System Operator service and sets the grid reliability standards. The Electricity Authority's Electricity Industry Participation Code includes a Benchmark Agreement that has default technical obligations and service levels where individual customer service level agreements are not separately agreed. The Electricity Authority also sets the methodology for transmission pricing, owns the Electricity Industry Participation Code, and requires information disclosure by Transpower on its interconnection assets.

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[1] Annual Asset Management plans and other disclosures available here: https://www.transpower.co.nz/keeping-you-connected/industry/rcp3/rcp3-updates-and-disclosures

Figure 1 - Where we fit in

3. Asset Management Journey

Our journey and operating context have developed and matured over the past 10-15 years and is outlined below in figure 2. In RCP1 the focus was on finishing the "Big Build" era and moving into the present regulatory environment. Over RCP2 and RCP3 significant effort has been placed on developing and maturing asset management capability within the business. More recently we have seen our operating context shift again through electrification, which coupled with the development of our asset management practice has yielded improvements in reliability and efficiency whilst minimising costs.

Transpower was accredited to the PAS55 Asset Management standard, and our current practice is aligning with the ISO55001 standard that succeeded PAS55. We actively review our processes and governance to improve our capability through our internal management operating system. We continue to be informed by industry best practice which when combined with a gap analysis, assists develop roadmaps to improve our asset management.

A key assurance step in our Regulatory cycle that supports both the Commerce Commission and Transpower is the use of an independent verifier. The role of the independent verifier to review our proposals and ensure our practices and funding proposals are consistent with Good Electricity Industry Practice. This process, which we will next undertake in March 2023 is more thorough and onerous than securing ISO accreditation.

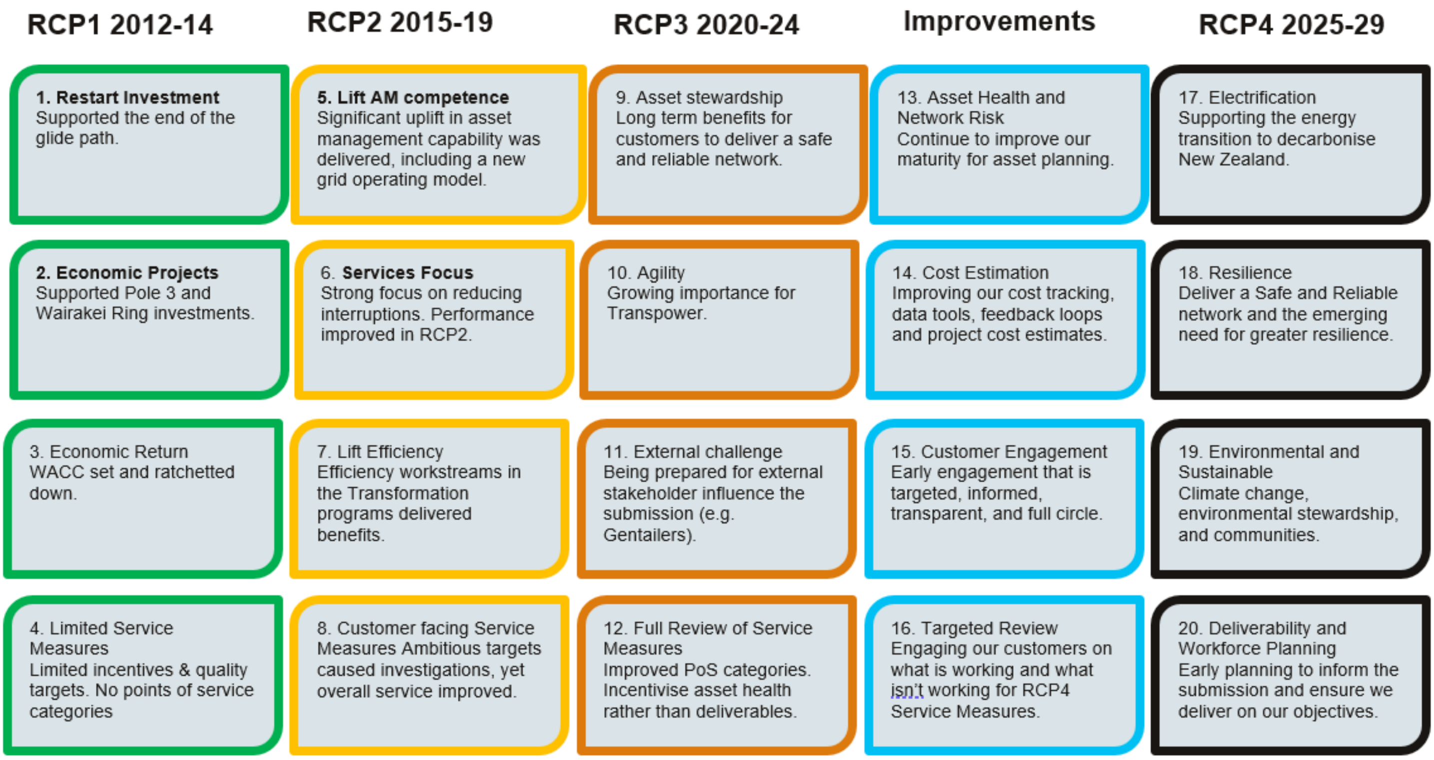

Figure 2 - Evolution of our practice and context

In 2015 we introduced our Grid Operating Model which resulted in a step change in asset management practice. We developed asset class strategies, asset health models and risk-based decision making that included life extension options for significant investments such as Power Transformers and Transmission Line Conductors. Using our life extension models we were able to defer full asset replacement and manage the uncertainty around the early years of the energy transition without affecting reliability. We now have certainty around the need and timing of demand, and our joined-up planning of replacement and capacity upgrades on the grid is delivering real savings to our customers.

Our asset management practices are continuing to improve, supported by our growing data and analytics capacity. For example: our management of transmission line conductor defects uses a model that combines visual data captured from our drone program and undertakes a fitness for service assessment for each defect identified. This technique, also used in petrochemical industry, is a first for power transmission asset management. We are extending this capability into programmes covering resilience whilst ensuring our decision making is strategically joined up.

Two examples of our developments in this area are the Asset Health and Network Risk Roadmap[2] and the System Operator Future Security and Resilience Roadmap[3]. Our progress against our Asset Health and Network Risk roadmap is presently being reviewed by GHD who have been engaged to provide an independent expert opinion. This will be provided to both the Commerce Commission and Transpower and acts as another form of assurance that we continue to develop and mature our asset management practice.

[2] https://www.transpower.co.nz/sites/default/files/uncontrolled_docs/AHNR%20Development%20Roadmap%2024%20Nov%202020.pdf
[3] https://www.ea.govt.nz/assets/dms-assets/29/Appendix-A-Phase-1-final-report.pdf

Figure 3 - Recent publications on Resilience

4. Asset Management for a Safe and Reliable network

Our Strategic Asset Management Plan uses our company priorities in Transmission Tomorrow to develop the key objectives that flow into our asset class strategies. Within our asset class strategies and investment planning, we measure the reliability and safety performance of an asset class such as transformers, to include targets based on benchmarking and improvement initiatives.

We review these targets and our asset class strategies based on performance and via our internal Reliability Working Group where we actively look for improvements in our practice and approach. Our maintenance plans are reviewed using Reliability Centred Maintenance and Preventive Maintenance optimisation techniques. This process is shown in figure 4 and is undertaken across all our key asset classes such as:

1. Transmission Lines:
    a) Towers
    b) Foundations
    c) Conductors
    d) Insulators and hardware

2. Substations:
    a) Power Transformers
    b) Indoor switchgear
    c) Outdoor switchgear
    d) Critical facilities such as buildings and substation fences

3. Secondary Assets
    a) Protection systems
    b) Substation management systems

4. HVDC and Reactive assets such as capacitors and Reactors

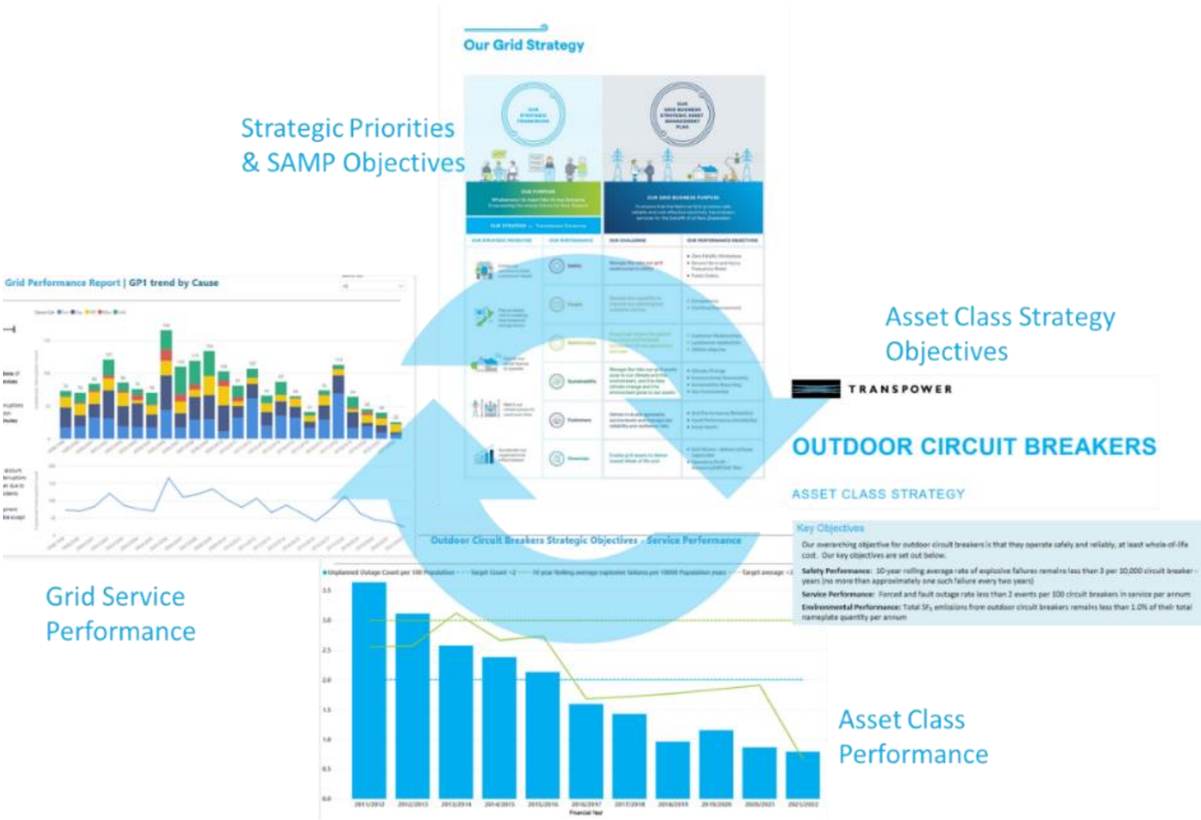

Figure 4 - Performance objectives

The reliability of our network is also measured through our customer performance reporting and the incentivised service measures. Our asset performance report and grid performance report are published every 6 months to keep track of trends and identify improvements. The Grid Performance Report is presented to the Commerce Commission every 6 months as an update on our service measures.

An example of this process in action is the Synchronous Condensers on the HVDC system. The reliability of these assets is critical in maximising the transfer capacity of the HVDC link.
Over the last decade there has been increasing unavailability of synchronous condensers which in turn has meant that HVDC link has not been able to operate at maximum transfer capacity at times.

Availability studies have identified that the 1200MW available capacity of the HVDC system is often reduced by either reactive power asset or AC circuit outages. An initial review of the past 12 months shows that capacity is rarely reduced more than 200MW, and that for the capacity reduction between 50-200MW occurs about 67% of the time, the majority of which is caused by the unavailability of the Synchronous Condensers. At present, the constraints caused by the Synchronous Condensers do not typically have a material impact on the operation of the electricity market. However, the future generation mix, and accelerated electrification will increase the requirements for HVDC availability and thus improving the reliability of the Synchronous Condensers is a focus.

The Synchronous Condensers have historically had various components refurbished and replaced however their overall health has been deteriorating. A majority of these issues were associated with the auxiliary plant rather than the main Synchronous Condensers.
By monitoring reliability and developing Asset Health models we have now identified the need to undertake further refurbishment and upgrades of these assets. This refurbishment work is commencing in RCP3 and we have put forward the remainder of this refurbishment program as part of our draft RCP4 proposal.

Our planning decision framework below in figure 5 shows the key inputs into investment decisions. The key inputs, guided by the asset class strategies, include asset health and criticality, known or committed customer investments, grid enhancements and asset feedback collected from service providers and investigations. Our progress in developing asset health information has enabled more systematic and repeatable decision making. Our condition data programs, analytics and data quality programs ensure on-going confidence and improvement in this information.

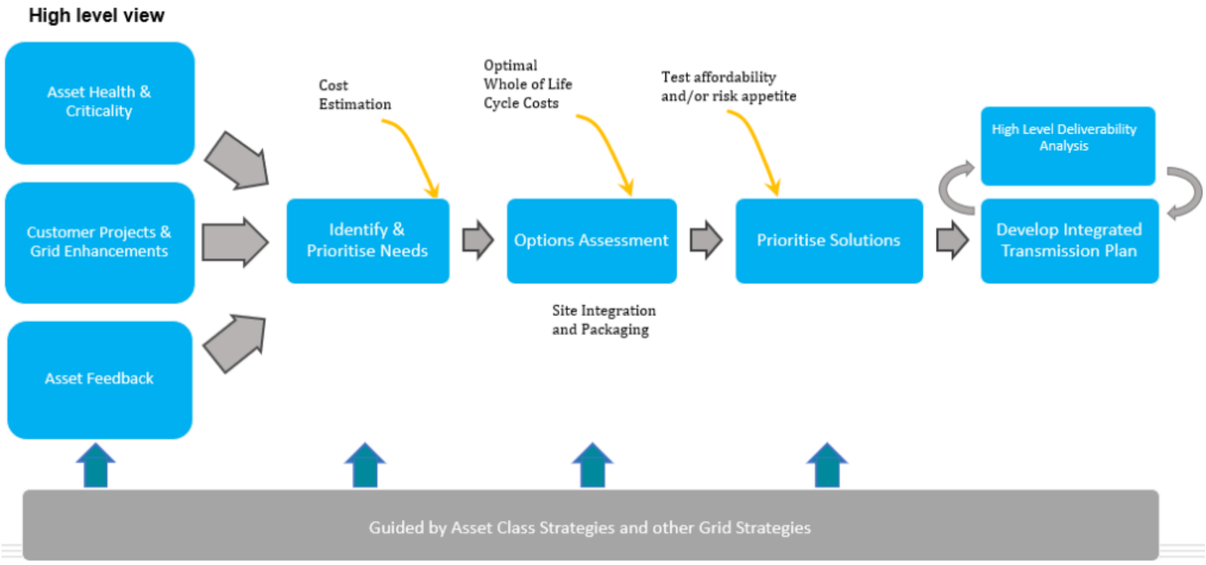

Figure 5 - Simplified decision framework

Through tracking failure rates and undertaking forensic assessments on replaced assets, we can reward good performing asset types through extending life in our health models, and fast track work where reliability issues are discovered. Our range of intervention options have advanced beyond simple asset replacement and now consider the trade-offs in refurbishment, a wait and see approach, and how contingency planning and defect management can manage risk and extend the useful life of an asset.

We have undertaken a number of forensic assessments on circuit breakers over the past 5 years, focusing on those makes and models with significant numbers in our fleet. Most of these detailed inspections have given us confidence that we can extend the expected useful life for many of these assets by at least 10 years. This has allowed us to recalibrate our asset health models and defer significant replacement investment without incurring more risk on these makes and models. Across RCP2 and RCP3 this has resulted in us deferring the replacement of at least 50 circuit breakers.

Examples to reduce whole of life costs of managing our assets include conversion of selected transmission steel lattice towers to steel poles, rather than continual tower painting, replacement of bushings on Power Transformers rather than full replacement and cathodic protection to extend life of transmission tower foundations. These improvements allow us to manage asset risk, sustainability ramp up skilled resources, reduce revenue price shocks to end consumers and buy time to align replacements with tactical upgrades to incorporate future electricity demand.

We are seeing a significant increase in the number of new connections and connection enquires as part of the on-going decarbonisation of the economy. Adding more connections to the transmission network can influence its inherent reliability. To mitigate this, we undertake probabilistic reliability modelling. This informs the configuration and type of new customer connections to the network. This enables us to strike a balance between providing cost effective new customer connections for new generation and demand, whilst minimising the reliability impacts into the future.

Given the important role our Asset Management plan has in communicating our overall approach, along with our reliability and investment plans, we seek to continually improve the readability and clarity within our Asset Management plan. This includes making use of infographics and visualisations to help convey key information to readers as shown.

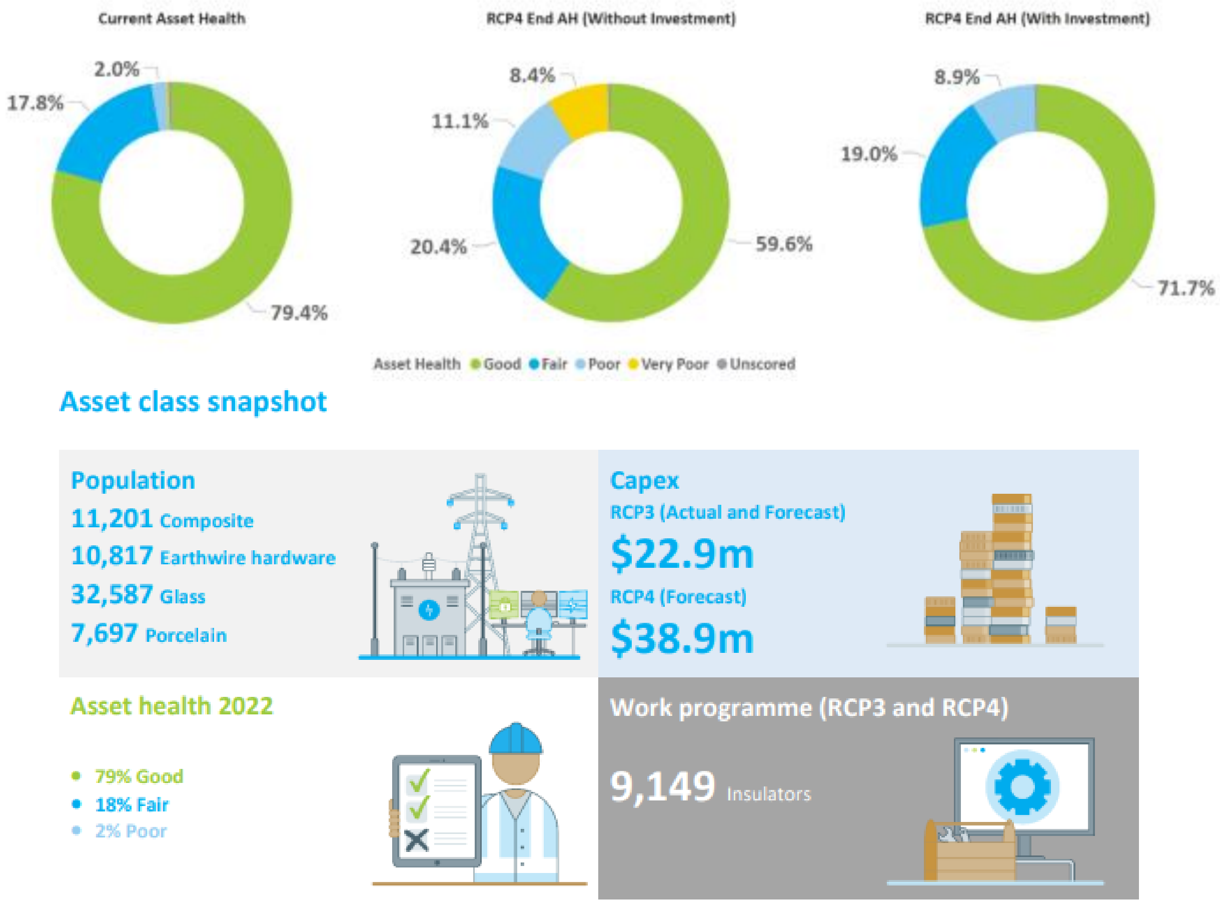

Figure 6 - Transmission Line Insulator asset health and plan snapshot

Our asset management plan is a core reference document, ensuring our stakeholders and customer can understand comprehend our plans is critical to ensure they can have meaningful engagement with us through this process. It is a key part of our RCP4 consultation process, that is presently underway.

5. Resilience is an emerging area

A large proportion of our infrastructure is situated within areas prone to a range of natural hazards. Climate change will increase both the frequency and magnitude of many of the climate related natural hazards that occur. Our infrastructure could also be impacted by a range of other major hazards which are outlined below in figure 7.

		THREATS	GRID MAJOR HAZARDS
NATURAL HAZARDS		Seismic	Substation buildings, equipment, and bus structures Transmission lines and cables Communications
NATURAL HAZARDS		Volcanic	Insulator flash over from ash and line loading damage Disruption to electronics / AC systems Lahar impacting sites/lines
NATURAL HAZARDS		Tsunami	Risk to towers/poles Risk to substations Risk to subsea cables and cable stations
NATURAL HAZARDS		Space weather	Geomagnetic induced currents Transformer damage, voltage control and protection issues No voice communications and no satellite communications
NATURAL HAZARDS		Land stability	Risk to towers poles Risk to access tracks Landslides damaging buildings and structures
NATURAL HAZARDS	WEATHER RELATED	Flooding	Risk from braided rivers (and other rivers) to towers/poles Risk to substation control equipment and cables Risk to ICT optic-fiber routes
NATURAL HAZARDS	WEATHER RELATED	Severe wind and tornados	Tower and pole collapse Increased bushfire risk Conductor failures increase
NATURAL HAZARDS	WEATHER RELATED	Snow	Snow ice loadings on lines Snow loading on buildings
NATURAL HAZARDS	WEATHER RELATED	Increased temperatures	Conductor derating Peak Loads move into Summer Insufficient cooling of control equipment at substations
NATURAL HAZARDS	WEATHER RELATED	Bush fire	Bushfire encroaching assets Transpower starting bush fire Flashover on lines due to flames
ASSET RISKS		Common mode failure	Asset failure causes widespread long duration outage Critical towers understrength Cascade failures and substation design
ASSET RISKS		Vandalism, sabotage, terrorism	Physical damage of assets and theft Interference with network operations and with market Denial of service, corruption of our data
ASSET RISKS		Asset fires	Substation building fire risk Transformer cascade fire risk Cable fire risk and other equipment fire risk

Figure 7 – Threats and major hazards to the grid

Our aim in addressing resilience needs, is the ability to avoid extended power outages and quickly restore power when major hazard events occur. It is important to understand the key differences between resilience and reliability: Reliability is influenced by localised impacts of shorter duration (usually minutes or hours). We are well practiced in addressing reliability events. Resilience is focused on major hazard events that have large impacts in a location or on load or generation. These can last for days or longer, are non-routine and more difficult to plan for. This is summarised in figure 8 below.

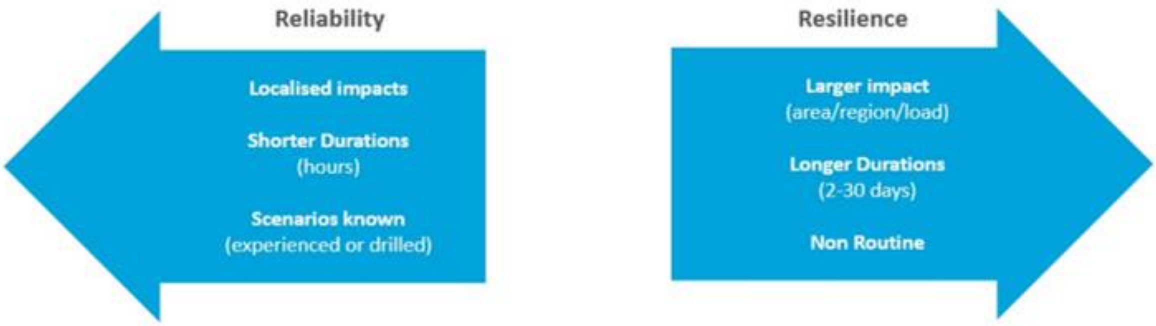

Figure 8 - Reliability versus Resilience

As a lifeline utility, Transpower must be able to function to the fullest possible extent, during and after an emergency, even though this may be at a reduced level. To achieve this, we work to understand the network vulnerabilities and acceptable risk levels and anticipate the future changes that may occur through load growth, new connections and Climate Change. Our grid infrastructure, including our information technologies (IT) and operational technologies (OT) that support it, are designed and operated to cope with major hazards and minimise impacts. Although it is impossible to fully prevent all major hazards, we seek to minimise the impact by ensure assets are appropriately robust to significant events and through contingency planning to ensure we have the capability and equipment to rapidly restore service.

We have a greater understanding of what is vulnerable and critical on the grid thanks to developments in scientific research and our risk modelling. When it comes to climate change related risks, we have determined which assets will become increasingly vulnerable and the range of interventions that are needed to mitigate the effects. Our capability to plan in this area has matured significantly in the last few years, and we are now proposing dedicated funding for resilience programs within our next regulatory submission.

There is increasing certainty of the timing and scale of the decarbonisation of the energy sector in Aotearoa New Zealand. Decarbonisation will see a greater reliance on electricity in the future, and we anticipate that societal expectations for a resilient and reliable transmission service will increase. Our discussions with customers and consumers already show an increased awareness of the need for resilience.

6. Our Resilience Approach

Infrastructure owners must consider the resilience of their assets within their asset management approach. Our strategic approaches that manage these major hazards are described by the four areas of resilience known as the “four R’s”- Reduction, Readiness, Response and Recovery (Figure 9). These approaches are implemented at varying levels of maturity dependant on our perceived risk or understanding to date of the specific major hazard.

Figure 9: Our Resilience Approach

Historically our resilience investment was mainly focused on building back better from events or through grid upgrades and asset replacement, rather than through targeted pro-active investment in risk reduction and readiness. For example, when replacing a Power Transformer or reconductoring a Transmission Line these replacement assets are generally designed and built-in accordance with our new build design standards. We began to change to a more pro-active approach in RCP2 (2015-2020) when we invested in the mobile substation and spare transformers as part of our readiness. This was followed during RCP3 (2020-2025), when we reviewed and increased our spares holding for critical equipment.

When deciding where to invest in resilience for next regulatory period, RCP4 (2025-2030), we need to balance our approach between a proactive approach of risk reduction and readiness, with a reactive approach of responding and recovery. Maintaining a purely reactive approach, when the frequency and severity of natural hazards increasing, would result in customers and end consumers bearing the cost of building back and the additional disruption to service.

7. Achieving Resilience through Risk Reduction

In developing proactive resilience programs to deliver risk reduction for our network, we are using resilience criteria and risk information to identify vulnerable and critical assets and then apply a prioritisation process to options. Having resilience criteria for existing infrastructure is important to identify vulnerable assets. It can be overlayed with asset criticality to prioritise our investigations and investment. In the future we will extend our resilience criteria to include expected restoration time from major events e.g. an Island wide blackout.

The benefits of having resilience criteria include:

- transparent assumptions can be scrutinised and help manage public expectations of achievable service levels
- dependent services can have a clearer understanding to inform their contingency planning incentivising and identifying resilience upgrades to improve existing levels of resilience.

The resilience criteria we have developed are summarised in figure 10. They have been used to identify vulnerable assets and helps provides an appropriate balance between providing resilience through strengthening existing assets compared to what we would do if we were building new. This ensures we set reasonable thresholds for vulnerability.

For example, our new substations are built to withstand a 1:450-year return period flood event even though our resilience criteria are defined as 1:250 years. For contrast, some of our existing older substations have 1:100-year return levels for some equipment on site and seeking to meet modern design standards is not generally practicable or cost effective.

Hazards	Climate Change related	New build design standard	Resilience criteria	Currently vulnerable and critical
Substation flooding	Yes	450-year RP	250-year RP	12
Transmission Tower Flooding	Yes	50-year RP	20-year RP	14
Wind event tower (excl. HVAC)	Yes	300-year RP	150-year RP	>400 HVDC
Slope stability of towers and poles	Yes	30-year RP	30-year RP	52
Seismic IL4 [4]	No	2500-year RP	2500-year RP	30
Tsunami	No	2500-year RP	2500-year RP	5
Volcanic tephra (ash)	No	50-year RP	25-year RP	~150
Space weather	No	300-year RP	100-year RP	14

Figure 10 – Resilience Criteria

Another example is the evolution of New Zealand's transmission line design criteria which has evolved over time with improved understanding of hazards and how this translates to mechanical loads on the individual towers. The changes in economic prosperity during the twentieth century also had a significant impact on design standards and the legacy of build. More than half of our fleet of transmission towers were built before 1980 and are subject to varying design standards and different construction methods.

Figure 11 below shows the evolution of tower design over the last 80 years. There is a clear reduction in the applied design standard post World War 2, which resulted in 40 structural failures between 1957 and 1963. Design standards changed in 1963, and were revised further in 1968 following the Wahine storm. Towers are strengthened as part of significant upgrades such as reconductoring projects or tower replacement work.

[4] IL4 is Importance Level 4 as defined under the building seismic assessment guidelines.

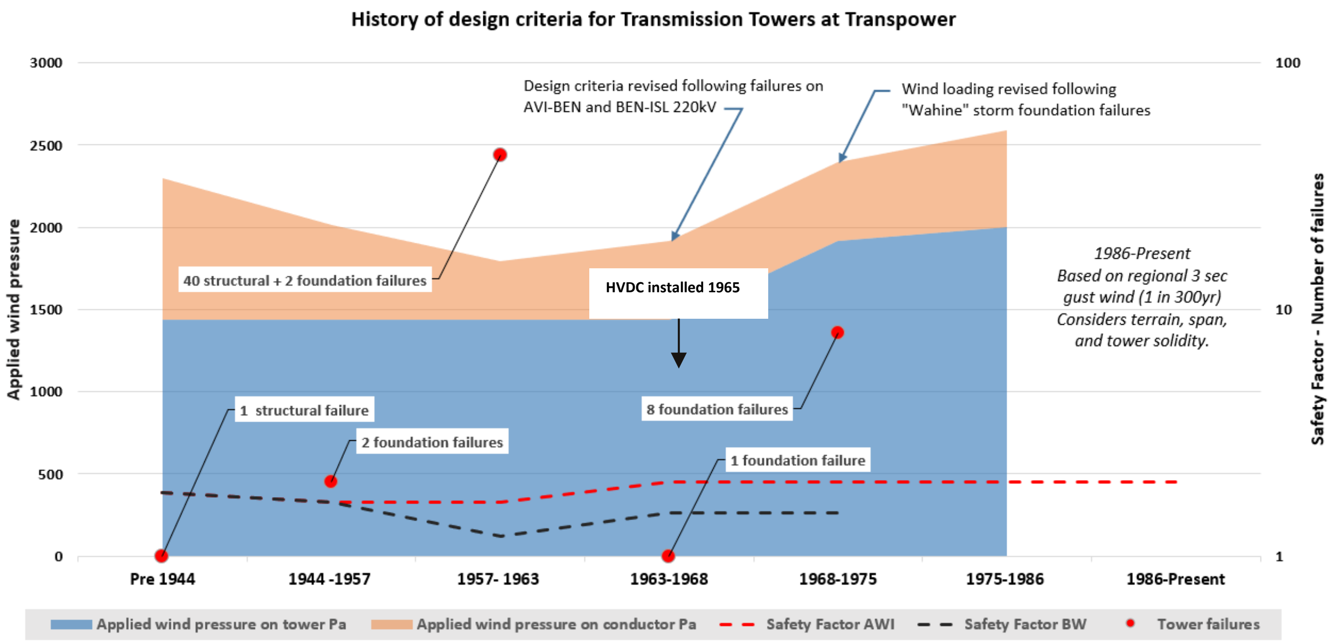

Figure 11 - Historical design standards

The effects of this changing design standard over time are particularly evident when looking at the history of the HVDC line. This line was built in 1965 and designed using relatively low wind pressure loads and a highly optimised design to minimise costs. During its 57-year history there have been 7 major asset failure events on the HVDC Transmission line, the majority of which were due to high wind with gust speeds exceeding 200km/h which are summarised below in figure 12. This averages to an event every 8 years.

Year	Location	Failure type	Towers	Conditions
1963	Weka Pass – Exposed Ridge	Transverse Tower collapsed during construction	820	Wind – Gale force
1968	Benmore-Fighting Bay (location not known)	Tower damaged and conductors down	Unknown	Wind 240km/h
1975	Cairn Ridge near Coalgate – Canterbury	Collapsed – Buckling failure above first horizontal	583-589 & 791	Wind >160km/h
1988	South of Christchurch – Exposed ridge	Collapsed – Buckling failure above first horizontal	673, 674	Wind 200-223km/h
2004	Molesworth – Acheron Valley	Towers collapsed	1121,1132, 1133	Wind 230km/h
2016	East of Blenheim – Near tributary to Wairau River	Tower damaged	1447	Kaikoura Earthquake
2021	Weka Pass – Exposed ridge	Insulator hardware component failure	811A	Wind >120km/h
2022	Oteranga Bay – near coast	Insulator hardware component failure	006	Wind 50km/h

Figure 12 - History of HVDC tower failures

There have been several dedicated strengthening or upgrade programs completed on the HVDC line, most notably in 1990 and 2010. Along with these dedicated programs of work, we have undertaken repairs or tower replacements in response to identified issues on the line and on-going foundation refurbishment programs[5] have strengthened approximately 500 tower

[5] Primarily through the grillage concrete encasement program and during recent reconductoring work on the OTB-HAY section of the line

foundations. Due to the evolving nature of the electricity system and the growing importance of the HVDC system to balance generation and demand we are intending to invest in a further strengthening program during RCP4 targeting vulnerable towers and those in difficult or remote areas. Our experience is that a tower on flat ground with good access can be repaired quicky in a matter of days while remote towers with difficult access may require several weeks until a permanent repair can be completed, often requiring Bi-Pole outages to undertake the work safely.

Comparing the resilience criteria against the legacy design is not always straightforward. In some instances, it can be simple such as comparing an expected flood height with known equipment levels. In other instances, limitations in historic records may require detailed surveys of equipment and the development of finite element models to determine the loading applied to equipment and expected capacity. Quantifying vulnerabilities is important step in prioritising investment into risk reduction or readiness.

Our risk reduction programs are typically the cost-effective strengthening or protection of those assets that are vulnerable and where their failure is likely to have the largest impact on the service provided. We use power system modelling to identify the likely effect on consumers considering the asset that has failed and its likely restoration time. When combined with expected unserved energy we can determine a monetised service performance criticality of an asset. We also monetise safety, the environment and direct cost at asset level for a major failure.

Another example of this is our approach to managing the risks associated with towers in braided rivers. In total we have 69 towers in braided rivers but have identified 14 that have the greatest impact if damaged, this is shown visually below in figure 13 with the size of each circle representing the criticality of each tower.

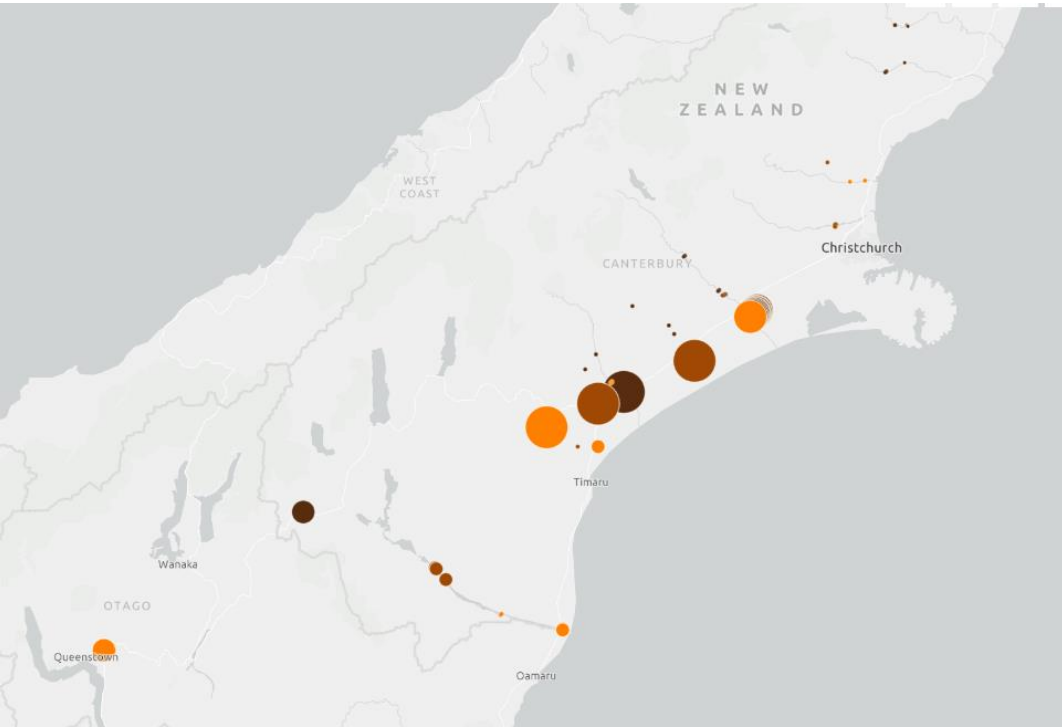

Figure 13 - Towers in braided rivers

Our criticality analysis helps us identify which assets have the largest impact to the system and the service we provide to our customers. We are mindful that our current criticality analysis considers short duration events. We can modify our analysis with different restoration times and values of lost load that are more appropriate to the event which is a key step within the more detailed cost benefit assessment. Where practical, we will prioritise on cost benefit whilst considering our risk appetite. We also consider the increased risk from climate change in the prioritisation process and will ensure the design of our assets takes this into account.

Proposed solutions will undergo further investigation and analysis including the option of non-transmission solutions to address the need to invest. The resilience programs align with our replacement, enhancement, and development investments, as those investments also improve our resilience through new build to current design standards. We anticipate that there will be the ongoing need for funding resilience programmes in future regulatory control periods and have developed a resilience funding envelope for RCP4.

Figure 14 - Land subsidence

In many instances, early identification and intervention is the most cost-effective means of managing these resilience risks. An example of this is the routine patrols we undertake after severe weather events to identify new damage such as land subsidence and slips such as figure 14. Early identification of these allows us to monitor on-going land movement, implement low-cost maintenance interventions and maintain an on-going prioritisation of our remediation program.

The example in figure 14 is a landslip that requires close monitoring and investment in drainage to help mitigate any further subsidence or risk to the tower. Given the location of this specific tower, relocation or restoration after failure would be extremely difficult and time consuming, thus the best course of action is to undertake proactive work to maintain or reinforce the status quo. These proactive interventions are relatively low cost and complexity compared to relocating a tower, ensuring we identify where these interventions are required is a key component of managing our overall risk.

The approach we take to each hazard must consider the site-specific complexities and consideration of the likely response should an event occur.

8. Readiness

Our readiness comes from the investments we make into purchasing and maintaining emergency response equipment and capability, such as our mobile substation, portable switch room, and temporary support structures as well as investment in spares, contingency planning, inspections, and monitoring. A key area is the investment in people through our service providers *who maintain and build our assets) and our own personnel. We have strong feedback loops and programs that support this management and ensure that learnings from events are captured in the business with changes in our operating model and processes implemented to be better prepared for the future.

Many of the smaller load centres within New Zealand are supplied at N-security with no redundancy as an appropriate cost/service level trade off. N security sites have only one level of resilience, where only one component of the system has to fail to interrupt supply. This reinforces the need to be ready to respond. We work with our customers to agree how we best mitigate the risk in the rare occasion a major component fails. For example, some of our smaller sites have been designed in a way that enables quick deployment and connection of diesel generation or the mobile substation.

A recent extreme weather event was the Rangitata river flood in 2019. This event required 9 towers to be replaced/repaired on the Roxburgh- Islington line across the river. This line is one of three that supply the entire upper South Island. A temporary line was installed within three months to ensure reliable supply to the major upper South Island load centre was in place for the winter peak, with the final repair happening within the river some 9-12 months later.

This event presented two challenges, the number of towers lost in the event and the difficulty making temporary repairs. We have temporary towers ready to deploy to cover tower failures due to wind of flood events. We have successfully restored damaged transmission lines to service within two to three days in the past. Both the number of towers damaged and access issues after the event have challenged our typical restoration approach. Following this event, we reviewed our conductor spares holding for similar cascade failures, and embarked on risk review of all towers sitting within or at the edge of braided rivers. This has resulted in us increasing the amount of conductor spares we hold and a planned investment program to improve the resilience of the 14 towers identified as vulnerable and critical.

We have detailed spares policies for all our major assets such as Transmission Lines, Substations and HVDC. We differentiate between strategic/emergency response spares and those required to be held as inventory spares within our warehouses. Some examples of the strategic spares we hold are outlined below:

1. One spare emergency portable 33/22/11 kV switch room that can be deployed at short notice in the event of a major failure of a MV switchboard or outdoor 33 kV switchyard in an event such as a major fire, landslide, or earthquake.
2. A mobile substation (15 MVA 110 kV/33-22-11 kV) which can be used at some N security sites where site made ready works have been undertaken (provided it is not in use for project works).
3. Nineteen strategic spare transformers which provide coverage for 98 percent of our entire present and future three phase power transformer assets with the aim to restore full security of supply within one calendar month of a major transformer failure. On site spares are provided at most sites where single-phase transformers are installed. Spare power transformer components are available.
4. A minimum of two circuit breakers per make and model are kept as spares including appropriate quantities of components.
5. Spare cables, cable joints and cable terminations.
6. Spare conductor, insulators and hardware are available to respond to outdoor structure and bus work failures.
7. Spare emergency structures and poles strategically located throughout the country
8. HVDC spares including converter transformer bushings, wall bushings, filter coupling caps, DC current transformers and circuit breakers.
9. HVDC subsea spare cable joints and cable terminations.
10. Eight HVDC temporary pole structures
11. Approximately 2000 spare protection relays for a population of over 12,000 relays with over 600 variants

We continuously review our spares holdings and are increasingly mindful that the frequency of weather-related events is likely to increase in the future, recent experience supports that view. This may require us to increase overall spares holdings to ensure we can respond to multiple events in a given year due to the extended lead times on some of this equipment.

To ensure our service providers are capable of deploying these assets when required we undertake routine training and familiarisation exercises (i.e. for temporary support structures). Under our new Grid Service Provider contracts we have agreed Emergency Response Plans for each service area. On average we undertake 1 deployment of a strategic spare transformer each year due to failures that occur[6], this means that in addition to on-going training it is a skillset that is well developed amongst our service providers. We have never had to deploy a mobile switch room to cover a failure but have plans in place to undertake a trial of this during our next regulatory period RCP4 (2025-2030).

One area of practice that has significantly improved in recent years is our preparation for weather events. This include monitoring of weather forecasts, including asset location specific forecasting information from MetService, ensuring assets are returned to service where possible in advance of events, and rescheduling of outages to increase resilience of supply. As part of this we also pre-position service providers around the country to help mitigate issues such as road closures due to slips or snow. This ensures we can patrol faults and return service quicker should an interruption occur.

Our on-going investigation into the major hazards and climate related risks on the Grid means we also monitor known vulnerabilities during weather events to ensure we can pre-emptively mitigate impacts as best possible should a failure occur. A recent example of this included the recent flooding in Nelson where we closely monitored, and actively cleared material from, a stream near our Substation, figure 15 below, and worked closely with Network Tasman to ensure contingency plans were in place should the flooding impact our site.

The bridge in the figure below had some of the important substation cables running along it, and in the event that the bridge should be damage it may have created disruption to the supply from the substation and also limited our ability to access the site across the stream. At this site, past projects had installed a separate cable bridge to a higher flood level which many of the highly critical cables now run across as we progressively improve the resilience of this site. Should the stream have ultimately burst its banks then the substation may have also been inundated with water created further potential for disruption and damage.

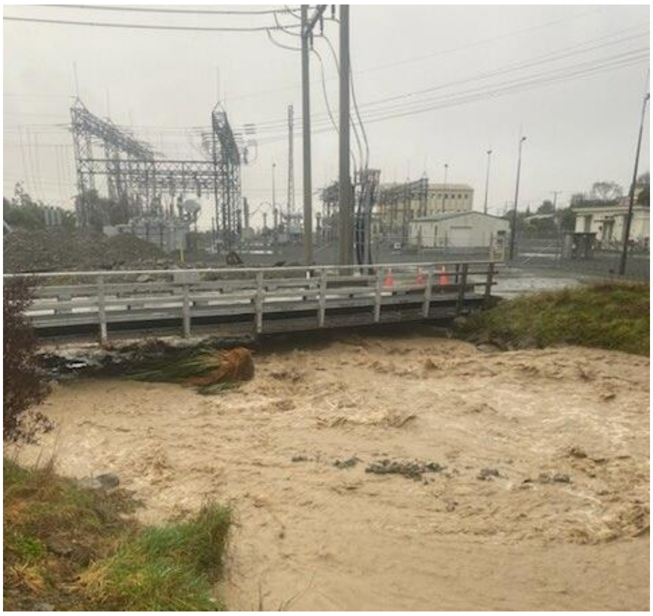

Figure 15 - monitoring of flooded stream at Stoke

[6] Our historical failure rate for Power Transformers is approximately 1 per year from a fleet of ~330 which equates to around 0.3%

9. Response

As a critical lifeline utility, we have we followed the lead of the National Emergency Management Agency (NEMA) and have implemented the Coordinated Incident Management System (CIMS) approach to managing significant Grid interruptions, enabling a good interface into multi-agency events. This ensures the correct separation and accountabilities between our "Business As Usual" response functions and those requiring more coordinated emergency response. These protocols are well established within Transpower and we undertake regular training and practice of this structure to ensure it operates well when required to do so. A recent example was the use of CIMS in our response to Covid-19 and the broader engagement with NEMA and the wider electricity industry. Transpower also runs the Electricity desk at the Beehive during a National civil defence event, co-ordinating the response of the industry.

Some examples of recent failures that have required us to utilise our strategic spare assets and deployment plans are outlined below along with some of the key learnings from each event.

A Power Transformer Failure at Albany – North Shore load on N security

We hold spare transformers located strategically across New Zealand with the objective of being able to replace a failed transformer at a substation with N-1 transformer capacity within four weeks. This transformer failure at Albany substation was an important interconnecting Transformer in the Auckland electricity transmission network that supplies Vector. As a result of this failure our Wairau Road substation was on N security. In responding to this failure, we were able to utilise a strategic spare asset already stored on site at Albany substation and reconfigure other existing assets to restore N-1 security within seven days. As part of our on-going review of the forward investment program we actively consider the location of our spares to ensure they are in locations that best suits the likely deployment. In this instance, having the spare available on site reduced the time to restore N-1 security by 10-14 days through not having to relocate the spare from another site.

A key learning from this failure response was the benefits in timely and open communication with the impacted stakeholders. While there was no loss of service from this event, to manage our customers concern on the potential impact should the remaining transformer have an issue before replacement could occur, we maintained daily communication with Vector to update them on our progress.

B Power Transformer failure at Gracefield - Lower Hutt load on N security

Load at Gracefield substation is supplied by two supply Transformers, due to the configuration at this site the failure of one Transformer puts the load on N security from Haywards. This means that a tripping of the Transmission Line from Haywards substation or the substation assets at Gracefield could result in a loss of supply. In responding to this transformer failure, we used a strategic spare transformer to restore service to full security within 3 weeks. There was no loss of service from this event.

Figure 16 - removal of failed transformer at Gracefield

In this case the spare transformer had to be mobilised from where it was stored at our Linton substation. This instance was different to the failure at Albany as it required us to firstly remove the failed transformer from site to make space for the replacement asset and mobilise the spare from a different site. This required significant coordination across multiple providers as while the failed transformer is being removed from site (figure 16 above), the replacement asset must also be prepared and mobilised from its installed position.

A key learning from this event was transport planning and getting the spare transformer into position requiring partial demolition of fencing and a hydraulic gantry system whilst maintaining overall site security.

C Weka Pass Conductor drop and tower failures

The failure of a tower insulator fitting on the HVDC line at "Weka Pass" in North Canterbury resulted in one of the two transmission line conductors dropping to the ground. It caused damage to adjacent towers on this section of the HVDC line as well as dropping across State Highway 6. Fortunately, the operation of the HVDC control system resulted in the conductor being automatically deenergised before it reached the ground including resting across the state highway and a Mainpower 33kV distribution line.

Figure 17 - HVDC crossarm repairs

Due to the location of this failure and nature of the damage sustained to the other towers, recovery from this event required at total shutdown of the HVDC link to complete the full repair safely. Work crews and equipment were mobilised from other maintenance and project works to restore the HVDC line as soon as possible. Despite significant damage across multiple structures and the timing of the event coinciding with New Zealand entering the Covid Delta national lockdown, we were able to repair the damage and reinstate the circuit within a little over a week. Work included creating new access tracks, building crane pads, fabrication of new cross-arms, re-installation of all damaged components and re-installing the conductor. Mainpower were able to restore their customers supplied by the 33kV line by backfeeding from other sources.

Once the failure mode was confirmed as a fitting within the insulator set, we quickly identified all other locations with this fitting in use and prioritised the removal of these on the HVDC Line. The investment in our Aerial Surveys and PLS-CADD models meant we could quickly identify the highest loaded components and prioritise our response to replace this fitting and those with a similar design.

A key learning from this event has been the critical role that accurate Asset Information has to enable timely and effective response to failures and further risk mitigation. This includes improving our reporting and assurance that routine maintenance and project work is completing all changes in our core systems such as asset information changes and updating as-built drawings.

10. Recovery

There are a number of key challenges for recovery of service in the Transmission system. This includes access and weather. Much of the grid is remote and mountainous making restoration work difficult as it can require bring in heavy construction equipment, especially during severe weather events which can damage access tracks or make them dangerous to use with heavy equipment. Access is also challenging in other ways, for example repairing or replacing structures within a flooded braided river.

Other issues include supply chain logistics, our nearest suppliers for some equipment are within Europe, and lead times for items such as Power Transformers or cable repair ships can be years.

Full recovery can take significant time and as part of our readiness we factor in lead times when determining our spares coverage. Another key step in the recovery phase is reviewing whether this is an opportunity to build back better or move/realign the assets to avoid future events. This was a key outcome from the Rangitata event discussed earlier in which the replacement foundation and tower design accounted for this risk.

A critical step in the Recovery phase is to undertake post event reviews and ensure lessons and improvements are captured so that business processes can be improved. This feedback is not just limited to the response phase and can include improvements to procurement specifications, design standards and changes to maintenance regimes.

11. Future challenges – areas the SRC may wish to explore

<u>Development of National and international resilience standards for Electricity Transmission</u> - The need for resilience funding is an emerging area for asset managers of critical infrastructure and increasing pressures such as the National Adaptation plan are requiring rapid maturity progression. Internationally, a few countries have prescriptive resilience standards, including NERC in the US, but even they are moving to strengthen their resilience requirements. Regulators in New Zealand will also be facing with these increasing pressures from infrastructure owner and

their customers, to modernise existing codes, standards and regulations to provide the support and guidance to deliver resilience.

Transpower Planned Resilience Programme in RCP4 - As part of our RCP4 proposal we are exploring the use of uncertainty mechanisms to support resilience programs and other ways to incentivise us without overly burdening consumers. As part of the Capex Input Methodologies review, we have provided a submission on suggested changes that will support and enable on-going investment in Resilience programs.

Probabilistic vs Deterministic Risk based decision making - Another challenge within the present planning environment is the disconnect between probabilistic risk-based decision making and deterministic requirements. For example, the deterministic n-1 circuit security requirements, yet probabilistically there are different levels of n-1 and in some case both circuits are supported by a structure that is vulnerable to slips or flooding. In other cases, Transpower has set its own standards on what we consider as economic e.g. towers to withstand a 300 year return period 3 sec gust wind speed.

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TRANSPOWER

Transmission Planning and Net Zero Grid Pathways Program

Electricity Authority Security and Reliability Council

Date: 26 October 2022

Contents

1. Purpose

The purpose of the paper is to summarise Transpower's System Planning approach to meeting New Zealand's future transmission development needs including the focus of our Net Zero Grid Pathways program.

2. Transpower Context

Transpower's view of the future, as outlined in *Whakamana i Te Mauri Hiko–Empowering our Energy Future*[1] and shaped by both the global and local environment, provides the context for our purpose and guides our strategy. It describes how our context is evolving and explores a range of potential energy futures out to 2050 and the role of the electricity sector to decarbonise the New Zealand economy. *Transmission Tomorrow* [2] our strategy, outlines our choices and strategic priorities for how we plan to deliver across these energy futures and a sustainable, affordable, and reliable power supply to electricity consumers across New Zealand. Transpower's strategic priorities are reflected in some of our recent work - Net Zero Grid Pathways, consulting on if and where Renewable Energy Zones are appropriate, and as the System Operator, how Future Security and Resilience contribute towards the energy future outlined in our *Whakamana I Te Mauri Hiko* publication.

We have chosen that our overarching responsibility is to enable a *Whakamana i Te Mauri Hiko energy future*, by fulfilling three roles:

- Operating and maintaining the transmission grid, including the connection of new generation and electrification loads
- Running the electricity market as System Operator as a service provider to the Electricity Authority, including building our capability to continue to operate a distributed and highly renewable (95%+) electricity system
- Ensuring the interconnected grid (incl. non-network alternatives) is in the right place at the right time.

Our Electrification Roadmap[3] identifies key policy options available to accelerate emissions reductions in the transport and process heat sectors. A net zero carbon future will be built with renewable energy and both *Whakamana i Te Mauri Hiko* and our *Electrification Roadmap* set the direction for making this future a reality. The Government's Emissions Reduction Plan has confirmed the Climate Change Commission (CCC) initial advice that electrification has an essential role to achieve our climate commitments in time.

We continue to build on this work to understand the implications of the possible changes and challenges we face, particularly in relation to investment uncertainty and the impact on our transmission system. We have a major investigation project underway, *Net Zero Grid Pathways (NZGP)* which will produce the transmission upgrade plans needed to enable renewable generation and electrification of transport and industry.

To support our objective of providing quality transmission services and investing appropriately in long-life assets in a changing environment, we have developed a set of grid strategic goals which lie at the core of our planning strategies and processes. The annual Transmission Planning Report (TPR) is a refresh of forecast demand and supply balances to identify the need and expected timing of grid investment. It is undertaken by our System

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[1] https://www.transpower.co.nz/resources/whakamana-i-te-mauri-hiko-empowering-our-energy-future
[2] https://www.transpower.co.nz/sites/default/files/plain-page/attachments/TP%20Transmission%20Tomorrow%20-%20Our%20Strategy%20-%20Published_0.pdf
[3] https://www.transpower.co.nz/sites/default/files/plain-page/attachments/TP%20Transmission%20Tomorrow%20-%20Our%20Strategy%20-%20Published_0.pdf

Planning Team and sets out how we plan for grid Enhancement and Development (E&D), how we will engage with stakeholders, and how we will progress towards the following grid strategic goals:

- **Service Performance:** The investments proposed in the TPR consider the needs of the interconnected grid and the service performance required by customers, enabling effective cost-service trade-offs to be made. The flexibility in the process for investigating transmission problems or opportunities supports consideration of a broad range of options to meet transmission development needs.
- **Cost Performance**: The changing environment for transmission services requires us to match our investments to grid needs, value the future flexibility some options may provide, and select 'least-regrets' investments. Our assessment of potential transmission investments gives significant weight to whole-of-life asset costs and the extent to which they enable us to achieve the desired service levels.
- **Customers and Stakeholders**: Our customers' development plans, preferred service levels and technology choices are central to our transmission investment decisions. The TPR describes how customer choices impact transmission investment choices and timing. Sharing investment planning information and processes, and working closely with customers and stakeholders, ensures best outcomes are achieved, nationally and regionally.
- **Asset Management Capability**: A key challenge for investment planning is managing uncertainty. The need for and timing of investments is inevitably affected by external factors such as changes in the wider economy and uptake of new technologies. We put considerable effort into understanding the main uncertainties affecting grid development and are cognisant of their potential impacts.

3. Regulatory Construct

To determine the development needs of the transmission network, we consider the following functions:

- providing a reliable and resilient electricity supply to consumers
- enabling an efficient energy market, which will result in energy delivered to consumers at least cost

We also consider the need to provide a transmission system that balances the cost of investment against the benefits gained from the expenditure. These functions consider the regulatory environment in which we operate. We are regulated by both the Electricity Authority and the Commerce Commission.

The **Electricity Authority** is responsible for ensuring the efficient operation of the wholesale electricity market. In our role as grid owner, we are a market participant and certain provisions of the Electricity Industry Participation Code (EIPC) apply to our operations. The EIPC prescribes Grid Reliability Standards (GRS); being the standards against which the reliability performance of the grid is assessed.

The **Commerce Commission** regulates our operating and capital expenditure. The capital expenditure required for Enhancement and Development investments (excluding customer investments) is governed by the Capex Input Methodology, which guides our planning for reliability investments. Each investment is categorised as either a Major Capex Project >$20m (MCP) or Base Capex, with the latter subject to our independent price path and incentive regime. We classify our transmission network development projects by funding arrangement, as shown in Table 3-1.

Table 3 -1 Regulatory investment type

Investment type	Definition
Base Capex	Replacement and Refurbishment projects of any value, or Enhancement and Development projects forecast to cost less than $20 million. We have flexibility to reprioritise across base capex, to increase or decrease overall base capex, and to shift between base capex and opex (e.g., procuring demand response to defer investments).
Major Capex Projects	These are individual investment proposals costing in excess of $20 million to enhance the National Grid, which are submitted to the Commission for approval on a case-by-case basis.
Customer-specific	Enhancement projects on assets specific to a customer or group of customers which are paid for under an investment contract between Transpower and the customer.

4. External Environment

Our external environment is changing quickly. New Zealand, along with the rest of the world is working to transition to a lower emission economy to limit our impact on the climate. The signing of the Paris Agreement in 2015 and the enacting of the Climate Change Response (Zero Carbon) Amendment Act in 2019 shows New Zealand's commitment to reduce emissions. The Government's Emission Reduction Plan (ERP) and our Whakamana i Te Mauri Hiko and Electrification Roadmap work, among others, all highlight the increasing role electrification could play in reducing our emissions. Electrification of low temperature process heat and light transport is a reality today and if accelerated will enable New Zealand to achieve its emission budgets and emissions reduction targets as outlined in the ERP.

In addition to electrification opportunities, the Government has also retained an aspirational target to achieve 100% renewable electricity generation by 2030 and set a target of 50% of total final energy consumption to come from renewable sources by 2035. The combination of electrification opportunities and an aspirational goal of achieving 100% renewable electricity generation by 2030 presents a once-in-a-generation challenge for Transpower to ensure the transmission system is the right size at the right time to enable New Zealand to meet its objectives.

In the publications Te Mauri Hiko - Energy Futures and Whakamana i Te Mauri Hiko, we highlighted that the uptake of technologies such as electric vehicles (EV), solar photovoltaic (PV) panels, battery storage and electrification of industrial processes, and the development of renewable generation opportunities will significantly impact future demand and generation in New Zealand. In the two years that have followed these technologies have further evolved with increased uptake worldwide. For electricity generation, our own research Net Zero Grid Pathways: Phase One to 2035 | Transpower has confirmed that onshore wind and solar PV provide the lowest cost new build generation in most regions of New Zealand. Currently, two new wind farms have been committed, with one under construction, in addition to a large number of grid scale solar farm enquiries in various stages of the planning process.

Offshore wind has also joined the portfolio of renewables being extensively developed around the world. Again, New Zealand has seen recent activity in this technology with four offshore wind developers currently interested in building off our coasts. On the demand side there has been a significant uplift in both EV numbers and the range of EVs available and also consistent growth in distributed solar PV. There are also reports of several grid scale Battery Energy Storage Systems under consideration with the first of these being installed by WEL Networks at Huntly.

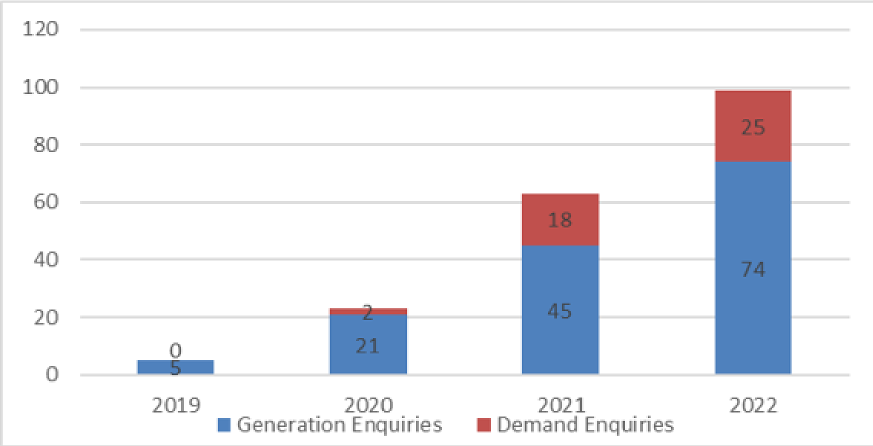


Figure 4-1: Demand and Generation inquiries

In Figure 4-1 this shows the significant uplift in enquiries for new generation connections; from 5 in 2019 to 74 in 2022. This uplift is a leading indicator of generation connection growth. We are also aware of significant increases in the number of embedded generators being connected or enquiring about connection. We are working with customers to ensure they are well informed as to the capacity of the existing transmission network and what investment may be justified if their project is committed. Including the development of our geospatial tool *Envision Opportunities*. Where possible, and when the timing aligns, we will build new capacity into our replacement work and upgrades to lower the overall cost of electrification.

Until recently, demand could be projected based on population, economic activity, and intensity of use. Changes in demand were gradual and there was a high degree of confidence in expectations about energy usage and forward-forecasting. This, in turn, heightened confidence in development or change in the generation landscape. Our customers are now forecasting and responding to step load supply increases from their customers. This has resulted in an uplift in forecast step loads as shown in Fig 4-2.

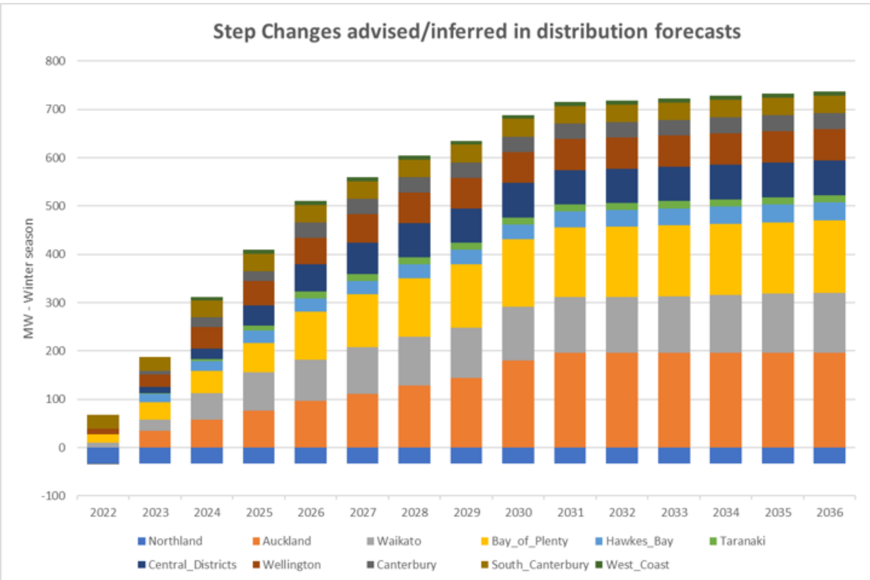


Figure 4-2: Demand step load increases from our customers (15years)

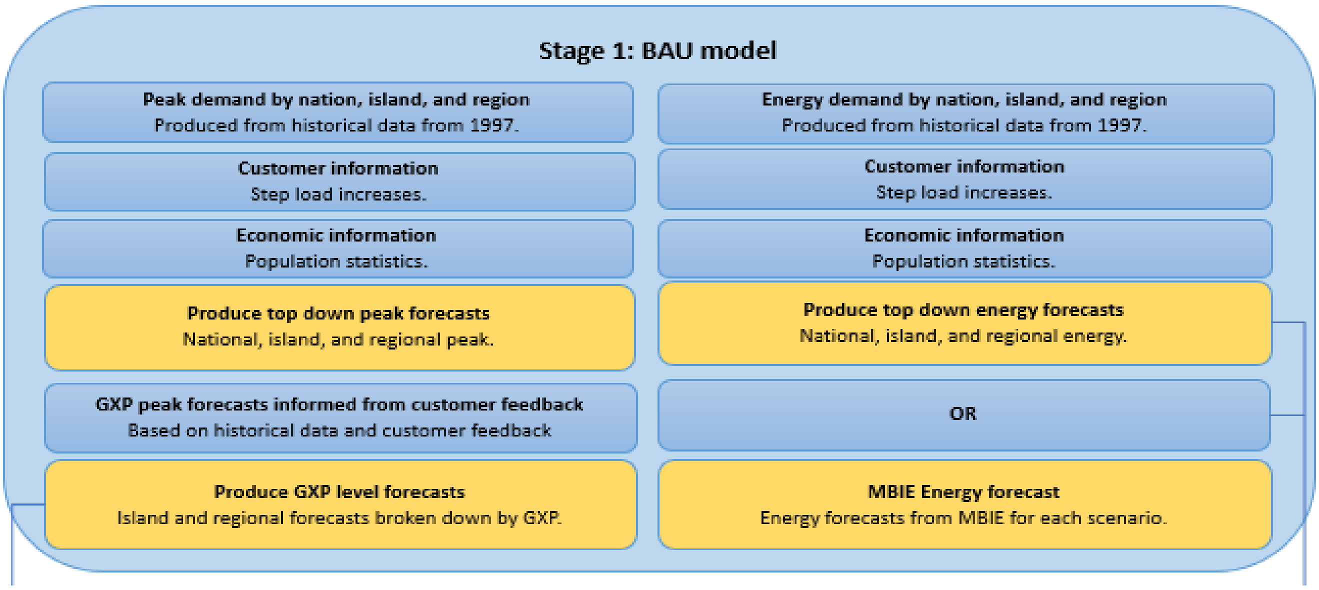
These increasing forecast step loads are coupled with generation inquiries and are accelerating at a pace not seen in recent history. Commitment and connection of new generation is a driver for Enhancement and Development investment to enable the economic dispatch of lower cost generation sources.

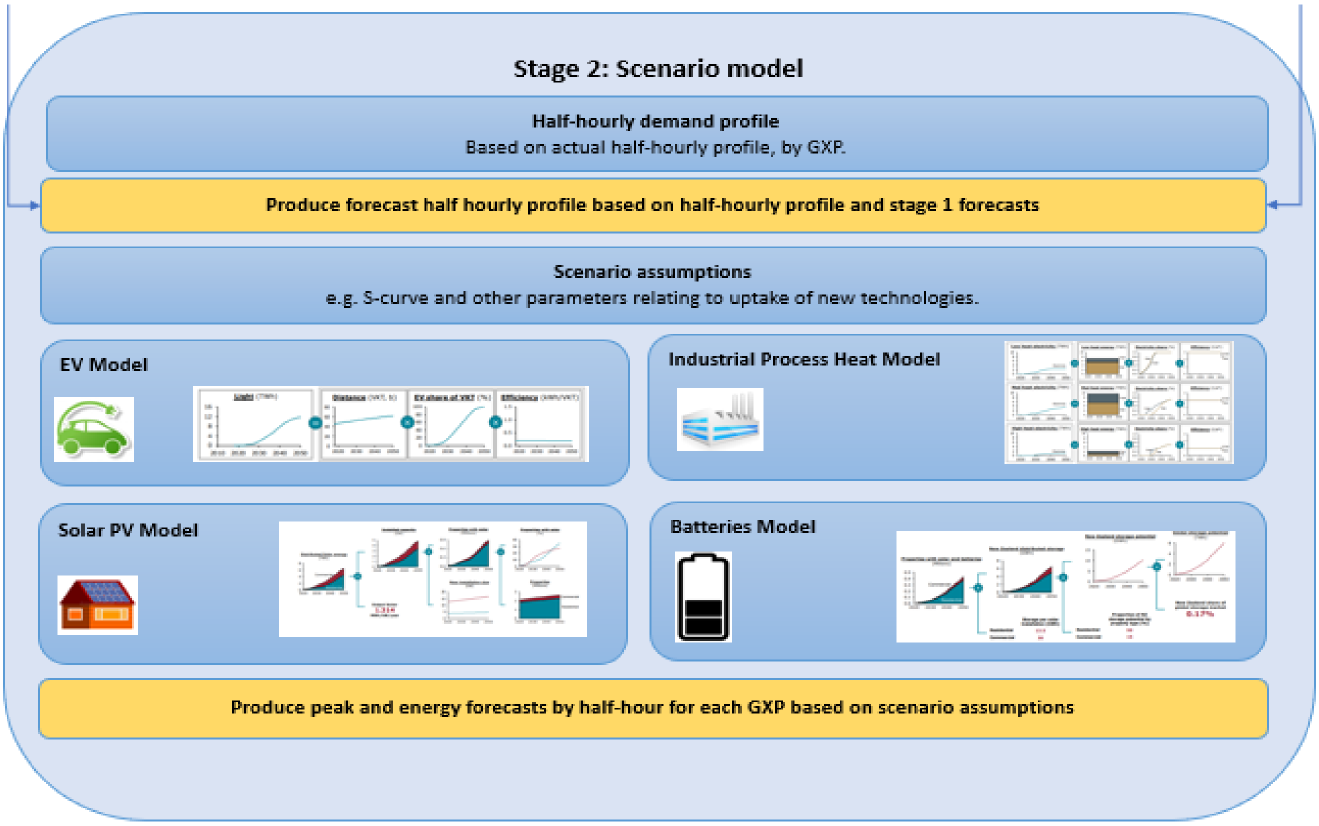
5. Demand and Generation Forecasting

To support development of Te Mauri Hiko - Energy Futures and Whakamana i Te Mauri Hiko we significantly enhanced our demand forecasting models to capture future complexities associated with the uptake of technologies such as electric vehicles, solar photovoltaic panels, battery storage and industrial electrification. These technologies have potential to significantly impact peak demand. For example, the timing of electric vehicle charging is a critical consideration in forecasting their impact on peak demand. Battery storage may be used to store electricity generated at times of low demand and discharged at peak times to reduce peak demand. We enhanced our models to consider how demand profiles across a day will change with the uptake of these technologies. This has significantly increased the complexity of our forecasting models.

To forecast demand, we developed a two-stage modelling process outlined in more detail below. Stage 1 considers how underlying, business-as-usual growth will evolve. We consider specific information from distribution companies and major electricity users about their expectations of future demand. Stage 2 considers how the uptake of electric vehicles, solar photovoltaic panels, battery storage and industrial electrification will impact demand. Our process incorporates information from a wide range of sources as is shown in

Figure 5-1: Demand modelling flow diagram





The stage 2 scenario process enables consideration of how the underlying stage 1 forecasts (including both energy and peak demand) may be affected by an assumed uptake of solar photovoltaic panels, electric vehicles, residential battery storage and the electrification of industrial heat processes. The future uptake of these technologies is still quite unknown, but for planning purposes we assume market uptakes in line with the Accelerated Electrification scenario.

We continue to consider the impact of distributed generation. Data supplied by the electricity Reconciliation Manager on existing distributed generation is used to forecast gross demand supplied by the grid and by distributed generation plant. From this we derive grid demand forecasts by making suitable assumptions about the generation output we expect from existing distributed generation at times of regional and island peaks[4].

For our Transmission Planning Report, we use a 'prudent' demand forecast to recognise the significant risks associated with investing too late to address grid enhancement and development needs. In effect, we add extra demand growth in the first seven years of the forecast to account for potential high levels of growth. After the first seven years we assume expected levels of growth. We determine the amount to add by calculating in our Stage 1 models both the expected level of base demand and the 'prudent' 10% probability of exceedance base demand. The ratio of the Stage 1 prudent base growth to expected base growth is then used to scale up the final demand from the stage 2 output to give the final "prudent" forecast.

In addition to demand growth, generation development (expansion and retirement) materially impacts transmission requirements. Here we rely on Electricity Demand and Generation Scenarios (EDGS), published by MBIE. These were last updated in 2019, and as such are deemed to be out of date for current modelling, as they do not reflect New Zealand current climate change ambitions. As part of our Net Zero Grid Pathways work, we

4 Use of an ensemble approach combines forecasts from different forecasting models, such as trend and econometric models, to derive a forecast of the underlying growth. Our approach derives a distribution for future demand growth that we use to inform the construction of a prudent forecast.

consulted on the approach to generation expansion modelling with particular focus on solar and wind resources to assist develop our investment case to the Commerce Commission for Stage 1 work. We understand that MBIE expect to refresh the EDGS by mid-2023.

6. The Transmission Planning Report

The Transmission Planning Report (TPR) is our prime document for assessing and prioritising grid investment needs, it is part of the Integrated Transmission plan we are required to publish. It is updated typically annually and serves several purposes including:

- describing how we assess the adequacy of the transmission network to meet future needs of users, and identifies potential investments to address future demand or alleviate expected constraints
- identifies investment opportunities in the interconnected grid that will improve grid operations, reduce losses, improve reliability at least cost or enhance market operation
- builds on previous versions, reflecting new information or changes in assumptions, and reflects our continuously evolving planning processes.

A Decision Framework (Fig 6-1) is a core element of our transmission planning process. This approach supports making effective, consistent, repeatable asset planning decisions that balance risk, service levels and investment, taking into account the uncertainty inherent in assumptions about the future. This is an area of increased focus, as we continuously improve our understanding of uncertainties and potential impacts on our investment planning and regulatory processes. It is designed to help make efficient and transparent decisions, consistent planning decisions that balance risk, service levels and expenditure (OPEX and CAPEX). As an important part of the Asset Planning Decision Framework, Options Assessment includes four stages that must be followed in sequence: Verify Need, Identify Options, Assess Options, and Identify Solution.

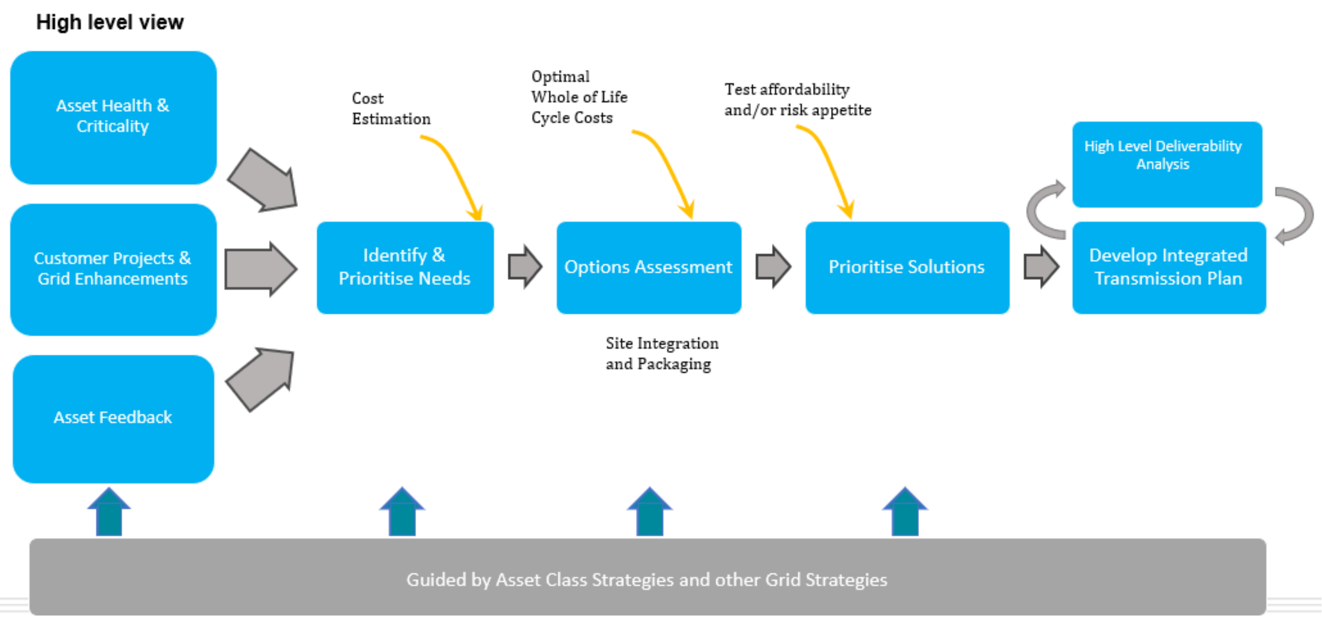


Figure 6-1 Asset Planning Decision Framework

The three key outputs for grid investment from the TPR include:

- Smaller grid enhancement and development projects less than $20 million that are funded from our five-year regulatory allowance
- Major grid enhancement and development that are separately approved by the Commerce Commission as individual projects
- Needs for investment in existing and new customer connections and other connection assets that are directly funded by customers

Impacts on Grid Investment Needs (Enhancement and Development)

Drivers of Enhancement and Development (E&D) investment needs are varied and often complex, with a myriad of intersecting issues requiring consideration and resolution. As our external environmental changes, so too does demand and generation patterns. This gives rise to E&D System Needs as the transmission grid must change to meet agreed or mandated service, security, or reliability standards. A change may increase or decrease grid capability, depending on the driver, and may be used to elicit a range of system outcomes including:

- providing more capacity to generators or connected loads.
- matching reliability or security of supply to the required standard or agreed service level.
- maintaining or improving power quality measures; and
- managing the dynamic response of the power system to disturbances.
- asset health and criticality may also drive E&D System Needs where, when making replacement and refurbishment decisions, our considerations identify the need for future grid capability change.

Our most recent demand forecasts indicate the energy environment is changing rapidly and this is expected to continue. In the last two years we have had unprecedented number of inquiries for generation connections, new load offtakes and modifications to existing grid exit points to allow for load growth and step loads. Some of the step load increases are a direct result of Government support of the decarbonisation of industrial processes (GIDI Fund) and additional funding of this program has recently been committed. We also anticipate the need for E&D investment to address changes in power quality due to new technology connections, the installation of intelligent control (such as special protection schemes) or to provide remote field control.

Our expectation of expenditure for smaller enhancement and development less than $20 million in RCP4 is $101 million, an increase of around 10% on RCP3 and we will formally propose a funding baseline in December 2023 as part of our RCP 4 Submission. As we progress through RCP3 we expect our plans will evolve as we gather new information and refine our analysis and respond to external drivers, such as input costs and industry developments.

A Major Capex Project is an E&D investment with an expected cost greater than $20 million. Table 6-1 details our proposed Major Capex Projects, both approved and unapproved. Note: for those currently unapproved, some are under investigation. Others would only be progressed if generation development or significant load changes occurred, stretching the capability of the existing transmission system. Investments are classified as either Economic, forming part of the Grid Economic Investment Report (GEIR), or Reliability, forming part of the Grid Reliability Report (GRR).

Table 6.1 Approved and unapproved Major Capex Projects within the planning horizon (source 2022 TPR)

Region	Project name	Indicative commissioning	Economic or Reliability?	Status
Approved Major Capex Projects				
NI Grid Backbone	Waikato and Upper North Island Voltage Management (WUNIVM)		Reliability ($50M)	In delivery
Auckland	Bombay-Otahuhu Regional Major Capital Proposal	2023	Reliability ($20M)	In delivery
Unapproved Major Capex Projects – under investigation				
Grid Backbone	Net Zero Grid Pathways – HVDC, central North Island, Wairakei Ring	2023-2030	Economic ($350M)	Investigation currently underway
NI Grid Backbone	Waikato and Upper North Island Voltage Management (WUNIVM) – Stage 2	2027-2035	Reliability ($70M)	Investigation currently underway
Upper South Island	Upper South Island voltage stability	Tentatively 2026, depending on demand step changes	Reliability ($80M)	Investigation currently underway
Unapproved Major Capex Projects – investigation scheduled for options analysis				
Bay of Plenty	Te Matai transmission capacity	Tentatively 2027	Reliability ($60M)	Investigation to start 2022/23
Grid Backbone	Net Zero Grid Pathways 2 Further enhancement to grid backbone and regional networks	2030+	Economic ($70M)	Investigation to start 2022/23
Unapproved Major Capex Projects – investigation scheduled to confirm Need				
Waikato	220/110 kV interconnection capacity	Tentatively 2026	Reliability ($40M)	Investigation to start 2022/23

Each Major Capex Project is individually submitted to the Commerce Commission for approval. We endeavour to provide the Commission with indicative timings for submissions for transparency and to assist with workload planning.

Customer-funded projects are investments covered by a customer investment contract between Transpower and the customer (primarily covering connection assets). As such, these investments are not included in our regulatory submission (for the E&D portfolio or otherwise), as while the reliability needs are identified in the TPR, the decision to investigate and invest resides with the customer.

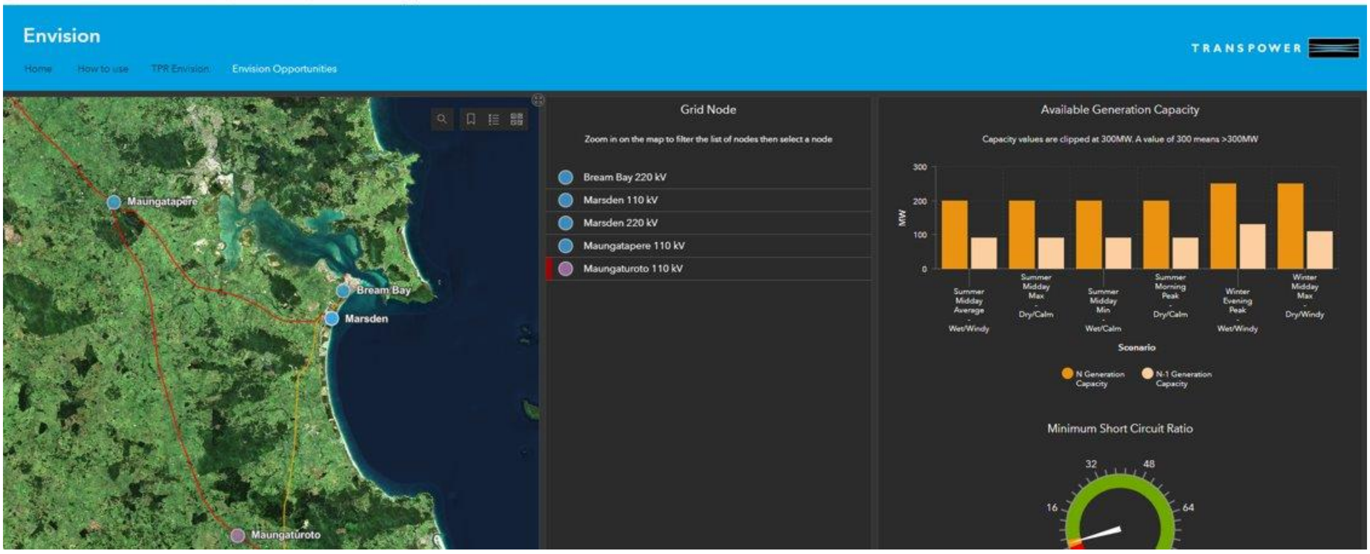
7. Envision – our navigational instrument for the TPR

In late 2021 Transpower launched *Envision Opportunities*, a new geospatial tool to help developers of new generation projects better understand the current capacity of the New Zealand transmission network, when identifying where it is best to connect.

The tool was launched on the back of increasing interest in new generation applications in New Zealand, mostly renewables such as wind and solar. *Envision Opportunities* provides an indicative view of the likely capacity available for generation at any given connection point in Transpower's nationwide high voltage transmission network.

Deciding on locations for new electricity generation is complex, with factors such as energy source, environmental approvals, constructability, and property rights to name a few and this tool provides a key part of the picture with an indication of current transmission capacity. While a potential generation developer will still need to come to Transpower for a detailed assessment of their application, *Envision Opportunities* can help identify more suitable locations to connect before they approach us, potentially saving both developers and Transpower time and cost.

Figure 7-1: Envision Opportunities



The *Envision Opportunities* tool supports Transpower's wider work to prepare for a zero-carbon future.

8. Net Zero Grid Pathways

Transpower's Net Zero Grid Pathways project Net Zero Grid Pathways: Phase One to 2035 | Transpower is aimed at ensuring the grid is fit-for-purpose. The Net Zero Grid Pathways 1 (NZGP1) Stage 1 proposal will be the first Major Capital Proposal (MCP) from this investigation to be submitted to the Commerce Commission for approval.

Transpower has an enabling role in decarbonisation through electrification and the connection of renewable generation. The grid backbone needs to support the connection of renewable, lower cost generation as well as providing sufficient reliability to match an increasing reliance on electricity to power our economy.

We are undertaking this investigation in two phases. Phase 1 the grid reinforcements to 2035 is using a 'least regrets' approach when dealing with future electricity demand and generation uncertainty, including the development of scenarios. To ensure transparency in our planning, these scenarios have been developed with input from key stakeholders. This process has taken over a year, as we have needed to further evolve some assumptions given our landscape is changing quickly.

Under Phase 1 we are focussing on the least regrets to the existing grid backbone to enable the connection of new renewables an electrification. The investments in our planned $350m submission are largely extracting more capacity from existing infrastructure given the range of uncertainties.

These include the exact nature of when and where new generation will be built, new demand will arise or when, or if, major electricity users might exit are unclear. However, significant binary step changes such as the closure of New Zealand's Aluminium Smelter at Tiwai Point, hydrogen for export or a commitment to Lake Onslow storage could all impact the choices for grid investment out to 2050.

Phase 2 of NZGP looks out to 2050 and acknowledges decarbonising our energy use is not just a New Zealand issue – enormous research efforts are occurring globally into various alternatives. Noting that the role that various energy sources such as electricity, hydrogen and biomass will play in our future energy mix is not yet clear. Regardless, forecasts including our own Whakamana I Te Mauri Hiko (WiTMH) all point to a 55-80% increase in electricity demand by 2050, supported by renewable generation.

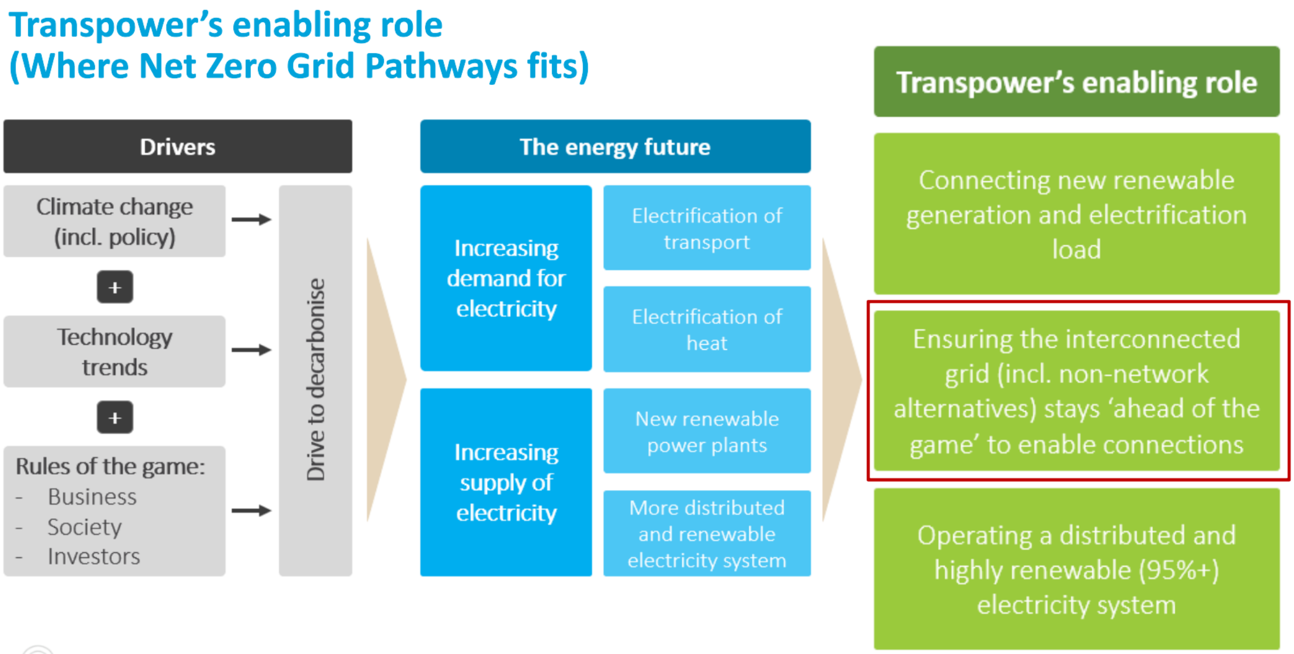


Fig 8-1 Transpower's Enabling Role in Electrification and Decarbonisation

The focus of NZGP Phase 2 is ensuring the grid backbone provides both the reliability and resilience to meet the requirements of a highly electrified economy, very dependent on electricity supply. That while distributed resources such as demand flexibility and local generation will play a role in meeting the challenge, there will still be a high dependence on remotely connected large scale generation. There may also be industrial developments of significant scale that are major electricity users.

Development of the future grid backbone to 2050 to serve a range of functions will likely require new transmission connections to both provide the added capacity and also added resilience against natural hazards. Already our Phase 1 work proposes possible new transmission lines.

We will commence industry engagement on NZGP Phase 2 or NZGP2 in 2023. This work will look out to 2050 to identify how the grid backbone and regional interconnections need to develop to provide the required reliability and resilience. The output from the NZGP project will form a long-term transmission plan to ensure that between now and 2050 we have the right grid in the right place at the right time. This plan will provide important information for electricity demand and generation investors, providing guidance on future transmission capacity.

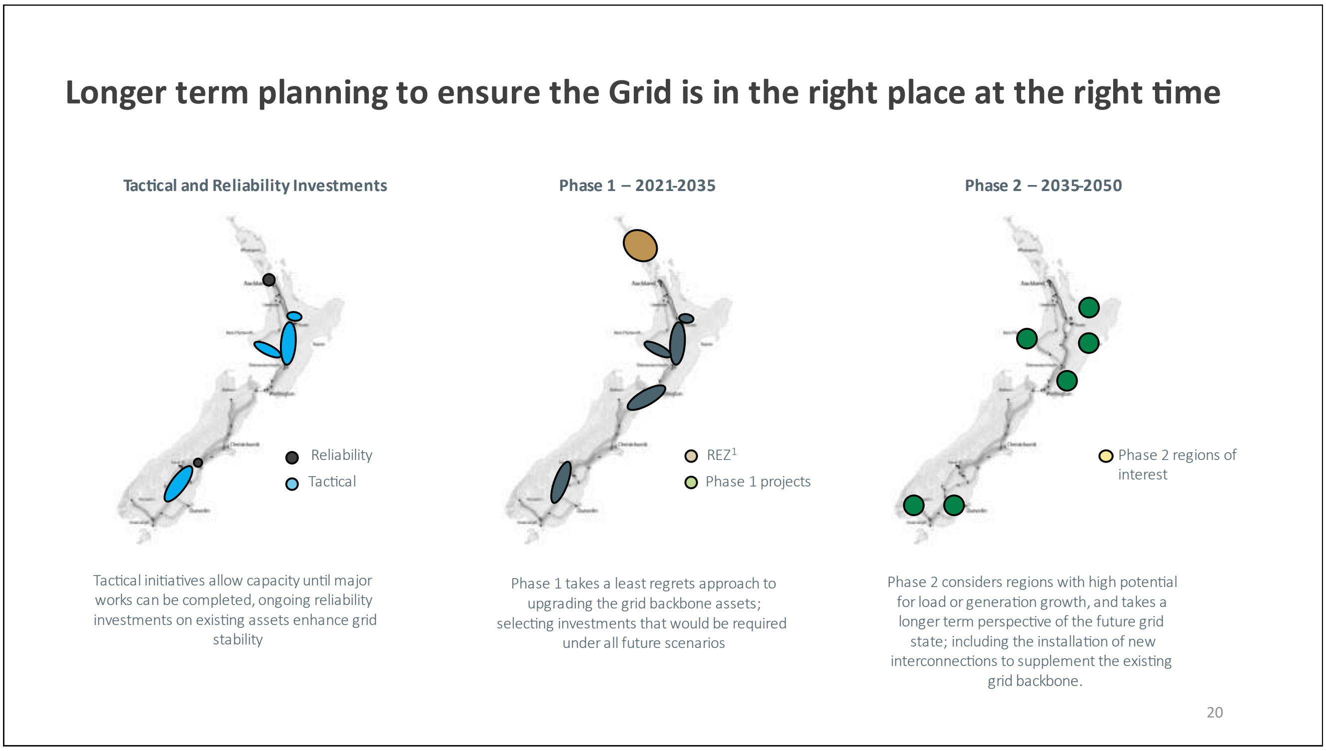


Fig 8-2: Planning to ensure the Grid is in the Right Place at the Right Time

Renewable Energy Zones

Our NZGP studies and recent industry consultation on future wind and solar generation have identified 11GWh of potential wind and solar development, however at least 5 GWh of this is in regions difficult to currently connect to the transmission grid. These difficult connections often dissuade generation due to 'first mover disadvantage', where the burden of the first connection is carried by the first investor. In addition, current distribution network regulations do not support the recovery of this initial connection investment. In the NZ context a Renewable Energy Zone (REZ) could be a way to unlock a coordinated and lowest cost transmission and distribution connection pathway, with the goal of REZ being to co-ordinate multiple new renewable electricity generation developments in one location and enable efficient and cost-effective investments in electricity infrastructure.

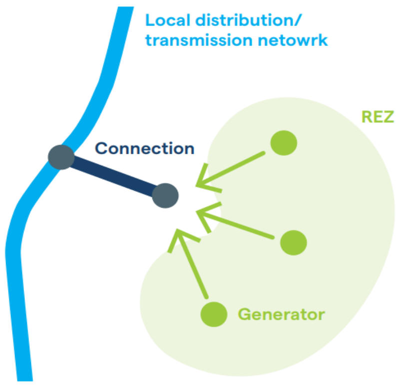
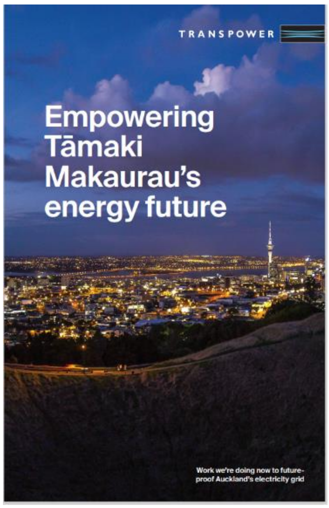


Fig 8-3: Simple Renewable Energy Zone

Transpower has spearheaded this with a national consultation on the potential of REZ's as well as a more focused consultation in the Northland region and now working with regulators on how this might be proposed. Transpower sees its role as an enabler, supporting the Governments goal to decarbonise the energy system, building the connections but not funding them. We are engaging with policy and regulatory agencies on how a REZ concept might be developed further.

Regional Planning and Strategies for an Integrated view of the Future



With growing regional demand and generation, along with step load changes increasingly predicted due to Government Initiative for Decarbonising Industry funding (GIDI) there is an increasing need to model at a regional basis to ensure that our forecasting takes account of local growth and national trends. From our latest round of demand forecasting, coupled with customer conversations, we have prioritised the Western Bay of Plenty, Waikato and Queenstown Lakes as those regions for further investigation at a regional basis.

These will build on our previous development of the approach to the development of our Auckland Strategy "Empowering Tamaki Makaurau's energy future" Our Auckland Strategy | Transpower, which focuses on the challenges of overcoming strong regional growth and the dynamic complexities including environment and especially in areas such as transport, land and infrastructure development. Coupled with this, the city's climate aspirations to halve emissions by 2030. Meeting regional growth with appropriate regional interconnections to the grid backbone is a key goal of NZGP. Our combined engagement with customers on regional growth potential to 2050 has provided some important insights and need for more immediate investments.

9. Challenges for Discussion

As outlined in the introductory sections of this paper, development of the electricity grid has a key role to play in the decarbonisation of the New Zealand economy. We are committed to playing a key enabling role through working with our regulators to refine the grid investment framework where necessary. The three questions below are for general discussion.

1. *How can we best anticipate the requirement for new grid investment and ensure a 'least regrets' outcome?*
   - We are aware of recent comments that certainty of grid plans provides valuable inputs for developers engaged in electrification and renewable generation.
   - The traditional approach which has matured over the past 20 years has been based on certainty of need, predicable demand growth rates and 'just in time' investment
   - How might investor certainty play a role in our investment decision making?

2. *What benefits could we include in the investment tests for grid development, where new generation is driven by market needs and regulated grid investment based on scenarios?*
   - Current regulatory grid investment framework is based on reliability standards and on "net electricity market benefits" from applying the MBIE EDGS scenarios, it includes reduced transmission losses and some other indirect benefits
   - How frequently should the scenarios on generation and demand options be updated?
   - What other benefits could we include related to Climate Change to ensure reliability expectations met?

3. *With electrification and electricity as the prime energy vector a more resilient grid and increased levels of reliability may both be appropriate*
    - How could we discover future electricity consumers desire for and how they value reliability and resilience to support the move to greater electrification?
    - Where could new technologies and distributed resources help deliver on these expectations and better utilise investment in the transmission grid?

Other factors such as consenting, property acquisition, construction times and resourcing all input to our ability to deliver timely investments.

It is in our remit and we are working with policy and regulatory agencies to:

a. Seeking review of input methodologies for investment and different approaches withing the existing framework. This could enable earlier staged project approvals and assist in smoothing resourcing demands
b. Taking the lead in reviewing and modifying the MBIE Electricity Demand and Generation Scenarios with industry input to ensure that they reflect the context of a specific investment need
c. Supporting MBIE in the development of the EDGS refresh by co-funding the updated generation stack studies
d. As system operator supporting the Electricity Authority Future Security and Reliability workstream
e. Socialising the concept of Renewable Energy Zones and potential benefits of co-location to generation investors as well as load customers

Prepared by: Grid Development, System Planning and Investment

Written by: Stephen Jones, System Planning and Investment Manager

Sponsored by: John Clarke, GM Grid Development

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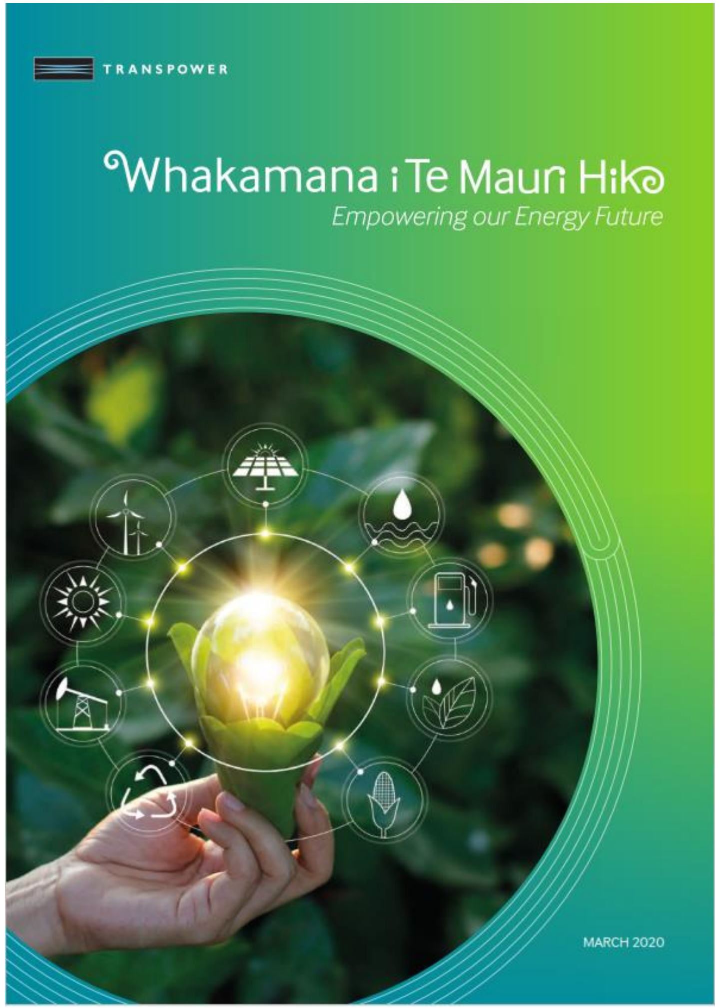
Approach to Transmission Planning and our Net Zero Grid Pathways Program

Security and Risk Committee Update

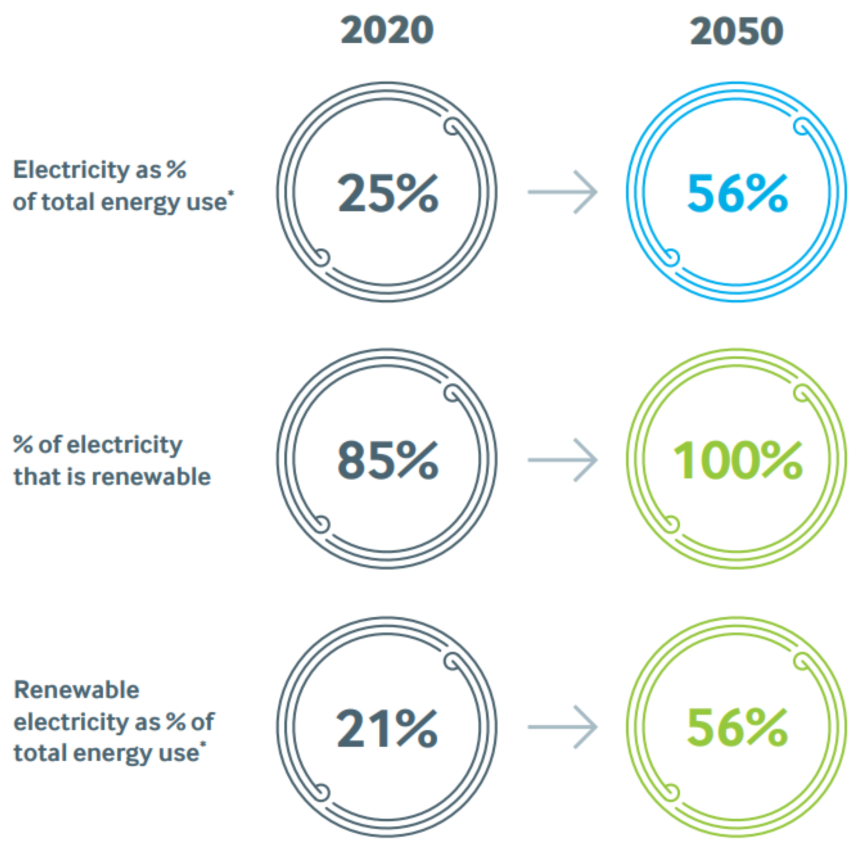
John Clarke and Stephen Jones

Whakamana i Te Mauri Hiko: empowering our energy future



Accelerated Electrification – the only way to meet our climate change commitments

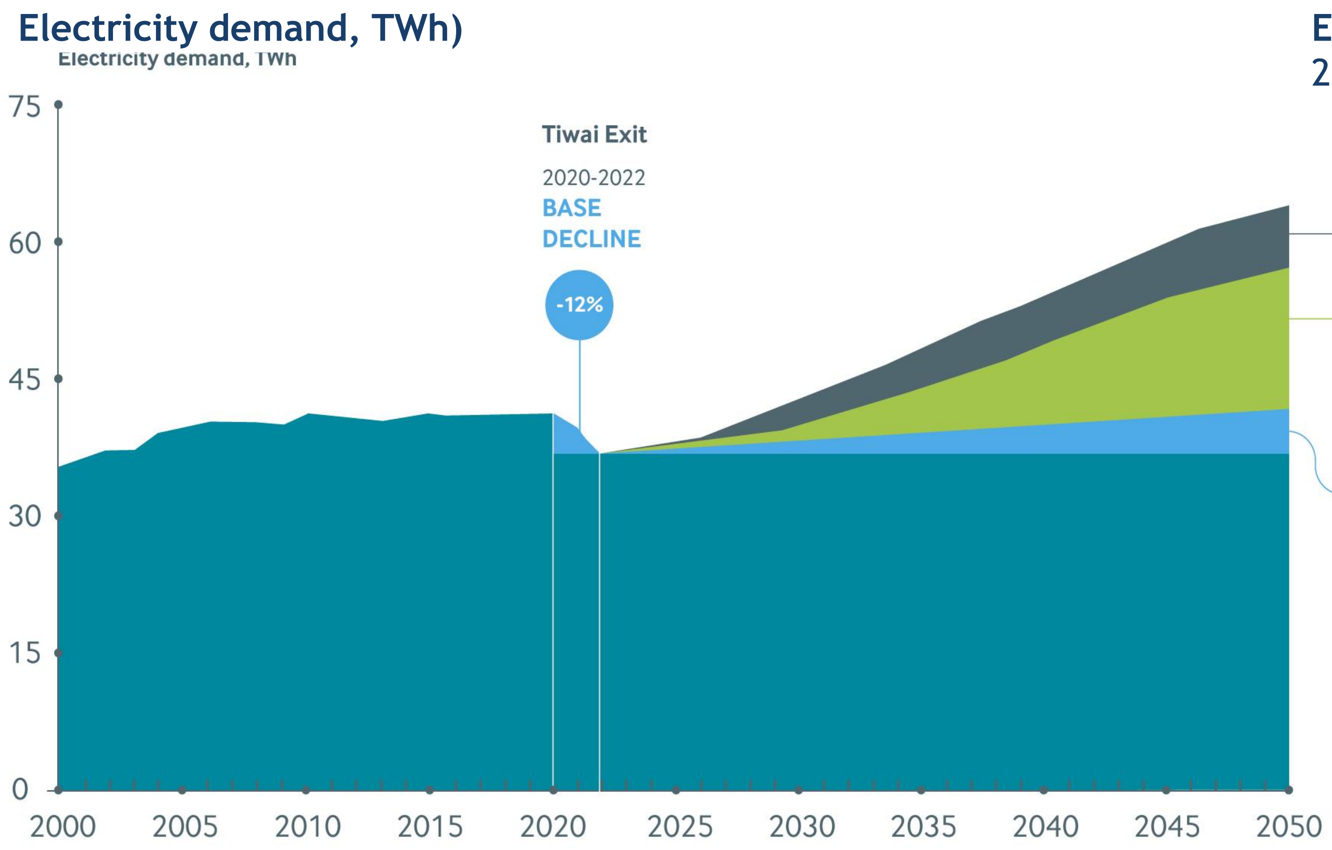
- We estimate that the demand for electricity will increase by approximately 68% by 2050 as we switch away from fossil fuels and decarbonise our economy
- We forecast New Zealand will have an estimated 1.5 million electric vehicles by 2035. Moving our transport from imported oil to electricity
- Transpower forecasts that this transformation will require 25 new grid-scale renewable power stations and battery storage projects over the next 15 years
- We need a modern, flexible and robust grid to distribute a wave of renewable energy projects to customers and to enable new technologies and energy markets to function properly

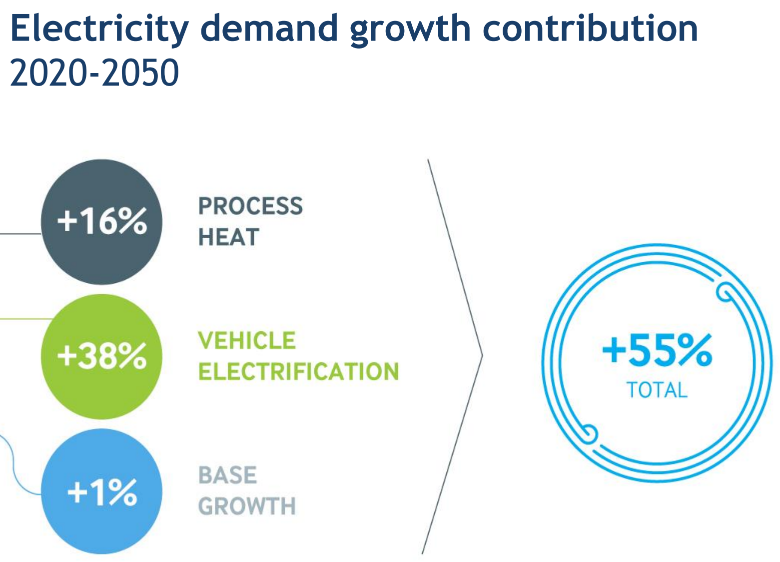


While net growth and base growth are used across this document, both refer to total growth.
Net growth is used to define emissions growth. Base growth is used to define growth in electricity demand.

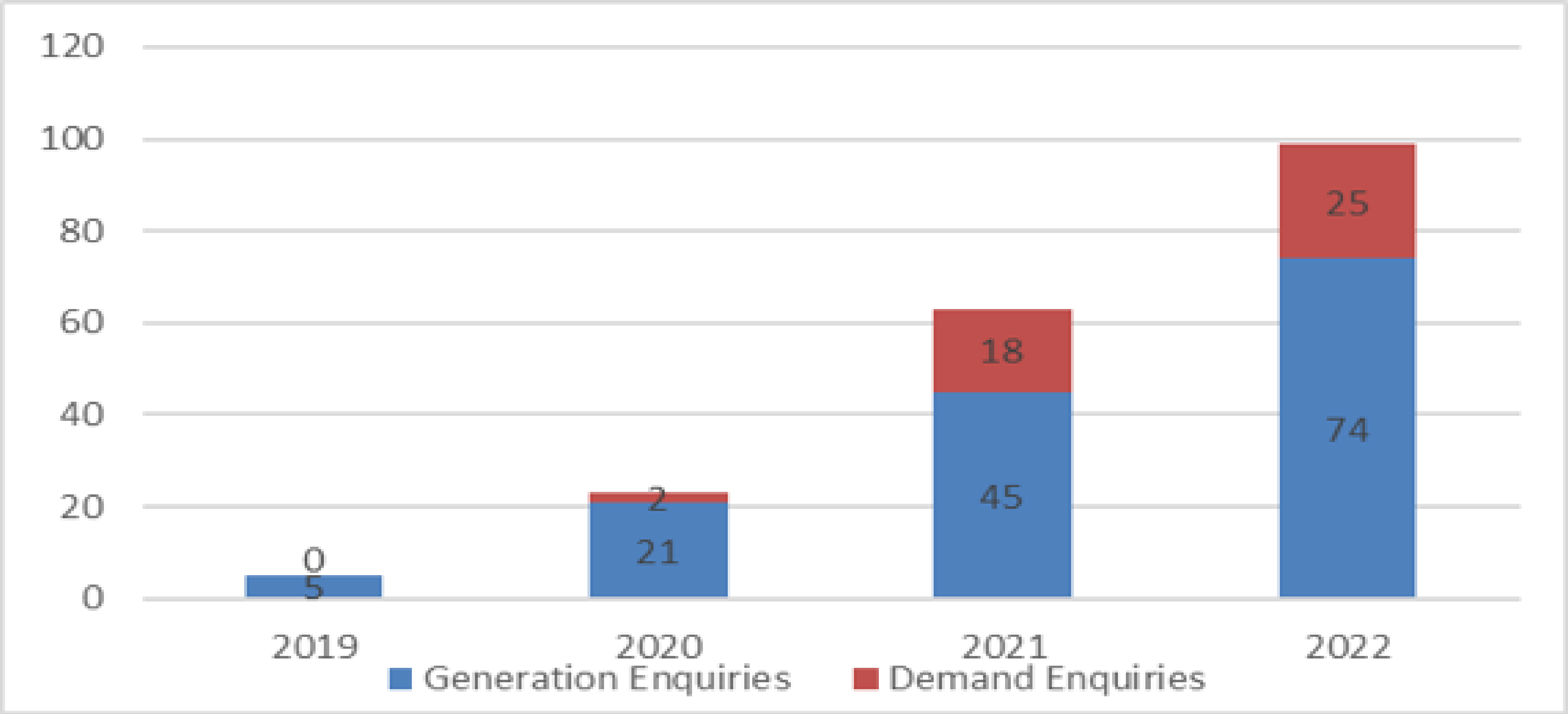
* Based on Consumer Energy use rather than Primary Energy use

Electricity demand to grow by 55% by 2050 with electrification ramping up from 2025

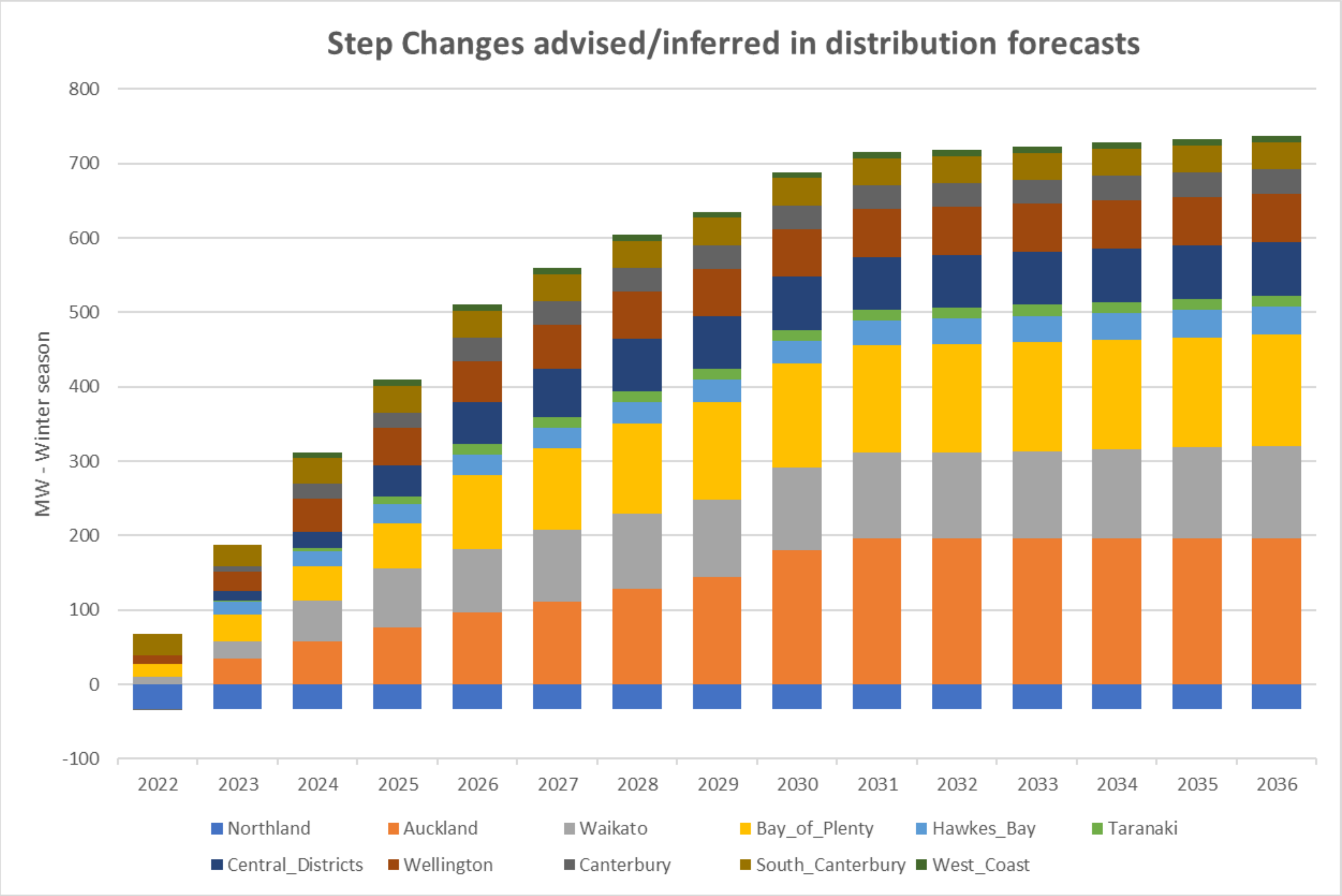




Generation and Demand Enquiries



TPR 2022 Network Companies Inputs - Demand Steps

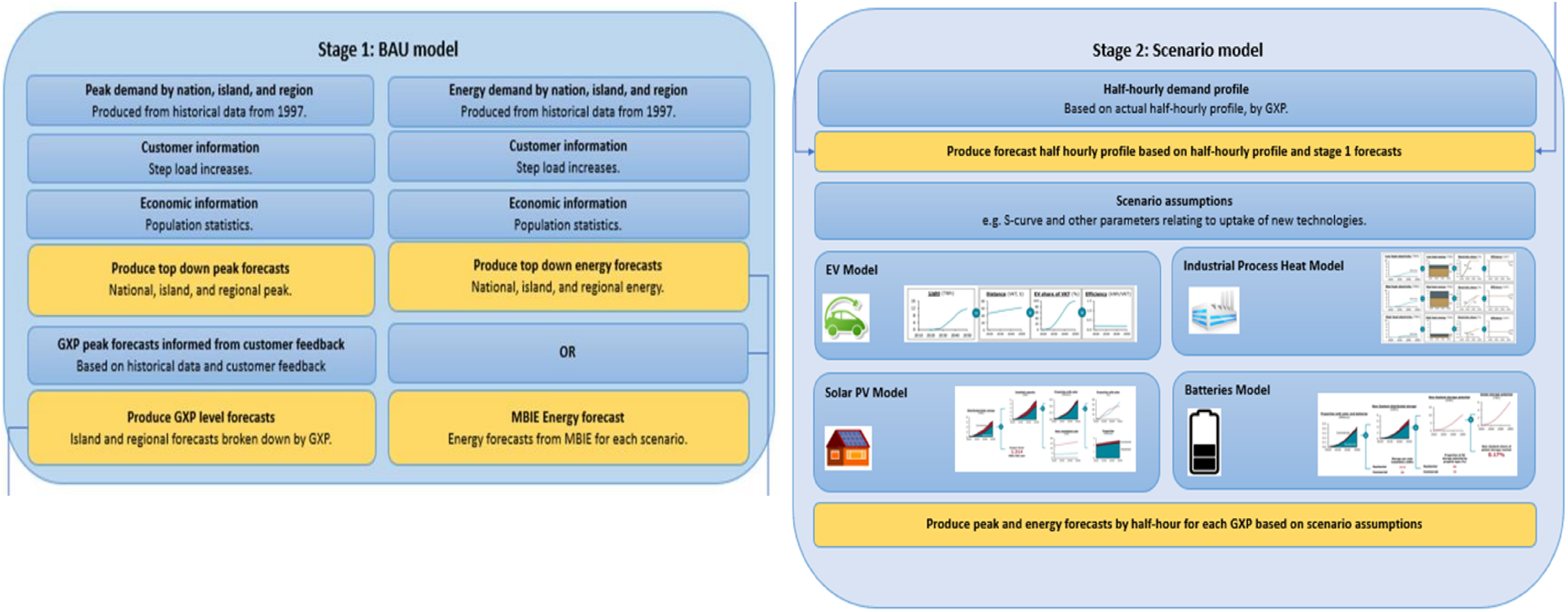


The Transmission Planning Report

The Transmission Planning Report (TPR) is our prime document for assessing and prioritising grid investment needs, it is part of the Integrated Transmission plan we are required to publish. It is updated typically annually and serves several purposes including:

- describing how we assess the adequacy of the transmission network to meet future needs of users, and identifies potential investments to address future demand or alleviate expected constraints
- identifies investment opportunities in the interconnected grid that will improve grid operations, reduce losses, improve reliability at least cost or enhance market operation
- builds on previous versions, reflecting new information or changes in assumptions, and reflects our continuously evolving planning processes.

Demand and Generation Forecasting

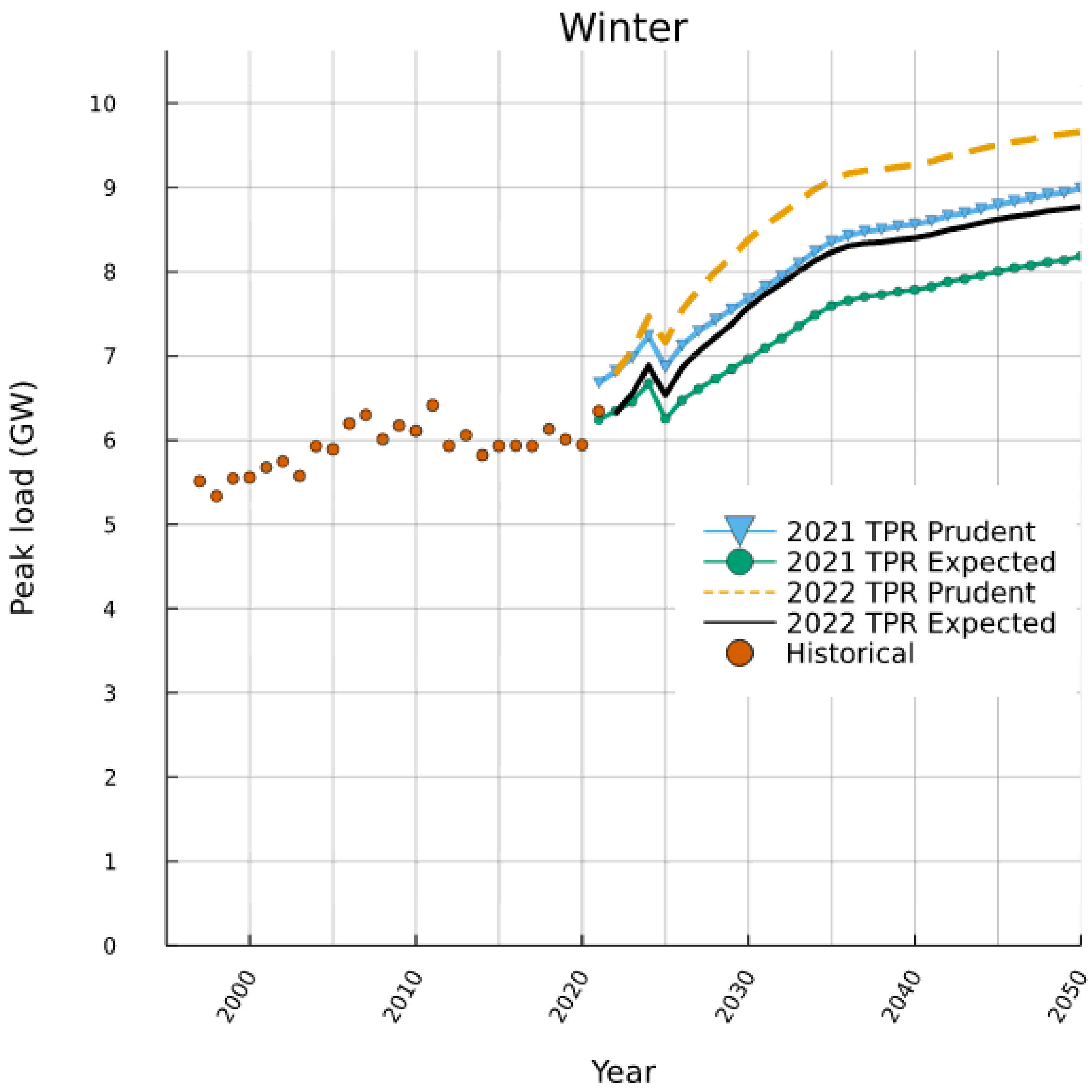


National Peak

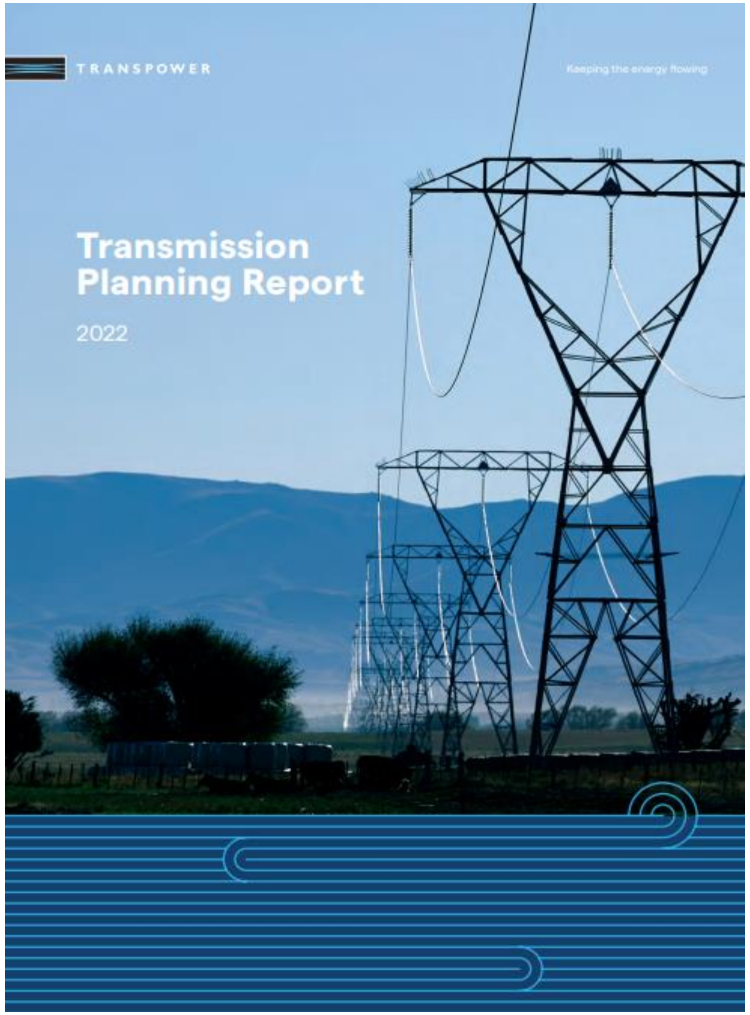
This chart shows national peak demand.

The **yellow** and **black** lines show the TPR 2022 forecasts, compared to last year's forecast in **green** and **blue**.

Early years are consistent with last year's forecast, but faster growth leads to +640MW increase over last year's forecast by 2035



Main outputs of TPR 2022



- Identifies investment needs both Transpower and customer funded for existing and new connections to the grid. Timing is driven by customer demand

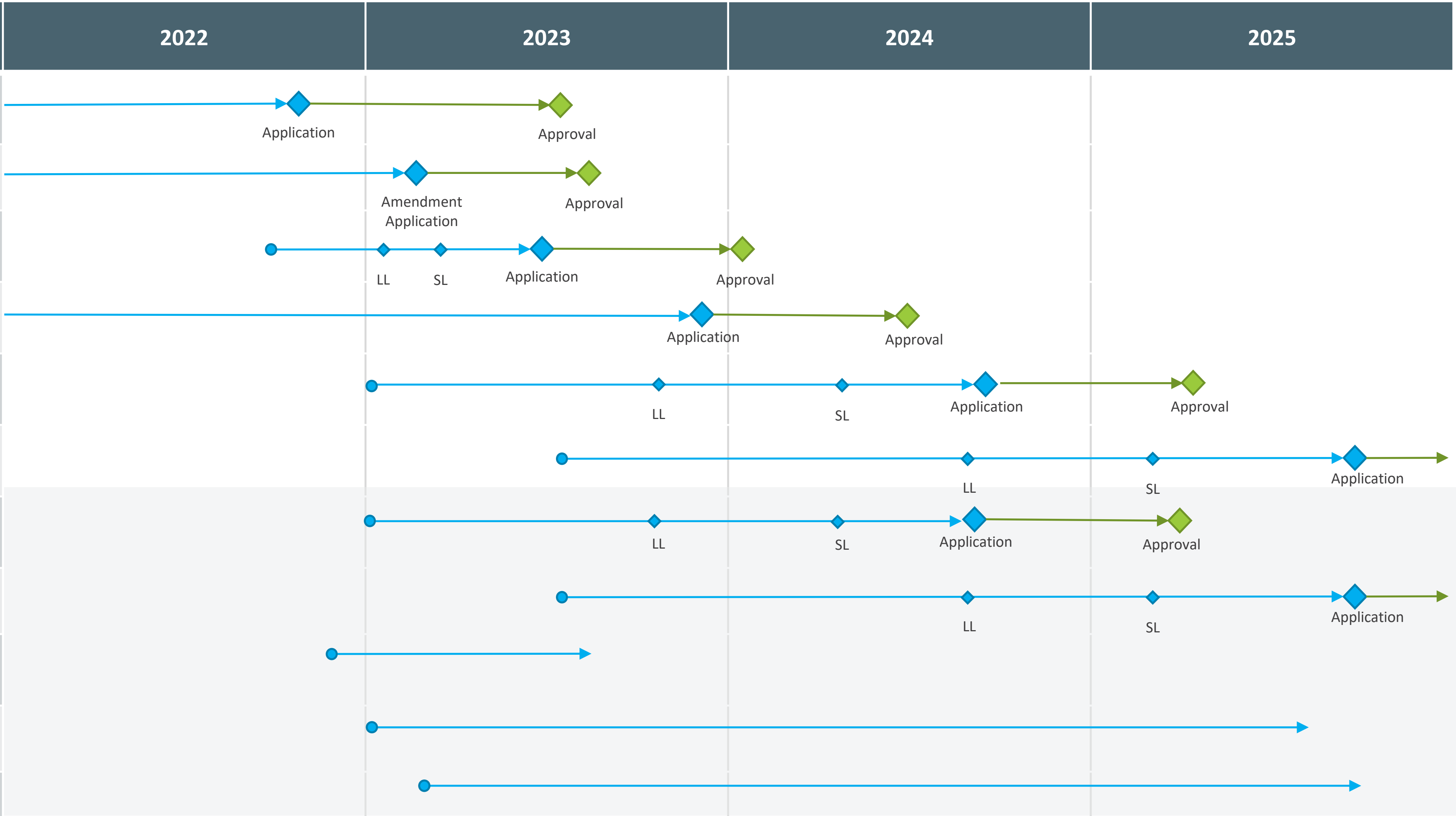
- Smaller scale enhancement and development investment needs $>20m. RCP3 allowed approx. $50m and now seeking a further $40m through a reopener to enable growth. Proposing $100m for RCP4 – RCP6

- Major Capital Proposals over $20m - seven investments with indicative cost of $740m by 2030. Enabling both Backbone capacity and Power Quality as well as Regional Growth

Upcoming Major Capital Proposals – as at Sept 2022

Transpower
Commerce Commission

Project	~Cost ($m)	Need Date
Net Zero Grid Pathways	350	2025-2027
WUNIVM	50	2025
Western Bay of Plenty	60	2025
RCP4 Application and Approval Window	-	>2030
Upper South Island Capacity	80	2026
Waikato/Thames Valley	40	2026
Northland Renew Export*	90	TBC
WUNIVM 2*	70	2028
NZGP Phase 1 Stage 2*	TBC	2028-2032?
NZGP Phase 2*	TBC	TBC
NZ Battery*	TBC	2034

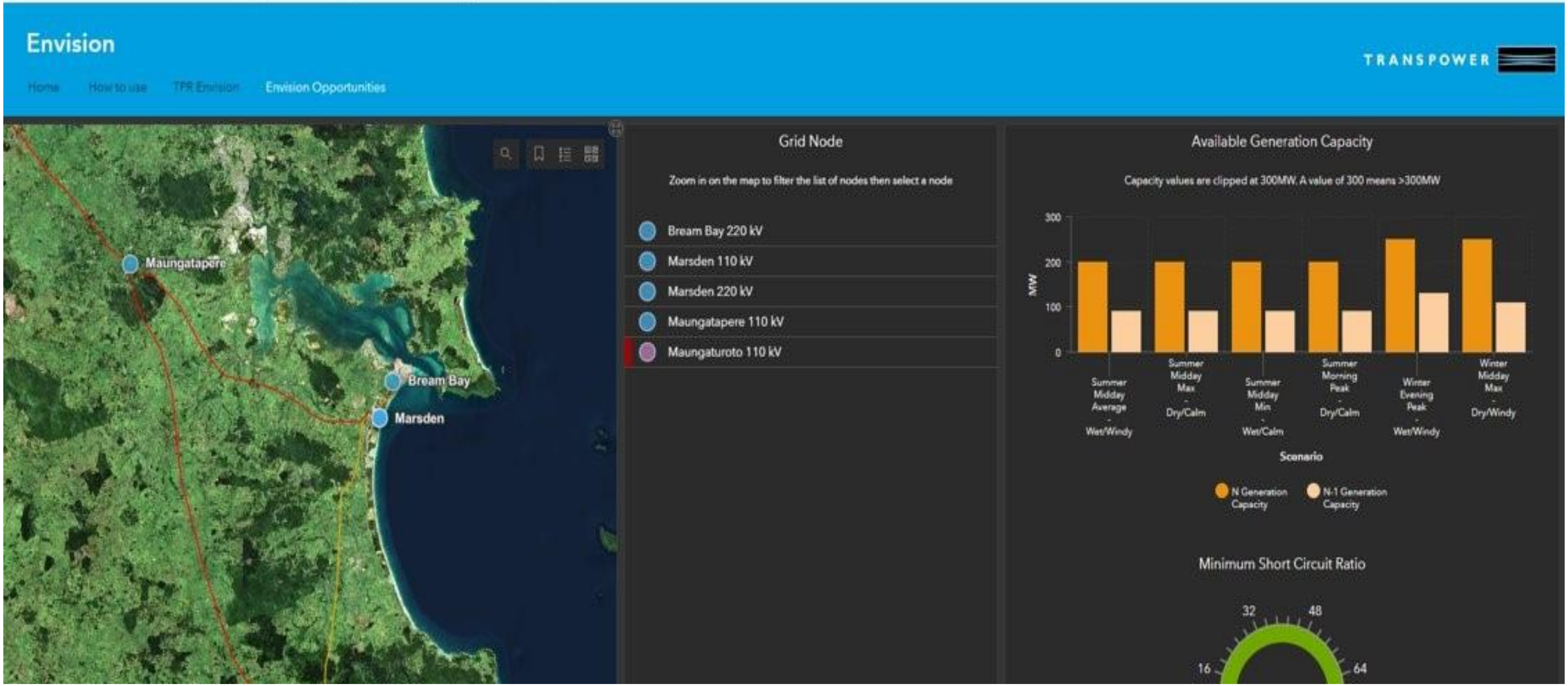


Project Details next slide

*Timings less certain

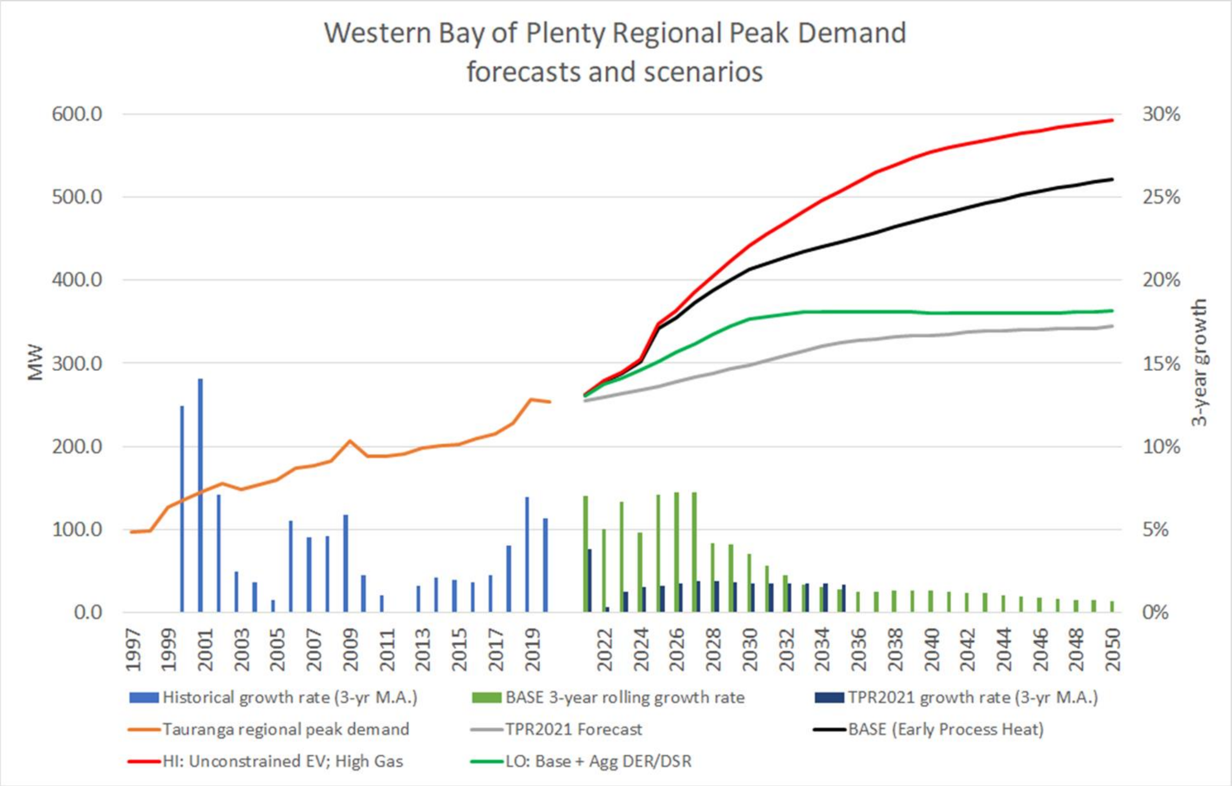
MBIE Investment Scenarios unlikely to be updated until 2024 – ~3 MCP's will have to use modified 2019 Scenarios

Envision – our navigational instrument for the TPR

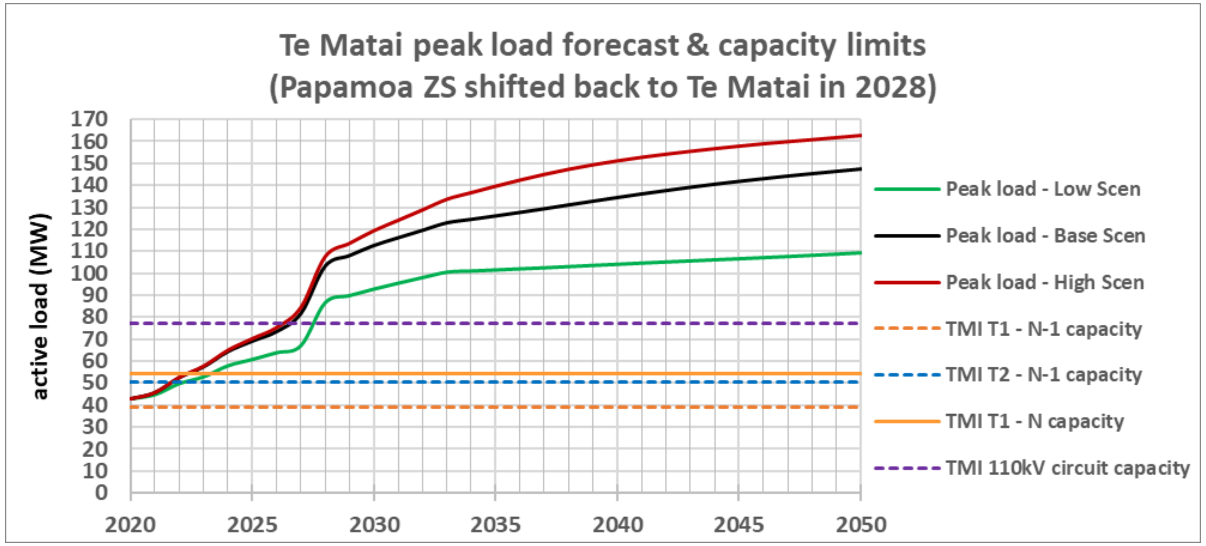


Regional growth challenge : Bay of Plenty Demand

- Despite some grid upgrades between 2000 and 2010, the regional grid is not able to handle that load growth without further major upgrades



- **Many of our assets are in an urban environment, which makes consenting a major issue** (and we have had a few setbacks in the area recently)



Transpower and PowerCo are working together to develop a long-term grid enhancement plan for the region.

Transpower’s enabling role
(Where Net Zero Grid Pathways fits)

Drivers

Climate change (incl. policy)

+

Technology trends

+

Rules of the game:
- Business
- Society
- Investors

Drive to decarbonise

The energy future

Increasing demand for electricity
- Electrification of transport
- Electrification of heat

Increasing supply of electricity
- New renewable power plants
- More distributed and renewable electricity system

Transpower’s enabling role

Connecting new renewable generation and electrification load

Ensuring the interconnected grid (incl. non-network alternatives) stays ‘ahead of the game’ to enable connections

Operating a distributed and highly renewable (95%+) electricity system

What is NZGP Phase One and Phase Two?

NZGP

Transpower’s forward investment plan to ensure the Grid stays ahead of need

NZGP Phase 1

Investments now to 2035 –The Grid Backbone, least regrets

Underway since Dec 2020

NZGP Phase 1, Stage 1

Investments that will be funded by our Nov 22 Application, largely upgrades to the existing grid

NZGP Phase 1, Stage 2

Investments that will be further refined after our Nov 22 submission, to be built by 2035, this may include new lines and HVDC cables

NZGP Phase 2

Investments post 2035 – Adding resilience to the Grid Backbone and accommodating growth in regions, including REZ

Starting soon

Likely Focus:
Greater resiliency through regional inter connections to support the grid backbone, initial focus on high growth regions (incl. Renewable energy zones)

Our Phase 1 Stage 1 MCP progress to date

Need identified

Initially triggered by Tiwai close 2021

MBIE's EDGS variations developed

To support industry view that '19 EDGS did not reflect electrification

December 2020

Longlist Consultation

Including RFI for transmission alternatives, none offered

August 2021

EDGS variations finalised

Base case is Tiwai exit 2024

December 2021

Option Refinement and Modelling

Optimising three key grid sections HVDC, WRK and CNI

Shortlist Consultation

Where we are now, proposal for a staged MCP

July 2022

Preferred Option Refinement

Account for consultation and costs, preferred option maximises electricity market benefits

Application Submission

Approval to submit sought at the November Board

End of 2022

CNI – Transmission lines through the central North Island – ie those alongside SH1 Dessert Road
WRK – Transmission lines from the Hawkes Bay and Bay of Plenty into Wairakei (Wairakei “Ring” constraint)
HVDC – High Voltage Direct Current link – focus on Cook Strait cables and extra equipment at Haywards and Benmore terminals

The NZGP1 Plan

Tactical - Started in Advance of the Nov Submission	Responding to Growth (Stage 1 approval for delivery) - Fully Funded by Nov Submission	Enabling the Future (Stage 1 approval to investigate/design) - Funding for construction as part of a Stage 2 submission
• (WRK Reactor) • TKN–WKM TTU	• Duplex TKN–WKM line • TTU BPE-TKN line • HVDC Reactive Plant (1200MW) • TTU WRK C line • TTU EDG-KAW 220kV line • ONG 110kV system split • Lower NI system dynamic studies • Lower NI system stability studies	• BPE-TKN line duplex design • BPE-WRK line TTU design • Resiliency benefits of new lines • HVDC cable upgrade (1400MW) • New line design and ACRE processes to a natural point for CNI and WRK • Quantifying Resilience Benefits • BRK-SFD reconductor • BPE diversification study

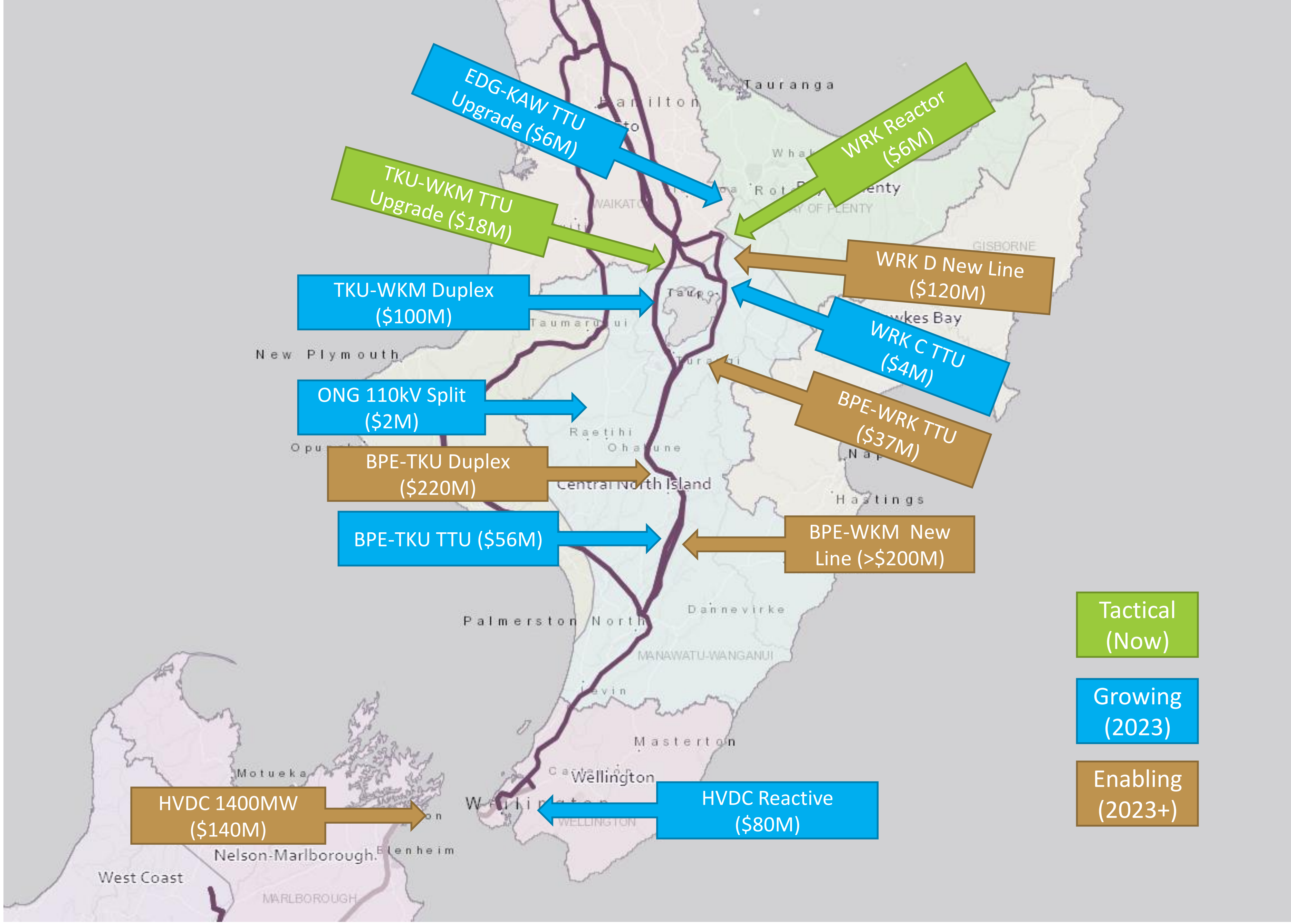
TTU – Thermal Transmission Upgrade, tower strengthening and ground clearance improvements to allow an existing line to carry more electricity
Duplex – Doubling the capacity of an existing line by doubling the number of conductors (wires)
System splits – preventing lower capacity local lines from restricting electricity flow on higher capacity grid backbone lines

The staged approach to NZGP1 results in…

A comprehensive package of major investments and enabling projects

HVDC reactive – Additional equipment at the Haywards terminal to increase HVDC capacity

HVDC 1400MW – adding a 4th undersea cable to the existing three cables to increase capacity from 1200 MW



What is NZGP Phase 2?

- Further investment to maintain a Resilient Grid Backbone

- New Regional interconnections to accommodate high growth regions

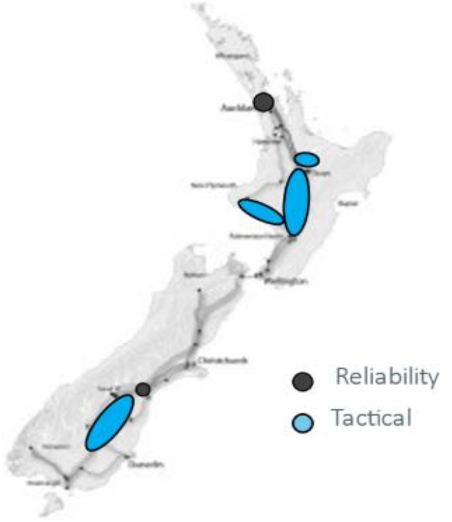
- Renewable Energy Zones (REZ) – a potential enabling addition to support regional supply and demand growth

Phase 2 – 2035-2050

Phase 2 considers regions with high potential for load or generation growth, and takes a longer term perspective of the future grid state; including the installation of new interconnections to supplement the existing grid backbone.

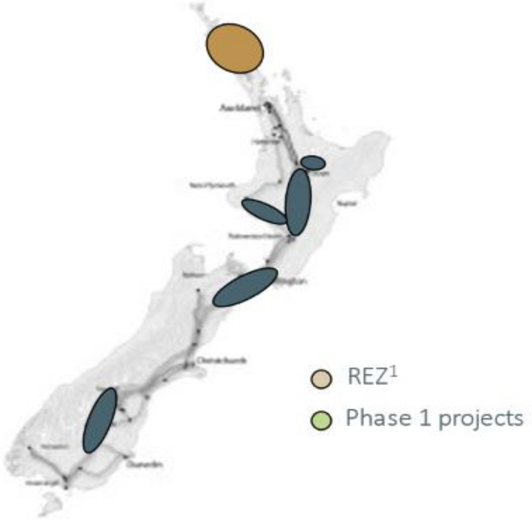
Longer term planning to ensure the Grid is in the right place at the right time

Tactical and Reliability Investments



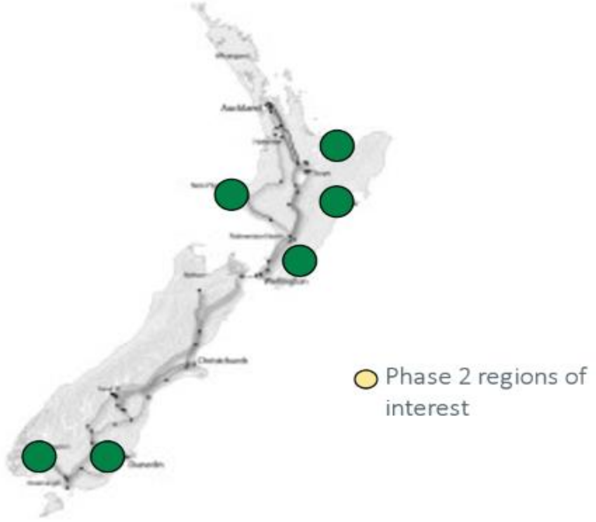
Tactical initiatives allow capacity until major works can be completed, ongoing reliability investments on existing assets enhance grid stability

Phase 1 – 2021-2035



Phase 1 takes a least regrets approach to upgrading the grid backbone assets; selecting investments that would be required under all future scenarios

Phase 2 – 2035-2050



Phase 2 considers regions with high potential for load or generation growth, and takes a longer term perspective of the future grid state; including the installation of new interconnections to supplement the existing grid backbone.

Challenges for Discussion

1. How can we best anticipate the requirement for new grid investment and ensure a ‘least regrets’ outcome?

2. What benefits could we include in the investment tests for grid development, where new generation is driven by market needs and regulated grid investment based on scenarios?

3. With electrification and electricity as the prime energy vector a more resilient grid and increased levels of reliability may both be appropriate How could we discover future electricity consumers desire for and how they value reliability and resilience to support the move to greater electrification?

Thank you

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