TRANSMISSION TOMORROW

THE ENDURING GRID

Keeping the energy flowing

TRANSPOWER

CONTENTS

Executive Summary

We have undertaken a study, using scenario analysis, to gain an understanding of the future role of the New Zealand high voltage transmission grid.

We developed four scenarios that reflect possible variations in the future growth of electricity demand and the location of generation. We have also considered the five scenarios developed by the Electricity Commission in 2008. While there are many uncertainties in determining New Zealand's electricity future, we believe the resulting nine scenarios provide a reasonable range of possible outcomes.

We then modelled the power flows (both long term energy flows and at peak times) out to 2040 under each scenario to determine their impact on the grid. Because of the importance of hydrology to New Zealand (under any scenario), we also ran dry, average and wet inflow scenarios.

Our work found that:

- there is an ongoing need for the backbone grid from Roxburgh to Otahuhu and its capacity will need to increase over time
- the need to increase capacity on the backbone grid is consistent across scenarios and only varies in timing
- additional capacity for the regional connections to the backbone grid is less certain with more variation between scenarios.

The implications of these findings are as follows:

- We can plan for future additional capacity on the backbone grid where it is required. This allows us to develop options for additional capacity well ahead of the critical dates.
- For the regional connections to the backbone grid, newer technology options for better utilising the grid, such as extracting more capacity from the existing lines or the use of demand-side management, have added value.

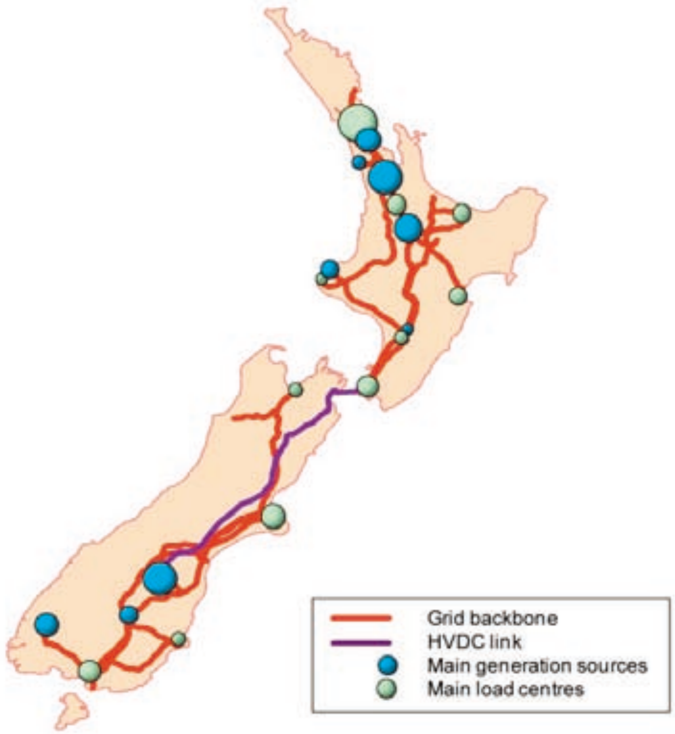
1 Introduction

Proactive long term planning is an important part of managing the transmission grid. Our assets are long-lived (many have lives in excess of 50 years), our solutions take time to build (a new line can take 7 or more years), and the product we transport – electricity – is the lifeblood of a country's economic and social wellbeing.

This document provides an overview of our analysis into the enduring role of the grid. It is a high level analysis over a 30 year horizon - in contrast to our Annual Planning Report (APR), which is a detailed view over a shorter time frame. It is principally concerned with the backbone grid shown in Figure 1-1, and has been prepared as part of our "Transmission Tomorrow" work.

The New Zealand grid[1] comprises a backbone spanning the length of the country (some 2000 kilometres) with a number of regional grids connected to the backbone.

Figure 1-1: New Zealand's backbone grid



We are a long, narrow country, with our electricity generation located far from the large cities where demand is highest.

[1] "Grid" refers to the national grid of transmission lines and cables (aerial, underground and undersea, including the high-voltage direct current link), stations and sub-stations and other works used to connect grid injection points and grid exit points to convey electricity throughout the North and South Islands of New Zealand.

2 Future requirements

While we can't predict the future, we need to understand the requirements of tomorrow's grid, as there is a long lead time to deliver additional grid capacity. If we wait until the need for additional capacity is certain, we will be too late. On the other hand, building capacity too early can be expensive, and risks building assets that become stranded.

The future need for the grid is driven by a combination of electricity demand growth and the location of new generation. New generation built close to, rather than remote from, load centres requires less additional capacity on the backbone grid. However, even in very low growth scenarios, renewable generation is still provided by remote generation and if older thermal generation is also replaced by new generation remote from load, the transmission grid will need to expand.

3 Scenarios

We have used diverse scenarios to develop a credible range of future operating conditions. In this way we can identify the likely future requirements of the grid to meet a range of possible outcomes.

Our scenarios vary both demand growth and the type of generation built (thermal versus renewable for example). They reflect different demand futures on the one hand (varying GDP, population growth, uptake of electric vehicles, etc) and potential generation futures on the other (varying gas availability and price, carbon price, etc).

We have used nine different scenarios of electricity generation and demand development in New Zealand looking forward 30 years. Four of these we have developed ourselves,[2] with the remaining five taken from the Electricity Commission's 2008 Statement of Opportunities.[3] We modelled future grid flows for each of these nine scenarios. This allowed us to assess the:

- suitability of the existing grid for the future
- additional grid capacity that may be required.

While it is unlikely that any one specific scenario will eventuate, the results from our analysis of the nine scenarios provide information which allows us to develop strategies for prudent management of the grid. Where future grid flows are confined within a reasonably narrow band over a wide range of scenarios, for instance, we can be reasonably confident of the future grid requirements and can develop long term plans where increases in grid capacity are required. Where future grid flows vary – high in some scenarios but low in others – we cannot plan with the same certainty and we should consider developing and securing options that deliver additional capacity if or when it is required.

The four Transpower scenarios varied demand and generation in to test the limits of grid design:

LDLG – low demand growth, new local generation located close to load

LDRG – low demand growth, new remote generation located far away from load

HDLG – high demand growth, new local generation located close to load

HDRG – high demand growth, new remote generation located far away from load

Figure 3-1 illustrates the four scenarios.

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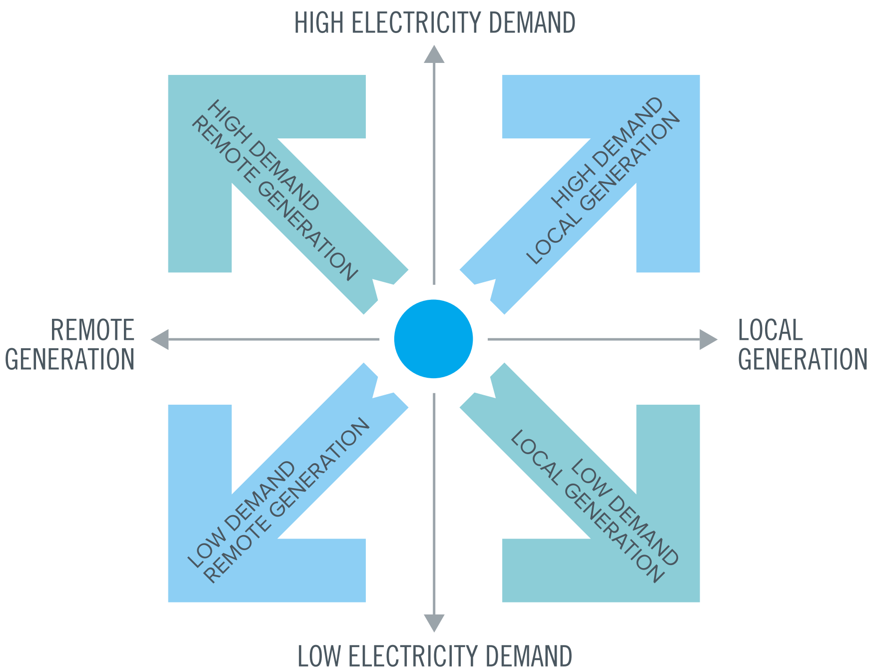
[2] These were developed through extensive consultation, in 2009/10, as an input into Transmission Tomorrow's predecessor long term planning exercise, T2040.

[3] At the time of analysis, the 2010 Statement of Opportunity scenarios were still under development.

Figure 3-1: Key features of the four Transpower scenarios



Whereas our Transpower scenarios are based around testing the parameters of the grid, the 2008 Statement of Opportunities scenarios are based on specific potential futures.[4] They are:

MDS1 – Sustainable path (high renewables)

MDS2 – South Island surplus

MDS3 – Medium renewables

MDS4 – Demand-side participation

MDS5 – High gas discovery

Both sets of scenarios (ours and the 2008 Statement of Opportunities) are not exclusive. The resulting nine scenarios span a credible range of potential future developments and, by considering their impact on the grid, we get a good range of potential requirements for the grid into the future.

A summary of the key characteristics of all nine scenarios (both demand and generation) are shown in the table below.

[4] Full details can be found at http://www.ea.govt.nz/industry/ec-archive/

Table 3-1: Summary of some key drivers, by scenario

Scenario	Eventual carbon price, \$/t CO_2e	Eventual gas price, \$/GJ	Demand	Notes
Transpower Scenarios				
High Demand Remote Generation	\$80	\$13	High GDP growth + high electric vehicle uptake + high fuel switching	New local oil and gas discoveries result in some new thermal plant. Large remote renewable generation, including marine energy, is harnessed
High Demand Local Generation	\$0	\$10	High GDP growth	Large thermal plants built close to cities and small micro-generation becomes popular
Low Demand Remote Generation	\$40	\$12	Low GDP growth	Some new gas discoveries and Methanex plant closes resulting in new Taranaki CCGTs. Major hydro projects in the South Island and utilisation of Southland lignite
Low Demand Local Generation	\$80	\$14	Low GDP growth + medium fuel substitution + medium solar substitution	A severe economic climate results in a focus on conservation and local generation. Although unrelated, the price of solar photo voltaic panels drops rapidly
Electricity Commission Scenarios				
Sustainable path (MDS1)	\$60	\$13	Base + high electric vehicle uptake	90% renewables reached by 2025. Huntly coal units closed by 2020
South Island surplus (MDS2)	\$50	\$13	Base	Mostly as above, but more South Island based generation is built
Medium renewables (MDS3)	\$30	\$11	Base + Tiwai smelter phased out around 2025	Renewables share around 75%. Huntly coal units in dry year reserve from 2020
Demand side participation (MDS4)	\$20	\$11	Base + High electric vehicle uptake with V2G	Significant thermal plant developments. Few new hydro plants can be consented
High gas discovery (MDS5)	\$40	\$8	Base + little DSP	More CCGTs, partly replacing Huntly, supplemented with wind and geothermal

3.1 Electricity demand

The demand forecasts included in the scenarios have been derived using econometric[5] models. They forecast future energy and peak electricity demand based on historical relationships between key indicators and electricity demand.

Demand growth across New Zealand has averaged 1.6% per annum since 1990, driven largely by average GDP growth at 2.7% per annum and a growth in the number of households averaging 1.4% per annum.

The key indicators used in most electricity demand forecasting models are population, household numbers, GDP, electricity prices and increasingly (including in our own scenarios), climate.[6]

Three demand models are used to forecast demand separately for each of three consumer sectors – residential; commercial and industrial; and heavy industrial. These sectors have different characteristics and the relationships between the key indicators and demand differ:

In some scenarios, adjustments are made for discrete changes not captured by the key indicators:

- Use of electric vehicles resulting in higher electricity demand.
- Fuel switching, where carbon constrained scenarios result in an increase in electricity demand.
- Decreases in residential demand due to an increase in the installation of solar hot water panels.

Our forecasts are long term projections and do not include regional step changes in electricity use which are very difficult to predict.[7] For example, during the 1980's no-one predicted the impact that extensive conversion to dairy farming would have on summer peak demand and as a result, grid utilisation, along the east coast of the South Island.

We forecast both overall electricity consumption (in Megawatt hours) and peak electricity demand (in Megawatts). Typically, peaks occur on weekdays in winter, or increasingly, hot days in summer (due to irrigation and air-conditioning). There is evidence that the growth in peak electricity demand has been slower than growth in overall electricity demand in recent years with increasing demand in summer with irrigation and heat pumps. Equally though, there are convincing arguments that peak growth could be higher than overall demand growth in the future. For the purposes of our demand forecasts, we have assumed that peak growth occurs at the same rate as overall demand growth.

The resulting national peak demand forecasts, used in each scenario, are shown in Figure 3-2.

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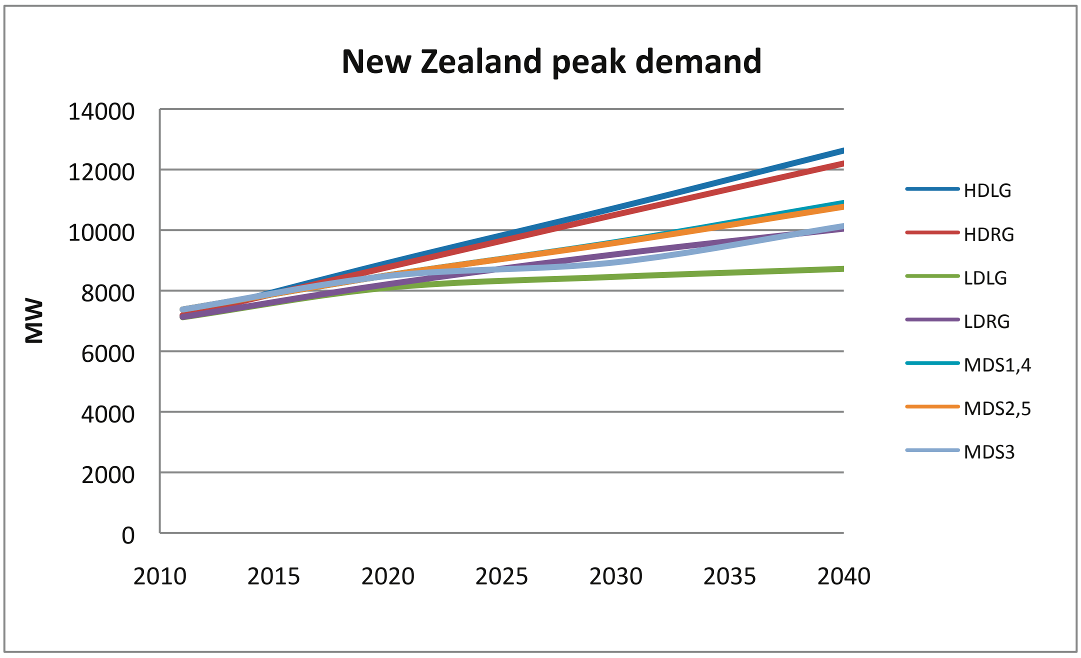
[5] Econometric models are statistical forecasting models. An econometric model specifies the statistical relationship that is believed to hold between the various economic quantities under study based on historical information and assumes that relationship will hold into the future.

[6] Projections for these key indicators are from publicly available sources.

[7] With the exception of Tiwai aluminium smelter closing, which is reflected in one of the Electricity Commission scenarios.

Figure 3-2: New Zealand peak demand forecast by scenario



The approach used in the 2008 Statement of Opportunities forecasts includes a central estimate plus high and low estimates, derived using Monte Carlo analysis.[8] We have used the central forecasts in our analysis.

Our own forecasts span the range covered by the high and low forecasts in the 2008 Statement of Opportunities, resulting in the following annual peak growth rates and overall demand growth, per scenario:

Table 3-2: Average peak demand growth by scenario

Scenario	Average peak growth per annum, %			Overall demand growth to 2040, %		
	NI	SI	NZ	NI	SI	NZ
Transpower scenarios						
HDRG	2.0%	1.4%	1.8%	79%	53%	70%
HDLG	2.0%	1.6%	1.9%	80%	62%	76%
LDRG	1.3%	0.8%	1.1%	48%	26%	40%
LDLG	1.0%	0.4%	0.8%	33%	14%	26%
Electricity Commission scenarios						
Sustainable Path	1.6%	1.0%	1.4%	60%	36%	51%
South Island Surplus	1.5%	1.0%	1.4%	58%	35%	50%
Medium Renewables	1.5%	0.1%	1.0%	58%	-5%	36%
Demand-side	1.6%	1.0%	1.4%	60%	36%	51%
High Gas	1.5%	1.0%	1.4%	58%	35%	50%

[8] Monte Carlo analysis involves determining a distribution for a parameter by randomly selecting model inputs and calculating the value of the parameter many times, typically several thousand. It is useful for modeling phenomena with significant uncertainty in inputs (such as future demand growth).

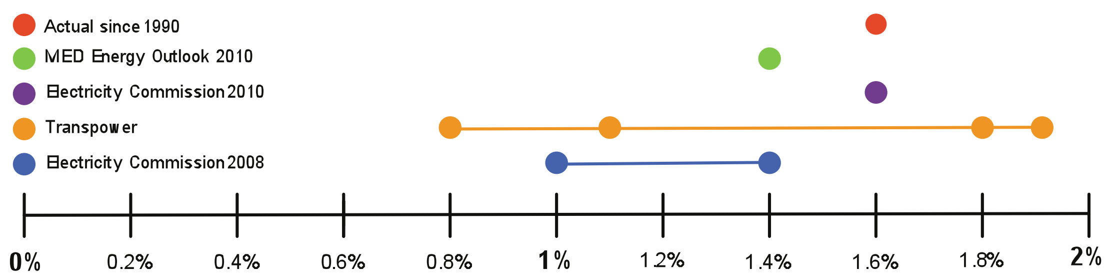
The growth rates in electricity demand covered by the nine scenarios are comparable to updated forecasts by the Electricity Commission and Ministry of Economic Development:

- The 2010 Electricity Commission Statement of Opportunities demand forecast (which was not available in time for this study) reflects an increase over their 2008 demand forecast and averages 1.6% per annum. This increase reflected more optimistic GDP forecasts and higher population forecasts.

- The MED have recently published their 2010 Energy Outlook and their reference scenario reflects demand growth averaging 1.4% out to 2030.

On a spectrum, the different forecasts and the historic average demand growth since 1990 are all shown in Figure 3.3 below.

Figure 3-3: Comparison of various New Zealand electricity demand forecasts and actual average growth since 1990



The range of demand growth possibilities in the nine scenarios span a wide range of possible outcomes, including both high and low economic growth.

There are two key observations which influence future grid capacity:

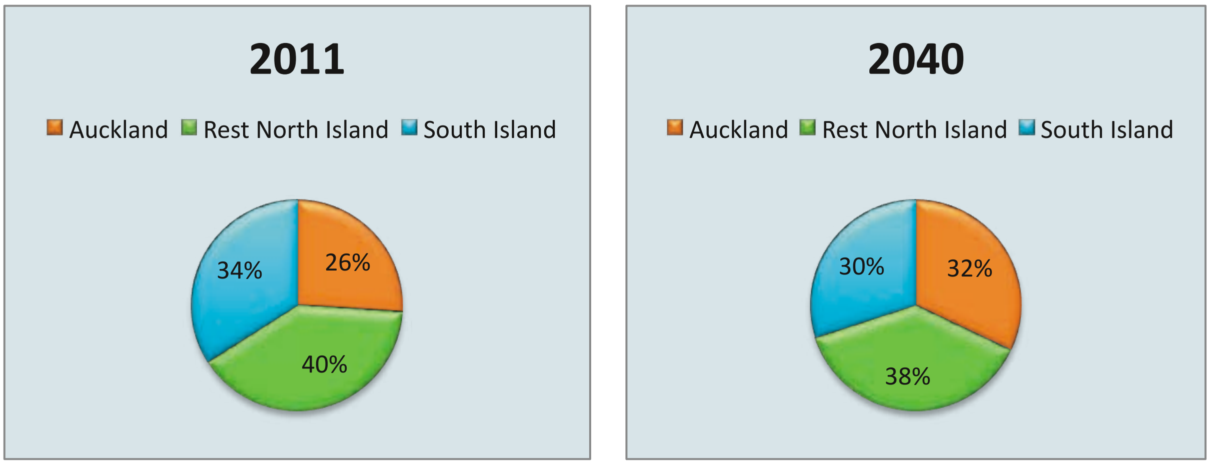
- Electricity demand is expected to increase at a higher rate in the North Island. This has been the trend for the last twenty years and is expected to continue.[9]

- Auckland is the largest load centre and is likely to grow at a higher rate than other load centres.

The diagrams below show the proportion of demand and how it changes over time as averaged over all scenarios.

[9] In the last five years, South Island load growth has been similar to North Island load growth, because of a step change in demand driven by dairy conversions. While this may continue in the near term, it is expected to plateau.

Figure 3-4 Percentage of peak demand in Auckland, North Island and South Island



3.2 Generation

For both our own and the Electricity Commission generation scenarios, the following generation technologies were included:

- Hydro
- Wind
- Geothermal
- Gas and Oil
- Coal
- Marine (to a lesser extent)

We assume that solar electricity generation will initially only offset electricity use in our homes and thus any nearer term increase in the use of solar technology would show as a slowing in demand growth. Our range of demand assumptions adequately covers that potential.

The scenarios include both base-load and peaking generation,[10] plus the use of demand-side response as an alternative to peaking generation.[11]

Different generation drivers[12] are used in each scenario, consistent with the economic and environmental climate assumed for that scenario. The range of scenario drivers assumed is described in more detail below.

Generation expansion modelling is used to derive a generation expansion schedule.[13] For both the Electricity Commission scenarios and our own, the Electricity Commission's model GEM, has been used. This is described in detail on the Electricity Authority website.[14]

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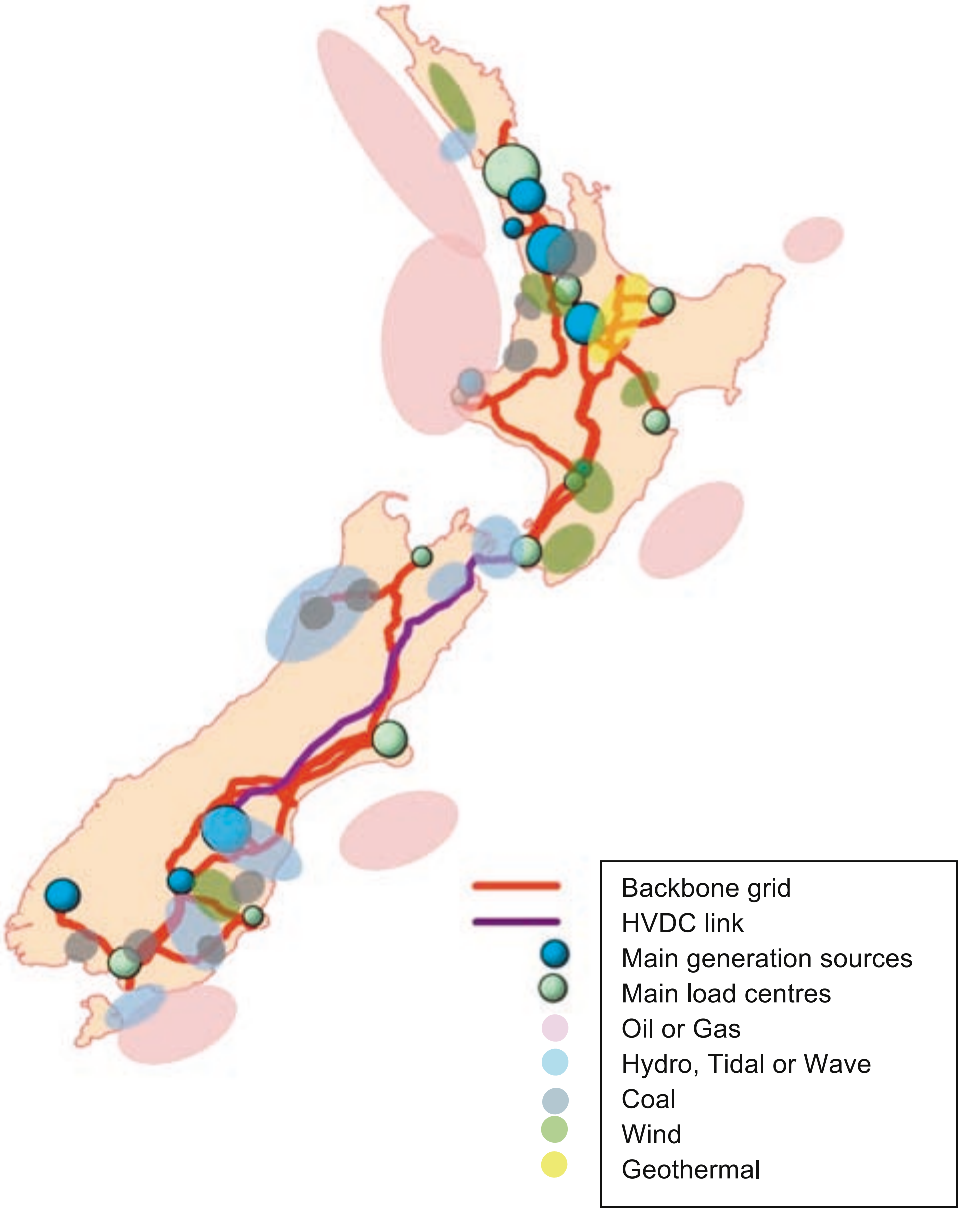
[10] Peaking generation are power stations that generally run only when there is a short term need to meet high demand.

[11] Here we have relied upon the 2008 SoO scenarios. While we have some concerns in regard to the quantity of peaking assumed, this will be the subject of a separate investigation at a later date.

[12] Drivers in this context are cost variables which might be taken into account when considering an investment in new generation. Gas prices and carbon prices are two examples.

The location of generation investment is often dependent on the location of the fuel resources. This is particularly true for renewable generation, but less so for gas and coal since they are both transportable fuels. Figure 3-5 below summarises the location of the various potential fuel resources and illustrates the potential geographic diversity of new generation.

Figure 3-5: Location of potential resources for future electricity generation



The energy resources we have for electricity generation in New Zealand are substantial and geographically diverse. While we have considered a range of generation technologies in

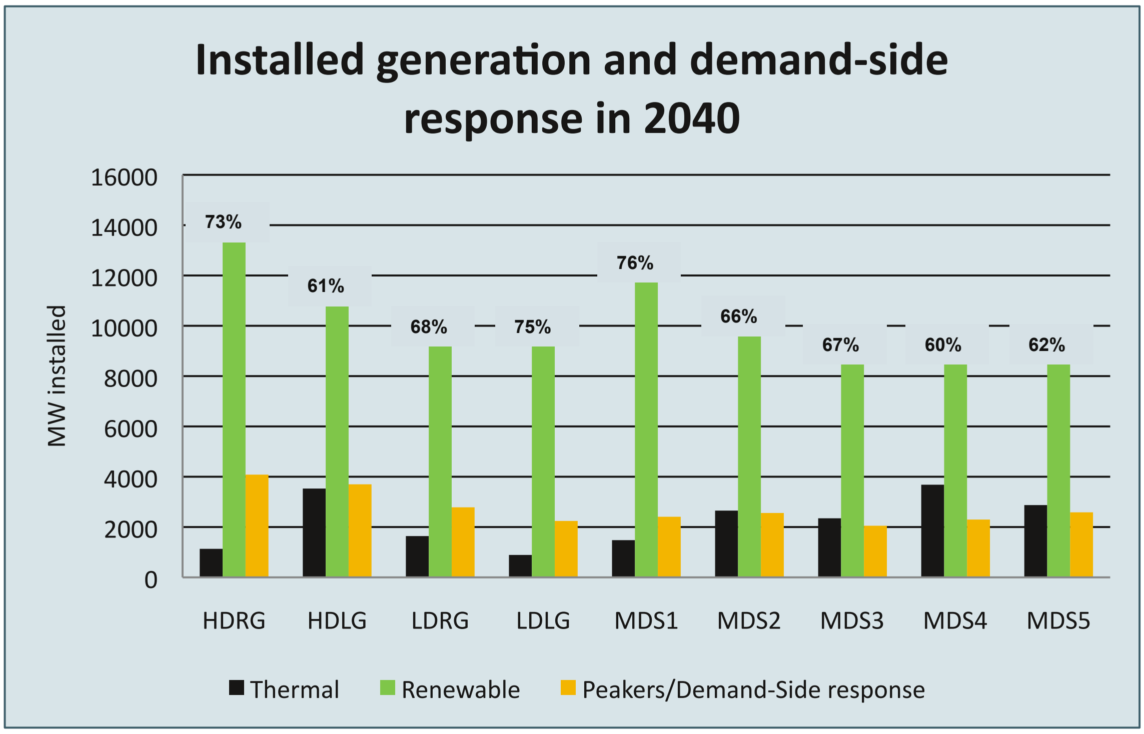
[13] Generation expansion models are mathematical models which develop a schedule of new generation build, over a specific time period (30 years in our case). The model objective is usually to build sufficient new generation to meet forecast demand, at minimum cost,

[14] http://www.ea.govt.nz

developing the scenarios, we acknowledge that the type, location, size and timing of generation development provides the greatest source of uncertainty for transmission planning.

Accordingly our scenarios endeavour to capture a broad range of future outcomes. They are summarised in Figure 3-6 below, which shows total installed generation (and assumed demand-response) in New Zealand in 2040, under each scenario along with the percentage of renewable generation.[15]

Figure 3-6: Installed generation and demand-side response in 2040



We can conclude from the scenarios that:

- demand growth is increasing faster in the North Island than the South Island
- unless new generation is built in the North Island to match this increase there will be increasing flows on the backbone grid
- in addition, generation development would need to match regional demand growth simultaneously in every region – this seems unlikely and is not reflected in any of our scenarios.

Hence we will need to invest in the backbone grid. We will also need to invest in the regional connections but the need for investment is harder to predict.

[15] The aspirational target that 90% of New Zealand's electricity will be generated from renewable sources by 2025 refers to the percentage of energy produced, not the mix of installed generation.

3.3 Impact on the Grid

As a means of verifying the conclusions above, we have used power flow modelling[16] to determine the electricity flows on the grid for each scenario. Both long term energy and peak flows have been considered, and the following assumptions were made:

- The existing grid configuration has been used up to the full thermal capacity to determine the optimal energy transfer along the backbone grid.
- For each scenario, we have considered dry, average and wet hydrology, as the volatility of hydro inflows will continue to have a major bearing on grid flows.

We have only considered thermal transmission capacity. Full grid planning studies as used in our Annual Planning Report also include voltage support and system stability studies which may result in more or earlier investment. In addition, there is also a need to lift the reliability and resilience of our grid and this may advance the need for investment in the grid.

We determined the total flows on the backbone grid between fourteen key regions. These represent the major generating and demand regions.

As an example, flows between Waikato and Auckland were considered based on the flows across the five major transmission lines which transfer electricity into the Auckland region from Huntly and further south.

Figure 3-7: Transmission lines between Waikato and Auckland

The nine scenarios and three different hydrological sequences (dry, average and wet), give a total of 27 different scenarios and flow patterns for every year going forward, across the fourteen regions considered.

3.4 Scenario Outcomes

The flows on the backbone grid for each scenario provide an indication of the need for grid capacity over the next few decades.

Long term energy flows are one driver of the need for grid capacity, but peak flows determine the timing of capacity upgrades. The higher the peak flow, the more capacity is required to

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[16] Using the modelling tool Plexos

prevent bottlenecks in the transport of electricity between regions. Such bottlenecks can result in a higher overall cost to New Zealand if more expensive generation is required to meet the demand.

Where future energy and peak flows are confined within a reasonably narrow band over a wide range of scenarios, we can be reasonably confident of the future demand for transmission services. Accordingly, we can plan long term for a consistent increase in grid capacity.

Where future grid energy and peak flows vary – high in some scenarios but low in others – we cannot plan with the same certainty. In such circumstances we can, however, look at securing options that deliver additional capacity if or when it is required. This reduces the risk of:

- not investing prudently and not providing sufficient capacity in time
- incurring large capital costs from building earlier than required
- stranding investments at a future date.

To form a view on which situation dominates over the backbone of the grid, we have looked at long term energy flows over the full 30 years out to 2040 and peak transmission flows in 10 year steps out to 2040.

3.5 Long term energy flows

Consistent with our conclusions from the demand and generation scenario assumptions, we found that under most high demand scenarios, northward flows increase over the next 30 years. In some scenarios, flows increase by over 100 percent. Predominant long term energy flows remain from south to north under all scenarios.

A summary of forecast energy flows between the fourteen regions considered, between 2011 and 2040, are shown in the figure below. The maximum and minimum total energy flows over 30 years from the nine scenarios and three hydrological conditions are shown. Northward flows are shown as positive and southward flows as negative.

Figure 3-8: Total energy flows between 2011 to 2040 in TWh

More detailed results, showing the flows for each scenario, are summarised in Table 3-3 below.

Table 3-3: Total 30 year energy flows, south to north, by scenario 2011 to 2040 (TWh)

	HDLG	HDRG	LDLG	LDRG	MDS1	MDS2	MDS3	MDS4	MDS5	Min	Max
Auckland to Northland	40	5	20	-1	15	5	55	31	39	-1	55
Waikato to Auckland	336	345	262	298	329	305	319	306	302	262	345
Waikato to Bay of Plenty	39	33	11	40	19	54	33	-3	42	-3	54
Central North Island to Hawkes Bay	-52	-34	-56	-40	-30	-44	-57	-55	-64	-64	-30
Taranaki to Central North Island	32	61	25	43	52	54	53	15	62	15	62
Taranaki to Bunnythorpe	34	79	53	62	72	76	62	33	-4	-4	79
Bunnythorpe to Central North Island	23	71	15	44	58	74	54	-5	57	-5	74
Wellington to Bunnythorpe	47	133	60	100	96	126	90	18	21	18	133
HVDC	158	227	147	184	174	192	183	111	111	111	227
Nelson to West Coast	-1	16	5	17	-4	-18	-18	-18	-17	-18	17
Christchurch to Nelson	43	15	21	6	22	54	37	37	37	6	54
Waitaki Valley to Christchurch	227	179	170	140	157	209	191	191	190	140	227
Roxburgh to Twizel	98	107	50	53	61	106	88	43	41	41	107
Southland to Manapouri	-158	-165	-162	-165	-158	-158	-149	-158	-158	-165	-149

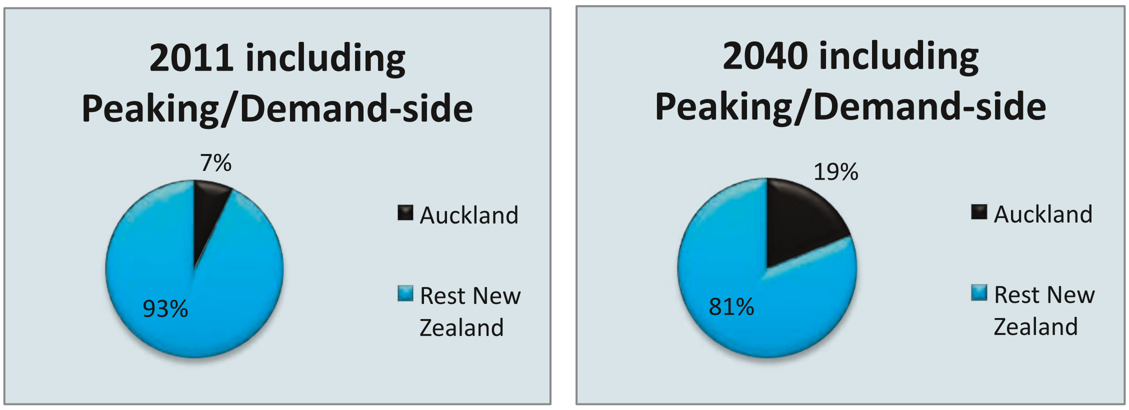
The Southland to Manapouri flow is negative as Manapouri is geographically north of Tiwai.

Because Auckland demand is so large relative to New Zealand total demand (32% by 2040) compared to total generation located in Auckland (19% by 2040), the flows into Auckland from the south dominate the pattern of long term energy flows over the entire New Zealand grid.

The scenarios all have significant amounts of new generation built in the Auckland region, but it is not sufficient to met Auckland's growing demand for electricity. Over the next thirty years, electricity imported from the south increases.

This is shown below by comparing generation in Auckland and Northland now, with generation in Auckland and Northland in 2040. If peaking plant demand-side response is not excluded, Auckland's share of total generation is only 14% in 2040.

Figure 3-9: Percentage generation Auckland/rest of New Zealand including peaking plant/demand-side management



Because Auckland is such a significant portion of total demand, the result is an enduring energy flow from south to north[17] over the backbone grid, for the entire 30 year modelling period.

3.6 Peak grid flows

Long term energy flows across the grid provide a broad indication of grid capacity requirements. However, peak flows are an important indicator of the timing need for future transmission capacity increases. To investigate peak flows we have analysed the scenarios in 10 year snapshots - 2011, 2020, 2030, and 2040 - and developed a series of flow duration curves between each of the regions. These show the energy flow between each region for each of the 8,760 hours in each year snapshot.

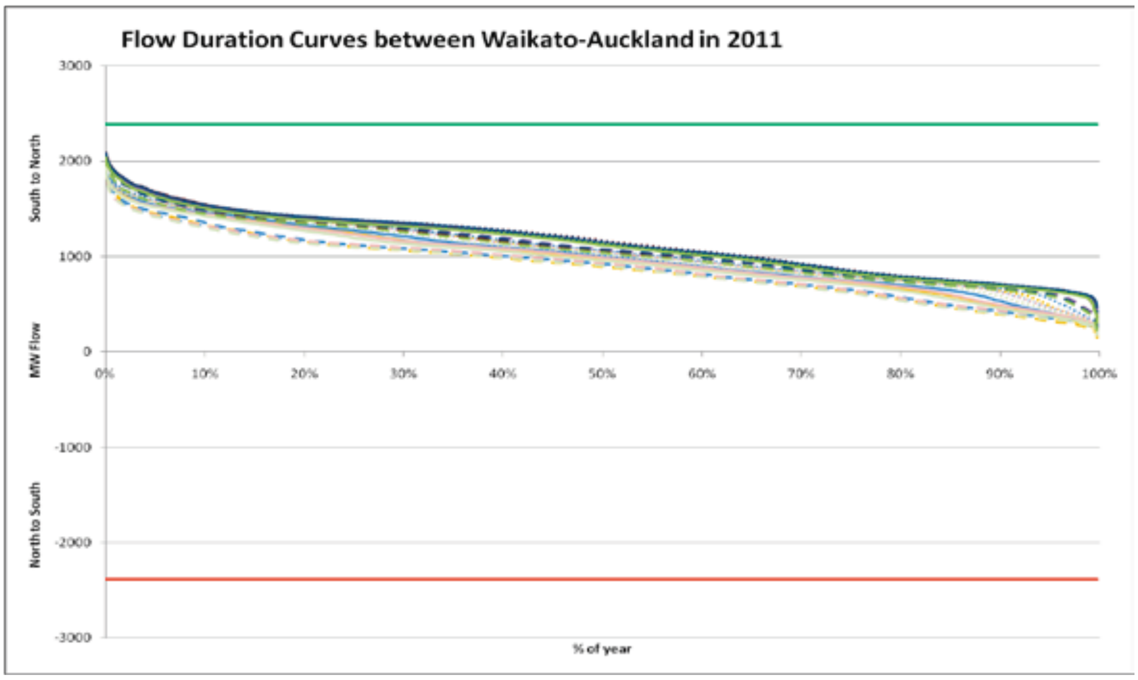
Figures 3-10 and 3-11 are examples of flow duration curves in 2011 and 2040. In this case these show the flows across all of the lines between Waikato and Auckland, north of Huntly.

The vertical axis shows the net hourly energy flow. Flows greater than zero are south to north (into Auckland) and negative flows are north to south (out of Auckland). The current (2010) thermal capacity limits (N-1) for north (green) and south (red) transfer are also shown on the chart as horizontal lines.

[17] These conclusions and observations are consistent with a previous study where future grid flows were considered using the Electricity Commission's 2008 Statement of Opportunity scenarios – a report "Tilted Postage Stamp Analysis – Characterising the Grid" can be found at http://www.transpower.co.nz/reports

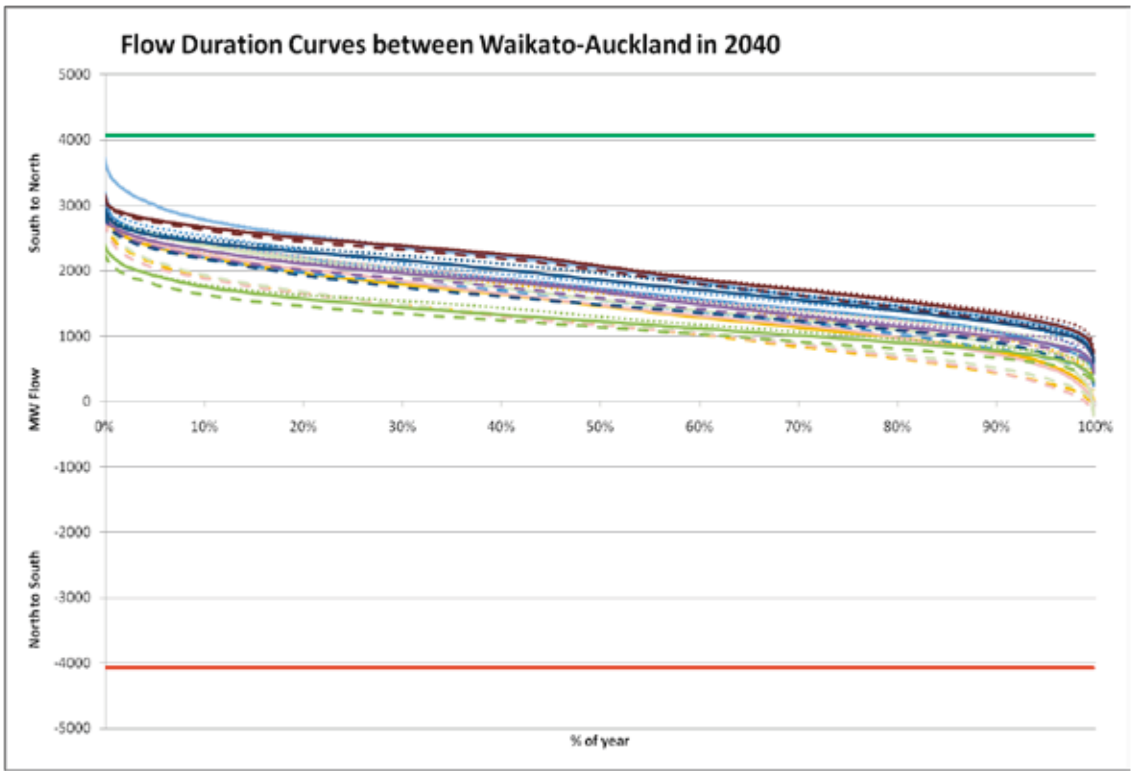
All 27 scenarios are shown on each chart to demonstrate the range of potential outcomes. The wider the range between the lines on the graph, the more volatility and uncertainty there is about future grid capacity requirements.

Figure 3-10: Flow duration curves between Waikato and Auckland in 2011, all Scenarios



In 2011 there is a narrow spread between the flow duration curves. The spread is primarily due to differing hydrological conditions in the scenarios. The flows are all south to north, consistent with this part of the grid being through transmission supplying Auckland.

Figure 3-11: Flow duration curves between Waikato and Auckland in 2040, all Scenarios



By 2040 there is a wider spread between the flow duration curves, reflecting uncertainty in future demand and generation build, but the curves are all of a similar shape and nature. Despite the future uncertainty, flows on this part of the grid remain consistent. Here we can plan long term for increases in grid capacity with certainty.[18] The residual uncertainty mainly relates to the timing of when enhancement is required.

This is illustrated in 10 year steps in the following figure. The green shaded areas illustrate the range of peak flows for south to north transfers, over all scenarios. The blue shaded area is the range of peak flows for north to south transfers over all scenarios. . The area of solid colour in each bar ranges from the 25th percentile of peakflows to the 75th percentile of peak flows. The percentage shown is a measure of the uncertainty around the peak.[19] The higher the percentage, the higher the uncertainty. The horizontal lines show the security constrained thermal capacity into the region. Green shows the south to north capacity and red (where applicable) shows the north to south capacity. Capacity increases with the commissioning of the North Island Grid Upgrade project in 2012 and then future conversion to 400 kV in the 2030s. These are shown as step changes between 2011 to 2020 and 2030 to 2040 respectively.

Figure 3-12: Peak flows between Waikato and Auckland, all Scenarios

These charts illustrate clearly the ongoing and growing need for peak capacity into Auckland across all the scenarios well into the future.

We found similar outcomes for other parts of the backbone grid.

Possible future grid flows where the grid backbone connects into the regional grid vary more (eg Northland to Auckland and Roxburgh to Invercargill). As an example, the grid flow duration curves for the grid into Northland in 2011 and 2040 respectively are shown in Figure 3-13 and Figure 3-14 below.

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[18] In fact, planning for this part of the grid was covered in the North Island Grid Upgrade Plan. The 2040 flow duration curve graph shows the new n-1 limit, following conversion of the new Whakamaru to Brownhill line from 220kV to 400kV during the 2030's.

[19] The percentage is the standard deviation of the range for each bar, divided by the difference between the mean of the south to north transfer peak and the north to south transfer peak. This is similar in principle to the statistical parameter, coefficient of variation.

Figure 3-13: Flow duration curves between Auckland and Northland in 2011, all scenarios

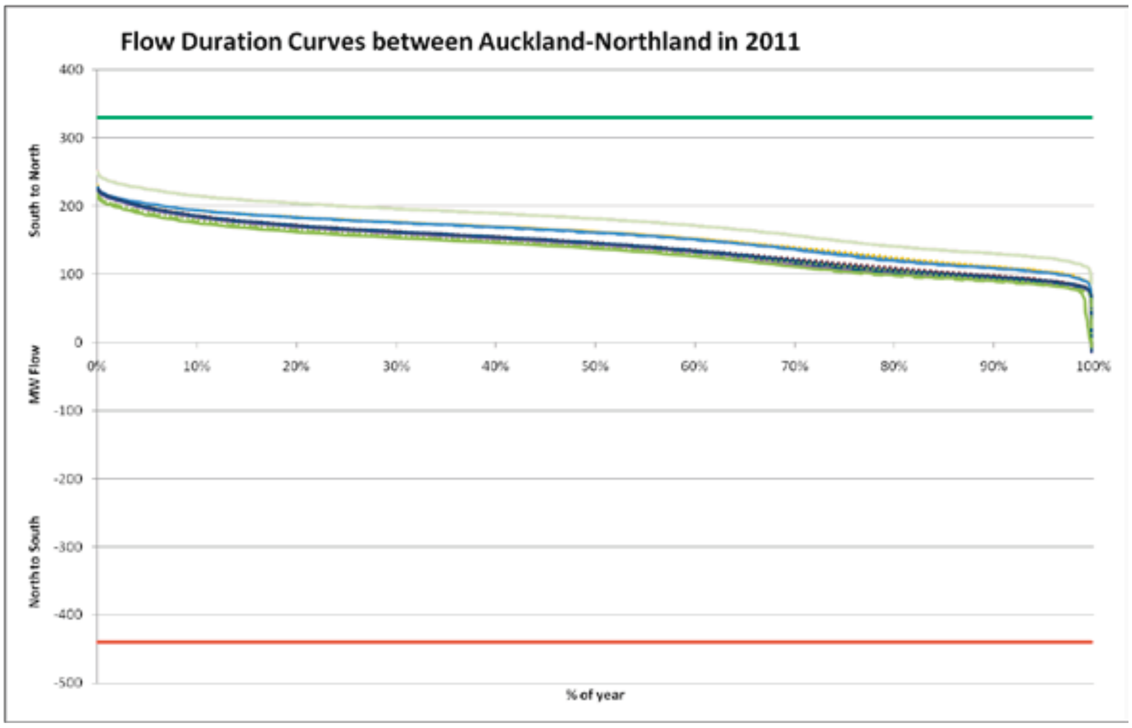
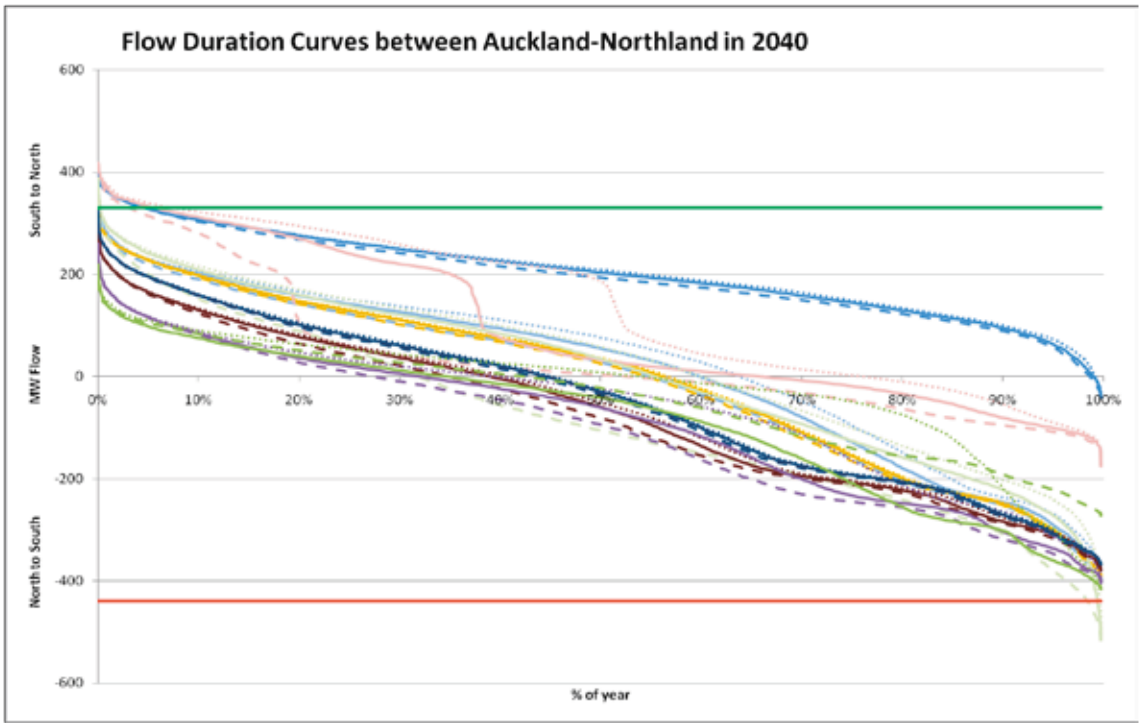


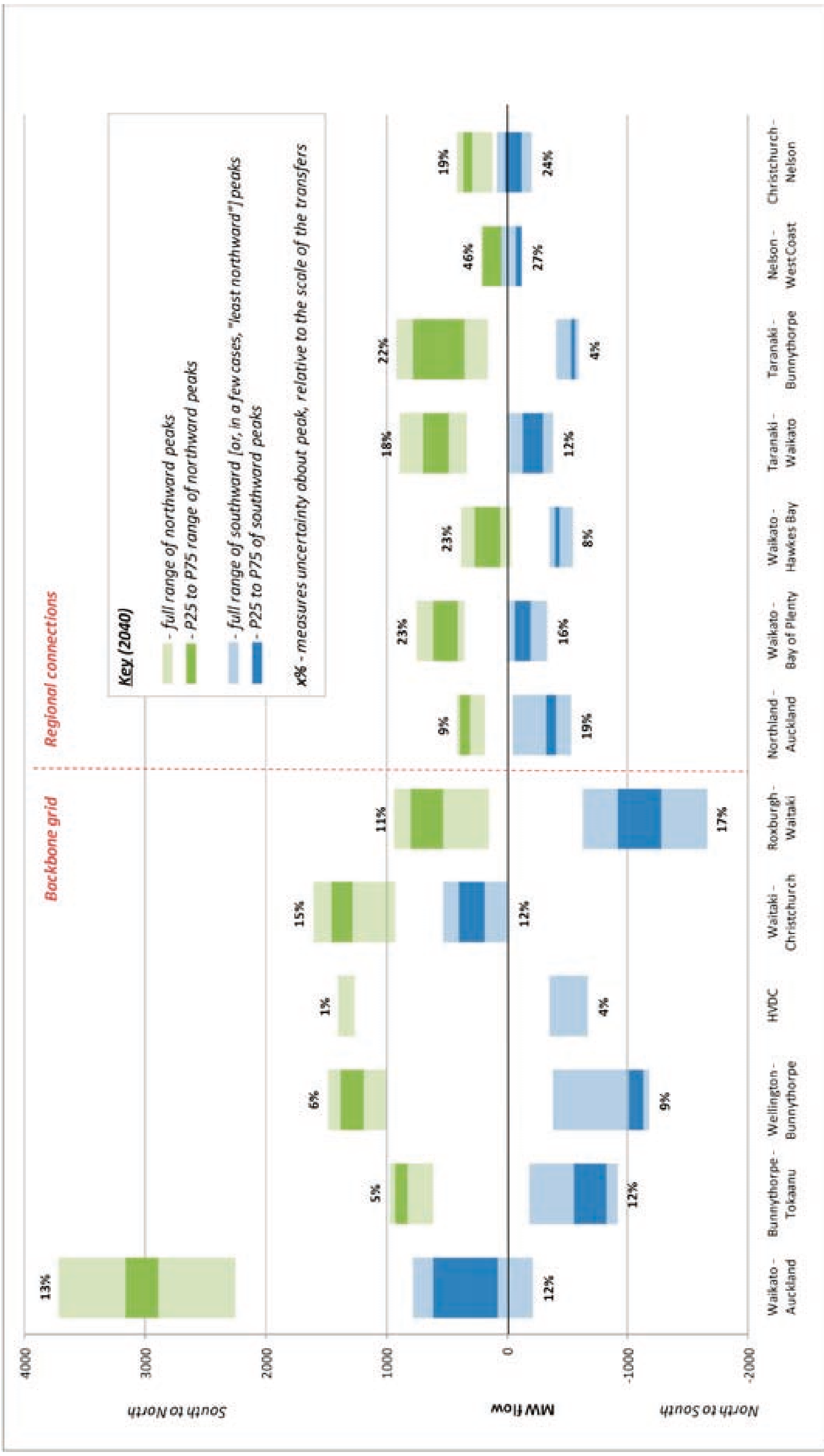
Figure 3-14: Flow duration curves between Auckland and Northland in 2040, all scenarios



As with the Waikato-Auckland flow duration curve, there is only a narrow spread between the flow duration curves in 2011.

By 2040, there is a wide range of possible outcomes from our scenarios reflecting the potential for generation development in Northland. This is illustrated by the large spread between the flow duration curves in Figure 3-14. We found similarities in other regional connections, with large spreads, mostly driven by disparate generation development futures. Our findings, for those parts of the grid considered in this study, are summarised in Figure 3-15 below, which is similar to Figure 3-12, but for 2040 flows only.

Figure 3-15: Peak flows between regions in 2040, all scenarios



The chart separates the backbone grid elements from the regional connections for easier comparison. Several observations and interpretations can be made:

- The solid band of colour in each bar shows the mid 50% of all peak flows. Where the solid band is narrow, the peak flows are concentrated and relatively certain, compared to a wider band. The same applies to the shaded area on each bar.
- South to north flows generally exceed north to south flows for most elements of the grid. Exceptions include Roxburgh to Southland, which is driven by Tiwai demand in dry years and Northland to Auckland which is driven by new generation assumed to be built in Northland by 2040.
- The percentages are an indication of uncertainty, with higher percentages suggesting higher uncertainty. However, the Waikato to Auckland and Waitaki to Christchurch graphs are special cases, as the south to north uncertainty is due to the varying assumptions relating to the use of peaking plant and demand-side response in Auckland and Christchurch respectively. Allowing for these special cases, uncertainty in south to north flows on the regional connections is higher than on the backbone grid. This is primarily due to uncertainty around new generation, which affects each regional connection more than it does the backbone.
- Uncertainty in north to south flows is similar on both the backbone grid and regional connections. This is because these flows are largely a function of hydrology.

Our analysis has confirmed the initial conclusions from the demand and generation scenarios. Our additional conclusions about the future of the backbone grid are:

- There is an ongoing need for the backbone of the grid from Roxburgh to Otahuhu and its capacity will need enhancing over time.
- The existing configuration for the backbone grid will meet the demands of a wide range of future outcomes.
- Whilst the capacity of the backbone grid will need to increase and the need for such increases may not vary significantly between scenarios, the timing does vary.
- Timing aside, long term plans to increase grid capacity from Roxburgh to Otahuhu can be developed with reasonable confidence.
- With the higher uncertainty about future outcomes on the regional connections, we cannot plan with as much certainty. In some instances, only small capacity increases may be required. The use of technologies for better utilising the existing grid have added value here.

4 Conclusions

We have demonstrated an enduring need for a national grid when considering a wide range of future potential demand and generation scenarios. Our scenario modelling has confirmed the suitability of the configuration of the existing backbone grid, although its capacity will need to increase over time.[20]

Grid flows will continue to be dominated by the large loads in the Upper North Island region and electricity will continue to predominantly flow from renewable generation in the south.

Flows over the backbone grid from Roxburgh to Otahuhu vary less between scenarios than where the backbone grid connects with the regions.

Accordingly, we can plan for future capacity on the backbone grid with much greater certainty. Identifying this now gives us the opportunity to determine strategies which will reduce the cost and footprint of providing this additional capacity and allows us to consider a wide range of technology options for providing this well ahead of critical need dates.

The location of generation and step changes in regional demand may require significant additions to the regional connections from the grid backbone - but in these cases, the requirement is less certain. Grid capacity expansions at the regional connections are not required in every scenario. Newer technologies for better utilising the grid, such as extracting more capacity from the existing lines or enhancing system performance with the use of demand-side management are likely to have added value here.

[20] The exact timing and magnitude is dependent upon the rate of demand growth as well as the location, size and timing of new generation.

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