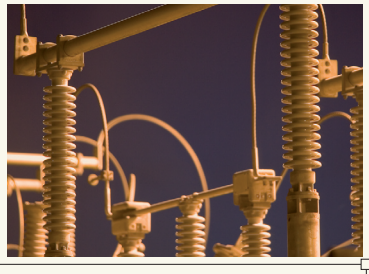
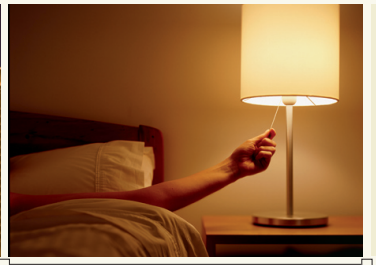
OCTOBER 2006

Amended North Island Grid Upgrade Project – **Transpower Overview**

TRANSPOWER



FROM GENERATION SOURCE

VIA THE NATIONAL GRID AND SYSTEM OPERATOR

TO THE CUSTOMER

contents

AT A GLANCE

Transpower's Amended North Island Grid Upgrade Proposal

Who Is Transpower?

Transpower is the state-owned enterprise that owns and operates the National Grid – or high voltage transmission network – that carries electricity around the country.

Why is a new transmission line needed in the upper North Island?

To meet the growing demand for electricity in the upper North Island and to ensure that homes and workplaces have a secure electricity supply, new investment is required.

There are six transmission lines running north to Auckland. The last of these was built in the 1960s. In the intervening 40 years, the population of the upper North Island has more than doubled and electricity use has more than trebled.

What has been the process to date?

2003: Transpower began investigating the need for a major upgrade of the transmission network in the upper North Island.

2004: Transpower announced in October 2004 it was seeking a route for a proposed 400 kilovolt transmission line from Whakamaru, north of Lake Taupo, to Otahuhu in South Auckland.

2005: A detailed funding proposal was submitted to the Electricity Commission in May and was resubmitted as part of a wider Grid Upgrade Plan in September 2005.

2006: In April the Electricity Commission issued a draft no decision to Transpower's proposal. In May Transpower suspended its application, to allow discussions to be held with the Commission about the best way to proceed. In October Transpower submitted an amended proposal.

THE AMENDED PROPOSAL – THE DETAILS

- An overhead transmission line from Whakamaru to near the South Auckland urban boundary, which will be 400 kV capable but will operate initially at 220 kV.
- A transition station near the South Auckland urban boundary, where the overhead line will connect to underground cables.
- An underground 220 kV cable section from the transition station to Pakuranga substation.
- A second underground cable section to Otahuhu substation at a future date.
- The voltage of the overhead line to be raised from 220 kV to 400 kV at a future date.
- Estimated cost of $683 million (in 2006 dollars, including contingencies, interest during construction and foreign exchange risk management).

What changes have been made to the original proposal?

- By operating the overhead line initially at 220 kV, expenditure on costly transformer equipment can be delayed.
- Triplex conductor (a bundle of three wires) rather than duplex conductor (a bundle of two wires) will be used to maximise the capacity of the line.
- The first underground cable section will connect to Pakuranga substation rather than Otahuhu, to provide greater diversity of supply into Auckland.

What other options were considered?

Since the beginning of the original project, a wide range of alternatives have been looked at including:

- The use of HVDC technology
- The use of new conductor types
- Different voltages including 500 kV, 330 kV and 220 kV
- Undergrounding more of the route
- Different termination points
- Generation and other non-transmission options.

In recent months ten specific transmission options were assessed, which were then reduced to a short-list of four. The four options are:

1 A new 220 kV transmission line from Whakamaru to Pakuranga (with an underground cable section in South Auckland), with a second 220 kV line between Whakamaru and Otahuhu built by 2031.
2 A new 400 kV transmission line, operating initially at 220 kV, with a cable section to Pakuranga and at a later date, to Otahuhu substation.
3 Duplex (replace the single conductor with twin conductor) the existing Whakamaru to Otahuhu A and B lines and connect them to Pakuranga via an underground cable, build a new 220 kV line by 2020 and a second 220 kV line by 2035.
4 Duplex the existing lines using a new high-temperature conductor, and build a new 220 kV line by 2029.

THE AMENDED PROPOSAL – WHY WAS IT CHOSEN?

Option 2 was chosen because it represents:

- The most cost effective option
- The best option for promoting renewable generation
- The least 'land hungry' option (no additional new line is required in the next 35 years)
- The most strategic option (it fits in with the long term development plan for the National Grid)
- The best option for promoting confidence to business investors

What about new generation?

In developing its proposal, Transpower has taken into account the possibility of new generation in Auckland. Transpower has used the Electricity Commission's future scenarios, which envisage new generation in the region as early as 2010.

All of the major generators have repeatedly stated that new generation in the Auckland area is not an alternative to transmission investment. Long term security of supply for the upper North Island requires new investment in both transmission and generation.

What happens now?

The Electricity Commission is seeking submissions on the amended proposal and intends to make a draft decision around the end of the year, with a final decision expected around May 2007.

Transpower will consult with those communities potentially affected by the South Auckland transition station and the underground cable route through to Pakuranga substation.

Transpower is the state-owned enterprise that owns and operates the National Grid – or high voltage transmission network – that carries electricity around the country. Transpower's role is to build, operate and maintain the National Grid. It does not generate own or sell electricity.

Planning for New Capacity into the Upper North Island

Transpower began investigating the need for a major upgrade of the transmission network in the upper North Island in 2003. At that time, based on a medium forecast, it was found that there was a risk that electricity demand could not be met in the upper North Island region from 2010 without major investment.

After assessing this need, Transpower began a consultation process in October 2004 on route options for a new 400 kV transmission line between Whakamaru and Otahuhu to be commissioned by 2010. This was known as the North Island Grid Upgrade Project.

Obtaining Approvals

Under the Electricity Governance Rules, Transpower must get approval from the Electricity Commission for proposed investments like the North Island Grid Upgrade Project. In September 2005, Transpower submitted a North Island Grid Upgrade proposal to the Electricity Commission for approval. On 27 April 2006, the Commission issued a Draft Decision to not approve the project, and on 31 May 2006, Transpower requested that the Commission suspend consideration of its proposal.

What Has Been Happening Since the Original Proposal was Suspended?

In light of the Draft Decision, Transpower has reviewed its approach. A particular issue that arose from the Commission's Draft Decision is the value of "optionality." Simply put, this means proposals that can be developed earlier, or later, to meet the changing needs should be more highly valued.

With the Electricity Commission's intentions and values now clearer, Transpower has responded by revising and reviewing aspects of its proposal, although the core of it has remained unchanged.

Reviewing all Relevant Options

Transpower has built on the concepts of optionality and the economic assessment methods used by the Electricity Commission to determine:

- The assumptions for testing an amended proposal and alternatives.
- The transmission options for assessment.
- The generation options for assessment.

New Developments

During this intensive review process, other events have influenced Transpower's approach:

- On 12 June 2006, a significant failure at Transpower's Otahuhu substation highlighted the importance of connections at Otahuhu substation and diversity of supply into Auckland.
- In August, a draft Government Policy Statement was released which also underlined reliability, diversity and corridor access issues, some sourced from the 12 June event.
- The high peak demand records set over the past winter have provided an opportunity to re-calibrate load forecasts. This has generally resulted in predictions of higher demands at peak times during extreme weather conditions.

Transpower anticipates its amended proposal, which incorporates much of the methodology of the Electricity Commission, will now facilitate the approval process.

Section 2 of this document provides more detail on how the assessment framework for the proposal was refined and determined.

Identifying the Need

Section 3 of this document outlines the need for this proposal. Importantly, the need is based on a different demand forecast. For the amended proposal Transpower has used a prudent high demand forecast, which has a probability of being exceeded, on average, one year in ten. It was identified that if there was not more capacity added to the network by 2013, the electricity supply to the upper North Island would be at risk. In other words, some times not all electricity demand in the region would be able to be met.

Options Considered for Meeting the Need

The transmission and non-transmission options considered for meeting the need identified are discussed in Section 4. A total of ten transmission options, including some sub-options and variants, were identified. These options were considered to provide a full spectrum of comparable options, which responded not only to the initial need, but also the events of 12 June. They are summarised in the table below:

OPTION #	NAME
1	220 kV overhead line/underground cables to Pakuranga (initially) and Otahuhu (later).
2	400 kV overhead line/220 kV underground cables into Pakuranga (initially) and Otahuhu (later). Operating at 220 kV initially with late conversion to 400 kV
3	220 kV augmentation (duplexing Otahuhu-Whakamaru A&B lines)
4	220 kV augmentation variant (as for 3. but with High Temperature Conductor)
5	400 kV overhead line/underground cable into Otahuhu (including two sub options)
6	220 kV overhead line/underground cable into Otahuhu
7	400 kV overhead line/underground cable into Pakuranga and Otahuhu (including two sub options)
8	400 kV overhead line/220 kV underground cable into Pakuranga and Otahuhu – with early conversion to 400 kV

From this list, three options (Options 1, 2 and 3) were short listed for further comparison. The criteria for short-listing the options were:

- Capital cost
- Diversity – alternative supply routes and options (a key lesson learnt from June 12)
- Meeting the Rules definition of an "alternative project"

Option 4 was taken forward as a non-qualifying alternative in that it was not a project that met the requirements of the Rules, but was useful to include in the Grid Investment Test analysis for comparison purposes.

Non-transmission Options

As well as the transmission alternatives, Transpower worked to identify three non transmission alternatives to assess further. They were:

- 155 MW peak load gas turbine generation station
- 240 MW base load gas turbine generation station
- 380 MW base load coal fired steam turbine generation station

These were also taken forward for further analysis.

Short listed Option Analysis

Section 5 of this document sets out the application of the Grid Investment Test to the short listed options. A summary table of results is provided below

OPTION	DESCRIPTION	NPV
		$ 2006
1	220 kV into Pakuranga and Otahuhu	$698 M
2	400 kV to the vicinity of the South Auckland Urban Boundary, 220 kV into Pakuranga and Otahuhu. Operating at 220 kV initially	$688 M
3	220 kV augmentation (duplexing and new line).	$813 M
4*	220 kV augmentation (duplexing as above using a high temperature conductor)	$963 M

* Non qualifying alternative, taken forward for comparison purposes only

The highest ranked project is the one that has the least cost – in this case Option 2, which is the Transpower proposed project.

The Transpower proposal, Option 2, is better than the alternatives (in 2006 NPV terms) by:

- $10M compared to the 220 kV alternative (Option 1)
- $125M compared to the duplexing alternative (Option 3)

- $275[1]M compared to the duplexing with high temperature conductor alternative (Option 4)

The Transpower proposal and the 220 kV alternative (Option 1) are therefore very close in outcome; however, the other alternatives are significantly more expensive by a considerable margin.

Sensitivity Analysis Confirms Option 2

To test the sensitivity of the result, a number of assumptions were varied to see the extent to which they changed the result above. That sensitivity analysis across 20 assumptions, demonstrated that the benefits from Option 2 consistently exceeded those from Option 1, 80% of the time. It also confirmed Option 2 to be far better than the duplexing options (Options 3 and 4).

For the non-transmission options, analysis showed that none of the generation options or variants delivered greater benefits than Options 1 or 2.

Benefit Assessment

There were two other issues to consider that while not easily valued under the Grid Investment Test also impacted on the option chosen:

- Capacity benefits (e.g. the benefit of getting easily releasable capacity from the line)
- Strategic benefits (e.g. the interface between this and other projects)

These benefits were assessed for the short listed options:

OPTION	CAPACITY BENEFITS?	STRATEGIC BENEFITS?
1	Some constraints affecting perceived and actual capacity likely immediately prior to investment in the next new line (e.g. around 2031). Designation and consenting risk for new corridor and a 6-7 year lead time for capacity beyond the first line.	Some – uses known technology and rationalises spares, maintenance and operations. On the negative side, requires multiple corridors and provides little flexibility to rationalise the upper North Island transmission into fewer corridors.
2	Easily releasable capacity through higher voltage provides actual and perceived certainty of supply. Short delivery time – around 2 years – because all works would be in consented substations.	Specific benefits for a 400 kV backbone development as substation equipment savings can be realised. Overall system losses will be reduced; high available capacity would provide options to rationalise upper North Island transmission into fewer corridors.
3	Limited capacity to release until after 2020. Perceptions about extent of capacity available to the upper North Island expected to affect investment until significant new capacity delivered.	Limited incremental approach with some optionality benefits at the expense of uncertainty. Not consistent with renewables futures requiring high degree of flexibility on transmission grid. Higher losses.
4*	As per option 3 but possibly more severe as relatively small increments in capacity are released over time using unproven (in New Zealand) technology.	As for option 3 but with even higher losses. Some benefits in reducing the number of corridors but at the expense of providing little or no flexibility to rationalise corridors into upper North Island and exposing under-built dwellings etc to higher magnetic fields.

* Non qualifying alternative, taken forward for comparison purposes only

1 The costs of this option assume a conductor cost provided for a short line quotation. Costs may be reduced for a long line quantity of conductor. Because of the overall cost difference, even if the conductor was the same cost as conventional conductor, the ranking of options would not change.

The Amended Proposal

The analysis has shown that the preferred proposal for the North Island Grid Upgrade Project is Option 2. This option includes in summary:

- A 400 kV capable double circuit overhead line between Whakamaru and a transition station in the vicinity of the South Auckland urban boundary, using the same route as the Original Proposal.
- Underground 220 kV cabling from the transition station to Pakuranga followed by later cabling from the transition station to Otahuhu.
- Line to operate initially at 220 kV.
- Conversion to 400 kV when economic.
- Amended cost of $683 million in 2006 dollars including contingencies, interest during construction and foreign exchange risk management ($824 million in 2011 dollars).

Timing

Section 6 of this document details the considerations in determining a 2011 date for the project taking into account:

- The economic 'need timing'
- The delivery risk timing

Need timing

'Need date' is the date by which the project is required in order to meet the requirements of the Grid Reliability Standards and/or economic requirements. Transpower has used two methods for determining the 'need date' of the proposed project – probabilistic and deterministic, but both methods have resulted in the same need date – 2013.

The timing is thus conclusively set at 2013 for the 'need timing'. This date assumes the following interim projects are in place by 2010:

- 220 kV Huntly East switching station
- 220 kV Otahuhu – Whakamaru A & B thermal upgrade
- Bombay bus split
- Reactive power investments for the upper North Island as approved by the Electricity Commission

Allowing for delivery risk

A major project of this nature has significant delivery risks associated with designations, consenting and easement acquisition. In addition, there are the normal construction and implementation risks. The expected costs in unserved energy (i.e. the cost for every MW not able to be supplied) for late delivery escalate rapidly beyond the 'need date'.

Transpower has developed a scenario based approach to examine project risk and has concluded that a two year advancement on the 'need date' is prudent to mitigate the risk of a one or two year delay in delivery.

The delivery time for the project is thus 2011, taking into account delivery risk.

Impact on Original Proposal

The Amended Proposal builds upon the work that went into the Original Proposal that was submitted as part of a Grid Upgrade Plan in September 2005. The core aspects of the proposal are the same with the following principal amendments:

- The new line will operate at 220 kV initially, and upgrade around 2030 to 400 kV.
- The ultimate line rating is increased to 2700 MVA from 1600 MVA.
- The underground cables will now be 220 kV only not 400 kV.

- The termination point will now be Pakuranga substation (connection to Otahuhu will now form part of a later stage – likely beyond 2020).
- The commissioning date is now 2011 not 2010.

Moving to 400 kV

Section 8 provides a wider context for the eventual upgrade of the line to 400 kV, including Transpower's National Grid Vision work and international experience.

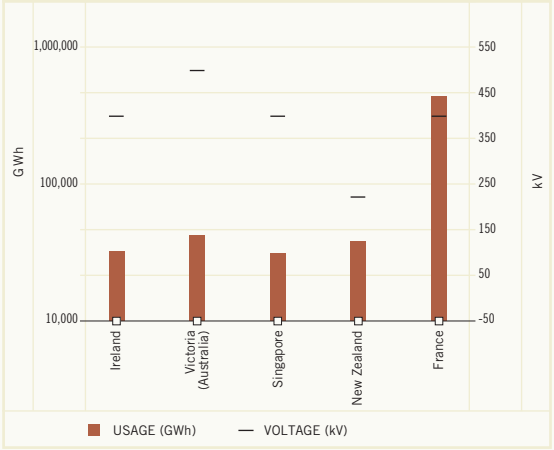
Transpower had earlier worked on a 40 year vision for the National Grid which selected 400 kV as the natural voltage step up for the grid backbone. This was based on the demand and generation likely to develop over this period and beyond.

Transpower is aware that while the public appetite for a reliable electricity supply is high, this does not equate to a hunger for new transmission lines. The 400 kV development path responds to that concern by not only providing fewer lines over time than a 220 kV path, but also allowing a greater planning flexibility in their introduction.

Internationally, New Zealand is following a long list of developed countries that have already increased their backbone transmission voltage to levels near or in excess of 400 kV, including:

- United Kingdom (400 kV)
- France (400 kV)
- Germany (380 kV)
- Norway (420 kV)
- Ireland (400 kV)
- Australia (Victoria) (500 kV)
- North America (765/500 kV)
- South Africa (765/400 kV)
- Japan (500 kV)
- Singapore (400 kV)

ELECTRICITY USAGE VERSUS HIGHEST TRANSMISSION VOLTAGE



Recommendation for Approval

Transpower's Amended Proposal is based on thorough analysis, utilising data assumptions and applications consistent with the Electricity Commission's methodology. Transpower concludes its proposal is superior to the alternatives and recommends that the Commission approve the project for a 2011 commissioning date.

1 Introduction

1.1 Background

In the September 2005 Grid Upgrade Plan (GUP), Transpower proposed to meet the emerging Auckland and upper North Island electricity demand by building a 400 kV transmission line. This project was declined by the Electricity Commission in April 2006.

1.2 Purpose

The purpose of this document is to:

- Summarise the work undertaken by Transpower since the original project was suspended.
- Set out the analysis undertaken by Transpower on a number of options for reinforcing electricity supply into the North Island.
- Based on the analysis undertaken, explain and justify the proposed amendments to the North Island Grid Upgrade Project.

For further reference, the *North Island Grid Upgrade Project Amended Proposal, Application for Approval* provides the full proposal as submitted to the Electricity Commission.

1.3 Regulatory Setting

The North Island Grid Upgrade Project is the first major project to be considered for approval under the regulatory arrangements defined in the Electricity Governance Rules.

Transpower has learnt a great deal from the submission of its first Grid Upgrade Plan in September 2005 and the processes that lead up to the Electricity Commission declining the proposal in its Draft Decision in April 2006. There have consequently been significant improvements in the processes leading up to the submission of the amended proposal.

It is important that transmission investments are assessed in a transparent, robust and consistent manner. Getting the assessment framework right is therefore a key outcome for Transpower and also for the electricity sector as a whole. The right assessment structure provides confidence for future investments and approvals. In August 2006, the Government issued a draft Government Policy Statement, which focused on supply reliability and diversity issues. While this document is only a draft and has not (in mid-October) been finalised, there are clearly aspects of the amended proposal that need to be consistent with the Government's intent.

This paper provides some context to the more formal and Rule based amended application.[2] The paper deals specifically with the following areas of interest:

- The assessment framework for the amended proposal.
- The need for the project, taking account of recent experience .
- The options that have been considered and how a short-list was selected.
- The comparative results for the selected options.
- The final recommendation based on these results.

The document is also interspersed with explanatory text to provide a higher level of detail on critical aspects of the amended proposal and alternatives.

2 North Island Grid Upgrade Project Amended Proposal, Application for Approval

2 Getting the Assessment Framework Right

During the period leading up to the release of the Draft Decision, it became apparent there was a divergence of opinion between the Electricity Commission and Transpower. The differences centred on how to assess the North Island Grid Upgrade Proposal under the Grid Investment Test, as developed by the Electricity Commission.

Since the Draft Decision, Transpower has worked on developing an assessment framework that better meets the assessment requirements of the Electricity Commission. Results from that work are:

- Determination of over 80 separate assumptions needed to be able to test any proposal and alternative options under the Grid Investment Test.
- A list of transmission options to test.
- A list of generation options to test.

Part F of the Electricity Governance Rules sets out the rules governing investment in transmission. Up until this proposal, they had not been tested by any other investment. In order to be approved, the North Island Grid Upgrade Project must:

- reflect good electricity industry practice in meeting grid reliability standards (Rule 13.4.1.1);
- comply with the processes set out in the Rules (Rule 13.4.1.2); and
- meet the requirements of the Grid Investment Test (Rule 13.4.1.3).

2.1 Electricity Commission Draft Decision

The Electricity Commission's Draft Decision on the original proposal highlighted that while the project reflected good electricity industry practice and complied with the processes set out in the Rules, it failed to be the preferred option under the Grid Investment Test. The Grid Investment Test is a type of cost/benefit test, so the Draft Decision suggested that there were cheaper options to meet the need than the North Island Grid Upgrade Project.

Transpower reviewed its project in light of how the Electricity Commission applied the Grid Investment Test to the original proposal. Three key aspects were noted:

1 The Commission places a high value on optionality. Projects that are adaptable to change as the need changes, are preferable to projects that do not exhibit such optionality. As an example: in the original proposal, easily releasable capacity was provided for if demand was higher than forecast; however, it was not a cost effective option if demand was lower than forecast.

2 Assumptions: Transpower noted that the Commission had used several different assumptions to Transpower in its inputs.

3 Options: Transpower noted that the Commission's treatment of comparable options was different to what it had initially considered.

2.2 Project Suspension

After reviewing the Draft Decision and the differences in interpretation with the Commission, Transpower requested a suspension of the proposal to allow it to work on an amended proposal that would better meet the way the Grid Investment Test was being applied.

The Electricity Commission duly suspended its consideration of the original proposal on 1 June 2006.

Through this period, Transpower also worked on determining:

- the key assumptions to be input into the Grid Investment Test; and
- the transmission and generation options that should be assessed.

2.3 Key Assumptions

Since the Draft Decision, Transpower has reviewed and determined over 80 separate assumptions. These include a wide range of inputs under headings like:

- Demand forecast information
- Generation scenarios
- Cost assumptions
- Technical assumptions (e.g. voltage stability, power factors etc)
- Grid Investment Test assumptions
- Project risk assumptions

This work helps provides certainty and consistency for both Transpower and the Electricity Commission in applying the Grid Investment Test in this and future projects.

A full description of the assumptions can be found in Attachment J of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval*.

2.4 Transmission and Generation Options

Having determined the basic assumptions around the inputs to be used, the next step for Transpower was to determine a range of transmission and generation options, which met the requirements of the Rules. In other words, any options needed to:

- reflect good electricity industry practice in meeting grid reliability standards (Rule 13.4.1.1);
- comply with the processes set out in the Rules (Rule 13.4.1.2); and
- meet the requirements of the Grid Investment Test (Rule 13.4.1.3).

During this phase of the work, an unforeseen event at Otahuhu substation on 12 June saw an outage to around half of Auckland's power supply for 4 or 5 hours. This provided fresh direction on the issues of:

- How to take into account low frequency (e.g. one in 50 year) events, which while infrequent have such a major impact on power supply (as the Otahuhu outage did).
- The question of diversity of supply with respect to both substations and line routes.

From consideration of all the options that should be considered, Transpower selected ten different transmission options, and three generation options. They are discussed in more detail in Section 4.

3 Establishing the Need

The needs analysis concluded that there is a risk of some electricity demand not being met in the upper North Island region at times of peak demand. This risk would apply from 2013 onwards and new investment is therefore required to maintain security of supply into the region.

The difference between this 2013 date and the 2010 date set out in the original proposal is due to a combination of factors:

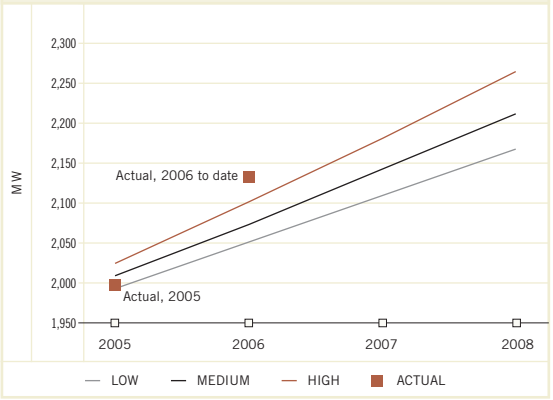
- The following projects have now been approved by the Electricity Commission to be in service prior to 2010:
  - Establishment of Ohinewai substation (Huntly East).
  - Thermal upgrade of the 220 kV Otahuhu-Whakamaru A & B lines.
  - Bombay bus split.
  - Reactive power investments for the upper North Island as approved by the Electricity Commission.
- A different demand forecast has been used to better cater for extreme year events.

Further information on the needs analysis can be found in Section 3 of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval*.

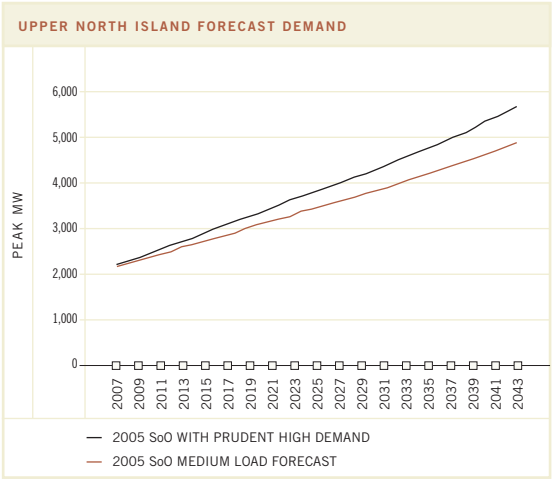
A key assumption for any amended proposal was on the demand forecast to be used. For its original proposal, Transpower was required to use a standard medium forecast to determine the timing of the project as set out in the Electricity Commission's Statement of Opportunities. However, as a medium forecast, it represents an average only – demand could be significantly higher, year on year.

An example of the effect was seen this winter where a number of new records for peak demand were set both nationally and regionally. The chart below shows how the actual peak demand for 2006 in the upper North Island was significantly higher than even the highest demand forecast.

2006 PEAK DEMAND



To better cater for the extreme year events such as winter 2006, and to reflect good electricity industry practice, the Commission provided a prudent high demand forecast, which provides only a 10% probability of the forecast being exceeded. So on average this forecast should only be exceeded once every ten years. The difference between this prudent and the original medium forecast used is shown in the chart below:



The needs analysis identified that there is a risk of some electricity demand not being met in the upper North Island at peak times from 2013. Also highlighted was that new investment is required to maintain security of supply into the region beyond this date.

Without investment, the electricity supply to the upper North Island would be increasingly constrained, increasing risk that not all demand in the region could be met.

The 2013 date is only the date at which supply is at risk, it does not set the timing of the project which will rely on the delivery risks associated with a project given its complexity and size. This is discussed in more detail in Section 7.

4 Option Analysis

Prior to selecting the best options for closer analysis, a broad range of possible options were canvassed. A short list of options was then created based on merit and the Grid Investment Test then applied to determine the most cost effective ones.

Further information on the option analysis can be found in Section 4 of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval.*

A total of ten transmission options and three generation options were initially selected for assessment by Transpower. In selecting these options, Transpower incorporated the analytical results from the Electricity Commission's Draft Decision.

A particular issue in selecting options was the question of technology evolution. Naturally, changes in technology over time have the potential to impact on any option at key decision points. However, Transpower, like the Electricity Commission in its Draft Decision, has selected options based on known technology, with development of each option consistent with that technology. For example, choosing a 220 kV line of certain design characteristics would be followed by a similar development when required later.

OPTION AND NAME	DESCRIPTION
OPTION 1: 220 kV into Pakuranga and Otahuhu	• New 220 kV double circuit overhead transmission line between Whakamaru and the South Auckland urban boundary. • New 220 kV underground cables from the South Auckland urban boundary to Pakuranga (initially) and Otahuhu (later). • New series compensation on the transmission line when required to increase the transfer capacity. • Additional new 220 kV double circuit transmission line between Whakamaru and Otahuhu when the transfer capacity to the upper North Island is exhausted (around 2031).
OPTION 2: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu	• New 400 kV double circuit overhead transmission line between Whakamaru and the South Auckland urban boundary. • New 220 kV underground cables from the South Auckland urban boundary to Pakuranga (initially) and Otahuhu (later). • The transmission line would operate at 220 kV initially. • New series compensation on the transmission line to increase the transfer capacity when required, and then subsequently increase voltage when needed.

OPTION AND NAME	DESCRIPTION
OPTION 3: 220 kV augmentation of existing assets	• Add new conductor to the existing 220 kV Otahuhu-Whakamaru A&B lines. • Re-terminate the Otahuhu-Whakamaru A&B lines that currently terminate at Otahuhu to a point in the vicinity of the South Auckland urban boundary. • New 220 kV underground cables from the South Auckland urban boundary to Pakuranga. • Additional new 220 kV double circuit transmission line between Whakamaru and Otahuhu when the transfer capacity to the upper North Island is exhausted (around 2020). • Second additional new 220 kV double circuit transmission line between Whakamaru and Otahuhu when the transfer capacity to the upper North Island is exhausted (around 2035).
OPTION 4: 220 kV augmentation of existing assets with high temperature conductor	• Variant on Option 3 involving the replacement of conventional conductor with high temperature conductor on the duplexed and possibly other circuits. This would permit higher transfer capacities over existing assets. • Additional new 220 kV double circuit transmission line between Whakamaru and Otahuhu when the transfer capacity to the upper North Island is exhausted (around 2029).
OPTION 5: 400 kV into Otahuhu	• New 400 kV double circuit overhead transmission line between Whakamaru and the South Auckland urban boundary. • New 400 kV underground cables from the South Auckland urban boundary to Otahuhu. • Transmission line to operate at 220 kV initially then: – Option 5.1 – Converting to 400 kV operation first and then installing series compensation to increase transfer capacity. – Option 5.2 – Installing series compensation to increase the transfer capacity first and then converting to 400 kV operation when required.
OPTION 6: 220 kV into Otahuhu	• New 220 kV double circuit overhead transmission line between Whakamaru and the South Auckland urban boundary. • New 220 kV underground cables from the South Auckland urban boundary to Otahuhu. • New series compensation on the transmission line to increase the transfer capacity when required. • Additional new 220 kV double circuit transmission line between Whakamaru and Otahuhu when transfer capacity to the upper North Island is exhausted (around 2031).

OPTION AND NAME	DESCRIPTION
OPTION 7: 400 kV into Pakuranga and Otahuhu	• New 400 kV double circuit transmission line between Whakamaru and the South Auckland urban boundary. • New 400 kV underground cables from the South Auckland urban boundary to Pakuranga (initially) and Otahuhu (later). • Transmission line to operate at 220 kV initially, then: – Option 7.1 – Converting to 400 kV operation first and then installing series compensation to increase transfer capacity. – Option 7.2 – Installing series compensation to increase the transfer capacity first and then converting to 400 kV operation when required.
OPTION 8: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu (early conversion to 400 kV)	• New 400 kV double circuit overhead transmission line between Whakamaru and the South Auckland urban boundary. • New 220 kV underground cables from the South Auckland urban boundary to Pakuranga (initially) and Otahuhu (later). • The transmission line would operate at 220 kV. • Increase voltage to 400 kV when needed, then install series compensation on the line to increase capacity when required.

Transpower did not include an HVDC option within this list because, based on the Electricity Commission's Draft Decision, an HVDC option was more costly than either a 220 kV or 400 kV option at the same date. Further discussion on the disadvantages of HVDC are provided in Section 4 of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval*.

In addition to the transmission options identified in the table above, Transpower also worked to identify and analyse three generation options:

OPTION #	GENERATION OPTIONS
G.1	155 MW peak load gas turbine generation station
G.2	240 MW base load gas turbine generation station
G.3	380 MW base load coal fired steam turbine generation station

QUESTIONS ABOUT THE OPTIONS SELECTED

What is the High Temperature Conductor used in Option 4?

A High Temperature Conductor is a conductor capable of operating at much higher temperatures than conventional conductors to allow them to provide more capacity. Operating temperatures for HTC can be in excess of 200° Celsius compared to conventional conductor temperatures of around 75°-120° Celsius. The specialized composite conductor is more costly and, when run at its upper temperature limit, can incur high transmission losses. Losses quadruple with a doubling of the flow in a transmission line and the resistance of a line increases with temperature, further exacerbating the net loss.

What about other transmission options – different voltages, HVDC?

Transpower researched different voltages and technologies as part of its work to determine the National Grid Vision for the next 35 years. It also undertook a number of studies into alternatives that were suggested as part of the consultation on the original proposal. Alternatives considered were:

- Rebuilding existing 220 kV lines to a higher (330 kV) voltage.
- Undergrounding all or more of the proposed route including the possibility of undergrounding in the Waikato River.
- Deployment of HVDC rather than HVAC technology – including both conventional and so called HVDC-lite technologies.

The Electricity Commission also considered HVDC alternatives as part of its Draft Decision. That work confirmed that an HVDC development option was more expensive than an equivalently rated 220 kV option. Given that a 220 kV option was included in Transpower's option assessment, it was not considered necessary to consider the more expensive HVDC option.

4.1 Short-listing the Options

Transpower used three key criteria to determine a short-list of projects to assess under the Grid Investment Test:

- Capital cost
- Diversity
- Meets the "alternative" definition of Part F of the Electricity Governance Rules

TRANSMISSION OPTIONS	SWITCH-YARD DIVERSITY	SUBSTATION DIVERSITY	CORRIDOR DIVERSITY	MEETS DEFINITION OF "ALTERNATIVE PROJECT"
Option 1: 220 kV into Pakuranga and Otahuhu	Yes*	Yes	Yes	Yes
Option 2: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu	Yes*	Yes	Yes	Yes
Option 3: 220 kV augmentation of existing assets	Yes*	Yes	Not until 2021	Yes
Option 4: 220 kV augmentation of existing assets with high temperature conductor	Yes*	Yes	Not until 2029	No
Option 5: 400 kV into Otahuhu Sub Option 5.1: Early 400 kV conversion	Yes*	No	Yes	Yes
Sub Option 5.2: Late 400 kV conversion	Yes*	No	Yes	Yes
Option 6: 220 kV into Otahuhu	Yes*	No	Yes	Yes
Option 7: 400 kV into Pakuranga and Otahuhu Sub Option 7.1 Early 400 kV conversion	Yes*	Yes	Yes	Yes
Sub Option 7.2: Late 400 kV conversion	Yes*	Yes	Yes	Yes
Option 8: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu (early conversion to 400 kV)	Yes*	Yes	Yes	Yes

* Assumes Otahuhu substation upgrade proceeds when Otahuhu substation is connected to transition station some time after 2020.

Options 7.1, 7.2 and 8 were discarded for cost reasons. Specifically:

- Options 7.1 and 7.2 required two 220/400 kV substations in Auckland (duplication of expensive 400 kV transformation costs); and
- Option 8 involves building 220/400 kV substations earlier than comparable options (bringing forward the cost of 400 kV conversion).

Options 5.1, 5.2 and 6 were discarded for diversity reasons in that they did not provide diversity of supply into Auckland.

Option 4 did not meet the requirements of Part F of the Electricity Governance Rules because it was considered:

- Not reasonably practicable (Rule 19.2); and
- Not reasonably likely to proceed if neither the proposal or other alternative does not proceed (Rule 19.3).

However, for comparison purposes, Transpower included Option 4 as a non-qualifying alternative in the next stage of analysis.

This left the following short listed options to assess further under the Grid Investment Test:

SHORT LISTED TRANSMISSION OPTIONS
Option 1: 220 kV into Pakuranga and Otahuhu
Option 2: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu
Option 3: 220 kV augmentation of existing assets
Option 4: 220 kV augmentation of existing assets with high temperature conductor*
* Non-qualifying alternative, taken forward for comparison purposes only

The table below provides a better context for these options in terms of their environmental impact:

OPTION #	NAME	EASEMENT WIDTH	TOWER HEIGHT MAX	NEW TOWER NO'S BY 2040	NEW LINES REQUIRED BEFORE 2040
1	220 kV overhead line/ underground cables to Pakuranga (initially) and Otahuhu (later).	50m	58m	880	2
2	400 kV overhead line/220 kV underground cables into Pakuranga (initially) and Otahuhu (later). With late conversion to 400 kV.	65m	70m	426	1
3	220 kV augmentation (duplexing Otahuhu-Whakamaru A&B lines).	existing	-	880	2
4*	220 kV augmentation variant (as for 3. but with High Temperature Conductor).	existing	-	450	1

* Non qualifying alternative, taken forward for comparison purposes only.

QUESTIONS ON SHORT-LISTING OF PROJECTS

Why are the transmission towers so high for the 220 kV alternative?

The 220 kV development path utilises a higher rated transmission line (1200 MVA),which in turn requires a 'heavier' and taller tower than used on existing 220 kV lines (up to 58m compared with around 45m for existing lines and up to 70m for the 400 kV proposal). The height and number of towers is a cost trade-off between fewer high towers and more low towers. The optimized design uses fewer towers and therefore reduces material and construction costs. Using more, lower towers increases costs and would therefore make the alternative compare less favourably with the 400 kV proposal.

Why has Transpower considered such a high rating for the 220 kV alternative?

Transpower regards new corridors as scarce resources and is trying to minimise the number of new corridors and lines into the Auckland area. Transpower has therefore configured the 220 kV solutions to utilise a heavier conductor to provide a bigger capacity (1200 MVA compared to, for example, 700 MVA on the existing Otahuhu-Whakamaru C line). If Transpower had used a lower rated 220 kV line, at least three such lines would be required over the study period. This would have increased costs and the number of new corridors to an extent that the option would have compared far less favourably to the 400 kV proposal.

Why is Option 4 a non-qualifying alternative?

Transpower considered that Option 4 was not an "alternative project" as defined in Part F of the Electricity Governance Rules. Specifically, this option is significantly high risk, and not one that Transpower could prudently propose, for the following reasons:

- Transpower is concerned at the potential risk of conductor failure because:
  - Transpower has no experience with this type of conductor.
  - Transpower is not aware of any transmission lines of a comparable length where such a conductor is relied on to operate for extended periods at high temperature.
- At optimum capacity, the conductor's magnetic field is up to 240% higher than the conductor on the existing lines (after uprating), and about 50% higher than Option 3 (after conventional duplexing). While still within the guidelines set by the International Committee on Non-ionizing Radiation Protection, Transpower did not consider it prudent to choose a conductor that would dramatically increase the magnetic field of a line that has significant areas of under-building.

5 Applying the Grid Investment Test

All transmission investments made under Part F of the Rules must be evaluated using the Grid Investment Test. The Grid Investment Test is a type of cost/benefit analysis, which is used to compare and determine the most cost-effective option from a range of other options. Like any cost/benefit test, it is as robust as the inputs or assumptions that are used to undertake the assessment.

Because of the importance of the Grid Investment Test to ongoing investment beyond the North Island Grid Upgrade project, Transpower has developed assumptions fundamental to this assessment, which Transpower believes are consistent with those of the Electricity Commission. This assumption framework will provide a valuable direction for future proposals.

While much work has been achieved to improve the application of the Grid Investment Test to future proposals, Transpower believes it would benefit from further refinement to bring it more into alignment with international best practice.

For further information on applying the Grid Investment Test, refer to Section 6 of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval*.

From Section 4, the following four transmission options were selected for assessment under the Grid Investment Test:

SHORT LISTED TRANSMISSION OPTIONS
Option 1: 220 kV into Pakuranga and Otahuhu.
Option 2: 400 kV into the South Auckland urban boundary, 220 kV into Pakuranga and Otahuhu. Operating at 220 kV initially.
Option 3: 220 kV augmentation of existing assets.
Option 4: 220 kV augmentation of existing assets with high temperature conductor.*
* Non-qualifying alternative, taken forward for comparison purposes only

In addition to the four short listed transmission options there were three non-transmission alternatives taken forward:

OPTION #	GENERATION OPTIONS
G.1	155 MW peak load gas turbine generation station.
G.2	240 MW base load gas turbine generation station.
G.3	380 MW base load coal fired steam turbine generation station.

Part F of the Electricity Governance Rules requires that a proposed reliability investment such as the Amended Proposal, meets the requirements of the Grid Investment Test. The Rules further set out that a proposal meets the Grid Investment Test where the Electricity Commission is reasonably satisfied that:

1 the investment maximises the expected net market benefit, or minimises the expected net market cost compared with a number of alternative projects; and

2 if sensitivity analysis is conducted, that the proposed investment is sufficiently robust against the results of that analysis.

What is sensitivity analysis?

Sensitivity analysis is undertaken by varying the key assumptions in the Grid Investment Test to see how a proposed investment is affected by different circumstances, which might happen by the time the investment is underway. Examples of key assumptions that might change include:

- Capital cost
- Demand forecasts
- Generation scenarios

5.1 Grid Investment Test Assessment

The table below provides the results from applying the Grid Investment Test to the short listed options.

ITEM	OPTION 1 220KV WKM-PAK	OPTION 2 400KV WKM-PAK	OPTION 3 DUPLEX OTA-WKM A&B	OPTION 4* HTC DUPLEX OTA-WKM A&B
	PV 2006 DOLLARS (MILLIONS)			
Mean capital cost (A)	687	682	737	808
Mean O&M costs (B)	24	25	21	20
Mean unserved energy cost ©	0	0	0	0
Mean relative loss cost (D)	0	-1	60	126
Mean terminal benefit (F)	12	13	4	-9
Strategic benefit (G)	0	-5	0	0
Expected net market cost (A+B+C+D-F+G)	698	688	813	963
ENMC Difference, Proposal v reference case	-	-10	115	265

* Non-qualifying alternative, provided for comparison purposes only

As can be seen from the results above, Option 2 passes the Grid Investment Test by having the lowest net present cost of the three alternatives. The results for the non qualifying alternative – Option 4 – showed that it was significantly more expensive than any of the three other options.

5.1.1 Non-transmission Alternatives

Assessment of the three non-transmission alternatives showed that generally they were not as cost effective as transmission solutions. A full account of this analysis can be found in Attachment K of the Amended Proposal document[3] submitted to the Electricity Commission.

In summary, for the base load options, it was found that even when taking into account the benefits from deferring transmission, there are generation options with lower long run marginal costs (LRMCs),

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that in an efficient market, should be built before Auckland base load plant (these include renewable options located where they are most economic).

For the peak generation options, two separate variants were also tested, including the relocation of the Whirinaki dry year reserve plant. The table below shows the results of that assessment.

GENERATION ALTERNATIVE	NET MARKET COST (COMPARED TO 220 KV BASE CASE) $ 2006
155 MW peak load gas turbine generation station (new)	$212 million
155 MW peak load gas turbine generation station (second hand)	$111 million
Relocate Whirinaki and increase reliability	$26 million

As can be seen above for all cases of peak generation, there was a net market cost of up to $212 million more than the 220 kV transmission reference case.

5.2 Sensitivity Analysis

The second requirement under the Rules is that the proposed investment is robust against sensitivity analysis. The results from that assessment against the three transmission options are provided below, together with the difference between the proposed investment (Option 2) and the next best investment (Option 1). The grey shaded cells identify that Option 2 was superior to Option 1, the light copper cells indicate where Option 1 was superior to Option 2. The dominance of Option 2 in this analysis, reinforces the choice of Option 2 as the preferred option.

For comparison purposes, Option 4 was also included in the sensitivity analysis. This reinforced the initial finding under the Grid Investment Test that Option 4 was the least preferred investment path, with the sensitivity analysis showing the option to be between $147m and $600m more costly than Option 2.

$2006 MILLION	OPTION 1 220KV WKM-PAK	OPTION 2 400KV WKM-PAK (PROPOSAL)	OPTION 3 DUPLEX OTA-WKM A&B	OPTION 4* DUPLEX OTA-WKM A&B (HTC)	DIFFERENCE 400KV-220KV
Mean NPV Costs (from table above)	698	688	813	963	-10
Sensitivity analysis:	-	-	-	-	-
$2011	1112	1096	1296	1534	-16
Capital cost +20%	835	824	961	1124	-11
Capital cost -5%	664	654	777	922	-10
System SRMC	698	687	827	1011	-11
Loss cost +30%	698	687	834	1009	-11
Loss cost -30%	698	689	793	917	-9
Discount rate 4%	934	883	1159	1438	-51
Discount rate 10%	545	553	602	694	8
Property escalation 0%	682	680	784	941	-2
Property escalation 6%	724	697	857	997	-27
Exchange rate 10 yr average	691	687	807	955	-4
Hydro/Renewable scenarios - 0 new generation	750	722	903	1092	-28
Reduced demand scenario - 1 new generation	714	701	846	1010	-13
Coal scenario – 2 new generation	674	674	776	903	0
Gas scenario - 3 new generation	629	640	688	784	11
New generation prior 2030 only	680	675	793	937	-5
Urban sprawl 10km	701	688	813	963	-13
Upper 50% runs	747	721	882	1044	-26
Lower 50% runs	653	658	753	890	5
10% POE Demand path only	769	737	924	1141	-32

* Non-qualifying alternative, included for comparison purposes only

QUESTIONS ON GRID INVESTMENT TEST

The analysis shows the 220 kV and 400 kV build options to have similar costs and benefits, why not propose the 220 kV option?

There is little separating the 400 kV or 220 kV new build options applying the Grid Investment Test. The most significant differentiator between the two options is that the 220 kV development option will require a new additional line route in later years (around 2030). It is likely that any additional route will face significant challenges in the consenting and easement processes. By contrast, at similar capacity, the 400 kV constructed line, can easily increase voltage through installing new transformers at the substation near the South Auckland urban boundary.

Why is Option 3 so high in NPV costs compared to options that actually build new lines initially?

Option 3 relies on a great deal of remedial, refurbishment and tower replacement works on existing towers, most of which are over 50 years old. This work is required to allow the towers to accommodate the heavier loading from adding new conductor.

Additionally, two new 220 kV lines are still required for this option – in the early 2020s and again in the 2030s. As with the new 220 kV build options, these will face significant consenting and easement challenges.

An additional cost to the duplexing options is from high transmission losses, mainly in the first ten years prior to the first new 220 kV line. By contrast both Options 1 & 2 benefit from having two new low-loss circuits delivering energy north.

Why doesn't Option 4 rate better?

As with Option 3, this option suffers from:

- High costs of transmission losses.
- Higher costs for the special purpose conductor.
- The same remedial and refurbishment works on the existing transmission towers as for Option 3.

Transmission losses are exacerbated by using the High Temperature Conductor (HTC), which while forcing more current down the line, also increases the transmission losses.

Additionally and peculiar to Option 4 is the cost of the HTC conductor, which is 2 to 6[4] times more expensive than conventional conductor. This, together with the higher risks associated with HTC deployment, has reinforced the view that Option 4 is not a preferred solution.

4 The wide range of costs appears to be related to the size of the order – shorter lengths tend to be at the higher end of the estimate.

5.3 Other Factors Impacting on Choice

There are a number of factors that while not easily valued under the Grid Investment Test, or sensitivity analysis, tend to underline Option 2 as being preferred:

OPTION	CAPACITY BENEFITS?	STRATEGIC BENEFITS?
1	Some constraints affecting perceived and actual capacity likely immediately prior to investment in the next new line (e.g. around 2031). Designation and consenting risk for new corridor and a 6-7 year lead time for capacity beyond the first line.	Some – uses known technology and rationalises spares, maintenance and operations. On the negative side, requires multiple corridors and provides little flexibility to rationalise Upper North Island transmission into fewer corridors.
2	Easily releasable capacity through higher voltage provides actual and perceived certainty of supply. Short delivery time – around 2 years – because all works would be in consented substations.	Specific benefits for a 400 kV backbone development as substation equipment savings can be realised. Overall system losses will be reduced; high available capacity would provide options to rationalise upper North Island transmission into fewer corridors.
3	Limited capacity to release until after 2020. Perceptions about extent of capacity available to upper North Island expected to affect investment until significant new capacity delivered.	Limited incremental approach with some optionality benefits at the expense of uncertainty. Not consistent with a renewables future, requiring a high degree of flexibility for the transmission grid. Higher losses.
4*	As per option 3 but possibly more severe as relatively small increments in capacity are released over time using unproven (in New Zealand) technology.	As for option 3 but with even higher losses. Some benefits in reducing the number of corridors but at the expense of providing little or no flexibility to rationalise corridors into the upper North Island. Also exposes under-built dwellings etc to higher magnetic fields.

* Non-qualifying alternative, taken forward for comparison purposes only

6 Timing

Having determined that Option 2 satisfies the Grid Investment Test and is robust against sensitivity analysis, actual project timing needs to be confirmed taking into account the actual system need timing and project delivery risks.

For a full description and analysis of timing, refer to Section 7 of the *North Island Grid Upgrade Project Amended Proposal, Application for Approval*.

The Grid Investment Test is a calculation tool designed to rank comparable projects against each other but is not useful as a means of determining the timing of the project. This requires an analysis of:

- when the project is required ('the need timing'); and
- any project delivery risks that may need to be accounted for.

6.1 Probabilistic and Deterministic Approach to the Need Timing

There are two methods of determining the need timing of the project:

- Probabilistic
- Deterministic

In its Draft Decision, the Electricity Commission used a probabilistic means of determining when investment was required. A probabilistic approach method uses the Grid Investment Tool in conjunction with the Grid Reliability Standards to balance the cost of expected unserved energy through delay of the project against the benefits of deferring the investment.

Under a deterministic model, power system analysis tools are used to determine the point at which the grid is no longer able to provide a secure supply in accordance with pre-defined security criteria.

In the case of the Amended Proposal, the difference between these two methods is theoretical only, as both calculations showed the same optimal date for building the project – 2013:

METHOD	PROJECT NEED TIMING
Probabilistic (EC model) (combining the Grid Reliability Standards and Grid Investment Test)	2013
Deterministic (using an n-g-1 security criteria and a prudent forecast)	2013

6.2 Accounting for Project Delivery Risk

A major project of this nature has significant delivery risks associated with designations, consenting and easement acquisition, as well as the normal construction and implementation risks. The expected costs in unserved energy for late delivery escalate rapidly beyond the 'need timing' date.

By definition, a one year delay in the project has expected unserved energy costs that are greater than the net cost of the project. A two year delivery delay has expected unserved energy costs considerably more than twice the net project cost. This reflects a strongly asymmetrical risk, where the penalties for late delivery far exceed the costs of early delivery.

Transpower has developed a scenario based approach to examine project risk and has concluded that up to a two year delay is probable and a three year delay is possible, although less likely. Transpower has formed the view that a two year advancement on the 'need date' is prudent to mitigate the risk of a one or two year delay in delivery.

The delivery date for the project is thus 2011, taking into account the delivery risks.

7 The Recommended Proposal

From the Grid Investment Test and sensitivity analysis, Option 2 is the preferred option, and the timing for project completion is 2011 taking into account project delivery risks. The table below describes the full extent of works for approval:

THE RECOMMENDED PROPOSAL: 400/220 KV TO PAKURANGA

- Procure, construct, commission and operate a 220 kV switching station in the vicinity of Drury and upgrade the 220kV Otahuhu – Whakamaru C line by 2010.
- Procure, construct, commission and operate 350 Mvar of new static reactive plant at Otahuhu substation by 2010.
- Procure, construct, commission and operate a new double-circuit, steel lattice tower, overhead transmission line of approximately 190km from a new substation near the existing Whakamaru substation to a new transition station in the vicinity of the South Auckland urban boundary, that is capable of:
  - 220 kV operation.
  - future 400 kV operation of around 2700 MVA. This move would be subject to later approval for and commissioning of 220 kV-400 kV transformers and associated switchyards near the existing Whakamaru substation and in the vicinity of the South Auckland urban boundary.
- Procure, construct, commission and operate two underground cables from the new transition station in the vicinity of the South Auckland urban boundary to Pakuranga substation that:
  - are capable of 220 kV operation; and
  - have a continuous rating of around 660 MVA per set of cables.
- Procure, construct, commission and operate the necessary substation / transition station facilities near the existing Whakamaru substation (Air Insulated Switchgear [AIS]), a transition station in the vicinity of the South Auckland urban boundary (AIS), and Pakuranga substation (Gas Insulated Switchgear [GIS]).
- Plan the works, including the acquisition of designations, consents and easements to allow for future upgrade to 400 kV operation through future addition of:
  - new 400/220 kV transformers and associated works near the existing Whakamaru substation to interconnect with the existing 220 kV system;
  - a new switchyard in the vicinity of the transition station with new 400/220 kV transformers and associated works;
  - new overhead lines or underground cables to connect the new switchyard with the new transition station;
  - new 220 kV underground cables to Otahuhu substation; and
  - extensions to the Otahuhu switchyard(s).
- Carry out the works necessary to convert and connect the existing 110 kV Otahuhu-Pakuranga line to 220 kV operation, for which it is already designed and consented.
- Dismantle the existing 110 kV Arapuni to Pakuranga transmission line.
- Obtain designations, easements, resource consents and property purchases necessary for all the above work.
- Plan for a commissioning date for the major projects above of 2011 to prudently allow for potential delays due to delivery, designation, consenting and easement risks.

The capital cost of the proposal for which Transpower is seeking approval from the Electricity Commission is $683 million in 2006 dollars including contingencies, ($824 million in 2011 dollars). The table below provides a breakdown of that cost.

COST CATEGORY		AMENDED PROJECT $ 2006 (MILLION)	AMENDED PROJECT $ 2011 (MILLION)
Investigations		22	27
Property		96	116
Environmental		7	8
Transmission Works:			
– Lines	400 kV line	168	203
	Up-rate OTA-WKM C	3	4
	OTA-PAK 110 kV circuits	1*	1*
	Drury	2	2
– Substations	Otahuhu	10	12
	Whakamaru	11	13
	Pakuranga	46	55
	Drury	13	16
	Static Compensation	7	8
– Cable		91	110
Dismantling		4	5
Project Management		28	34
Subtotal		**509**	**614**
Contingency		87	105
Exchange Rate		21	25
Interest During Construction		66	80
TOTAL		**683**	**824**

*This cost will increase by between $7M and $10M if the Otahuhu diversity project does not proceed.

Why are these costs more expensive than the Original Proposal?

Transpower's Original Proposal of $622 million was not priced in 2011 dollars. When converted to 2011 dollars the Original Proposal comes in at $709 million but there are other factors which have caused significant cost differences between the two proposals. These are:

- Contingency costs have increased by $30 million.
- Line costs have increased by $60 million from the Original Proposal due to constructing with larger capacity conductor, as well as the work required to convert the Otahuhu to Pakuranga 110 kV line to 220 kV, and uprate the Otahuhu to Whakamaru C line.
- Exchange Rate allowances have increased by $32 million reflecting an alternative treatment for addressing exchange rate volatility.

These cost increases were only marginally set off by the reduced cost of transformer and substation equipment.

Why isn't the cost of this proposal the same cost as that used for the Grid Investment Test?

The Grid Investment Test is a cost and benefit test, for assessing options against each other. It encompasses far more than just the capital cost needed to physically build the project, including for example:

- Extended costs and benefits (over 30+ years) for any particular option
- Transmission losses
- Unserved energy cost

7.1 Impact of Amended Proposal on Original Proposal

The Amended Proposal builds upon the work that went into the Original Proposal, which was submitted as part of a Grid Upgrade Plan in September 2005. The principal amendments are as follows:

ORIGINAL PROPOSAL	AMENDED PROPOSAL	RATIONALE
Central to Upper North Island	Unchanged	Project still meets the same need for additional capacity from central North Island to upper North Island. Project driver is the same.
Line route	Unchanged except for last 10 km	Route from Whakamaru is as consulted. Majority of landowners affected in the same ways.
Line construction and tower heights	Only minor changes	Some towers reduced in height, conductor optimised to reduce electrical noise. Visual impact almost identical.
Otahuhu destination	Pakuranga initially and Otahuhu at later date. (electrically a minor change)	Original Grid Upgrade Plan suggested Pakuranga for second line. Requirements for diversity now make Pakuranga first choice of destination to create 'eastern corridor'.
400 kV operation	220 kV then 400 kV to South Auckland urban boundary (staging of original project).	Grid Investment Test values optionality. Staged implementation of 400 kV allows optimal timing of substation works, deferring expenditure for many years.
400 kV substation at Otahuhu	400 kV substation 10 km south in vicinity of the South Auckland urban boundary (location change).	Gives more flexibility for connections into Auckland via Pakuranga, Otahuhu and Penrose. Better design with cables separate from transmission lines.
1600 MVA rating	2700 MVA rating (design optimisation)	Original design limited by cable capacity. Now able to maximise the use of a scarce resource – corridors. Capitalises on the capability offered by the higher voltage technology for marginal increase in line cost ($25M).
400 kV cables	220 kV cables (optimisation for diversity)	Avoids need for 400 kV substations in Pakuranga/ Otahuhu with associated consenting issues (noise and size). Multiple 220 kV cables are cheaper, can be staged, provide GIT optionality and give greater diversity, should one cable fail.
2010 commissioning	2011 commissioning	The commissioning date now explicitly recognises approved investments and proposed short-term investments. Delivery delays due to designations, consenting easements and construction are now explicitly recognised as a two year advancement of the need date.

8 Moving to 400 kV After 2030

Transpower's Amended Proposal forecasts upgrading the new transmission line from 220 kV to 400 kV sometime after 2030. This section provides an overview of how this eventual move to 400 kV fits in with:

- Transpower's long term vision for the National Grid.
- The international scene.

8.1 Transpower's National Grid Vision

8.1.1 Background

To ensure a secure electricity supply into the future, the National Grid must continue to be developed and extended to meet new demand. The grid must also provide for existing and new generation.

Transpower uses a 40 year vision to provide a framework to consider and propose upgrades to the National Grid. The National Grid Vision sets the scene of investment for the next 40 years, but it doesn't dictate that investment. Each project is assessed separately at the time at which the investment is needed.

8.1.2 National Grid Vision

Transpower's 40 year vision for the National Grid is to move gradually to a 400 kV backbone. The backbone of the National Grid includes the major transmission routes between:

- Wellington and Auckland running through the central North Island.
- Wellington and Auckland running through Taranaki.
- Waitaki Valley and Christchurch.
- Manapouri and Waitaki Valley.

This does not mean every new line between these areas will be built or operated at 400 kV. It will depend on how economic it is to do so at the time the investment is planned. Any investment still has to pass a cost benefit test (the Grid Investment Test) overseen by the Electricity Commission.

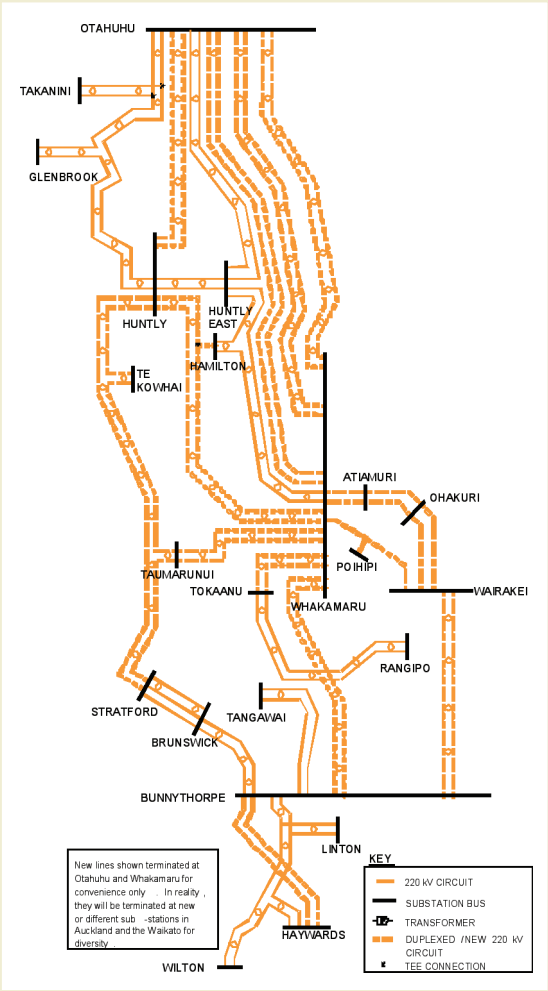
The exact nature of the network in 2040 will depend on demand, technology and generation development. Transpower has prepared its National Grid Vision using three different generation scenarios. Each of these scenarios would see a slightly different National Grid in 2040.

8.1.3 Mitigating the Impact of New Lines

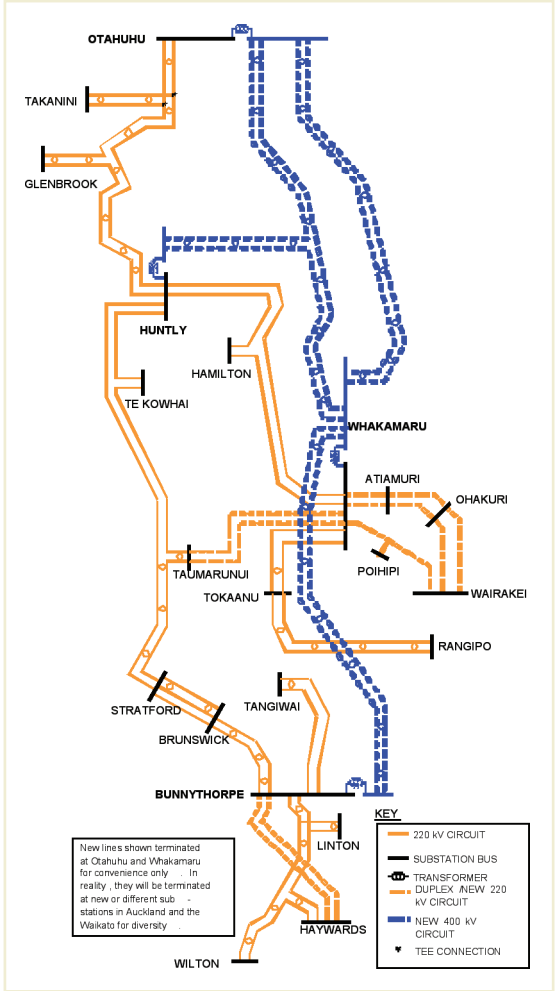
Transpower is aware that while the public appetite for a reliable electricity supply is high, this does not equate to a hunger for new transmission lines. The 400 kV development path responds to that concern by not only providing fewer lines over time than a 220 kV path, but also allowing a greater planning flexibility in their introduction. So as part of Transpower's vision for the future, consideration of ways in which the impact of major new lines can be mitigated will be undertaken for the communities they affect. This includes:

- An undergrounding policy to detail our position with respect to new lines in urban areas.
- Considering the extent to which major new lines can replace older lower capacity lines so that the overall number of lines on a scarce resource – land - is kept to a minimum. For example, the amended proposal includes the removal of the old Arapuni to Pakuranga 110 kV line consisting of 460 towers and 147 route km of conductor.

In practice, removing lower capacity lines when new lines are commissioned, will bring forward the commissioning dates for new lines. However, as can be seen from the diagrams below, there would be a marked benefit in the number of lines and line routes required over time.



North Island 220 kV Development post 2040 (Scenario 3)



North Island 400 kV Development post 2040 (Scenario 3)

Is Transpower's National Grid Vision new?
No. Transpower's National Grid Vision has been the culmination of work that began in 2001. Executive and Board endorsement over 2002 and 2003 was followed by the release of Transpower's vision within its "Future of the National Grid" document. Parts of the National Grid Vision were also submitted with Transpower's original Grid Upgrade Plan of September 2005.

The diagram for 400 kV development above shows two 400 kV lines to Auckland after 2040. How does that compare with this proposal where only one line by 2043 is needed?
The difference between the work undertaken for the National Grid Vision, and the work undertaken for the Amended Proposal, is that the former expressly allows for lower capacity lines being removed, whereas the latter does not. This has the effect of bringing forward the need for a new line, along with benefits such as rationalising the number of routes and lines over time. Upgrading the grid over time to a 400 kV voltage, provides an opportunity to replace lower capacity lines, where 220 kV development does not.

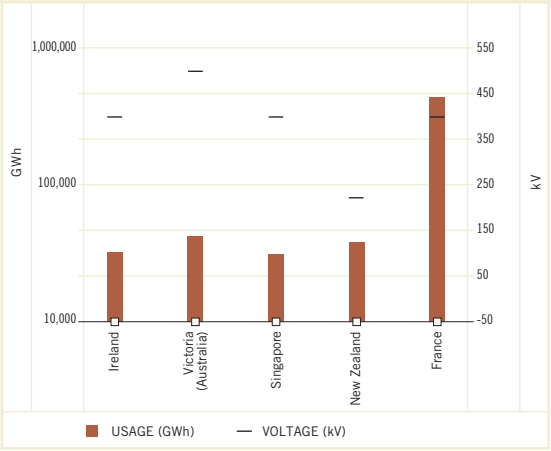
8.2 What voltages do other countries operate at?

New Zealand is following rather than leading international practice in eventually stepping up to a higher voltage for its National Grid. Other developed countries with transmission voltages similar or in excess of 400 kV include:

- United Kingdom (400 kV)
- France (400 kV)
- Germany (380 kV)
- Norway (420 kV)
- Ireland (400 kV)
- Australia (Victoria) (500 kV)
- North America (765/500 kV)
- South Africa (765/400 kV)
- Japan (500 kV)
- Singapore (400 kV)

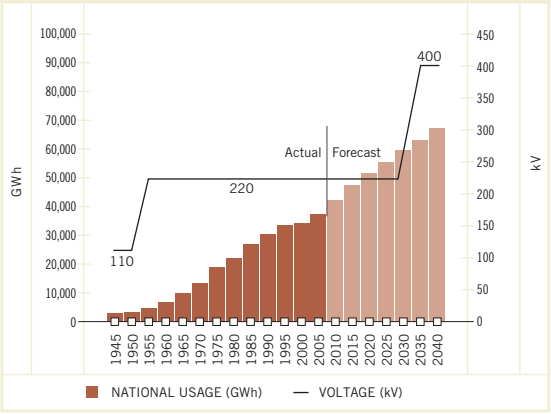
Glossary of Terms

ELECTRICITY USAGE VERSUS HIGHEST TRANSMISSION VOLTAGE



As seen from the graph above, New Zealand's move to 400 kV is timely in comparison to other countries (or states) of a similar size. France's electricity usage is some ten times larger than New Zealand's – suggesting that 400 kV will remain our highest voltage for many decades beyond 2040.

NEW ZEALAND POWER USAGE VERSUS HIGHEST OPERATING TRANSMISSION VOLTAGE



Bus – A low impedance conductor within a substation to which several circuits/conductors can be separately connected.

Bus split – A low impedance conductor divided into separate electrical sections (for example by way of a circuit-breaker) to provide greater security of supply.

Circuit – A set of conductors (normally three) plus associated hardware and insulation on a transmission line, which together form a single electrical connection between two or more stations.

Conductor – The wire making up each phase of a transmission line consisting of copper, aluminium and/or steel including stranded, tubular and solid.

Duplex – A twin arrangement of the conductors (wires) making up each phase of a high voltage transmission circuit.

Grid Reliability Standards – Standards for reliability of the grid developed in accordance with Rule 4, Section III, Part F of the Electricity Governance Rules.

Grid Upgrade Plan – Plan for grid expansions, replacements and upgrades, developed in accordance with Rule 12, Section III, Part F of the Electricity Governance Rules.

MVA and Mvar – MegaVoltAmpere – the flow of active power is measured in megaWatts (MW). When compounded with the flow of reactive power, which is measured in Mvar, the resultant is measured in MegaVoltAmperes (MVA). MVA means 1000 kVA.

Reactive power – Energy that flows in the power system between alternators, capacitors etc. and inductive and capacitive equipment such as transmission lines and low power factor loads.

Series compensation – Equipment which effectively shortens a transmission line by compensating for the reactive power loss and voltage drop in the line that occurs naturally over long distances.

Thermal upgrade – Increasing the operating temperature of the conductors (wires) of a transmission line to allow more capacity to be carried.

Transition station – A station to connect overhead transmission line(s) with underground cable(s).

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