TRANSPOWER

Transmission 2040
(Grid Development Strategy)

Work Package #1 – Generation and Demand Scenarios

Consultation Material

November 2008

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Table of contents

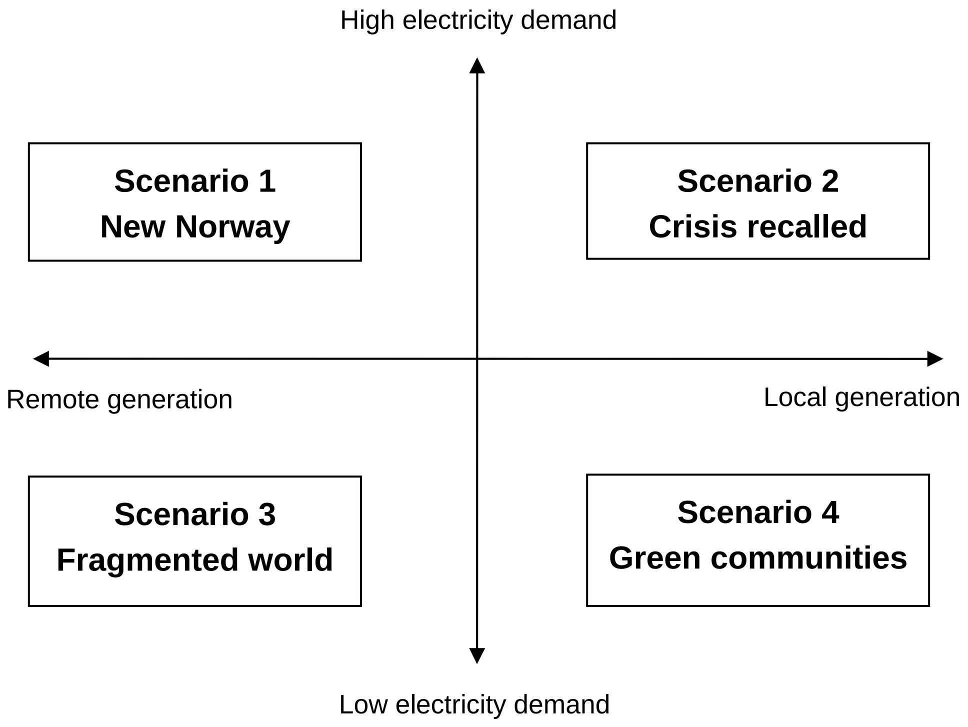
Executive summary

This report describes Transpower's first cut of the scenarios to be used for the more detailed grid studies, ultimately leading to a new Grid Development Strategy by early 2010. Based on the feedback received, Transpower will update the scenarios with a view to finalising the scenarios by the end of 2008.

Scenario design

The objective of the scenario work is to analyse the future demand for transmission services at a regional level out to 2050. The design of the scenarios has been based with that in mind. The design builds upon a review of previous scenario studies and inputs from the industry, in particular through a focus group session held at Transpower.

As a result, Transpower suggests forming the scenarios around different levels of electricity demand and degree of remoteness of the generation. This gives four scenarios as illustrated below.



Brief scenario description

New Norway is a green, oil bonanza scenario. Oil prices are high due to global supply constraints but New Zealand is gifted with large discoveries of oil and natural gas, which are exported. As a result, the economic growth and thus energy demand growth is high. The scenario assumes ambitious global targets for greenhouse gas reductions have been set. The demand thus has to be met with low-emission generation.

Crisis recalled sees global warming disappear as a problem, as technology makes cheap removal of carbon from the atmosphere possible. Without constraints on the use of fossil fuels, worldwide economic growth returns to the high growth rates seen in the late 1990s and first years of the new millennium.

The resulting high electricity demand will be mostly met with large power plants located close to the load centres, some fuelled by imported LNG, though some micro-cogeneration will also appear.

Fragmented world is a scenario focussing on security of supply as a result of disruptions of oil and natural gas supply worldwide. The economic growth worldwide is low. In New Zealand, the local energy sources are important and utilized through “think big” projects, which also aim at stimulating the slow-growing economy. The result is a low demand scenario supplied by mostly larger, remote generation.

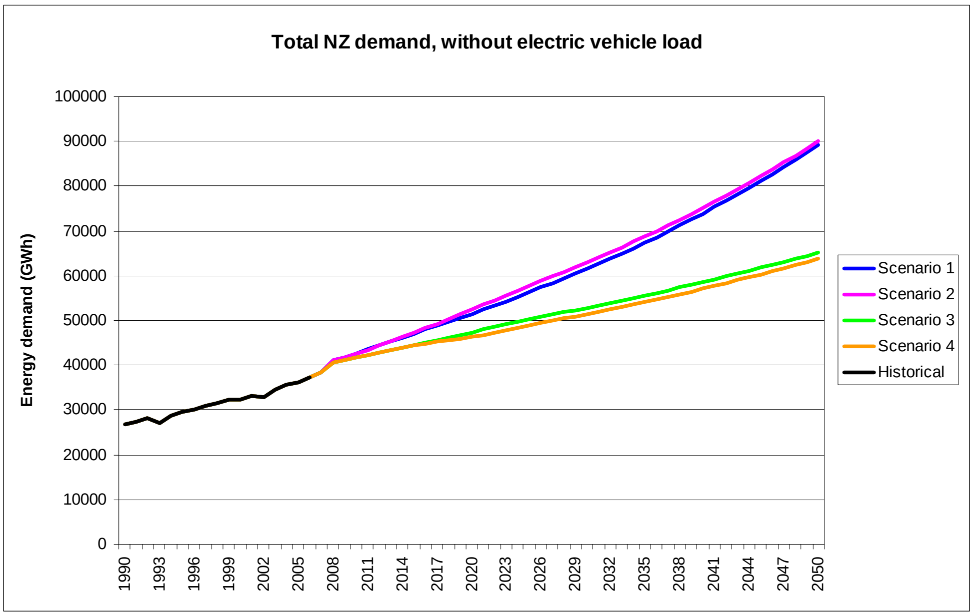
Green communities, like the New Norway scenario, has ambitious, global climate change goals set. High carbon prices hit New Zealand exports and the tourism industry. The result is low economic growth which combined with a high focus on energy efficiency results in a very modest growth in electricity demand. Distributed generation is popular, not least solar photovoltaics, which become cheap by the end of the horizon.

Scenario demand

Transpower has updated its demand forecasting model to allow sensitivity analysis around change in energy intensity over time and the impact of global warming on the heating requirements and thus electricity demand.

As the model only picks up the trends of the past projected into the future, it has to be adjusted for changes that go beyond historical observations. This can include uptake of solar hot water heating, which will lower electricity demand, and greater use of electric vehicles, which on the other hand will increase demand. A discussion of such potential changes in the demand is provided.

A demand forecast is made for each scenario with the drivers selected to be consistent with the scenario story lines. This demand is then adjusted for that fuel switching, which is assumed to be likely to appear in that particular scenario. The resulting demand levels are shown below.



Supply side options

The demand is to be met by generation, both to cover new demand and to replace generation from power plants decommissioned over the time horizon.

A major driver behind investment decisions is the capital costs of new generation. The costs of technologies, relative to each other, are assumed to change over time as a result of technological learning. Different changes in the relative costs have been assumed for the scenarios.

The variable costs, given by fuel prices and carbon prices vary by scenario as well. Oil price assumptions vary between US$60/bbl and US$150/bbl and the gas price in New Zealand is assumed to be closely linked to the oil price in most scenarios.

The carbon price assumptions vary between zero costs (Crisis recalled) and NZ$80/ton CO_2 (New Norway and Green communities).

Distributed generation is assumed to play a larger role in two scenarios: Crisis recalled and Green communities. The former see micro-cogeneration emerge as cost effective technology while solar photovoltaic power is the main choice in the latter.

Resulting numbers

The report includes some figures illustrating how the scenarios look based on the current assumptions and methodology. These results are preliminary and not fully consistent with the scenario stories outlined above. Thus, they are mainly included to illustrate the process of getting the results rather than the results themselves.

1 Introduction

The purpose of this Consultation Paper is to consult on the work carried out to date in the Grid Development Strategy Work Package 1 – Generation and Demand Scenarios. The paper provides an overview of the approach taken, methodology, assumptions made and a preliminary look at the resulting demand and generation figures. Transpower seeks feedback on all those issues. After each of the main chapters, a number of consultation questions have been raised. These are also summarized at the end of this document. The questions should be seen as a guideline only and Transpower welcomes all feedback.

Details on the consultation process and deadline can be found on the website: www.gridnewzealand.co.nz/gds-consultation

1.1 Background

In August 2008, Transpower began a process of producing a long term Grid Development Strategy by early 2010.

The objective of the Grid Development Strategy project is:

> *To form a long term national grid development strategy taking into account New Zealand's future social and economic requirements and long-term technology trends.*

A key input into the Strategy is a set of scenarios, which describe possible future development paths of the New Zealand power system. These scenarios are storylines of how the electricity demand and supply landscape may develop based on which future trends become most dominant.

Based on an assessment of the grid impact of the different scenarios, a strategy for long-term development of the grid in an economic, reliable and sustainable manner will be developed. This is the Grid Development Strategy.

1.2 Scenario objective

This document describes the scenarios used for the Grid Development Strategy and how they have been developed.

The objective of the scenarios is:

> *To analyse the future inter-regional demand for transmission services out to 2050*

The term “transmission services” has been used as the transmission grid is not confined to only providing capacity (MW’s). Rather, it provides the following services:

- connecting generation with demand;
- providing connection at different service levels; and
- facilitating an efficient market for electricity.

The later work packages of the Grid Development Strategy project will in general only cover the expected development of the grid out to 2040. For the scenario work, Transpower proposes to look beyond this date to ensure the grid is robust beyond this time horizon. The year 2050 has been selected as the end-year of the analysis given that:

- transmission assets have a long life time. Investments under consideration now will typically be part of the grid in 2050;
- by 2050, all existing non-hydro power plants may well have been replaced or fully decommissioned. The grid must at that stage match the new generation mix, which may include new technologies, such as marine energy;
- many international targets will be set by mid-century, such as discussions of emission reductions in the IPCC forum. From that perspective, 2050 is a natural choice;
- Statistics NZ's base population forecast has population growth slowing to a minimum around that time and some projections have a decreasing population from the 2040s. Combined with increased energy efficiency, the impact on transmission services could be significant; and
- transport sector transformation is likely. However, even scenarios with a high penetration of electric vehicles may only have a modest impact pre-2040 due to the slow turnover of New Zealand's vehicle fleet. The growth between 2040 and 2050 could be significant and including the extra 10 years will help to adjust the strategy to deal with any impacts of this.

1.3 Overview of the document

The first part is qualitative-oriented. The next chapter discusses scenario design, including the methodology used and the high-level selection of the scenario drivers. This is followed by a more detailed description of the scenarios in Chapter 3, which ends with a discussion of how they are to be quantified.

The second part is the quantitative part, starting with Chapter 4. It describes demand and supply assumptions used, the modelling of those and finally, in Chapter 9, the scenarios outcomes in numbers.

Finally, Chapter 10 summarizes the finding.

Questions:

1.1 Are the objectives of the work package reasonable?

1.2 Should any other aspects be part of the definition of Transmission Services?

1.3 Is the proposed time horizon for the scenarios (2008-2050) reasonable?

2 Scenario design

This chapter describes what the scenarios are, why they are used and how the scenarios have been designed.

2.1 Background

The term scenario is commonly used for a potential future regardless of whether this is a likely future (forecast), a desired future (vision) or simply one possible future.

As the world evolves more rapidly due to technological progress and the impacts of globalisation, the future is increasingly uncertain. Traditional forecasting tools have their limits for long-term strategic planning. In the 1950s, a methodology for dealing with uncertainty was developed, typically called the scenario methodology – or when applied to strategic planning, scenario planning. In this academic discipline, a scenario is neither a forecast (likely future), nor a vision (desired future), but simply a constructed future. It is in the context of “a constructed future” that the term “scenario” is used in this document.

This constructed future has to be possible, i.e. a logical path of events can lead to this outcome. A main element in ensuring this is the internal consistency in the scenario assumptions. There cannot be contradictions like assuming oil is running out rapidly while the price of oil at the same time is dropping back to the US$20/barrel level that it was in the 1990’s.

Furthermore, the scenarios are typically designed to be challenging. An objective is to challenge the implicit assumptions and to assess the consequences of certain events. This will help to test the robustness of current strategies and train the organisation developing the scenarios in how to deal with change. A scenario with no challenges will provide little new insight into what may happen or learnings in how to deal with change.

The two most important characteristics of successful strategies in a rapid changing, complex world are the robustness of the strategy and the flexibility of the strategy in terms of dealing with change[1].

By using the scenario methodology, creating a diverse set of probable and challenging scenarios, an organisation will be able to test the robustness of a business strategy against a diverse set of futures. Also, some of the challenges analysed in the scenarios may actually unfold themselves, in which case the organisation already knows how to deal with them. Being the first to react can create opportunities from an otherwise negative change. A typical example is the oil crisis that arose from the Yom Kippur war, which had been analysed by Shell prior to this and helped to position Shell among the five largest international oil companies in the years that followed[2].

Even if none of the challenges analysed actually eventuate, other so-called ‘unknown, unknowns’ are likely to pose challenges for the organisation. By having dealt with other challenges during the scenario exercise, the organisation will be trained in responding to change. This gives an advantage over companies that have not prepared themselves similarly.

As forecasting to 2050 in the current environment is impossible, Transpower has adopted the scenario methodology approach. Over the shorter term, e.g. within the

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[1] Lindgren & Bandhold (2003): “Scenario planning – the link between future and strategy”. Palgrave/Macmillan

[2] Schwartz (1996): “The art of the long view”. Currency Doubleday

10-15 year planning horizon of Transpower's Annual Planning Report (APR), forecasting is the better option.

2.2 Design methodology

Scenarios are typically shaped by varying the most important and uncertain drivers while keeping the trends that can be projected into the future constant. This is explained further below. First, an overview of some terminology:

Driver: a driver or driving force is a variable that will shape the future of the issue in focus. A driving force behind electricity transmission built is electricity demand, which itself has some drivers (population, GDP, etc.)

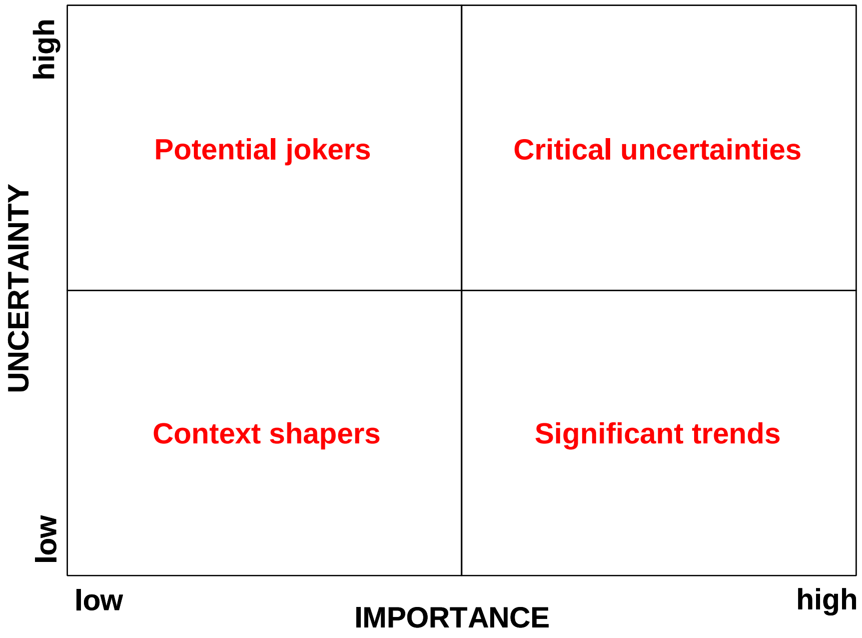
Trend: a pattern of change over time for a variable of interest (the driver). One of the most obvious, and largest trends, is the increase in world population. The term "megatrend" is often used to indicate a widespread (i.e., more than one country), long-lasting trend of major impact, typically composed of subtrends which in themselves are capable of major impacts.

Emerging issue/Trend break: This term describes sources of change, which could be a break away from an otherwise perceived trend.

Wild cards: low probability but high impact changes – like a global plague – usually in the form of (sudden) events rather than gradually unfolding changes.

Different realisations of the chosen drivers, typically those with the greatest impact and most uncertainty, will define how the scenarios span the future. Such drivers are called the critical uncertainties as illustrated in Figure 2-1 below.

Figure 2-1: Ranking of drivers by importance and uncertainty[3]



As seen, critical uncertainties are the drivers that are affecting the organisation most whilst, at the same time, are highly uncertain.

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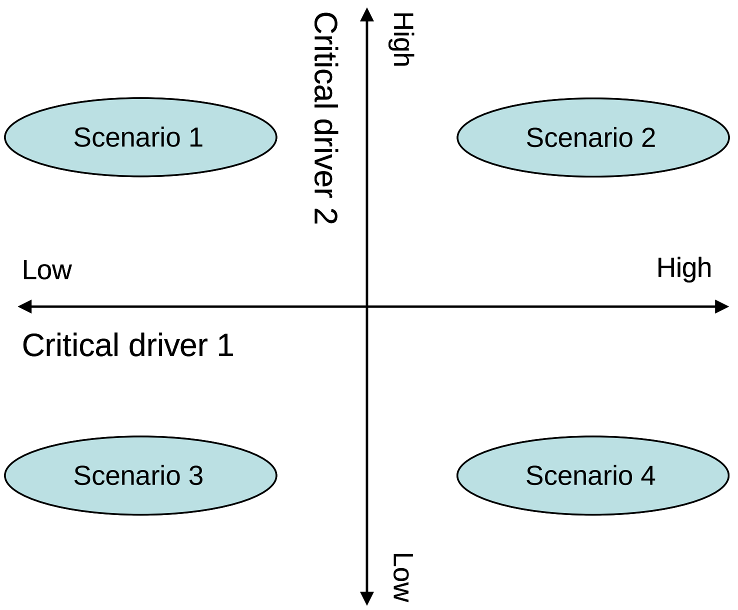
[3] Galt, M. et al. (1997): "Idon Scenario Thinking – How to navigate uncertainty of unknown future". Idon Ltd.

Other important drivers are those with high importance but low uncertainty. These are the significant trends that can be predicted and therefore can be used in all scenarios to various degrees. Trends are discussed further in Section 3.3.

Typically, the two most important and uncertain drivers outside the organisation's control are selected and used to form a scenario matrix as shown below. This defines four different and contrasted scenarios.

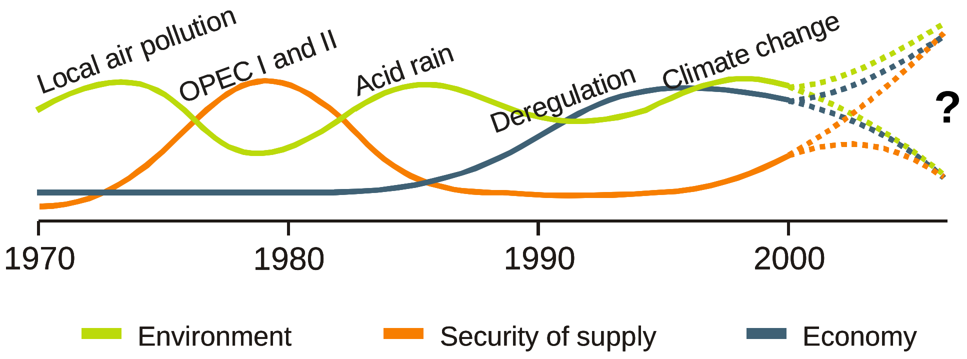
Figure 2-2 - Scenario matrix based on the two most critical uncertainties



In New Zealand, this approach has been used in multiple energy related scenario studies, such as those by Solid Energy, which had energy demand and climate change policy as dimensions, and the New Zealand Business Council for Sustainable Development which used economic growth and energy demand as dimensions. Both of these studies are described more fully in Appendix A.

While the long term outcomes are defined by the critical drivers, the near term direction is set by the current issues of importance, such as environmental concerns and economic growth. Such issues most often arise from the three opposing forces[4] that govern the electricity industry worldwide in a rather cyclical way. This is illustrated in Figure 2-3 for the European power sector.

Figure 2-3 - Historical change of focus of energy sector regulation in Europe



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[4] Opposing, as focus on one of the issues typically leads to less optimal outcomes for the other issues

As an alternative to using the critical drivers to form the scenarios, the three forces shown above could be used, so that the different scenarios would have a general focus on one of those subjects. This approach was used by ECON in their Testing Times book[5] (from which the figure derives) and by Shell for its "Global Scenarios to 2025"[6].

While the opposing forces methodology may make intuitive sense, it is not suitable for scenarios which span significantly longer than the length of the cycles. Looking at the figure above, it will clearly be the case for scenarios spanning 2010-2050. In that time horizon, the focus is likely to have been on all three issues at one point in time rather than consistently one or the other. Hence, the scenario matrix design based on the critical uncertainties has been adopted.

The following section describes the process Transpower used to identify the critical uncertainties.

2.3 Identification of the critical uncertainties

In order to identify the critical drivers, Transpower sought inputs from a wide cross section within the electricity industry and the energy sector more generally.

Firstly, a request for information (RFI) paper was released[7] in August 2008 outlining the purpose of the scenario study and the driver terminology before asking the public for assistance in identifying the drivers that were going to shape the future need for transmission services.

Within the consultation period, a workshop was held at Transpower including 19 industry participants representing 19 different organisations. The participants were divided into 3 groups – one with a dominance of generators, one with a small dominance of lines companies and one very diverse group. Each group started with a brainstorming session identifying the drivers that were going to shape the future of the industry. This was similar to what was asked for in the RFI document. However, the workshop went a step beyond this and the groups went on and ranked the drivers according to Figure 2-1 above. The outputs from the 3 groups can be seen in Appendix B and C.

The outputs from the workshop were made available online for others to use in submissions to the RFI, however most participants took the opportunity to provide their inputs verbally at the workshop while relatively few inputs were given by others in response to the RFI paper when submissions closed in September 2008.

The table below shows the critical uncertainties identified by the three groups in the scenario workshop, i.e. those circled in the graphs shown in Appendix A.

Table 2-1: Critical uncertainties as identified by the three groups at Transpower's workshop

Critical uncertainties	Group 1	Group 2	Group 3
International Fuel Prices	Yes	Yes	Yes
Cost of Carbon	Yes	Yes	Yes
Government Energy Policy		Yes	Yes
Climate Change	Yes		Yes
New Technology, cost stack		Yes	
Resource Planning Requirements (RMA issues)	Yes	Partly	Yes

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[5] ECON (2001): "Testing times: The Future of the Scandinavian Electricity Industry". ECON, Oslo, Norway.

[6] Shell (2005): "Shell Global Scenarios to 2025", Shell International BV, The Hague, Netherlands, 2008.

[7] See: http://www.gridnewzealand.co.nz/f1881,3253008/3253008_work-package-1-rfi.pdf

NZ fuel availability and price (gas, biomass, wind, etc.)	Yes

It can be seen that all groups had international fuel prices and cost of carbon among the critical uncertainties. Related issues are climate change and government energy policy - both listed by two groups.

Finally, RMA issues were listed by two groups and partly by the last as well, which had the availability of various generation sources as a critical uncertainty.

2.4 Critical uncertainties in previous studies

The critical uncertainties of recent scenarios studies in New Zealand are listed below for comparison with the critical uncertainties found in this project. The studies are described in more detail in Appendix A.

Note that not all of the studies listed the drivers behind the selected scenarios, in which case the listed critical uncertainties are Transpower's interpretation of those.

1. CAE/SKM (2002): *Electricity supply and demand to 2015*
    - Technology choice (renewables uptake)
    - Security of supply
2. Massey University (2003): *Options for the future Energy Research, Development and Demonstration investment in New Zealand*
    - Fuel and carbon prices
    - World stability
    - Level of governmental intervention
3. Solid Energy (2004): *Energy options – securing supply in New Zealand*
    - Climate change policy
    - Energy demand
    - Security of supply
4. Parliamentary Commission for the Environment (2005): *Future currents – Electricity scenarios for New Zealand 2005-2050*
    - Climate change policy
    - Technology choice (smart, innovative solutions)
5. New Zealand Business Council for Sustainable Development (2005): *A Sustainable Energy Future for New Zealand by 2050*
    - Economic growth
    - Energy demand
6. Ministry of Economic Development (2006): *New Zealand's energy outlook to 2030*
    - Climate change policy
    - Energy demand (energy efficiency)
    - Technology choice (renewables uptake, CCS)
    - Electric vehicles
7. Greenpeace New Zealand (2007): *New Zealand Energy Revolution*
    - Energy demand (energy efficiency)
    - Technology choice (renewables uptake)
    - Electric vehicles
8. Electricity Commission (2008): *Statement of Opportunities*

- Climate change policy (carbon price)
- Gas prices/availability
- Technology choice (thermal ban, marine energy)
- Electric vehicles

It can be seen that climate change policy is among the critical uncertainties in most of the studies above, either directly as the carbon price, as in the Statement of Opportunities or indirectly as in the Greenpeace study, where climate change objectives were the driver behind the scenario variations of more energy efficiency, more renewables and electrification of the transport sector.

Climate change is also among the most popular critical uncertainty in scenarios studies abroad. This is not surprising, given the potential critical impact of climate change and the uncertainty in terms of assessing the impact and not least how the international community will tackle this problem. Shell assumed that climate change was a given in the last set of scenarios it published[8].

Other popular selected drivers include energy demand and technology choice, the latter partly related to the cost of fuel.

In comparison, many European scenario studies have international cooperation as the second critical uncertainty but this does not appear in any New Zealand scenario study. The scenario study from scenario pioneer, Shell, referred to above has only two scenarios:

1. Scramble assumes countries work on their own to secure their supplies;

2. Blueprints which assumes cooperation from the inter-government level down to communities.

The World Energy Council has selected “Cooperation and Integration” as one of two drivers in the 2007 study: “Deciding the Future”[9]. One last example is from CPB, a Dutch research organisation, which had “International cooperation” as one dimension, the other being the role of the public sector[10].

International cooperation is concerned with the extent to which countries work together in addressing issues like climate change and fuel security of supply or whether actions are driven by national policy either due to a lack of international agreement or a drive towards nationalism as one scenario extreme.

2.5 Comparison of critical uncertainties

When the critical uncertainties identified during Transpower’s process are listed against those from previous New Zealand studies, as summarised in the previous section, it can be seen that there is a considerable overlap between them. The comparison is done in Table 2-2. Note that the critical uncertainties listed have not been ranked by level of importance.

A resemblance between the critical uncertainties found at Transpower’s workshop and in previous studies can seen. Furthermore, if comparing the critical uncertainties found by the three individual groups at the workshop, see Table 2-1, it can be noted that there were significant similarities between them as well, even though the group composition differed significantly. This indicates a strong consistency of the critical drivers.

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[8] Shell (2008): “Shell Energy Scenario to 2050”. Shell International BV, The Hague, Netherlands, 2008.

[9] WEC (2007): “Deciding the Future - Energy Policy Scenarios to 2050”. World Energy Council, London, UK, 2008.

[10] CPB (2004): “Four Futures for Energy Markets and Climate Change”. CPB Netherlands Bureau for Economic Policy Analysis, The Hague, Netherlands, 2004.

Table 2-2: Comparison with critical uncertainties from previous scenario studies

Previous NZ scenario studies	Scenario workshop
Technology choice	New technology, cost stack, Resource planning requirements/RMA
Security of supply	NZ fuel availability
Fuel prices	International fuel prices NZ fuel price (gas, biomass, wind, etc.)
World stability	
Level of governmental intervention	Government energy policy
Climate change policy	Climate change Cost of carbon
Energy demand	
Economic growth	
Electric vehicles	

Climate change or the cost of carbon were among the drivers identified by all three workshop groups in line with most of the recent studies in New Zealand and abroad as discussed in the previous section.

Interestingly enough, security of supply of electricity was not among the critical uncertainties although the industry has just faced a severe dry year. However, security of supply of fuels and related to this, the price of thermal fuels were among the uncertainties listed. In New Zealand, the long run marginal cost of new generation (LRMC) is so close between different types of technologies, that even moderate changes in fuel (or carbon) prices can change which type of generation will be economic to build. So fuel prices were not necessarily added as a critical uncertainty because oil prices during the first half of 2008 skyrocketed to US$147/barrel and natural gas followed it up on the international market. In fact, when the Electricity Commission held a similar workshop back in mid 2006, i.e. before the recent turbulence in the international oil and gas markets, the critical uncertainties identified at the workshop included, apart from cost of carbon, also the price and availability of natural gas[11].

Demand is not among the critical drivers identified at Transpower's workshop though not all drivers were ranked due to the time available. However, while demand is a major driver for transmission, it is composed of several individual drivers (see Chapter 4), which by themselves have little impact on transmission compared with fuel prices or carbon prices. A small percentage change in demand at a location may not change the need for transmission by more than a year, but a few percent change in fuel or carbon costs may be enough difference to move a prospective generation project from one location to another. This could have a significant impact on the need for transmission.

However, if combining the individual drivers behind demand: GDP, energy efficiency, etc., the impact may become significant. Assumptions around the adoption of electric vehicles may in particular add to this since electricity storage was rated high on the list by most groups and there is the potential for a large amount of distributed storage capacity that could be added to the power system. This might have implications for

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[11] See: http://www.electricitycommission.govt.nz/pdfs/opdev/transmis/soo/pdfssoo/Workshop-13Jul06-presentation.pdf

the demand profile (load duration curve) as well as the integration of renewable generation.

2.6 Selection of scenario dimensions

As stated in Section 1.2, the objective of the scenarios is to analyse the future inter-regional demand for transmission services. Looking at most of the drivers that were suggested, many would lead to the same types of variations – remote vs. local supply, stable vs. intermittent supply, etc. It was desirable to have these dimensions while at the same time varying electricity demand.

The two drivers selected are electricity demand and the remoteness of generation relative to demand. The latter is measured as the physical distance between the generation and the demand. Hence, small embedded generation – including micro-generation, will typically be consumed locally and not be exported to the grid while large embedded generation may do so in order to be transported to an area demanding additional electricity. Similarly, larger generators connected directly to the transmission grid may be close to demand, e.g. the CCGT plant Otahuhu B in Auckland or remote from the demand, such as the hydro power plants in the Waitaki Valley. In the first case there will be little need for transmission whereas in the latter case there is a large need for transmission.

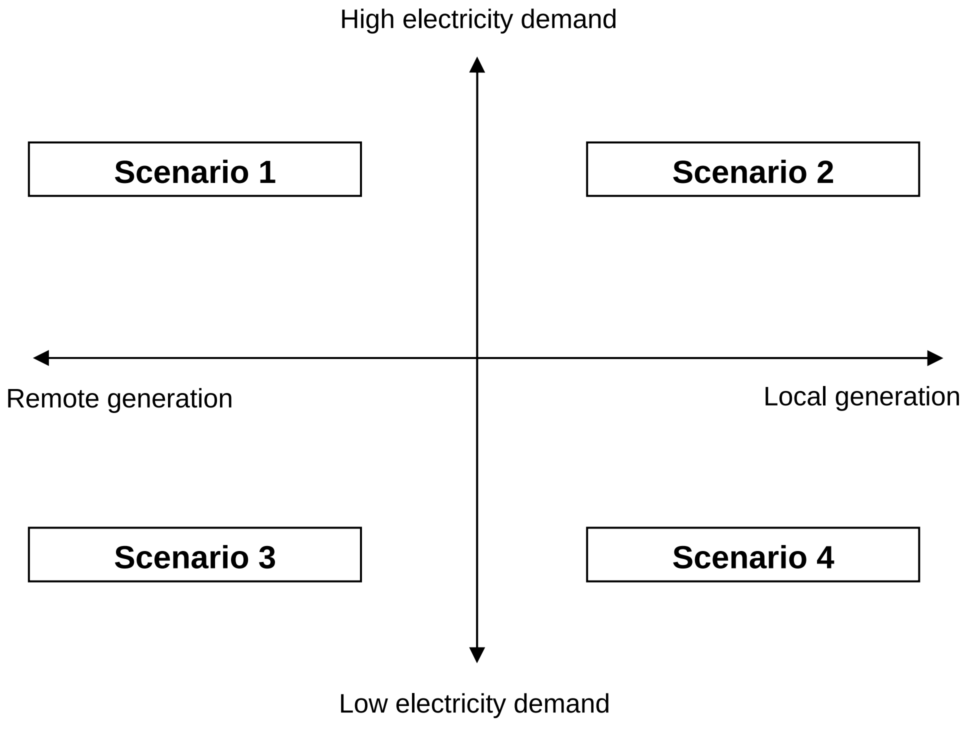
The drivers listed in Table 2-2 are likely to result in very different outcomes for generation as the merit order of the different technologies will change as cost of fuel and carbon are changed or new technologies emerge. Similarly, energy policy and wider climate change issues may well be a major driver behind energy efficiency and thus the level of electricity demand in the future.

Overall, the choice of drivers results in combinations of:

- High vs. low electricity demand, and
- Remote vs. local generation.

This is illustrated in Figure 2-4.

Figure 2-4 - Chosen scenario dimensions



Note that the *electricity* demand outcome, as chosen as one driver, may differ from the trend in *energy* demand because of fuel substitution. In carbon constrained scenarios, it will often make sense to convert from direct use of fossil fuels to electricity to reduce emissions. This may increase electricity demand significantly despite assuming an increased focus on energy efficiency.

The two extreme cases for transmission, high demand and remote generation (Scenario 1) and low demand with local generation (Scenario 4) have been made further extreme by assuming the former will have a larger share of intermittent generation while the latter will have a larger share of more controllable generation.

Overall, the selection of drivers as described here will ensure the extreme needs for transmission services is covered in the further Grid Development Strategy work.

Questions:

2,1 Is the approach (i.e. the use of the scenario methodology) suitable for the task?

2.2 Will the proposed application of the methodology give the best set of scenarios given the objectives of the study?

3 Scenario descriptions

Based on the dimensions selected in Section 2.6, the scenario stories were developed in more detail.

3.1 Scenario consistency

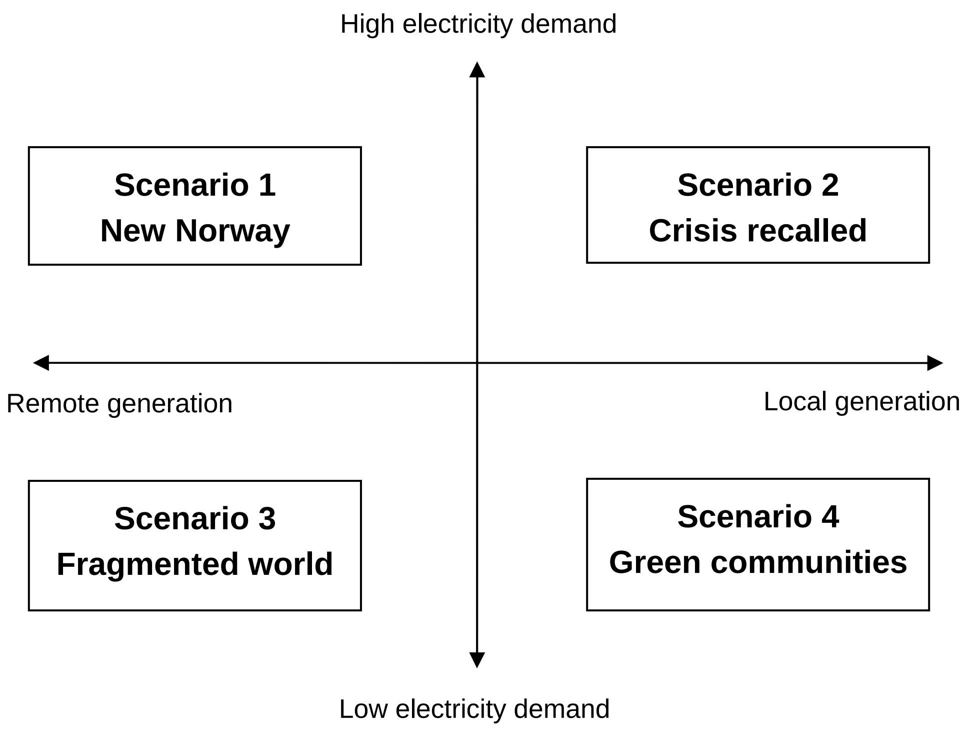
It is important that the scenarios are consistent. For instance, if a scenario assumes unlimited, cheap gas is available, then a likely result will be stronger economic growth, which again will lead to higher electricity demand (see Chapter 4 for a discussion on the demand drivers). Similarly, in a scenario with strong carbon reduction goals, it is likely both to see high carbon prices and an increased focus on energy efficiency.

However, with this in mind, it should be noted that while energy demand will be lower in strong carbon reduction scenarios, it may not be the case for electricity demand. Reasons for this include potential fuel switching from fossil fuels to electricity for stationary energy use and electrification of the transport sector. In both cases, greenhouse gas emissions reductions are sought by switching from a more carbon intensive fuel to electricity, which may well be generated from renewable energy sources.

3.2 Scenario stories

The scenarios have been named as illustrated in the figure below.

Figure 3-1 - Chosen scenario dimensions



In the following, a high-level qualitative “storyline” of each scenario is given.

Scenario 1 - New Norway

The global scene

An international agreement on combating Climate Change is made. An ambitious goal is set - stabilisation at 450 ppm (parts per million) concentration of CO_2 in the atmosphere. National and regional emissions trading schemes are linked and over time, one global market for carbon is established.

Increased unrest in the Middle East plus cost of carbon makes energy prices soar and with that inflation. That increases cost of oil substitutes further. World economy keeps a reasonable growth driven by China and India. As a result, the oil price is high. With many countries shifting from coal to gas to reduce emissions, demand for gas is high - especially if sourced outside the Middle East. As a result, the LNG price follows the oil price all the way up to the new level.

The local scene

The first decade of the new millennium ends with a big prize for New Zealand. At first, a medium sized gas field is found near Taranaki keeping supply secured well into the 2020s. Then, in early 2010 a large oil and gas field off the coast of the South Island is discovered. The evaluation of the discovery takes a couple of years. Apart from a significant amount of oil, there is more gas than in the Maui gas field when found. In 2018, the first export shipment of LNG is made to the Chinese market.

The economy is booming due to the discovery of hydrocarbons and immigration increases. More arrive as climate change refugees find living in their former countries becoming unbearable. To limit the demand growth in the booming economy, environmental taxes are introduced. Still, demand is growing fast, fuelled by a major transformation of the transport sector to electric vehicles.

Demand is met by generation placed where most economic - typically larger renewable installations, including marine energy. As a spin-off from the offshore industry, New Zealand is established as a world leader in harnessing wave energy.

Scenario 2 - Crisis recalled

The global scene

After a turbulent time in 2005-2012, oil prices stabilize in a new price band around UD$55-65/bbl assisted in part, by technological improvements in extracting oil from unconventional sources. LNG prices are similarly low.

The cost of carbon is close to zero as a disruptive technology innovation that cheaply removes carbon from the atmosphere. (It could also be seen as a scenario where due to a lack of international agreement on climate change, no country is taking significant action, or a scenario where it turns out climate change is not happening).

Large and timely investments in mineral exploration and extraction keep inflation down. As a result of this, the lower oil price and the limited carbon cost, the global economy is growing. Every year 100 million people worldwide are entering the middle class, demanding, amongst other things, more food.

The local scene

The global demand for dairy products, meat and fish is a major driver for the New Zealand economy. Tourism is also doing well. In comparison with the rest of the world, New Zealand is not outperforming, so immigration levels stay at the historical average.

With little constraints on the use of coal, energy prices are relatively low. As a result of the high GDP growth and low prices, demand is growing at a high rate.

Small micro-cogeneration units become popular, first in commercial settings but later on in households as well. They supply space and hot water heating and generate electricity as well. Typically, a Stirling engine is used but later on Fuel Cells capable of running on reticulated natural gas is taking over as the preferred technology.

Otherwise demand is largely met by thermal power plants built near Auckland and tidal turbines near Auckland and Wellington.

Scenario 3 - Fragmented world

The global scene

Tensions in the Middle East and Russia's quest to return to its former might result in energy security of supply being jeopardized worldwide. With the financial crisis that started back in 2007 still dragging on, most countries try to save themselves rather than cooperate on solving the issues.

The major countries scramble to secure their energy supplies with most prospective oil and LNG projects being taken by high-bidding countries sometimes backed with military threats.

The global economy is growing slowly - hampered by the import tax barriers being set up to protect national industry in many countries. As a result, oil demand is not growing as fast - and supply can keep up with demand. Carbon costs are moderate - with little international agreement on doing anything serious though it is clear that the climate is changing rapidly. Radical environmentalists start attacking oil and gas installations worldwide - including shipping of oil and LNG.

The local scene

Enough natural gas is found to meet local demand though the price closely matches the international LNG price. Methanex decides to close down its operations in New Zealand for good and as a result there is extra gas available for electricity generation. This is used by CCGTs in Taranaki with the CO_2 being extracted and stored in oil gas fields offshore Taranaki. Building a LNG terminal is considered uneconomic with the lack of LNG available for longer term contracts.

A new set of "Think Big" projects are initiated to assist the economy and increase the security of supply. The projects include major hydro developments along the Clutha river and utilisation of the South Island lignite reserve.

Scenario 4 - Green communities

The global scene

If weather was considered extreme in the beginning of the millennium, it got even worse in the second decade. Clear signs of positive feedback (self-accelerating climate change) were the driver behind an international agreement of stabilising the level of CO_2 in the atmosphere at 450 ppm.

LNG becomes popular in countries that traditionally had used coal for power generation as switching to gas was among the cheapest ways of reducing emissions. Biofuels from sea algae becomes an important source for transport fuels and results in a rather low penetration of electric vehicles.

The local scene

The New Zealand economy is taking a hit due to continuing global consumer concern over 'food miles'. Tourism also drops as international airlines start to bear the cost of carbon emissions as well. GDP growth is lower than the OECD average and immigration numbers are only kept up by climate change refugees, which see New Zealand as one of the last places to be severely affected by climate change.

No LNG terminal is built, partly due to local opposition dragging out the resource consent lodged in 2009, but also because of LNG prices in combination with the carbon price would make it uneconomic. Instead, New Zealand embarks of a road of conservation and local generation, the latter assisted by the price of solar photo voltaic panels coming down rapidly.

Apart from spanning the chosen dimensions of electricity demand and remoteness of generation, the scenarios can be viewed as encompassing a range of uncertainties around climate change policy and availability of gas, which both were among critical uncertainties identified.

3.3 Trends

While the future is unknown, certain future events will not be unexpected. These are the events driven by observed trends, identified patterns of change which are expected to keep on into the future. While trends may end, they will at least for a while, be a good indicator of what certain parts of the future will look like.

Certain trends are more important and resilient than others. These “megatrends” can be seen as large over-arching directions that shape our lives for a decade or more. In the following, a review of existing and expected future global trends will be given followed by a discussion of their relevance for New Zealand as a whole and the New Zealand energy sector in particular.

3.3.1 Global trends

Various studies have been conducted around the world trying to identify the factors that are shaping the future world. A discussion of the studies and findings are yet to be done[12].

As a preliminary list, some of the more relevant trends that could be included in the scenarios are:

- urbanisation;
- increased NIMBY’ism (not in my backyard); and
- global warming.

The extent could vary as e.g. Scenario 4 – Green communities may be more community focused compared with the individualism driving the NIMBY’ism. Hence, this scenario could see less public opposition to both generation and transmission assets to be built in their neighbourhood, especially if considered “green”.

3.3.2 New Zealand trends

While most global trends are “imported” into New Zealand in some form, there could be some trends that are specific to New Zealand. As for the global trends, more work needs to be done on identifying and describing such local trends. Inputs would be appreciated.

3.4 Scenario quantification

A main part of the scenario quantification is based on Transpower’s demand forecasting model. Chapter 4 describes this and the assumptions behind. This is followed by a chapter on potential load shifting, which presents some adjustments made to the base demand forecast for the scenarios. It includes considerations around electric vehicles.

The second major tool used for the quantification is the GEM model developed by the Electricity Commission[13]. The GEM model will assess the generation that might appear based on the demand forecast and supply side options.

The supply side options are discussed in Chapter 6 with focus on technology costs, fuel prices and carbon prices. Distributed generation (or embedded generation) will be discussed separately in Chapter 7.

The detailed scenario descriptions with numbers for demand and supply can be found in Chapter 9.

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[12] The final report, when available early 2009, will have a more comprehensive discussion of trends.

[13] See www.electricitycommission.govt.nz/opdev/modelling/gem/index.html

Questions:

3.1 Are the scenario stories as listed:

- plausible, i.e. possible (but not necessarily likely),

- internally consistent, i.e. they make sense, and

- relevant for the study.

3.2 Which trends, relevant for the study, should be considered as part of all scenarios?

- Global trends

- Local (specific to New Zealand)

4 Electricity demand

4.1 Introduction

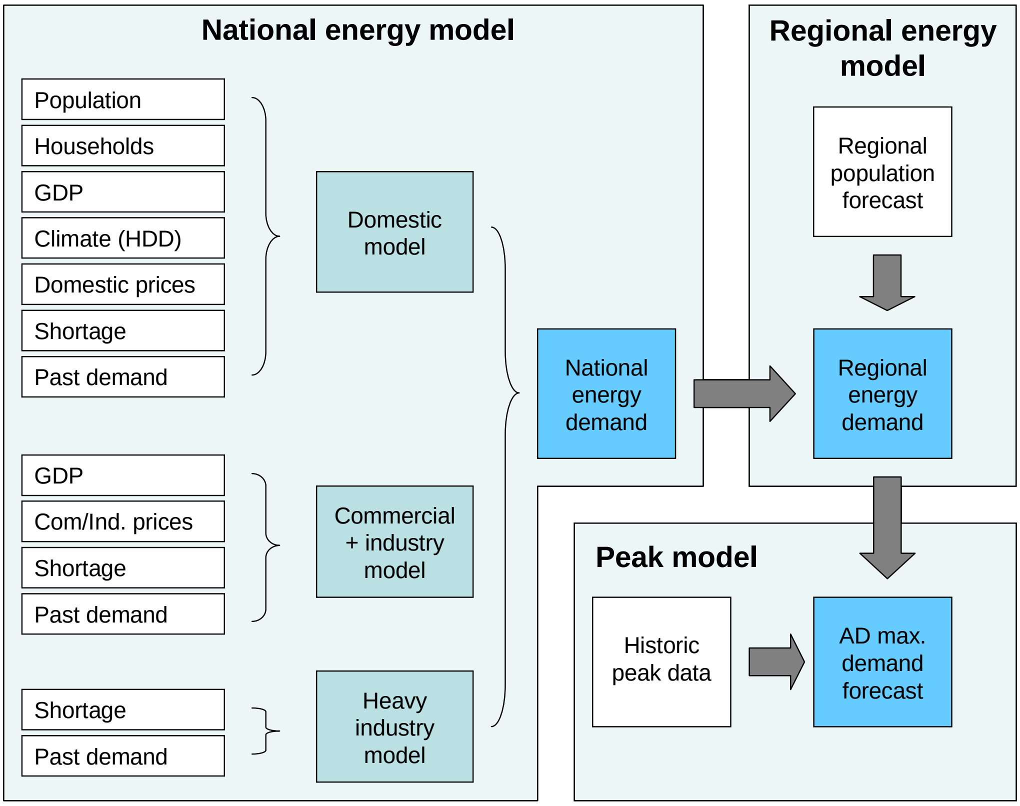
The Transpower demand forecasting model is an econometric model that forecasts future energy and peak demand (at individual grid exit points) based on historical relationships between key economic indicators and electricity demand.

Projections extending out 2050 are available for these key indicators enabling the model to forecast demand within this time horizon.

A description of the key indicators and the data sources behind the projections of those are detailed in the body of this chapter.

Forecasts are initially made at a national level based on simple models of the domestic, commercial and industrial sectors. The following diagram outlines the high level process followed by the model:

Figure 4-1 - Overview of Transpower's demand forecast model



The allocation of national growth in demand to regions is done on the basis of forecast regional population growth. Regional growth projections are obtained from Statistics New Zealand and prorated to match the long-term national projections. The regions defined for the allocation and projection process are consistent with the old Electricity Power Board areas.

A base for the peak demand forecast is derived from recent metering information and is grown at each point of connection. Individual points of supply within a “region” are grown at the same rate. A key assumption in the projections for the *base* demand scenario is that the rate of growth in peak demand matches the rate of growth in total demand. Deviations from this relationship will be discussed in Chapter 8.

As a final step, a forecast of the uptake of small scale distributed generation is made based on the current share. While the base case is assuming a constant share, this can be varied up or down within the time horizon.

4.2 Demand Forecast Assumptions

4.2.1 Population

Long term population and housing projections are published by Statistics New Zealand. The projections are scenario based and assume certain rates of births, deaths and migration. We have used the projections based on medium mortality, medium fertility and 10,000 annual net migration, consistent with the series used for short-medium term grid forecasting. The forecast is the most recent one from Statistics New Zealand and uses 2006 as base year.

For comparison, total New Zealand population increased by 1.4% p.a. on average in the period 1990-2000 while the forecast projects population to increase by 1.2% p.a. between 2000 and 2010. However, beyond 2009 the population growth rate is forecasted to decline to 0.7% p.a. by 2025 and 0.3% p.a. by 2050. The following charts show the historical and forecasted New Zealand population to 2050.

Figure 4-2 - Historical and Forecast Population

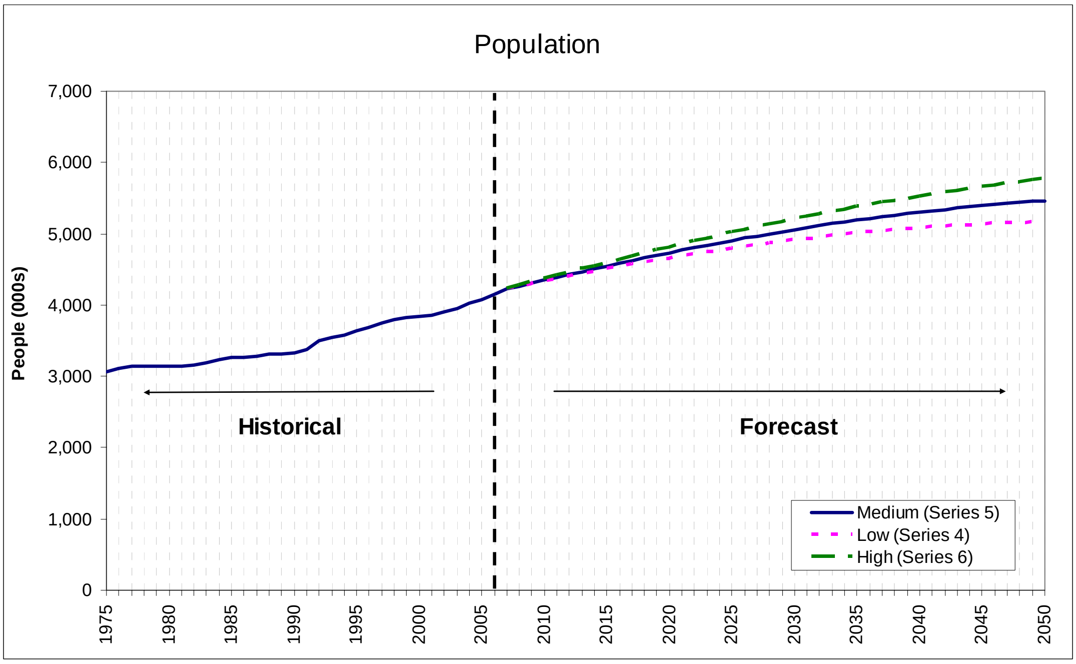


Figure 4-2 shows the forecast population steadily growing to 2050. Also shown are two other forecast series, where the only difference is the annual net migration, which is 5,000 in the low case (Series 4) and 15,000 in the high case (Series 6).

Housing projections follow much the same pattern as the population projections, with a gradual reduction of people per household from 2.7 in 2004 to 2.4 in 2021. Beyond 2021, it has been assumed to keep stable at 2.4 people per household.

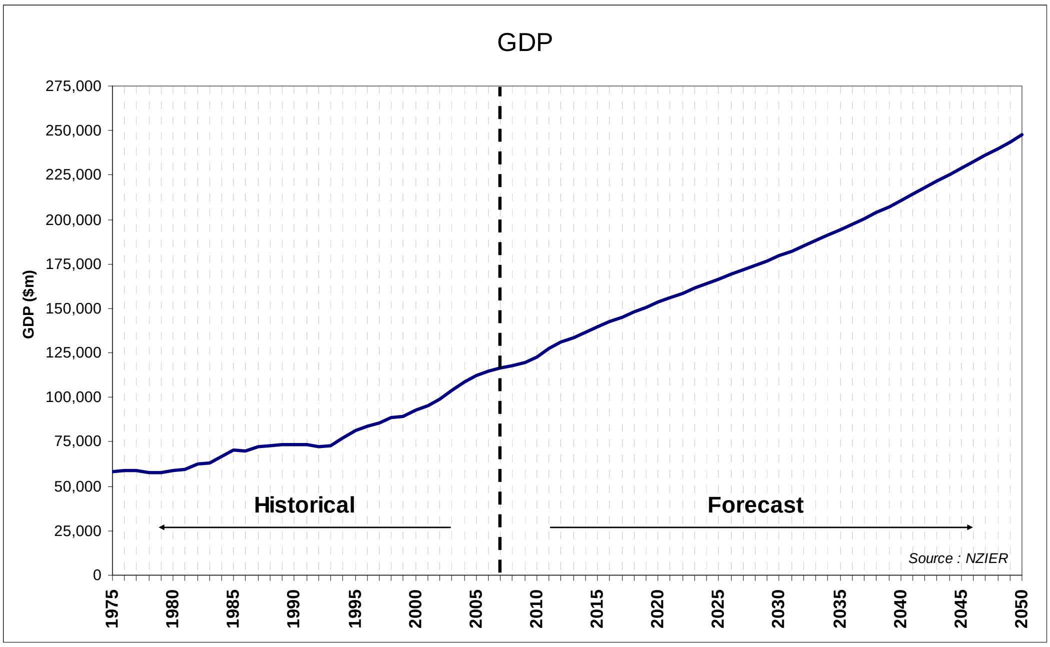
4.2.2 GDP

Long term GDP forecasts are available from NZIER. These are based on projections of labour force and productivity changes. The population assumptions used by NZIER to project the labour force are consistent with those used internally within the demand forecasting model as noted above.

GDP is the most dominant of the drivers in demand growth in the model and as such, moderate changes in GDP assumptions have a material impact on demand growth assumptions.

Economic growth over the next few years is expected to slow. This outcome is consistent with the current economic climate and the global outlook. Output is then expected to grow by the end of this decade as the Reserve Bank continues to relax monetary policy. As the time horizon extends into the next decade and beyond, the growth rate is expected to slow again. This is primarily due to a combination of the slower population growth and the population ageing which both result in a slower growth in the labour force. Figure 4-3 illustrates this.

Figure 4-3 - Historical and Forecasted GDP



4.2.3 Technology and Energy Efficiency

As noted earlier, the econometric technique used to forecast demand assumes that the historical relationships between demand and various drivers remain the same for the forecast period. Changes in technology and consumer behaviour over time are reflected in the historical demand data.

The base case modelling does not explicitly make any adjustments to demand based on technology or behaviour, and therefore assumes that the changes in the demand impact of these drivers will occur at the same rate as they have historically.

As a result of policy initiatives or changing consumer behaviour this assumption may not necessarily be true. The impacts of having a different relationship will be explored through adjusting of the historical rate of change (see example in Section 4.3.2) or through alterations made to the forecast as discussed in the following chapter on fuel switching.

The historical relationship found by Transpower’s regression model is 0.286 for the residential sector and 0.198 for the commercial/industrial sector. This relationship is typically referred to as the income elasticity (how much will demand increase as income increase).

A value of 0.3, which was the approximate result for the residential sector, indicates that an increase in GDP by 1% will increase demand by just 0.3%. This is consistent with numbers referred to by MED[14], which found a short-run income elasticity of 0.32 for the residential sector and 0.22 for the commercial/industrial sector.

Table 4-1 -Income elasticity for the residential sector in the model

Income elasticity	
1-year	0.286
2-year	0.345
3-year	0.357
4-year	0.360

Energy intensity is a related term specifying how many units of electricity are required to produce one extra unit of GDP. EECA has assessed that the energy intensity improved over the period 1995-2006 with a rate of 0.7% on average for the residential sector[15], i.e. every year the energy intensity dropped by 0.7%. With the shown elasticities, Transpower's demand forecast gives a similar improvement on average for the 2008-2050 horizon.

4.2.4 Electricity Prices

Historically, changes in end-user electricity prices have only had a marginal impact on national electricity demand. The elasticity value computed for New Zealand is -0.16 in the short-run and around -0.20 in the long-run (4 years after and beyond). So an increase in price by 1% will lead to 0.16% lower demand the first year and 0.20% lower demand 4 years after the price increase. Table 4-2 shows the elasticities.

Table 4-2 - Own-price elasticity for the residential sector in the model

Own-price elasticity	
1-year	-0.159
2-year	-0.191
3-year	-0.198
4-year	-0.199

For the commercial/industrial sector, the estimated own-price elasticity is lower, around -0.045 for the short-run. The elasticities are shown in Table 4-3 below.

Table 4-3 - Own-price elasticity for the commercial/industrial sector in the model

Own-price elasticity	
1-year	-0.045
2-year	-0.082
3-year	-0.112
4-year	-0.137

Again, these numbers correspond well with those presented by MED[16]. They have assessed a short-run elasticity for the residential sector of -0.08 and -0.06 for the commercial/industrial sector. The long-run elasticities were -0.21 and -0.28 respectively. Transpower's estimated elasticities are larger for the short-run and lower for the long-run elasticities, but in the same ball-park. Note however, that the elasticities from the Energy Outlook are for energy in general and not specific to electricity.

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[14] MED (2003): "New Zealand Energy Outlook to 2025", Ministry of Economic Development, 2003

[15] EECA (2008): "Electricity Efficiency Review in New Zealand – March 1995 to 2006". Energy Efficiency and Conservation Authority, May 2008.

[16] MED (2003): "New Zealand Energy Outlook to 2025", Ministry of Economic Development, 2003

If compared with the elasticities used by the Energy Information Administration in the USA, they are listed as -0.2 for residential and -0.10 for commercial for the short-run[17]. Three years after a price increase, the elasticities were -0.34 for the residential sector and -0.20 for the commercial sector. These values are from a different system with e.g. a lot less electric heating in the residential sector. Hence, these values cannot directly be compared with those estimated by Transpower.

As a base case, the model assumes the wholesale electricity price will rise to 100$/MWh by 2014 (subject to change when model runs have been done). The price increase is due to the assumption of increasing costs of thermal fuels and the emission trading scheme to start in 2010.

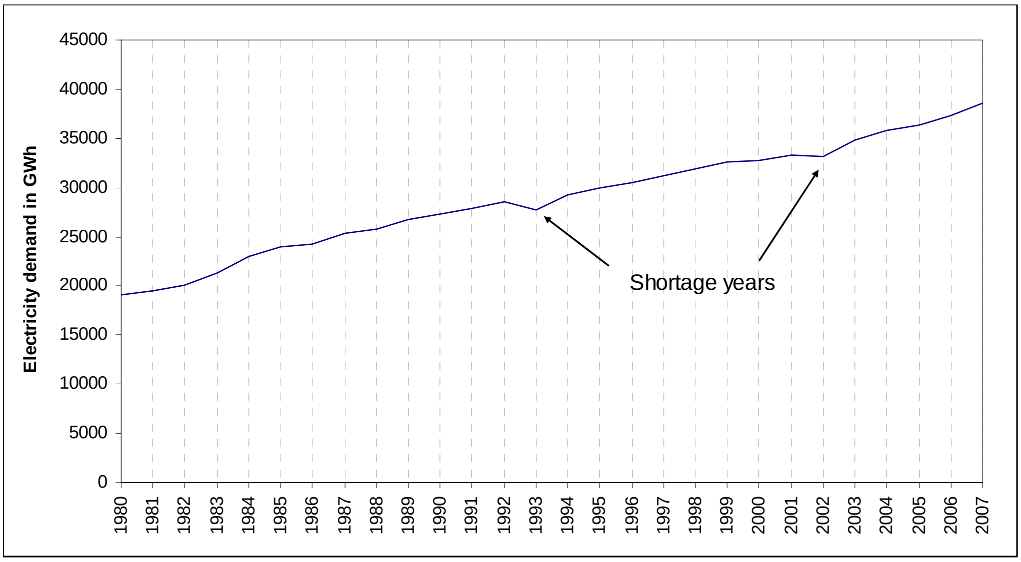
To the wholesale price is added a combined network charge and retail mark-up resulting in a domestic price of around 21 cents/kWh after GST. This value is slightly decreased every year to simulate efficiency gains in the distribution sector.

The price for commercial and industrial customers is treated similarly though the mark-up is less and there is no GST. As a result, these customers will pay close to 17 cents/kWh in 2014 after which, costs will decrease slightly on a year-by-year basis as in the residential sector.

4.2.5 Shortage years

In certain years, hydro inflows have been significantly below the historical average, which has led to public calls for consumers to reduce consumption. An example is the 1992 dry year as shown in Figure 4-4 below. As the figure is based on ending-March years, the 1992 shortage figures as occurring in 1993.

Figure 4-4 - Shortage years as defined for 1980-2007



4.2.6 Heating and cooling needs

The residential model uses an estimation of the heating requirements every year as well. Years with a long, cold winter will see a higher electricity use, which can be significant due to the large share of electric heated households in New Zealand.

As a proxy of the heating requirements, heating degree days (HDD) has been used. These have been obtained from NIWA for different regions in New Zealand and use a base of 18°C. Here, one day with an average temperature of 12°C will add 6 to the

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[17] EIA (2003): “Price Responsiveness in the NEMS Building Sector Models”. Energy Information Administration, US Department of Energy, 2003.

annual number of HDDs – 6 being the difference between 18°C and 12°C. The colder, the more HDDs is accumulated. If the temperature is above the base level, no HDDs are accumulated. Instead, temperatures above the base level are accumulated as cooling degree days (CDD), which can be seen as a proxy for when people may want to cool their houses, assuming they had the ability to do so.

Currently, only the HDDs are used, but the CDDs have been collected as they may become important in the future as the penetration of heat pumps with air conditioner functionality increases in New Zealand.

The regional values have been weighted by the regional population figures to create a national number. The demand forecast model shows that there is a correlation between this historical national number of HDDs and the residential demand. No such correlation was found for the commercial/industrial sector. Even for the residential sector, the estimated relationship was not statistically significant. Nevertheless, it has been decided to use the given estimate, as no other estimate of the relationship could be obtained. This allows the model to account for historical variations in climate and to model impacts on demand from future changes in temperature. This is illustrated in section 4.3.4.

4.2.7 Peak vs. energy growth

There is evidence that growth in network peaks has been slower than growth in total energy demand in New Zealand over the past number of years[18]. However, the trend has largely levelled off over the past 15 years and limited information makes forecasting potential changes in this relationship difficult, particularly as the relationship between peak and total demand may vary significantly between points of supply. For the purposes of the base case, forecast peak growth is assumed to occur at the same rate as forecast total energy growth.

4.3 Case studies

The following section illustrates the impacts on the forecasted demand of changing various input projections.

4.3.1 Population

Figure 4-5 shows the impact of changing the population in the model. The three series presented back in Figure 4-2 has been used as inputs while all other parameters have been fixed. This would normally not be the case, as GDP growth is depending on the size of the labour force and hence the population.

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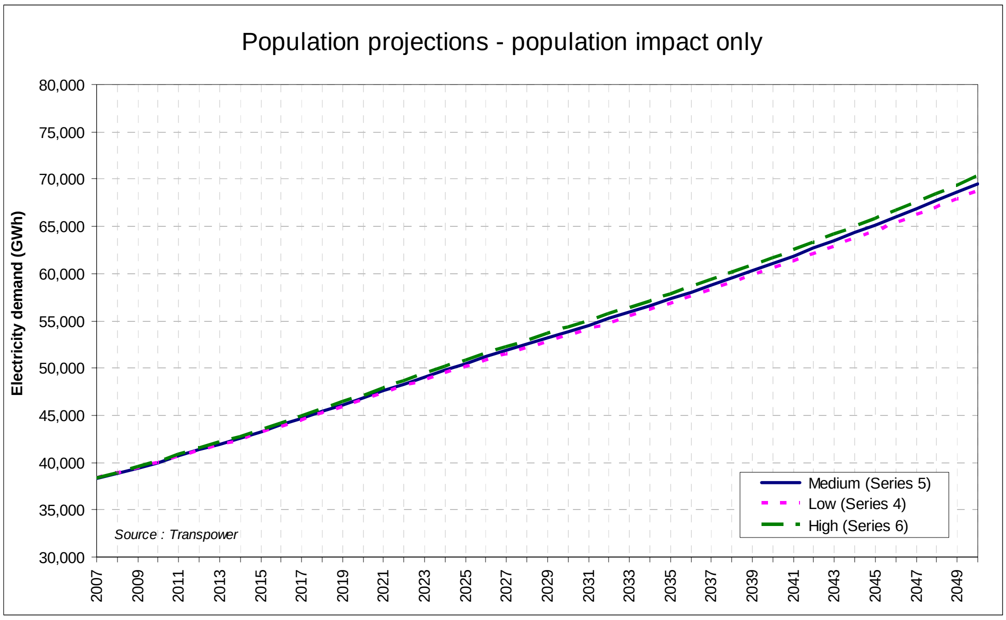
[18] New Zealand Electricity Department/Ministry of Energy Annual Statistics Publications 1973 to 1991 and Transpower Quality Performance Reports 1994-2000

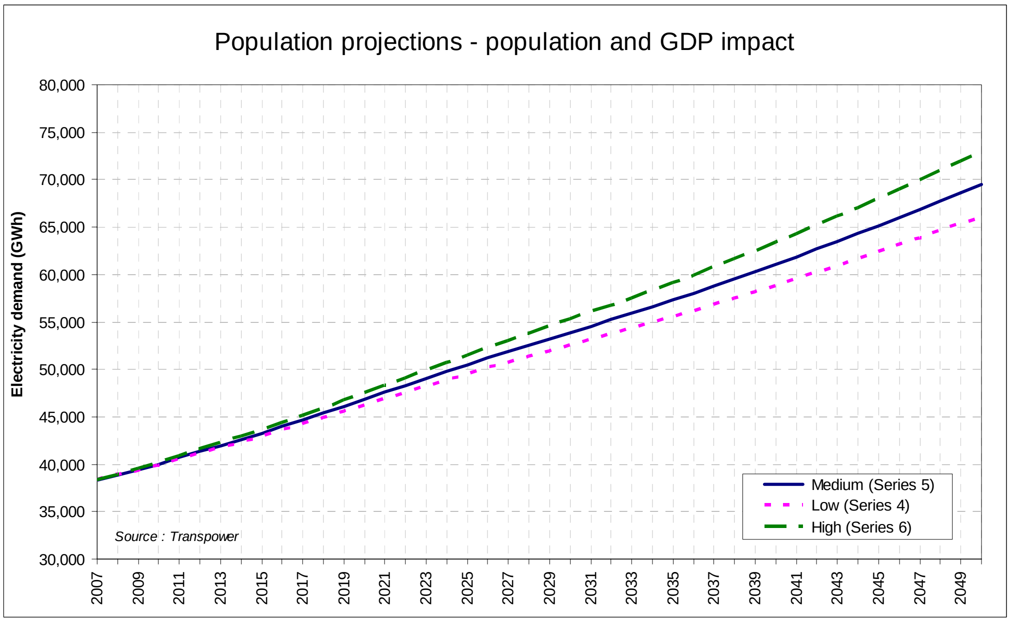
Figure 4-5 - Population only impact on demand



Source : Transpower

Figure 4-6 shows the impact when GDP has been scaled according to the population changes assuming that GDP per capita is the same as in the base case. It can be seen that the impact is now much higher as GDP is the main driver behind demand growth in both the residential and commercial/industrial sectors.

Figure 4-6 - Population and related GDP growth impact on demand

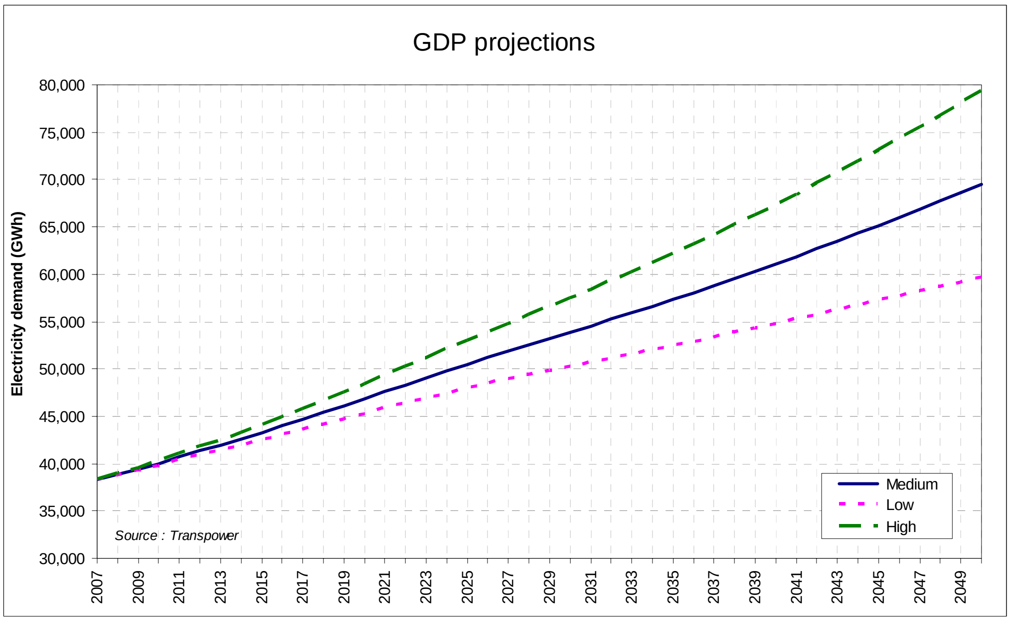


Source : Transpower

4.3.2 GDP scenarios

This section illustrates the impact of varying GDP growth while all other parameters are fixed. This creates projections for different levels of GDP per capita as opposed to the previous section, where GDP per capita was fixed while population was varied. Figure 4-7 shows this. GDP is varied by +/- 20% by 2050 resulting in a change in demand by approximately 10 TWh to either side or about 14%. Demand changes less than GDP because the assessed income elasticity is less than 1 as discussed in Section 4.2.3.

Figure 4-7 - GDP growth impact on demand



Another interesting case is when the GDP per capita is kept stable but the energy intensity is varied instead as discussed in Section 4.2.3. EECA has assessed the change in energy intensity for 1995-2006 in the residential sector to average a 0.7% annual decrease[19]. Figure 4-8 below shows two potential paths, where the base case is improving the energy intensity by a similar number on average between 2008-2050 and the other assumes more focus on energy efficiency and hence a decrease of 1.2% a year.

Figure 4-8 - Scenarios for energy intensity improvements

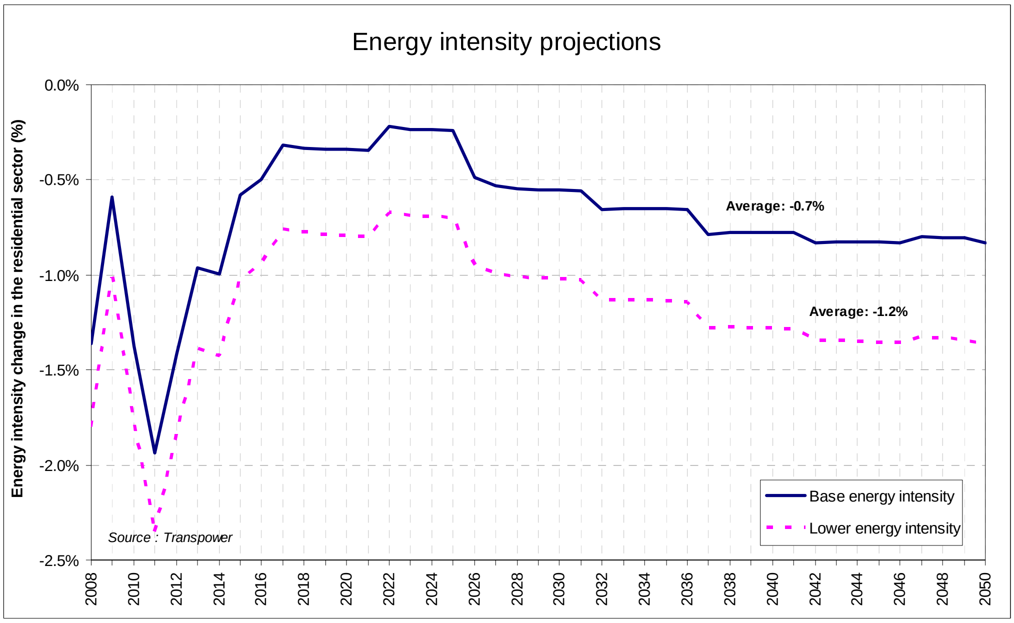


Figure 4-9 shows the resulting residential demand. It can be seen that the case with lower energy intensity (almost double the historical rate of improvement) reduces demand significantly if it can be achieved.

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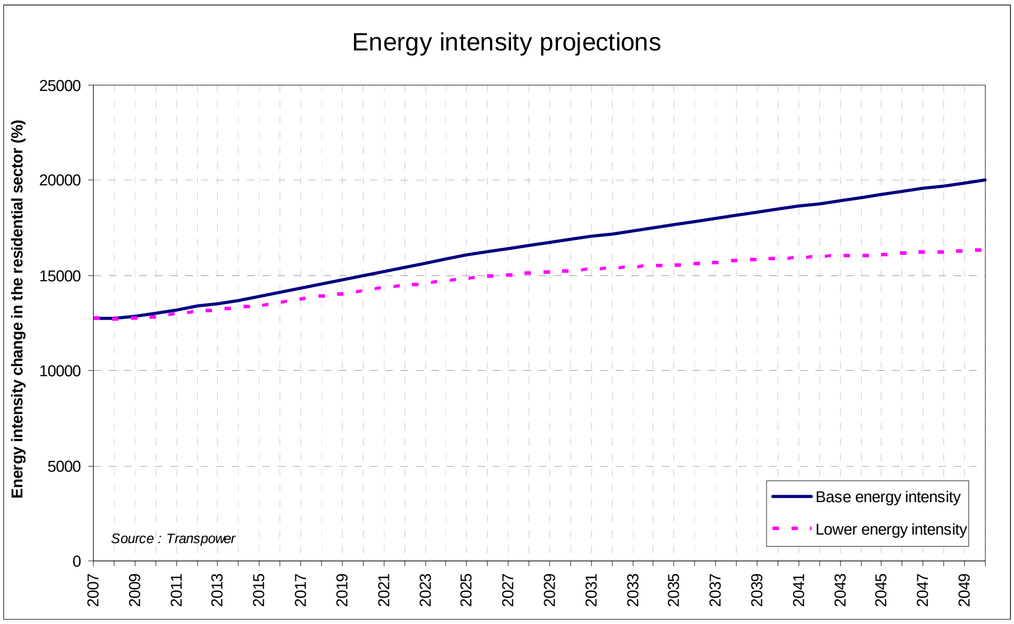
[19] EECA (2008): “Electricity Efficiency Review in New Zealand – March 1995 to 2006”. Energy Efficiency and Conservation Authority, May 2008.

Figure 4-9 - Energy intensity impact on residential demand

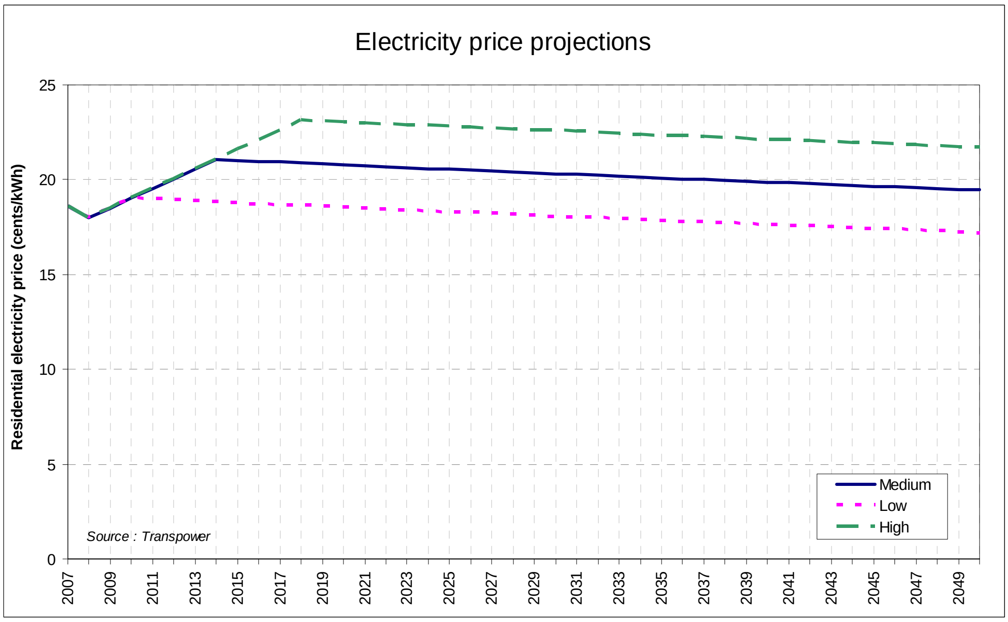


Source : Transpower

4.3.3 Price scenarios

This section analyses the impact of change in the electricity price on consumption. As stated in Section 4.2.4, the price elasticities of electricity demand for both the residential and commercial/industrial sectors are quite low indicating an almost inelastic demand. Figure 4-10 shows three different price paths, where residential price is varied with about +/-12.5%.

Figure 4-10 - Residential electricity price projections

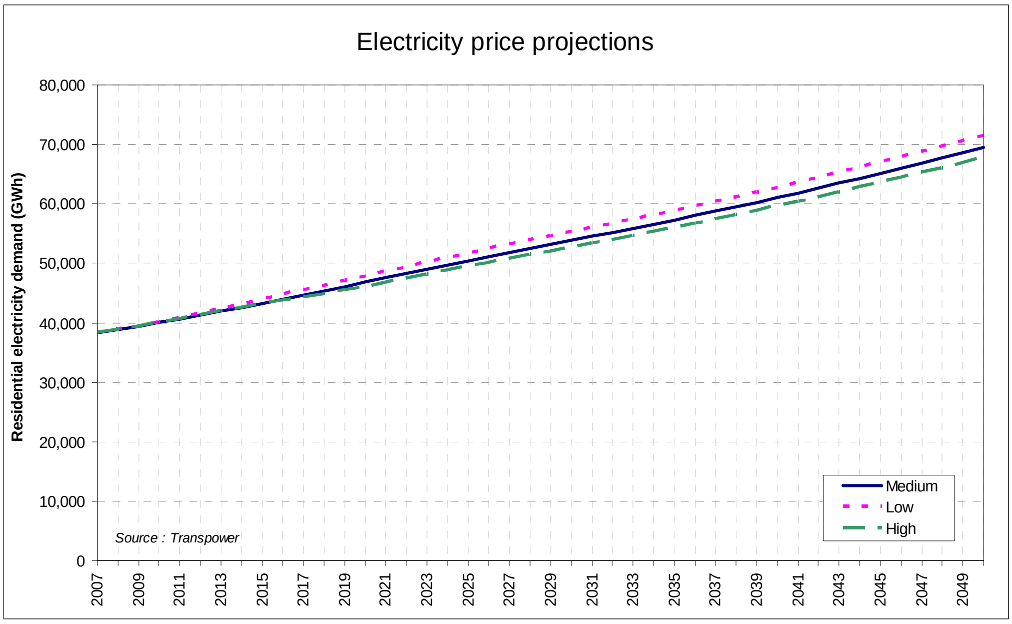


Source : Transpower

The resulting demand from applying each of the three price paths are shown in Figure 4-11. It can be seen that demand varies little indicating a minor impact on demand. Price elasticity may change in the future, though most likely a near real-time basis enabled by the rollout of smart meters. This will allow customers to respond to short-term (hourly) price signals.

The price elasticity discussed here is the longer term impact of change in the stock of energy consuming devices, either by having less devices or more energy efficient ones. Higher electricity price with be a driver for both, but as indicated, with minor impact.

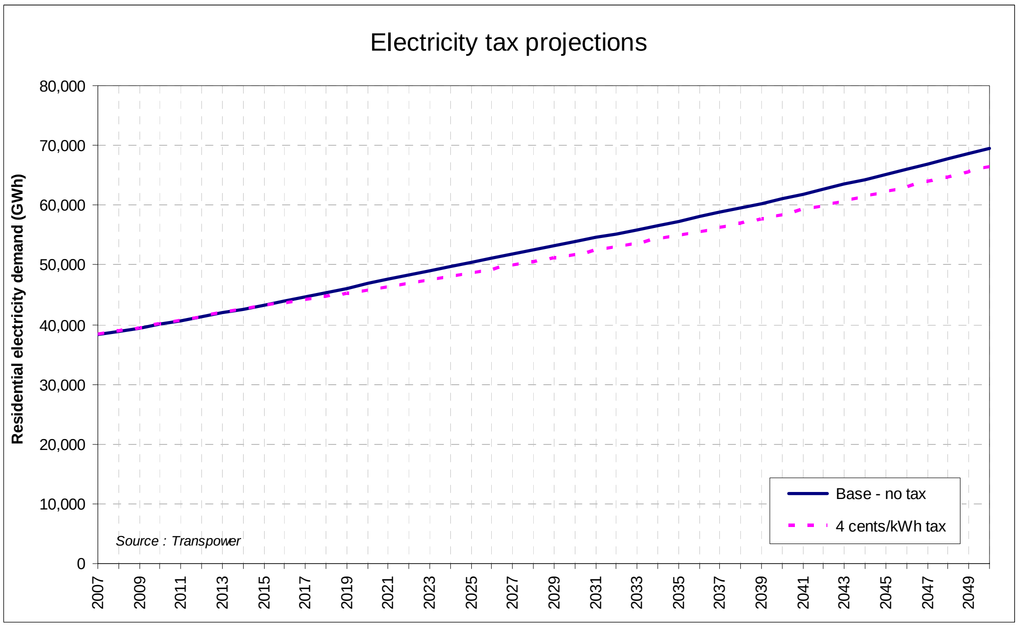
Figure 4-11 - Electricity price impact on residential demand



Source : Transpower

Figure 4-12 investigates another case, where a 4 cents/kWh tax on electricity consumption has been applied to all demand (plus GST for residential) from 2016. As seen, the impact on total demand is not insignificant, but prices are also increased by approximately 20%.

Figure 4-12 - Impact from electricity tax on demand

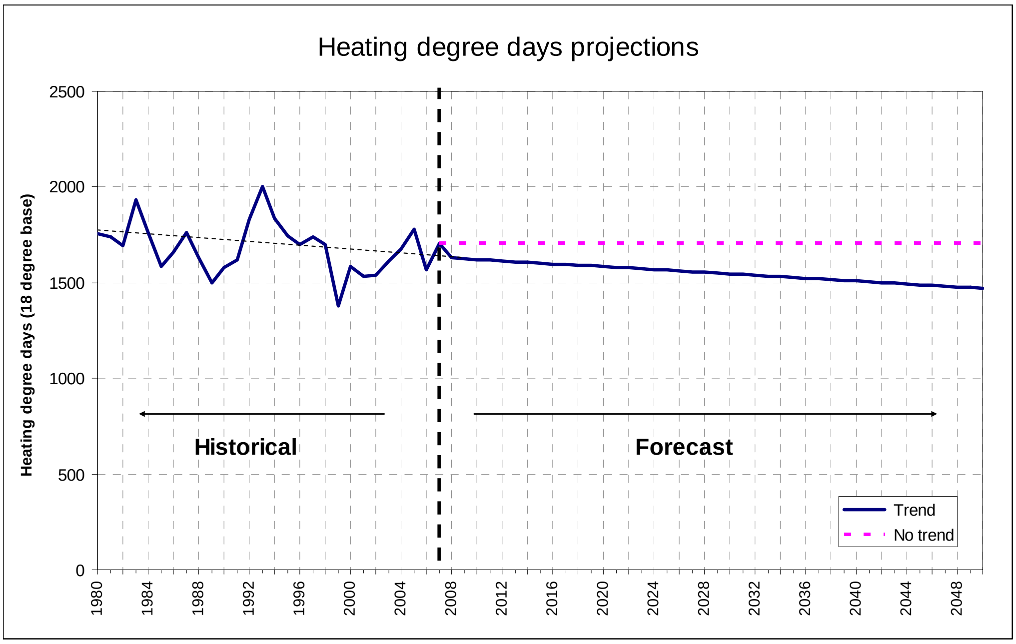


Source : Transpower

4.3.4 Heating degree day scenarios

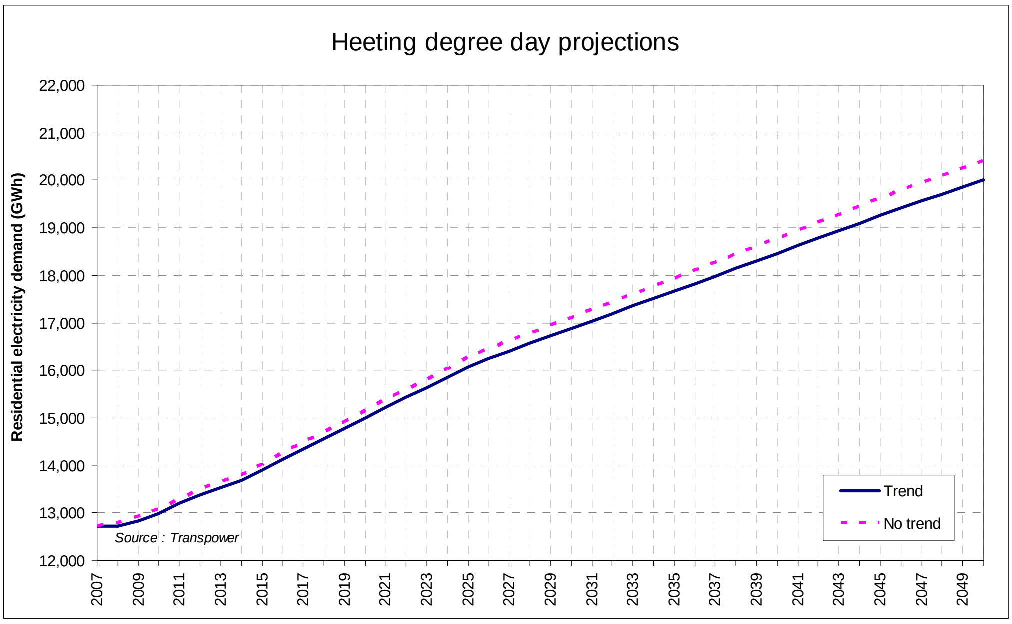
In the base model it has been assumed that the number of heating degree days decreases over time due to global warming. This is based on the historical trend. If there is no warming, the number should be kept constant, which would lead to a higher demand due to the extra heating requirements. These two cases are illustrated in the Figure 4-13.

Figure 4-13 - Heating degree days (HDD) projections



The resulting residential demand series are shown in Figure 4-14. It can be seen that demand is dropping by around 400 GWh, by the end of the period, due to lower heating requirements in the future relative to a scenario where heating requirements are kept stable. The drop in heating demand may in reality be partly offset by an increase in the cooling demands.

Figure 4-14 - Heating degree days impact on residential demand



Source : Transpower

4.4 Scenario selections

As discussed in section 2.6, four scenarios have been created based on variations of two critical uncertainties; electricity demand and remoteness of generation. Each scenario has a different story line and the demand figure must be consistent with these.

The table below show the parameter variations that have been assumed for the 4 scenarios.

Table 4-4 - Scenarios assumptions for demand drivers

Scenario	**Demand drivers**				
	Population	**GDP**	**Energy intensity**	**Price**	**HDD**
1 - New Norway	High	High	Low+	High	Lower
2 - Crisis recalled	Base	Very high	Base	Low	Level
3 - Fragmented world	Low	Low	Base	Base	Lower
4 - Green communities	Base	Low	Low	High	Lower

For population, the high, base and low corresponds to the projections shown in Figure 4-6. The GDP scenarios typically varied GDP by +/- 13% by 2050 which equates to a 0.3% change in the annual GDP growth rate. The exception is Scenario 2, which had a 0.5% change in the annual growth rate resulting in a GDP growth similar to the high projection pictured in Figure 4-7.

The scenarios with lower energy intensity, Scenarios 1 and 4, had the energy intensity changed for the residential sector only. The change is assumed to be as a result of energy savings, not fuel switching, which is dealt with separately in the next chapter. Scenario 4 had the energy intensity changed as shown in Section 4.3.2, while Scenario 1 had about half that improvement compared with the base case.

The electricity price paths used are based on wholesale price projections of 8 cents/kWh, 10 cents/kWh and 12 cents/kWh for the low, base and high cases. In addition, both Scenarios 1 and 4 introduce electricity taxes to encourage demand savings.

Scenario 1 introduces a 2 cents/kWh tax from 2020 for all but the heavy industry sector. In addition, GST is raised to 15% representing governments attempt to lower consumption in this high growth oil scenario. This increases residential price even further. Scenario 4 has a 4 cents/ kWh electricity tax but the GST is lowered to 10% limiting the impacts on domestic users.

Finally, the future trend in heating degree days (HDD) has been varied. Scenario 2 keeps the current value of heating degree days while all other scenarios had the number of heating degree days reduced by the current rate of change. The impact of these changed is shown in Figure 4-14.

Figure 4-15 and Figure 4-16 show the resulting demand figures for the residential and commercial/industrial sectors respectively. The demand level for the residential sector is a rather complex interaction between the different input drivers. As a result, Scenario 1 has a demand in the mid range though it assumed population and GDP growth was above average. However, higher prices and improvements to the energy intensity of the sector helped to lower the consumption, as did the lower amount of heating degree days. In comparison, nothing helped to reduce the consumption in Scenario 2.

Figure 4-15 - Base scenario projections for the residential sector

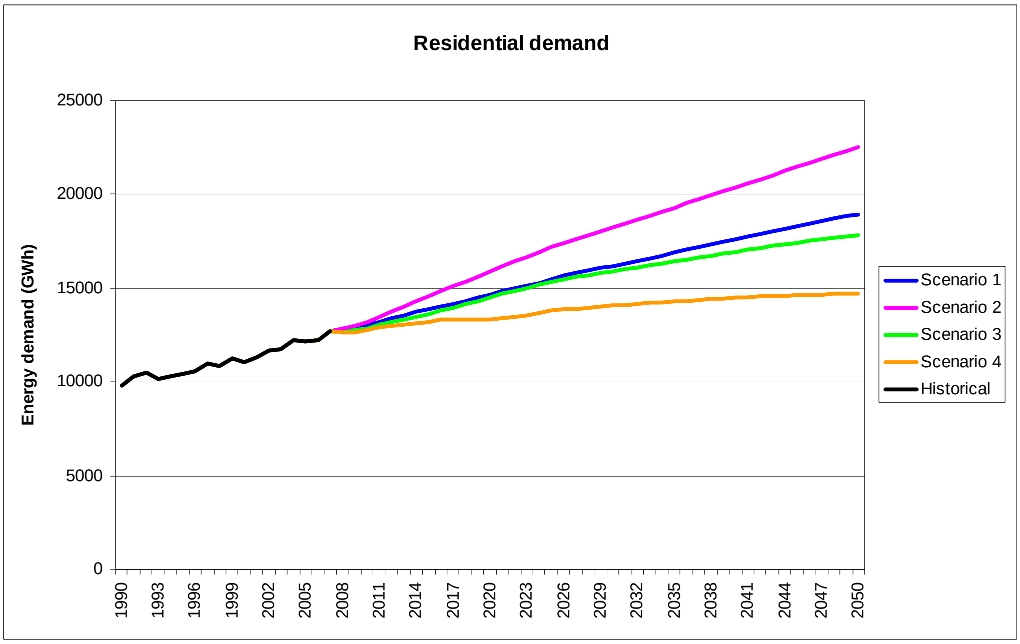
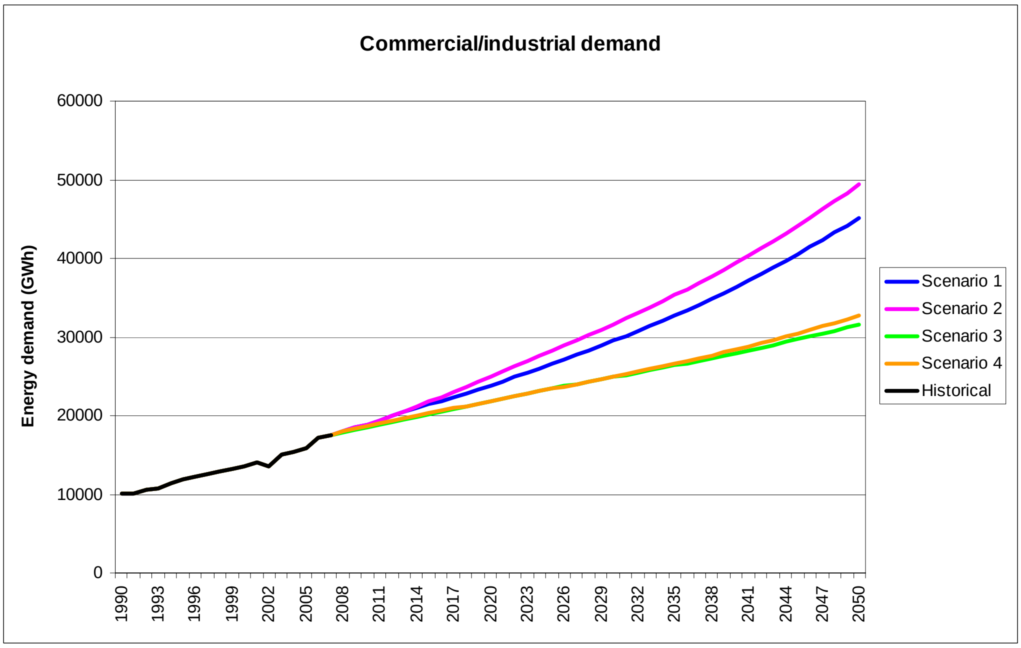


Figure 4-16 - Base scenario projections for the commercial/industrial sector



The commercial/industrial demand is mostly driven by GDP and this is clear from the picture above.

The next chapter will look at fuel switching and how it may affect the demand beyond the levels forecasted here.

Questions:

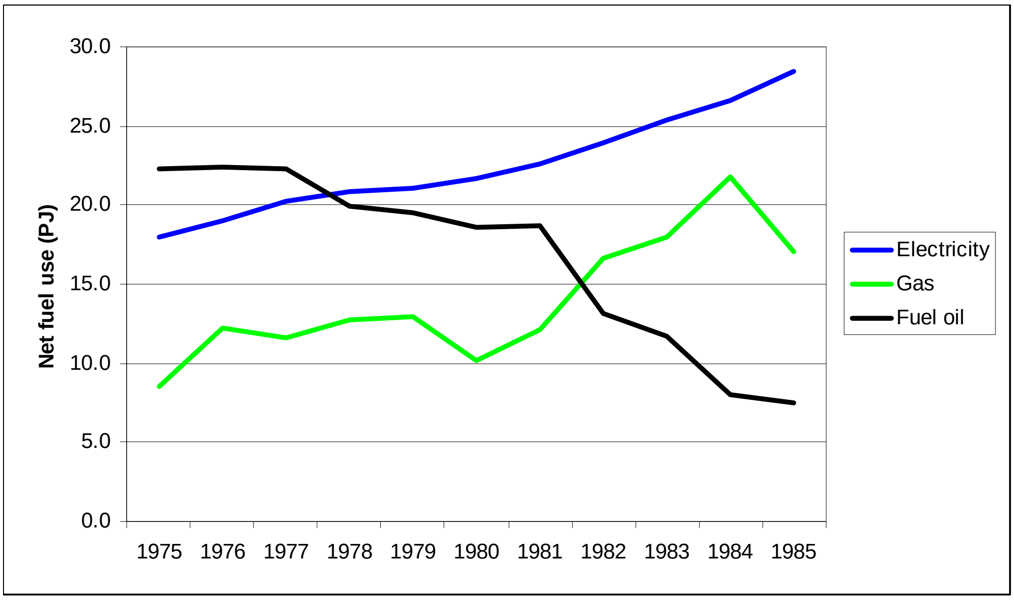
4.1 Is the model reasonable, i.e. does it include the most important historical relationships?

4.2 Are the assumptions used for the specific scenarios reasonable?

5 Fuel switching

There is evidence of fuel switching over time as a result of the relative changes in the price of energy sources. An example is the switch away from fuel oil to natural gas or electricity as a result of the oil crisis and landing of Maui gas in New Zealand. This is illustrated in Figure 5-1.

Figure 5-1 - Historical fuel use in the commercial and light industrial sectors



It can be seen that fuel oil use in the commercial and light industrial sectors was reduced by two thirds. It corresponded with the price increase from the second oil crisis and Maui gas becoming availability. Gas consumption increased, although not directly in line with the corresponding decrease in fuel oil consumption. Electricity is therefore expected to have substituted parts of the former fuel oil demand.

Future fuel switching may arise from major price movements, e.g. due to carbon pricing, development of technology or legality of using particular fuels, the latter exemplified by the ban of woodburners by certain city councils leading to electricity substituting wood for space heating in many houses.

Understanding fuel switching and the drivers behind it is important as there is a need to adjust for changes in consumption that is not modelled in Transpower's trend based electricity demand forecast. Such potential shifts in consumption are discussed below.

5.1 Transport

Substituting fossil fuels with electricity in the transport sector is considered a very likely scenario with the major uncertainty being around how much substitution will take place.

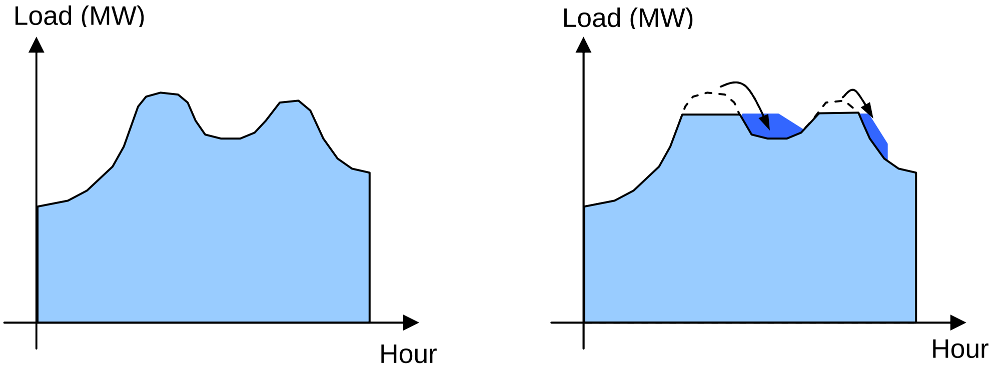
5.1.1 Transmission impacts

From a transmission point of view, electric vehicles have the potential to significantly impact on the utilisation of the grid.

Firstly, increased use of electric vehicles will obviously increase the demand for electricity though it is expected that peak demand is going to be almost unchanged. Secondly, the technology already exists to enable electric vehicles to re-inject electricity back to the grid, the so-called vehicle-to-grid technology or V2G. This allows owners of electric vehicles to supply ancillary services, such as instantaneous reserves, whenever the car is connected. If the number of cars is significant and the incentive for the vehicle owners to supply this service is large enough, it has the potential to replace most existing reserves.

If battery technology improves further, it may even be possible to use the distributed storage of all vehicles for load shifting. Power is delivered back to the grid during peak and recharged again off-peak. This can lower peak demand to a level below a system without any electric vehicles.

Figure 5-2 - Example of load shifting



Traditional load shape **Load shape with load shifting**

Load shifting example

Assume a future electric car will have a 25 kWh sized battery. The owner typically allows half of the capacity to be available to the market as the battery, even if only half full, allows him to get to work and back without any problems.

If 400,000 of such cars exists and 20% of them are available (the rest may be driving, not connected, or the owners unwilling to let the batteries discharge), this gives 1,000 MWh. This can be used to move 200 MW from peak to off-peak assuming the load needs to be shifted over 5 hours.

As a result, a system with higher energy demand but lower peak demand can arise. Thus, more MWh's are carried through a lower capacity system. There is a limit however. Maintenance will be done preferentially at times with lower demand, but if the load curve is too flat, there might need to be greater grid capacity and redundancy at peak to allow for off-peak maintenance.

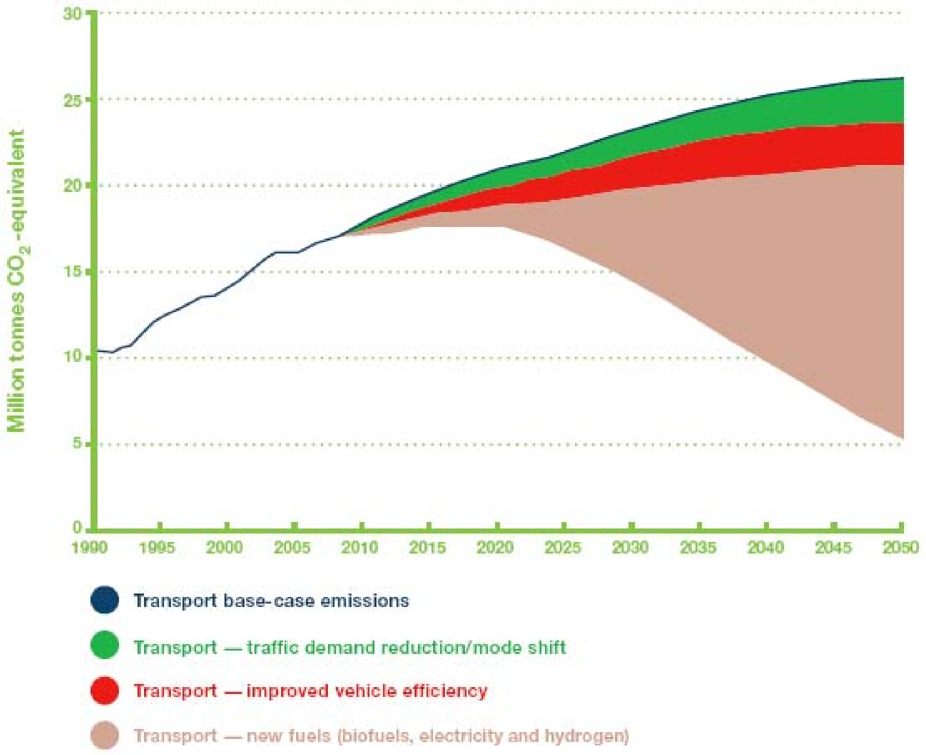
From a wider electricity system point of view, electric vehicles may also assist in the integration of more intermittent generation, such as wind power. Finally, hybrid plug-in electric vehicles, which can run on either petrol or electricity, can help during dry inflow years. If electricity price increases above the cost level of using petrol, a significant amount of energy demand can be moved from electricity to petrol.

Load shifting and the incentives behind is discussed further in Chapter 8.

5.1.2 Drivers

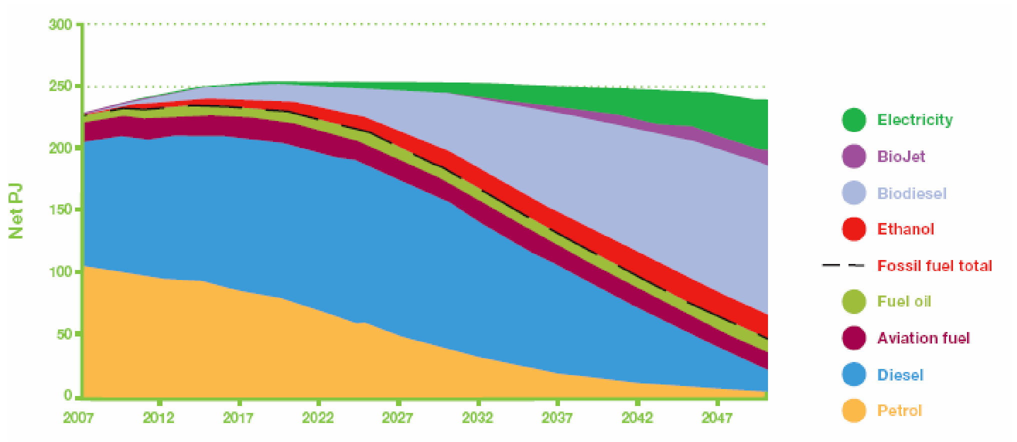
A major driver behind the future uptake of electric vehicles is climate change policy, in particular the requirements to reduce greenhouse gas emissions. As seen in Figure 5-3, breaking the trend of increasing emissions from the transport sector is a difficult task.

Figure 5-3 - Projected carbon emissions from the transport sector[20]



Change of traffic mode, demand reduction and improved efficiency can only stabilize emissions and this at level more than double that of 1990. The largest potential for reductions in the transport sector is through the use of alternative fuels, such as biofuels, electricity or hydrogen. Such a scenario was illustrated in the New Zealand Energy Strategy and is shown below. While the share of electricity is rather small, it still requires 40 PJ or ~11 TWh of electricity.

Figure 5-4 - Transport fuel use in a low carbon scenario[21]



While a target of reducing the level of carbon emissions is likely to be a major driver behind electric vehicles, a peak oil scenario can be another driver. The high oil prices seen in 2008 added significantly to the cost of driving in many countries. While electricity is expected to increase in price as well, it is far from the increase seen in oil prices since 2004. If oil prices move to a level above US$100/bbl or maybe

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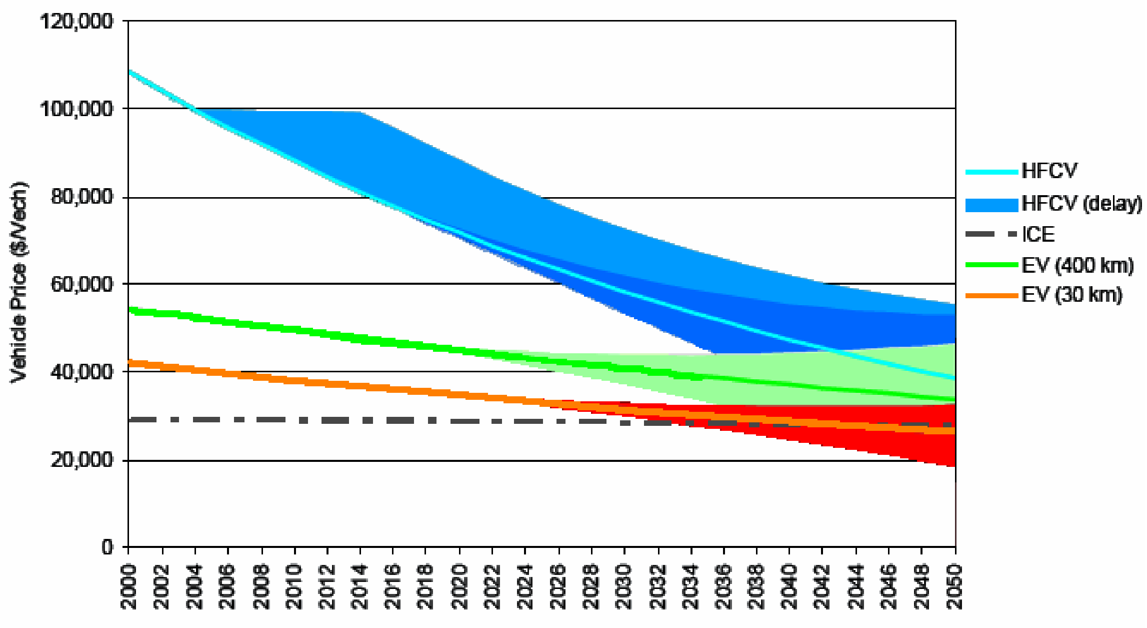
[20] MED (2007): "New Zealand Energy Strategy to 2050". Ministry of Economic Development, 2007.

[21] MED (2007): "New Zealand Energy Strategy to 2050". Ministry of Economic Development, 2007.

US$200/bbl in addition to a possible carbon tax, electric vehicles may soon be the cheapest transport available as cost comes down and efficiency improves. The technology improvements itself is a third driver behind the future uptake of electric vehicles (see Section 6.1.2 for a discussion of technological improvements and learning rates).

A presentation by NIWA shows one estimate of future cost developments as a result of technological improvements. It has been replicated in Figure 5-5 below[22]. As seen, costs of electric vehicles (EV) are reducing whilst traditional cars with internal combustion engines (ICE) represent a mature technology that is not expected to drop much in price. The costs of Hydrogen Fuel Cell vehicles (HFCV) are expected to come down even faster than those of electric vehicles, though from a higher starting level.

Figure 5-5 - Projected vehicle costs by technology, 2000-2050



Based on these numbers, NIWA has estimated the cost of operation for 10 years including capital costs, fuel costs and a carbon cost of $50/ton. These total costs are listed below.

Table 5-1 - Comparison of 10 year total operating costs of different vehicle types[23]

Car type	2009 costs	2030 costs
Compression ICE	$39,800	$48,600
Spark ICE	$57,800	$60,000
Battery Electric vehicle	$57,100	$27,400
Hydrogen Fuel Cell vehicle	$203,900	$27,800

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[22] See NIWA (2008): "New Zealand's EnergyScape". Presentation 16 July 2008 by Rilke de Vos. Available from: http://www.niwascience.co.nz/ncces/projects/energyscape

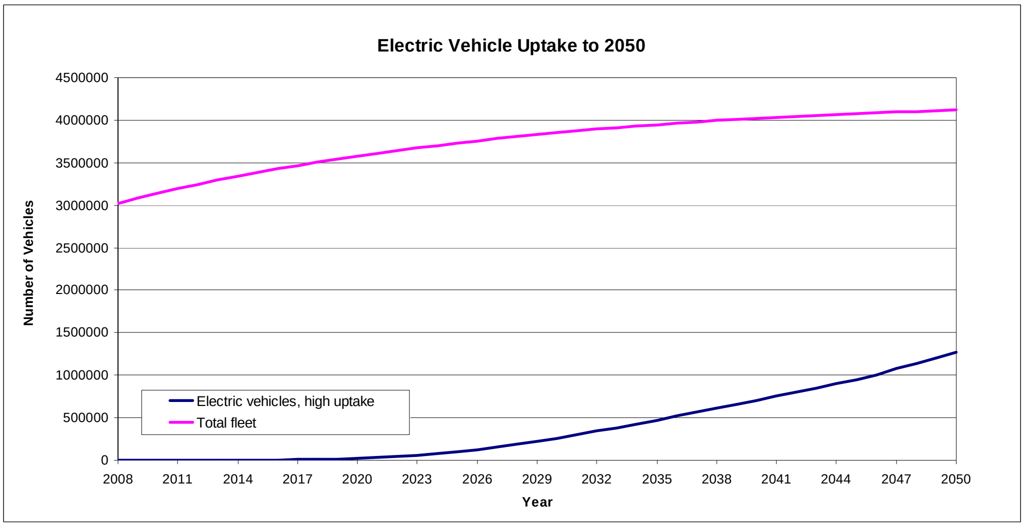
[23] See NIWA (2008): "New Zealand's EnergyScape". Presentation 16 July 2008 by Rilke de Vos. Available from: http://www.niwascience.co.nz/ncces/projects/energyscape

In carbon constrained scenarios electric vehicles quickly becomes competitive and high oil prices or lack of biofuels as alternatives may increase the penetration of those cars even further.

Two electric vehicles uptake scenarios have been considered. The high uptake scenario is based on the Electricity Commission's electric vehicle projection as detailed in its 2008 Statement of Opportunities. In this scenario, the vehicles increase electricity demand by 2050 with an extra 5.5 TWh. As a low – business as usual – uptake scenario, Transpower has assumed approximately half the uptake resulting in 2.7 TWh extra electricity demand by 2050.

Figure 5-6 shows the penetration of electric vehicles in the system out to 2050 for the high uptake scenario. It should be noted that the draft 2008 Statement of Opportunities had an even higher projection, consistent with Figure 5-4 above. Feedback concerning the feasibility of this projection made them lower the forecast to the one used here, which is still considered a high uptake scenario.

Figure 5-6 - Projection for electric vehicle uptake - high uptake scenario



5.2 Commercial/industrial use

There is a significant use of both coal and gas in the commercial/industrial sector. A significant share of this is used for heating, either space heating or process heat. Unlike e.g. demand for lighting and refrigeration, where electricity is the prime source, heat demand can be supplied from a diverse range of energy sources.

According to the New Zealand Energy Strategy, 208 PJ or approximately 27% of total energy consumption in 2005 was used for producing heat energy. Of this, 42 PJ (about 20%) was provided by electricity, with the remainder being from almost equal shares of, coal, oil, gas and renewables[24]. In carbon constrained scenarios the use of coal and oil is expected to go down, either due to efficiency measures or because electricity or renewable energy sources (typically geothermal or woody biomass) is used instead. As a result, electricity consumption may go up.

The availability of natural gas (discussed further in Section 6.2.2) is another issue. If gas prices increase as a result of shortage or high import prices of LNG, the use of natural gas in the industrial sector is expected to go down; some of this may be substituted with electricity. On the other hand, if gas prices increase at a lower rate than electricity prices in the future, more heating may be sourced from natural gas which will lower the electricity demand.

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[24] MED (2007): "New Zealand Energy Strategy to 2050". Ministry of Economic Development, 2007.

Emissions trading may also be a driver, which in this case can work both ways. For hot water and process steam applications, it may be more economic, when the carbon price also is taken into account, to use natural gas for direct heating in comparison with electricity. Natural gas has the lowest level of carbon emissions of the fossil fuels and a high efficiency when used directly in a boiler, typically up to 90%. If displacing electricity generation on a gas fired power plant, it will clearly have an advantage as CCGT's at best will have an efficiency of 60% and further losses will occur in the transmission and distribution networks.

Apart from the savings in emissions, there may also be a lower peak demand, which will result in lower investments in power generation capacity as well as in the transmission and distribution networks.

From an emissions point of view, it may be even better replacing coal use instead, so electricity use may be unaffected. Also, for a mostly renewable based electricity system, there might be little gas-based generation that can be displaced. In that case, it may result in less wind or hydro power generation, with the result that the national emission levels go up.

For applications where heat pumps can be used, typically space heating and to some extent also hot water heating, the benefits on direct use of natural gas is questionable as the efficiency of the heat pump, typically around 300%, makes it preferable to use the gas at the power plants instead, assuming gas is needed for power generation.

The benefits of shifting from electricity to natural gas are discussed further in the CAE report "Understanding the contribution of direct use of gas to New Zealand's future energy efficiency objectives"[25].

5.3 Residential demand

There is also a significant potential for fuel switching in residential heating.

Of the total residential electricity demand, hot water heating accounts for 34% making it the largest end use group[26]. By way of comparison, space heating accounts for only 12% of the electricity use in the residential sector. There is a future potential for micro-cogeneration units which delivers both electricity and heat at the household level. This is discussed further in Chapter 7, which deals with distributed generation.

5.3.1 Hot water heating

Of the 4.3 TWh used by households for hot water heating in 2007, about 75% was supplied by electricity, 20% by reticulated gas and the last 5% from wetback woodburners. Solar heating accounts for a minor share of the hot water heating as well. According to the Solar Industries Association, solar hot water heating each year accounts for more than 40GWh of equivalent electricity consumption[27]. There is however, a potential to significantly increase this share.

There are approximately 3,500 new solar hot water installations made every year, a number that EECA considers could potentially rise to 10-15,000. Typically, the households that convert to solar hot water heating are larger families (4 or more persons), currently using an electric hot water heater, and with a roof well positioned towards the sun.

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[25] CAE (2008): "Understanding the contribution of direct use of gas to New Zealand's future energy efficiency objectives". New Zealand Centre for Advanced Engineering – report produced for the Gas Association of New Zealand, May 2008.

[26] Branz (2006): "Energy use in New Zealand households – report on the year 10 analysis for the Household Energy End-use Project (HEEP)", Branz, Study report 155, 2006.

[27] See: http://www.solarindustries.org.nz/

If 500,000 households converted to solar hot water heating, assuming an average saving on 2.4 MWh per household and that 95% of those converted from electricity, the amount of savings that could be achieved is in the region of ~1.15 TWh per year. However, the current rate of conversion of about 3,500 should already be part of the trend forecasted by the demand forecast model. Correcting for this, the total correction for fuel switching that should be used is a reduction in demand of around 800 GWh. Adding some conversion from traditional heaters to heat pumps and the potential for solar hot water heating in the commercial sector (e.g. hotels, motels and holiday parks), an annual saving of 1 TWh has been assumed as a high reduction projection.

Fuel switching from electricity to natural gas or the other way around similar to the discussion in Section 5.2 could also be considered.

5.3.2 Space heating and cooling

Of the 12.7 TWh electricity used by the residential sector, 12% or approximately 1.5 TWh is used for space heating. This makes electricity the second largest heat source after solid fuels, typically fire wood, which accounts for around 2.5 TWh of the heat demand in New Zealand.

It is known from studies like HEEP[28] that New Zealand's houses are under-heated, leading to less comfort and sickness. EECA has accessed the extra demand needed to increase health and comfort in the households[29]. These estimates are shown in Table 5-2.

Table 5-2 - Heating requirements to heat all houses to 18°C

	Demand in PJ	Demand in TWh
2001 actual use	20	5.6
2001 required	43	11.9
2015 no insulation	57	15.8
2015 some insulation	45	12.5
2015 all insulation	35	9.7

It shows that with the housing stock that existed in 2001, 43 PJ or around 11.9 TWh was required to lift winter indoor temperatures to 18°C. However, only 20 PJ was used or about half the level needed.

For 2015, with the increase in population and number of households, the heating requirement is assessed to be 57 PJ assuming no retrofit of insulation to old houses and no improvements in insulation levels of new houses. The two other 2015 cases show various extents of retrofitting insulation to older houses and better insulation of new homes. It becomes clear however, that insulation will not solve the problem alone.

There is a high likelihood that as incomes increase, people will demand more comfort and increase their heat levels. This can create a significant extra heat load, which to a large extent, may be delivered by electricity.

Especially heat pumps seem to be attractive and a significant uptake will already be included in the trend based demand forecast. Local air quality regulations, e.g. the ban of inefficient woodburners in Christchurch, have been a major driver behind the recent growth in heat pump installations. Transpower has commissioned Branz to

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[28] Branz (2006): "Energy use in New Zealand households – report on the year 10 analysis for the Household Energy End-use Project (HEEP)", Branz, Study report 155, 2006.

[29] EECA (2008): "Electricity Efficiency Review in New Zealand – March 1995 to 2006". Energy Efficiency and Conservation Authority, May 2008.

conduct a study of the potential impact on peak and energy demand from future heat pumps in three regions. Initial results show that whilst heat pumps are three times as efficient as traditional resistance heaters, families who convert to heat pumps do not tend to use less electricity. Rather they will heat the house more often and to a higher temperature than previously.

Based on the EECA numbers from Table 5-2, assuming all households are heated to 18^{o}C with some extra insulation added to the housing stock, 12.5 TWh of energy is required for space heating compared with 5.6 TWh in 2001. Assuming electricity keeps it share, it will require 2.2 TWh of the heat to come from electricity, which can deliver this with 0.75 TWh assuming heat pumps with an efficiency of 300% is used. If electricity takes over some of the heating currently supplied by solid fuels, even more electricity is needed.

Overall, 1.5 TWh of extra electricity load has been assumed for a scenario with focus on creating more healthy homes together with a shift from woodburners to heat pumps. As a medium case, 0.5 TWh of extra demand will be considered while a low projection will use the current trend only, which picks up some of the current conversion to heat pumps.

The potential use of the heat pumps for cooling is currently not accounted for although this could be significant. It will not change the system peak, as most regions will remain winter peaking, but it may affect the need for transmission if there are insufficient maintenance windows where lines can be taken out for service because of the increase in cooling load during the summer months.

5.4 Scenario selections

The table below shows the extent of fuel switching in TWh extra electricity use that has been assumed for the 4 scenarios.

Table 5-3 - Scenarios assumptions for fuel switching (extra electricity use in TWh)

Scenario	Residential		Industry	Transport	
	Hot water heating	Space heating	Heating	Electric vehicles	Public transport
1 - New Norway	-0.5	1.5	4.0	5.5	0.0
2 - Crisis recalled	0.0	0.5	0.0	2.7	0.0
3 - Fragmented world	-0.5	0.0	0.0	2.7	0.0
4 - Green communities	-1.0	0.0	1.0	2.7	0.3

The demand for hot water heating has been assumed to be lower for Scenarios 1, 3 and 4. Scenario 4 has a very high uptake of solar hot water heating and to some extent conversion from gas to electric heating as gas prices in that scenario are assumed to be high. Scenarios 1 and 3 assume a little more than the current growth rate while Scenario 2 assumes nothing above the current rate of change. Scenario 2 could have assumed a switch from electricity to gas, which would be consistent with the scenario story, however, it was decided that on the balance, it made more sense to keep the scenario as an “extreme high demand” scenario.

Scenario 1, in which income is rapidly increasing, assumes to have the high “healthy homes” projection of 1.5 TWh extra demand for space heating. Scenario 2, which also assumes a high GDP growth, uses the base projection of 0.5 TWh extra demand as the larger part of the extra heating requirement is assumed to be served by gas.

Heating demand in the industrial sector was changed for scenarios 1 and 4. Scenario 1 envisions a major substitution from fossil fuels to electricity in order to lower emissions assuming that carbon capture and storage (CCS) would be more economic at central power plants rather than at smaller industrial sites. Again, Scenario 2 could have assumed electricity demand being substituted by gas. As for the residential demand, this was not done to preserve the high demand level of the scenario.

A high electric vehicle uptake has been assumed for Scenario 1 while the other scenarios use the base uptake rate. Finally, Scenario 4 has an extra demand for increased public transport including conversion of some of the bus fleet into trolley buses.

The scenario demand projections as shown in Section 4.4 has been adjusted by the numbers above to take into account fuel switching not accounted for in the demand forecast. While all entries add to the energy demand, the demand from electric vehicles will not affect the peak demand forecast assuming they will be changed off-peak.

Table 5-4 shows the resulting energy demand levels for 2050 before and after the adjustment for fuel switching both when including and excluding the load from the electric vehicles.

Table 5-4 - Demand levels (in GWh) before and after adjustment for fuel switching

Demand projection	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Base 2050 demand projection	84211	89521	65650	63533
Adjusted 2050 demand excluding EV's	89211	90021	65150	63833
Adjusted 2050 demand including EV's	94699	92766	67895	66578

Figures with the full demand projections are shown in Chapter 8.

Questions:

5.1 Is it reasonable to assume that electric vehicles in 10 years time will be charged off peak?

5.2 Should other types of fuel switching be considered?

5.3 Do the scenario specific assumptions fit the overall story lines?

6 Supply side options

A critical issue in the operation and long term planning of a transmission system is the location of generation relative to the location of load. While the make up of generation will change slowly over time, most of the power plants, with the exception of hydro, will be replaced within the horizon of this study. As a consequence, the demand for transmission services has the potential to be significantly different in the end year from where we are now.

There are many commercial factors which influence the size, location and timing of new generation build in a competitive market. These include individual company incentives, the generation mix, portfolio management and costs. Whilst all these factors should be taken into account when planning for the short to medium term, it is practically impossible to take these into account over a significant timeframe such as 40 years.

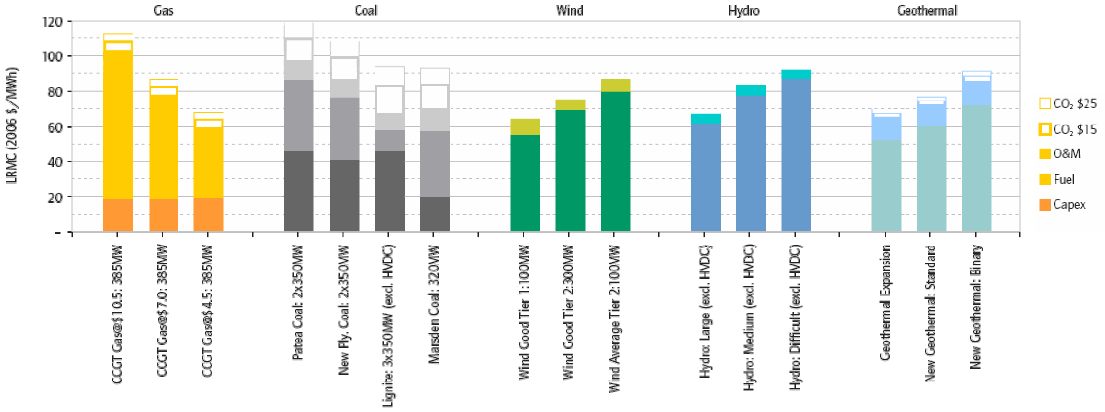
To this end, Transpower proposes to use cost as a driver for generation build in the scenarios

Within this framework, four main elements will determine the most cost effective investment in generation capacity:

- capital costs (CAPEX),
- operating and maintenance costs (OPEX), excluding fuel,
- fuel costs, and
- costs of carbon emissions.

Figure 6-1 below exemplifies this by showing the costs of various technologies base on different fuel costs and carbon costs.

Figure 6-1: Cost of generation for different technologies for different fuel and carbon costs[30]



This chapter deals with all four aspects. The first two are described in the following section, looking at the present costs and the expected improvements to the technologies over time. This is followed by two sections about fuel cost and carbon costs.

An additional section deals with the investment incentives and revenue adequacy and a final section summarises the supply side assumptions made in the four scenarios.

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[30] Figure taken from Meridian (2006): “Options, Choices, Decisions”, Meridian Energy, 2006

6.1 Technology costs – now and in the future

6.1.1 Starting cost assumptions

The cost assumptions used for generation options are similar to those used by the Electricity Commission in its 2008 Statement of Opportunities[31]. A summary of the main assumptions is shown in Table 6-1. The cost information is based on a review done by PBA[32] in 2006 though updated based on industry feedback and supplementary studies done since.

Note that Transpower has changed the costs of marine energy and included tidal energy projects based on information from IEA[33]. The reason for changing the cost of marine energy was the addition of technological learning. The previous cost was the estimate that applied for marine energy around 2030. Now these costs will be found based on the 2008 costs shown below and the change in capital costs over time shown in Figure 6-5.

Table 6-1 - Technology assumptions with costs in real $2008

Technology	Assumed size, MW	Capacity factor, %	Heat rate, GJ/GWh	Capital cost, $/kW	Fixed O&M, $/kW	Variable O&M, $/MWh
Coal	400	-	9500	2400	40	9
Lignite	400	-	10800	2460	44	10
IGCC w. CCS	400	-	8000	4000	50	12
CCGT	400	-	7050	1035	50	4
CCGT w. CCS	400	-	7800	1250	60	5
OCGT	150	-	10000	1000	40	4
Geothermal	200	95%	-	4000-6000	95	0
Hydro	50	50%	-	2000-6500	23	0
Hydro, pumping	300	-	-	3000	15	0
Wind	150	35-45%	-	2400-2700	0	16
Wave	50	40%	-	9000	0	20
Tidal	50	40%	-	8000	0	20

6.1.2 Technological improvements

In the manufacturing industry, it has been observed that unit costs decrease over time due to innovation, economics of production scale, and as experience is accumulated about the production of those items.

Figure 5-5 showed this trend for electric vehicles. It has also been observed for electricity generation as exemplified in Figure 6-2. It can be seen that technological learning can change the unit merit order over time as the unit cost of generating electricity drops below those of generation from a CCGT for a given set of assumptions on fuel and carbon costs.

Given the long time horizon, Transpower considers it prudent to include technological change in the modelling.

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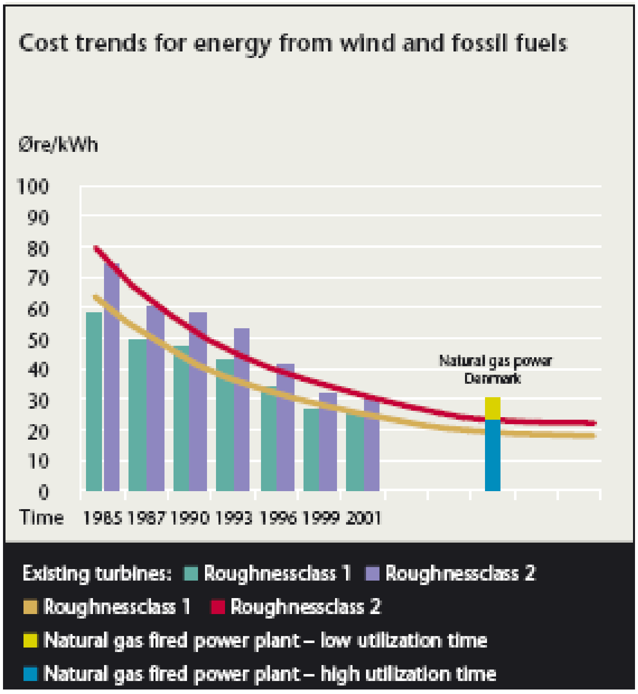
[31] EC (2008): “2008 Statement of Opportunities”. Electricity Commission, August 2008.

[32] PBA (2006): “Electricity Generation Database – Statement of Opportunities update 2006”. Parsons Brinckerhoff Associates, October 2006.

[33] IEA(2008): “Energy Technology Perspectives 2008 – Scenarios and strategies to 2050”. International Energy Agency, Paris, France, 2008.

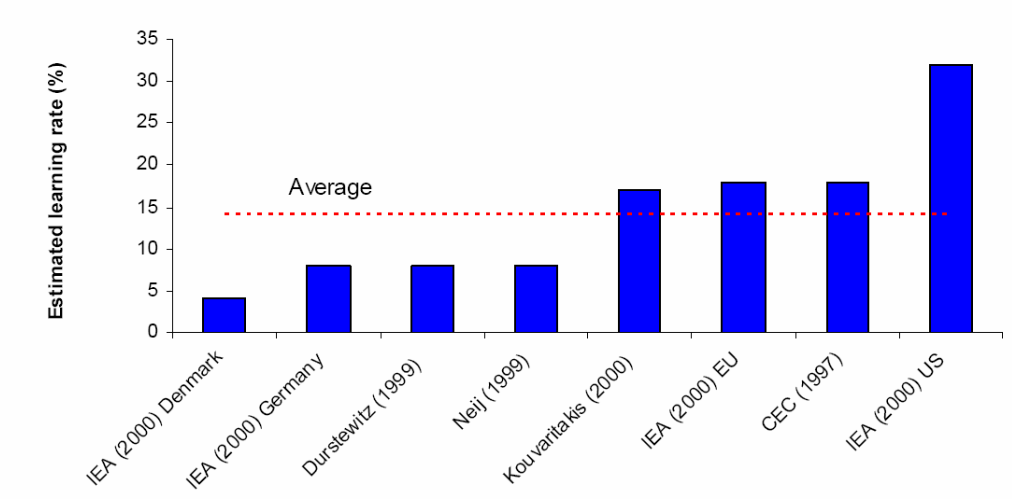
Figure 6-2 - Learning rates may change the merit order



The phenomenon of decreasing cost has been studied academically for years and in literature; the observed rate of improvement is typically referred to as the learning rate. The learning rate describes the unit cost reduction that can be expected from each doubling of the accumulated production.

The learning rate is expected to lower as technologies become mature. As a consequence, and because doubling of capacity typically happens faster for new technologies than old, unit cost improvements slows down. The figures below show some examples estimated learning rates based on a study by McDonald and Schrattenholzer[34].

Figure 6-3 - Observed learning rates for wind power



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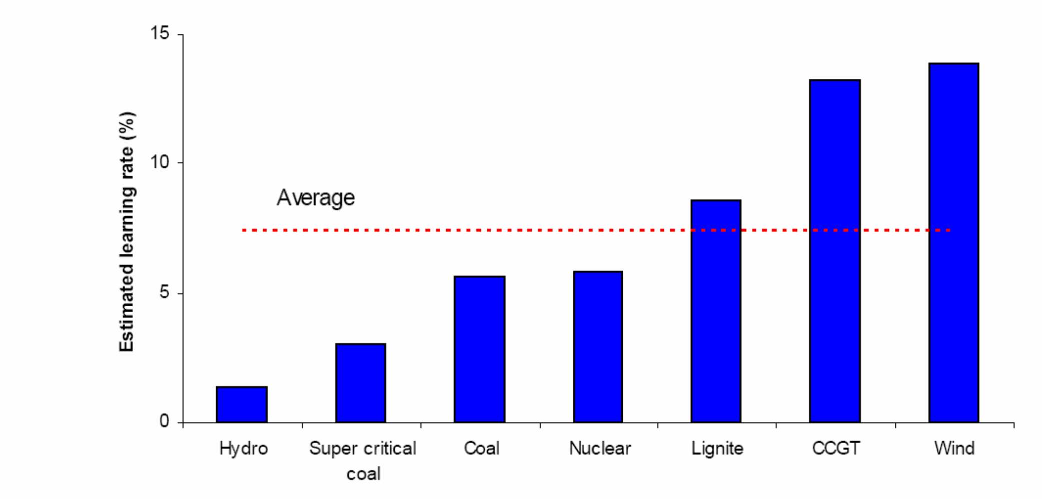
[34] McDonald and Schrattenholzer (2001): "Learning rates for energy technologies". Energy Policy Vol. 29, Elsevier, 2001.

Figure 6-4 - Observed learning rates for different generation technologies



It can be seen that different studies come up with different learning rates even for the same technology as seen in Figure 6-3. This is country-dependent, as there might be country specific learnings, such as skilled people for installation, and the time horizon as learning rates are expected to decrease over time. Finally, they may measure different improvements, e.g. improvement in capital costs vs. improvements in the long-run marginal costs of a particular technology.

For this study, the main reference has been "Energy Technology Perspectives 2008", a recent report from the International Energy Agency[35]. A summary of some expected future learning rates and the initial costs (as of 2008) is shown in Table 6-2.

Table 6-2 - Learning rates assessed by IEA

	Investment cost US$/kW	Learning rate %
IGCC	1800	3%
Biomass IGCC	2500	5%
CCS*	750	3%
Onshore wind	1200	7%
Offshore wind	2600	9%
Solar PV	5500	18%
Concentrated solar	4500	10%

* This is for the CCS part of a power plant only

Applying these learning rates to the various technologies, using other cost information from the report as a guideline, the following capital cost trends have been derived. These are used in the GEM model as a base.

They can be varied between scenarios, i.e. one could have a lower improvement for wind and higher for IGCC, which will lead to a different technology mix. Learning rates are assumed to reduce over time in all cases. As the doubling of the worldwide installed capacity is faster for new technologies like solar PV and marine energy, the cost drops more quickly for those.

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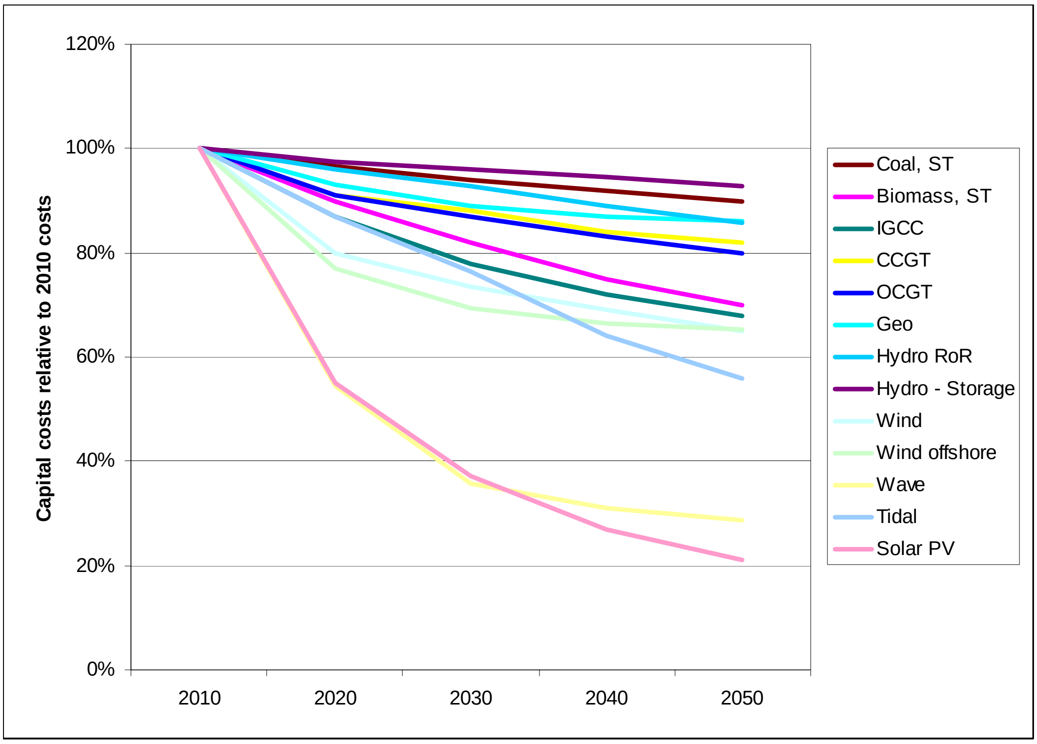
[35] IEA(2008): "Energy Technology Perspectives 2008 – Scenarios and strategies to 2050". International Energy Agency, Paris, France, 2008.

Figure 6-5 - The capital cost adjustment used in this study to represent technological improvements



6.2 Thermal fuel prices

Thermal fuel prices were among the top critical uncertainties that were identified in Transpower's scenario workshop as seen in Section 2.3.

6.2.1 Coal prices

The coal prices are assumed to be stable over the long term with the recent international price variation being mostly due to constraints in the shipping market and shorter term imbalances between supply and demand, e.g. driven by China and India shifting from being net exporters to being net importers of coal.

Compared with oil and, to some extent natural gas, coal is available from more sources and these sources are less affected by geopolitical instability. Hence, over the longer term, as supply catches up with demand, coal prices should be settled at a competitive level with minor price premiums for bottlenecks or fear of supply disruptions.

New Zealand has large coal reserves in the lower South Island (mostly lignite), the West Coast (bituminous) and around Waikato/Taranaki (mostly sub-bituminous).

Based on the EDAC (Energy Data and Analysis Coordination group) recommendations[36], black coal prices are assumed to be $3.50/GJ delivered at port in 2010 rising to $4.00/GJ by 2015. An additional $0.40/GJ should be added for transport cost for coal delivered to Huntly.

These prices correspond well with those shown in 2006 report[37] from Parsons Brinckerhoff Associates (PBA). It indicated coal delivered to the Huntly power station

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[36] EDAC (2008): “Recommended Modelling Principles and Assumptions”. Energy Data and Analysis Coordination group, as available Oct. 2008: http://www.med.govt.nz/upload/48668/EDAC-MPA.pdf

[37] PBA (2006): “Electricity Generation Database – Statement of Opportunities update 2006”. Parsons Brinckerhoff Associates, October 2006.

from the local mines (Huntly East and Rotowaro) was priced in the lower end of the interval $3.85/GJ to $5.16/GJ.

PBA stated West Coast coal delivered to a North Island port would cost between 3.10/GJ and $4.50/GJ, which again is consistent with the EDAC cost assumption for coal delivered at port.

Lignite prices are assumed to be $2.00/GJ for the entire horizon. This is based on the PBA report, which stated an interval of $0.90/GJ – $2.30/GJ. They expected the future price to be in the higher end of the interval. NZ Energy Outlook to 2030 cited Solid Energy for having 40,000 PJ of lignite available at a cost of less than $2.00/GJ.

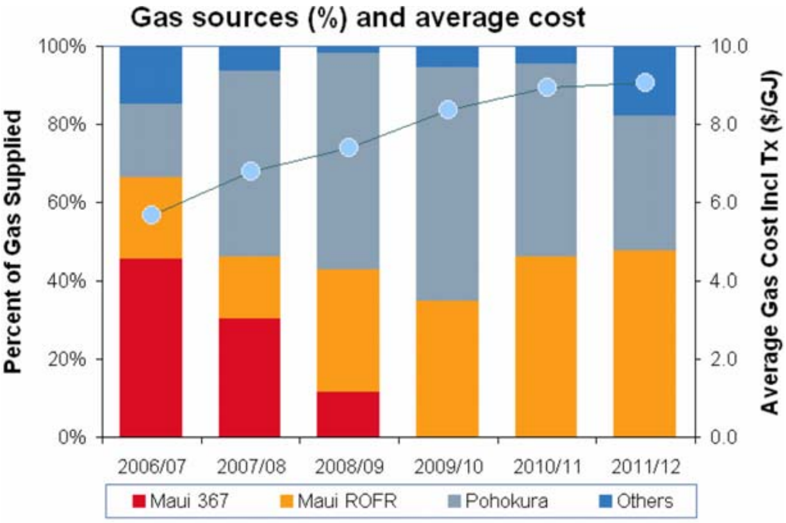
6.2.2 Oil and gas prices

The future prices of oil and gas considered to be highly uncertain.

Firstly, the last 4 years has seen oil prices track more significantly away from their long-term average as the fundamentals have changed. Prices are assumed to remain volatile until a new long term equilibrium has been found, but the level of this is highly uncertain.

Secondly, gas prices in New Zealand have risen as the old Maui gas contracts started to ran out and there are doubts whether enough new discoveries can be made to sustain the current demand beyond 2015-2020. This is illustrated in the figure below, which shows Contract Energy's average cost of gas deliveries forward to 2012.

Figure 6-6 - Gas sources and costs for Contact Energy[38]



Gas prices are significantly more important than oil price for the New Zealand power system, as the only use of oil is at the dry year reserve/peaking power station at Whirinaki. Also in the future, oil is only expected to be used for such type of plants, although the need for them for firming may increase if the system becomes more and more dominated by intermittent (wind/solar/marine) or baseload (geothermal) generation.

However, the gas price is likely to be linked to the oil price as the New Zealand gas price is expected to tend towards the international LNG price and this has traditionally been indexed to oil prices as discussed later. Figure 6-7 shows the expected linkage between the New Zealand gas price and the LNG price.

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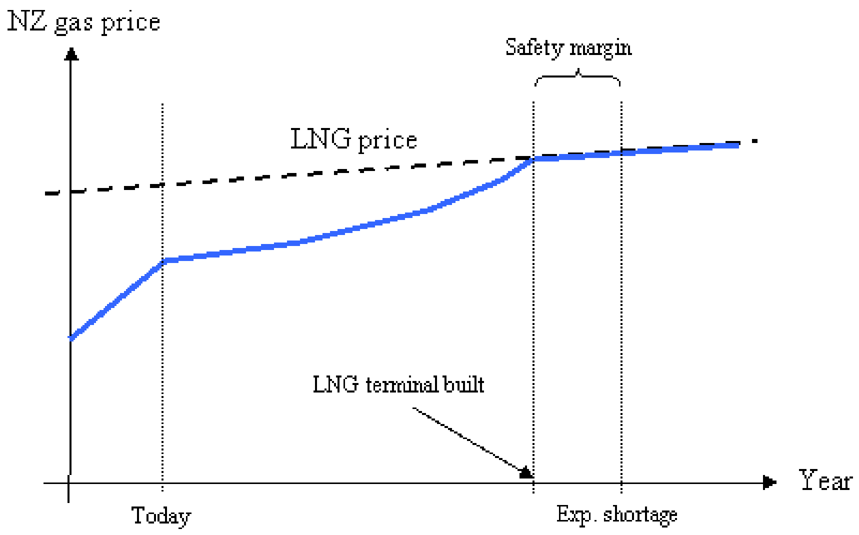
[38] Contact Energy (2008): "Annual Financial Results - Financial year ended 30 June 2008", presentation given 26 August 2008.

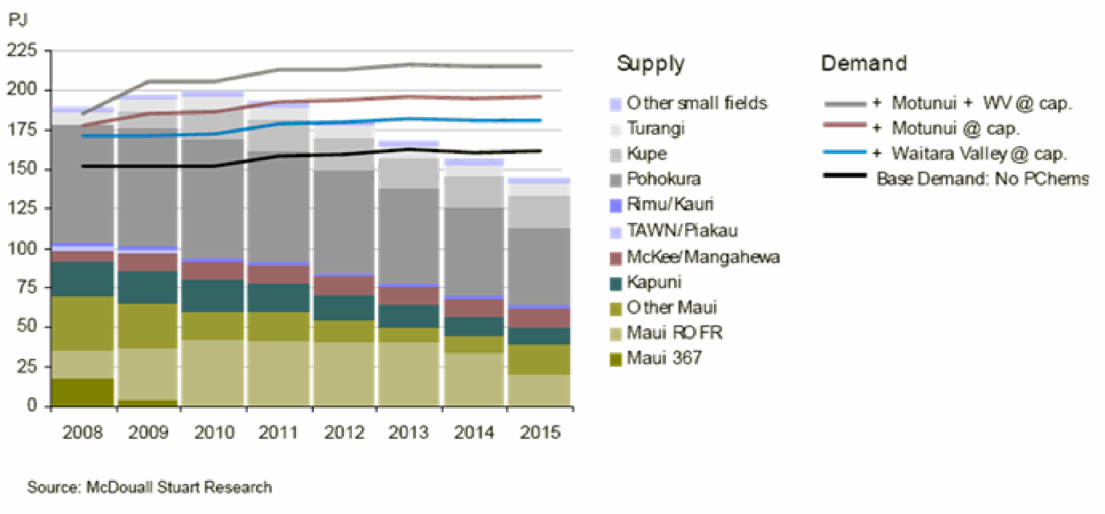
Figure 6-7 - NZ gas prices and link with time of shortage and LNG price



Gas prices

As seen in Figure 6-7 the New Zealand gas price is expected to depend on the LNG price and when demand will outstrip local supply. The latter will result in shortage of gas unless LNG import facilities are built. Figure below show the supply/demand balance for New Zealand as presented at by McDouall Stuart[39].

Figure 6-8 - Supply and demand balance for New Zealand gas



Source: McDouall Stuart Research

If and when a shortfall may occur is impossible to predict, as it is heavily dependant on demand and new discoveries. The figure above shows the current supply and demand balance for different assumptions around the consumption at the Methanex plants at Motunui and Waitara Valley. It can be seen that current supply is just enough to let both plants run at full capacity until around 2010. As the price of Methanol, the product produced by Methanex, has followed the price of oil, Methanex has been a willing buyer at the current prices. This leaves little gas that can be banked for later use should Methanex return to full production.

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[39] From the presentation “NZ Energy Sector Report 2008” given at the NZ Petroleum Conference 2008.

Figure 6-9 - Supply and demand balance extended adding 60 PJ new gas from 2012

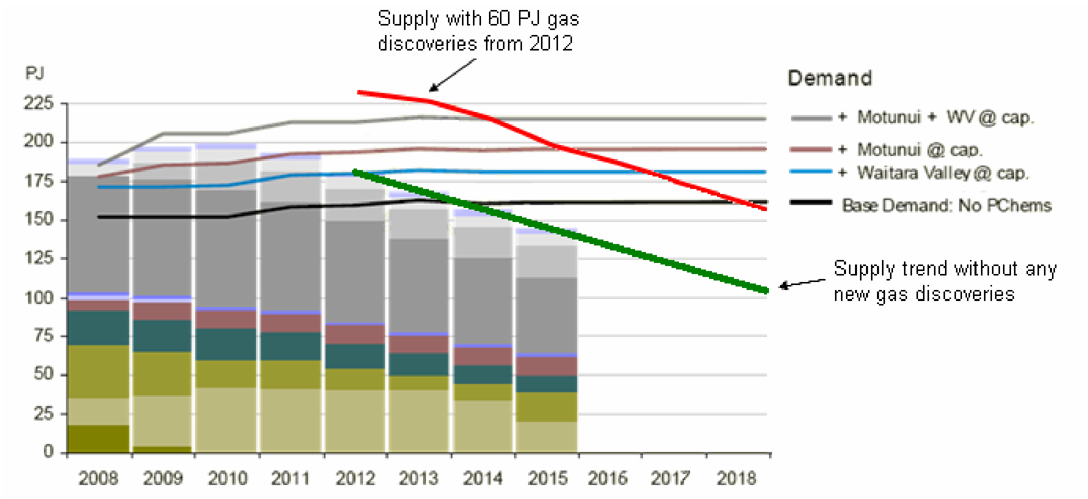


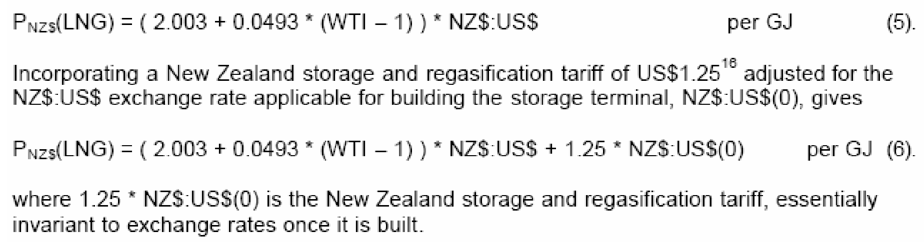
Figure 6-9 extends the trends of the supply and demand and adds new gas discoveries. As an assumption, 60 PJ of new gas is assumed to become available from 2012 consistent with the suggestion from EDAC[40]. This corresponds to the annual average volume discovered excluding Maui.

As seen, even with new discoveries in line with the historical average rate of discovery, shortage could occur as early as 2014 with Methanex running at full capacity or 2018 without Methanex running.

Large gas users, such as Genesis and Contact Energy, may therefore perceive the optimal time to build an LNG re-gasification terminal is sooner rather than later. Also, it should indicate a rather rapid increase in the price towards the LNG price, a movement that was observed in Figure 6-6. As comparison, MED's Energy Data File shows that industrial consumers paid between $3/GJ and $5/GJ in the period 2000-2004. The price increase is therefore as expected based on the conceptual model illustrated in Figure 6-7.

The international LNG price is as previously mentioned linked to the price of oil.

For the NZ Energy Outlook to 2030, MED analysed the link between LNG prices and oil prices[41]. The resulting paper presented a formula for LNG pricing suitable for New Zealand:



$$P_{NZ\$}(LNG) = (2.003 + 0.0493 * (WTI - 1)) * NZ\$:US\$ \qquad \text{per GJ} \qquad (5).$$

Incorporating a New Zealand storage and regasification tariff of US$1.25[18] adjusted for the NZ$:US$ exchange rate applicable for building the storage terminal, NZ$:US$(0), gives

$$P_{NZ\$}(LNG) = (2.003 + 0.0493 * (WTI - 1)) * NZ\$:US\$ + 1.25 * NZ\$:US\$(0) \qquad \text{per GJ} \quad (6).$$

where 1.25 * NZ$:US$(0) is the New Zealand storage and regasification tariff, essentially invariant to exchange rates once it is built.

It can be seen that the import price of LNG, PNZ$(LNG), is a function of the crude oil price (WTI used as index) and the exchange rate between NZ$ and US$.

Assuming an exchange rate of 0.6 US$ to NZ$, which is about the historical average, the LNG price would then be as given in the table below.

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[40] EDAC (2008): "Recommended Modelling Principles and Assumptions". Energy Data and Analysis Coordination group, as available Oct. 2008: http://www.med.govt.nz/upload/48668/EDAC-MPA.pdf

[41] Gary Eng (2006): "A Formula for LNG Pricing". Study done for the Ministry of Economic Development (MED)

Table 6-3 - LNG prices given different oil price assumptions

Oil price	LNG price delivered		LNG price + storage/regasification	
US$/bbl	*US$/GJ*	*NZ$/GJ*	*US$/GJ*	*NZ$/GJ*
30	3.43	5.72	4.68	7.80
40	3.93	6.54	5.18	8.63
50	4.42	7.36	5.67	9.45
60	4.91	8.19	6.16	10.27
70	5.40	9.01	6.65	11.09
80	5.90	9.83	7.15	11.91
90	6.39	10.65	7.64	12.73
100	6.88	11.47	8.13	13.56
110	7.38	12.29	8.63	14.38
120	7.87	13.12	9.12	15.20
130	8.36	13.94	9.61	16.02
140	8.86	14.76	10.11	16.84
150	9.35	15.58	10.60	17.66

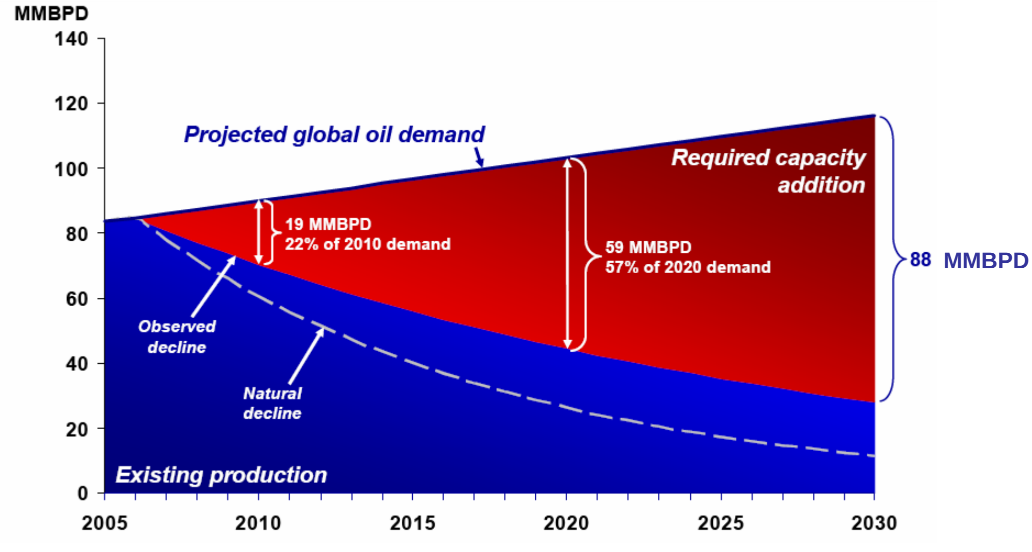
As seen, this would result in a LNG price of around $12/GJ for oil prices around US$80/bbl. This is the base oil price assumed as agued below.

Oil prices

Oil prices have increased rapidly since 2004 peaking mid 2008 at around US$147/bbl compared to the previous price band of $20-$40/bbl, which the price followed during the 1980s and 1990's.

The increase has been attributed to supply disruptions (e.g. Iraq and Nigeria) and a sharp increase in demand from countries like China, India, Russia, Brazil and many countries in Middle East. To this comes the fact that many developing countries subsidies petrol to keep consumers unaffected. The price increase has therefore not changed consumption behaviour in those countries as opposed to the OECD countries where demand has dropped as a result of the recent increase in price.

Figure 6-10 - Projected oil demand[42]



Source: Based on IEA World Energy Outlook 2007
Natural decline forecast at 8% rate
Observed decline forecast at 4.5% rate requires substantial investment

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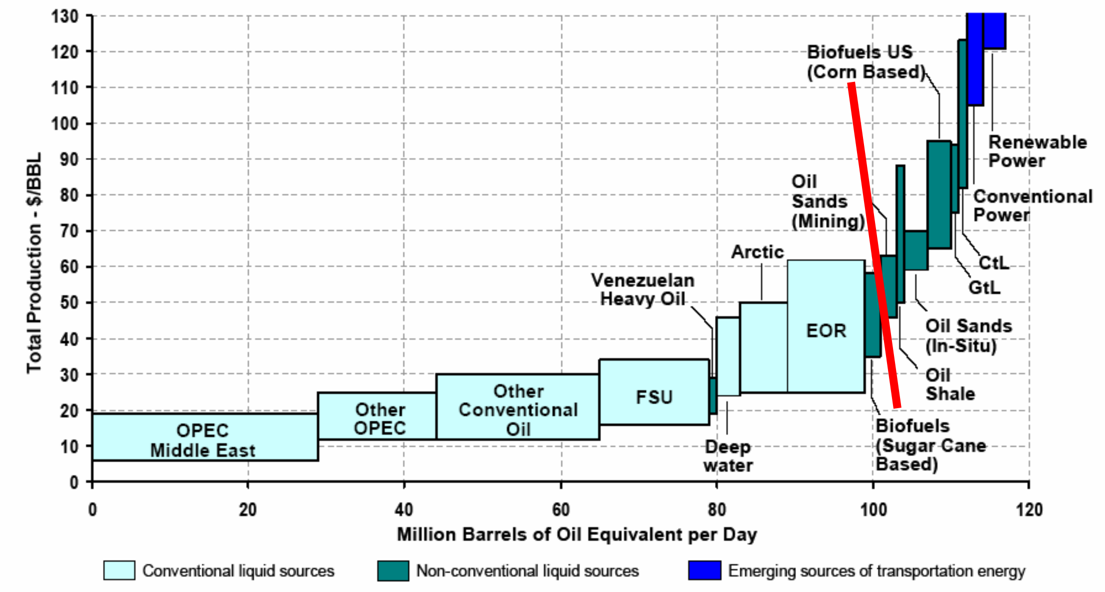
[42] From a presentation by ConocoPhillips "Key Questions on Energy & Environmental Challenges" at the International Energy Workshop, Paris, France, 2008.

Figure 6-10 illustrates how quickly the demand for extra capacity (the red area) is expected to increase taking into account production from existing oil fields are declining with around 4.5% a year (blue area).

The combination of these two aspects: strong demand and declining production from existing assets, results in a significant need for new sources, for instance 22% of the 2010 demand will have to come from sources that were commissioned from 2007 or onwards. This requires significant investments beyond those already committed to increase the recovery from existing fields (the difference between the shown natural decline rate and observed decline rate).

As seen in Figure 6-11, an oil demand of slightly more than 100 MMBPD (million barrels per day) is forecasted for 2020. A supply curve for oil for that year has been estimated by Booz & Company[43] and is shown as Figure 6-11.

Figure 6-11 - Estimated supply curve for oil for 2020



The red line is the demand estimated from Figure 6-10. The demand curve is assumed to be rather inelastic as the supply curve already includes most substitutes, such as biofuels, coal-to-liquid (CtL) and gas-to-liquid (GtL) technologies.

This gives an equilibrium price in the US$50-$60/bbl range. This corresponds well with the forecasts shown in the Annual Energy Outlook 2008[44].

Table 6-4 - Oil price estimates as listed in Annual Energy Outlook 2008

Projection	2010	2015	2020	2025	2030
AEO 2007 (reference case)	59.21	51.37	53.61	58.07	60.91
AEO 2008 (reference case)	74.03	59.85	59.70	64.49	70.45
GII	68.25	61.40	54.80	48.20	45.70
IEA 2007 (reference)	59.03	57.30	58.87	60.43	62.00
DB	56.65	60.00	66.00	72.00	80.00
SEER	69.41	58.85	60.83	62.88	65.00

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[43] Adapted from the presentation by ConocoPhillips listed above.

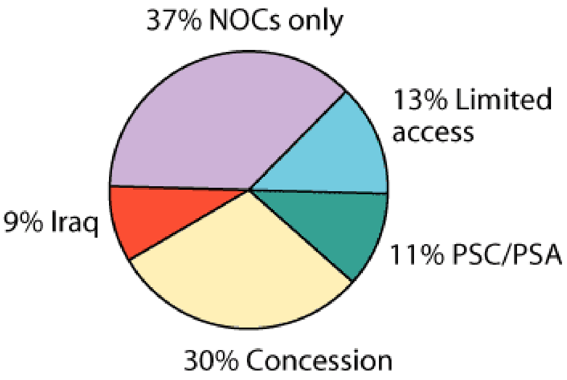
[44] EIA (2008): "Annual Energy Outlook 2008". Energy Information Administration, U.S. Department of Energy, 2008.

As seen, most of the projects, including the new Annual Energy Outlook (AEO) forecast, is within the US$50-$60/bbl band for 2020.

However, there are reasons to believe that the oil price may well be higher than that. Firstly, there is the issue of “receding horizons”; inflation caused by the increase in fuel prices may make the cost of certain alternatives more costly than assumed today. Increased energy costs significantly affect the costs of energy intensive processes such as the making of steel and cement. This adds again to the cost of energy and the longer term labour as well. In total, oil (especially oil extraction from oil sands, which requires a lot of energy), will become more expensive.

The second issue that may put an upwards pressure on oil prices is the future role of the International Oil Companies (IOC). These are the public listed companies operating around the world as opposed to the National Oil Companies (NOC), which will be fully or majority owned by a national government. In many countries, the local NOCs will be favoured for new concessions and some places foreign companies cannot get concession at all. This is illustrated in Figure 6-12. Only for 30% of the potential new resources have the free access to concession, while 37% are limited to NOCs only. Apart from Iraq, the remaining are limited access or production sharing agreements with NOCs.

Figure 6-12 - Access to oil exploration[45]



According to IEA’s World Energy Outlook 2007, the IOCs produce around 50% of today’s oil but they only have control of approximately 25% of the current reserves[46]. They will therefore have to replace their reserves more quickly than most NOCs to maintain their market share. However, as discussed, they often have restricted access to potential resources, including many of the lower cost options from the supply curve.

As a result, the IOCs may have to pursue more costly projects to maintain volume, the projects in the high end of the supply curve including exploring extreme deep water oil fields and producing oil from oil shale and oil sand as well as biofuels. As oil price is based on the marginal cost of production, the cost increases. Figure 6-13 shows Goldman Sachs’ estimate of the marginal cost of replacing reserves. This is backing up the arguments above.

For this study, Transpower proposes to use $80/bbl as the base price. Low and high estimates US$50 and US$150/bbl will be used. These represent the two cases where on one side technological improvements lower the costs of unconventional oil production thus lowering the price of oil while on the other side supply cannot keep up with demand causing inflation that increase costs even more.

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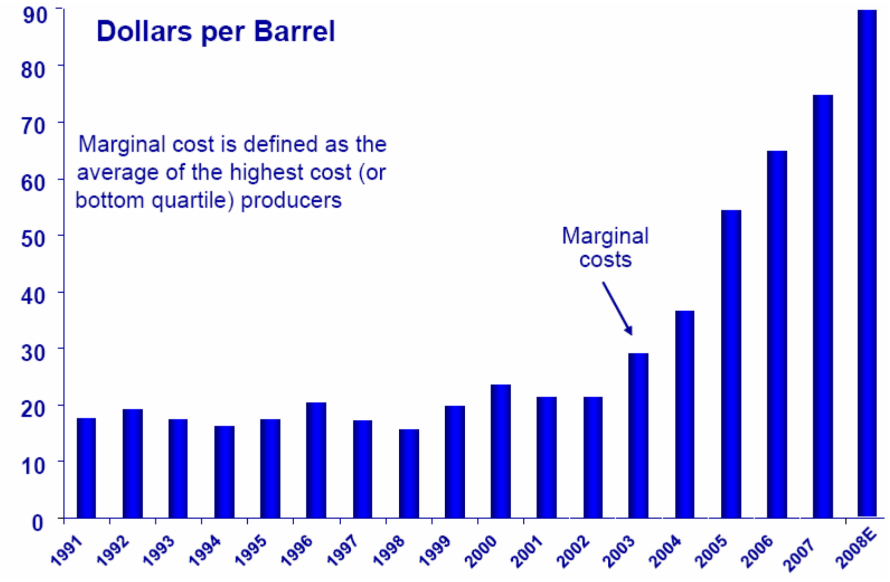
[45] World Oil Magazine (2008): “The power of the NOCs”. World Oil Magazine, Vol. 229, No. 5, May 2008.

[46] IEA (2007): “World Energy Outlook 2007”. International Energy Agency, Paris, France, 2007.

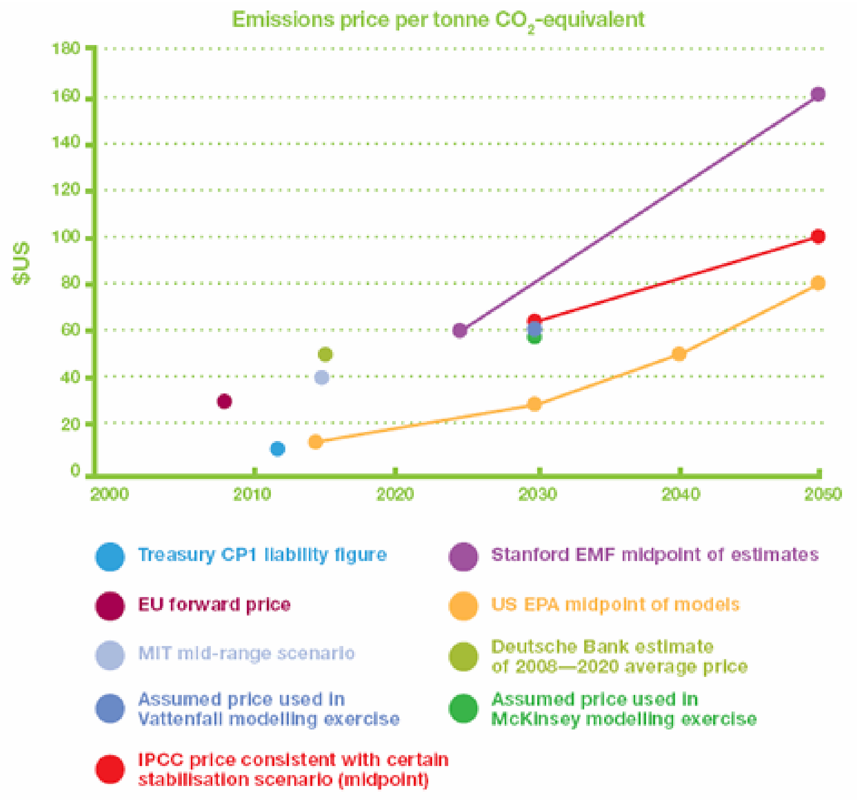
Figure 6-13 - Marginal cost of replacing reserves by Goldman Sachs Commodities Research[47]



6.3 Carbon costs

There have been multiple studies undertaking regarding the future cost of carbon emissions. The figure below, taken from the New Zealand Energy Strategy, summarises the results of some of them.

Figure 6-14 - Carbon cost estimates as shown in the New Zealand Energy Strategy to 2050



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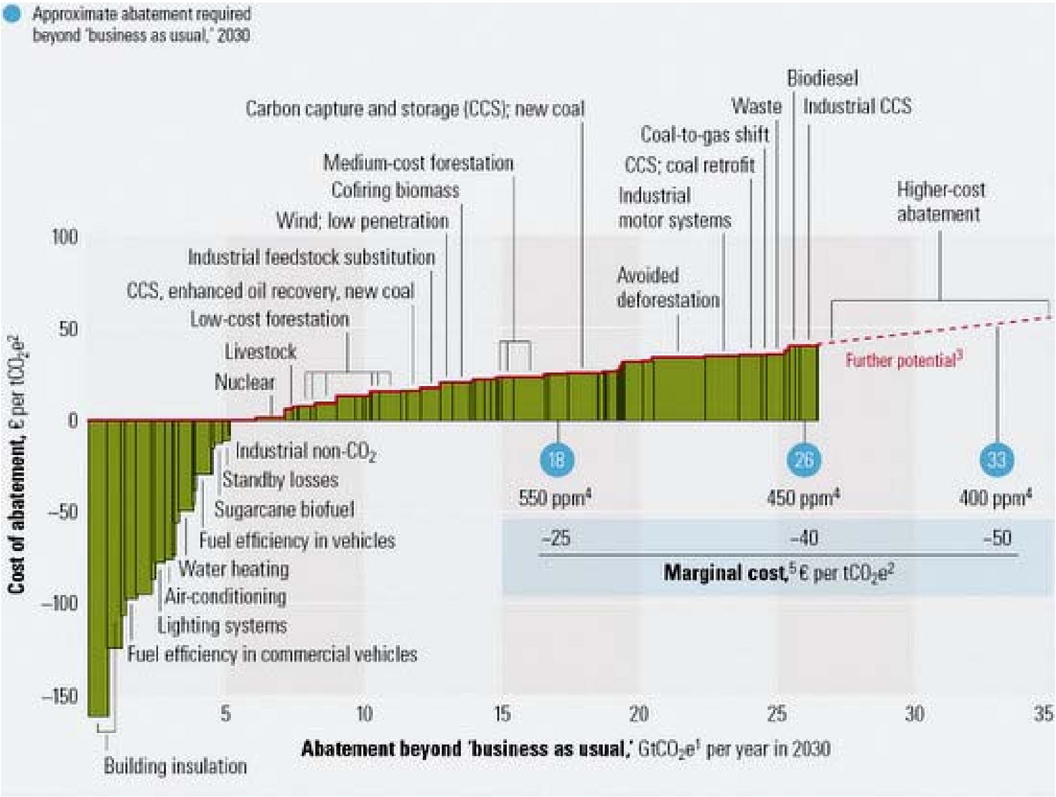
[47] From a presentation by ConocoPhillips “Key Questions on Energy & Environmental Challenges” at the International Energy Workshop, Paris, France, 2008.

As illustrated, there is a high degree of uncertainty around the future cost of carbon emissions as both future cost of supply (the supply curve) and the demand for reductions (the demand curve) are unknown.

There has been a lot of work carried out in projecting the supply curve and Figure 6-15 shows the results of one such study[48]. This comes from the McKinsey study, shown with green in the figure above[49].

Figure 6-15 - Global cost curve for greenhouse gas abatement measures in 2030 beyond "business as usual"



It should be noted that many technologies that could assist in reducing carbon emissions, such as Carbon Capture and Storage (CCS), are still in their infancy, so current cost estimates are based on expected technological improvements. There are few data points available yet to establish a learning curve as discussed in Section 6.1.2. Hence, the costs for some options in the supply curve are pure estimates. Similarly, the actual potential for many technologies are highly uncertain, e.g. the example of avoided deforestation.

The demand curve is also uncertain. There appears to be a tendency towards agreeing that a 2°C increase in temperature is a maximum limit of what is desirable and that this is only achievable if the concentration of CO_2 in the atmosphere is stabilized at 450 ppm (parts per million). This will require a big effort to achieve and the uncertainty in the demand for carbon reductions is related to what the international community can agree on committing to.

If all major countries eventually agree on the 450 ppm target and implement policies to get there, the carbon cost is expected to be rather high. The resulting price is found where the demand curve intersects the supply curve. The figure above shows €40/tonne CO_2e as the cost estimate for the 450 ppm reduction scenario. This

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[48] Enkvist *et al.* (200*7):"A cost curve for greenhouse gas reduction" .The McKinsey Quarterly 2007 number 1,* McKinsey & Company, 2007.

[49] Note that Vattenfall modelling exercise from the figure was also based on the McKinsey study

equates to around NZ$80/ton, which has been selected as the high estimate in this analysis.

For a medium scenario, a less ambitious target above the 550 ppm stabilisation scenario has been chosen. This is assumed to result in a carbon cost of NZ$40/ton Scenarios with lack of international agreement can see either very high costs in countries trying to do something by themselves or low to zero costs if the country does not implement any carbon reduction policy.

6.4 Investment incentives

This section is yet to come. It will cover generation investment signals of various kinds, both the current and potential future signals.

6.5 Scenario selections

The table below show the parameter variations assumed for the four scenarios. They are based on the findings presented above and adjusted for consistency with the scenario storylines presented in Section 3.2.

Table 6-5 - Scenario assumptions for the supply side drivers

Scenario	**Supply side drivers**				
	Crude oil price ***US$/bbl***	**NZ gas price** ***NZ$/GJ***	**Carbon price** ***NZ$/tonne***	**Exchange rate** ***US$:NZ$***	**Tech. change**
1 - New Norway	150	13.5	80	0.8	Wind - Wave -
2 - Crisis recalled	60	10	~0	0.6	Wind + Tidal -
3 - Fragmented world	80	12	40	0.6	CCS – Hydro -
4 – Green communities	80	14	80	0.6	Hydro + Wave +

Although the oil price is very high in the first scenario, the gas price in New Zealand is less affected as the assumed exchange rate is higher than assumed for the other scenarios. The oil and gas export is the driver behind this assumption.

In Scenario 4, the gas price is higher than Table 6-3 merits due to an assumption that imports of gas are not possible and few new local gas discoveries are made.

The capital cost estimates have been slightly adjusted for each scenario as indicated in the last column. For example, in Scenario 1 the wave and wind energy projects are less expensive while hydro power and wave power projects are more expensive in Scenario 4.

Further to this, Scenario 1 has assumed reduced capital costs in general due to the higher exchange rate.

Questions:

6.1 Is the use of learning curves for capital costs appropriate?

6.2 Are the fuel price assumptions reasonable?

6.3 Are the carbon price assumptions reasonable?

6.4 Do the scenario specific assumptions fit the overall story lines?

7 Distributed generation

Distributed generation, sometimes referred to as embedded generation, fits somewhere between the demand and supply sides. In terms of technical characteristics, the technologies employed are similar to the traditional generation technologies presented in the previous chapter, just the size tends to differ. However, distributed generation is per the normal definition connected at distribution level rather than transmission level. From a transmission perspective, it is the observed demand at the Grid Exit Points (GXP's) that is relevant, and from this perspective distributed generation can be considered as a demand side option.

7.1 Definitions

Distributed generation has been split into two broad groups for the purpose of this work. One group is micro-generation, generation that operates behind the meter at a specific consumer. This generation is not exported to the grid and offered on the wholesale market: rather, it competes with the retail price acting as a substitute for grid delivered electricity. To the extent that the local generation exceeds demand, the generation will typically be sold back to the retailer. The price the owner receives will, at least today, differ from place to place and varies typically between the retail price (minus network costs) and the wholesale price.

In the future, harmonisation of the rules is likely and some scenarios might see a government funded feed-in tariff for surplus generation to encourage development of distributed generation.

The second group is mini-generation. This includes larger units, typically sized from 100 kW to 50 MW, which are connected to the distribution network. Currently, these units compete at the wholesale level. In the future, such units may get a fixed feed-in tariff or maybe be part of a renewable portfolio scheme or green certificate market to make them competitive with fossil and/or large-scale renewable generation.

7.2 Distributed generation types

The following types of distributed generation have been defined:

- micro-cogeneration;
- solar photovoltaic panels;
- micro-hydro power;
- mini-hydro power; and
- mini-wind power.

A more fully description is yet to come.

7.3 Scenario assumptions

In the four scenarios, at least the current amount of distributed generation (in GWh) is assumed to remain in all scenarios. Scenarios 1 and 3 assume the amount of energy delivered by distributed generation increases beyond this equal to a total of 2.5% of the demand in 2050. For instance, by 2050 Scenario 1 has around 2,000 GWh (estimated as the current level of distributed generation) plus 2.5% of 90,000 GWh, i.e. another 2,250 GWh, for a total 4,250 GWh. The generation output in Scenario 3 will be less as the demand grows at a slower rate.

Scenarios 2 and 4 have higher targets for distributed generation. Scenario 2 has a target of 5% in 2050 while Scenario 4 has a target of 10% by 2050.

The GEM model builds an amount of distributed generation that matches the target set for each scenario. The mix is based on fuel and carbon costs (micro-cogeneration) and investment costs, which will change over time given the learning curves as presented in the previous chapter.

Capital cost for solar photovoltaics and micro-cogeneration have been roughly halved to account for these types of generation competing against the retail price rather than the wholesale price.

Questions:

7.1 Have any important distributed generation source been left out?

7.2 Are the given shares of distributed generation assumed in the scenarios reasonable?

8 Load shaping

This chapter will describe the future role of technology which will influence the shape of the electricity load curve. Historically, the major impact has come from ripple controlled hot water heaters used for shifting load from peak to off-peak periods.

The chapter is yet to be compiled but will include a discussion of both technology such as smart meters, electricity storages (e.g. from electric vehicles) and grid-friendly/frequency-responsive devices, and how those technologies could be used to change the load pattern, either in the wholesale or instantaneous reserves markets or as a potential transmission alternative.

Also, it will discuss how changes in consumption may lower the amount of controllable load. An example is conversion from electric hot water heaters, which are currently used for load shifting, to solar hot water heating or individual gas boilers.

Questions:

8.1 Have the most important technologies/trends for load shaping been mentioned in the brief overview above? If not, what other load shaping technologies or trends should Transpower consider?

9 The Scenarios by numbers

As discussed, the GEM model has been used to assess the generation built based on the adjusted demand forecast shown in Section 5.4, the supply side options and costs as discussed in Chapter 6 and the level of distributed generation listed in Chapter 7.

9.1 Scenario demand

Figure 9-1 and Figure 9-2 show the energy demand projections over time after the adjustment for fuel switching as discussed in Chapter 5, with and without the electric vehicle load.

Figure 9-1 - Total New Zealand energy demand without electric vehicle load

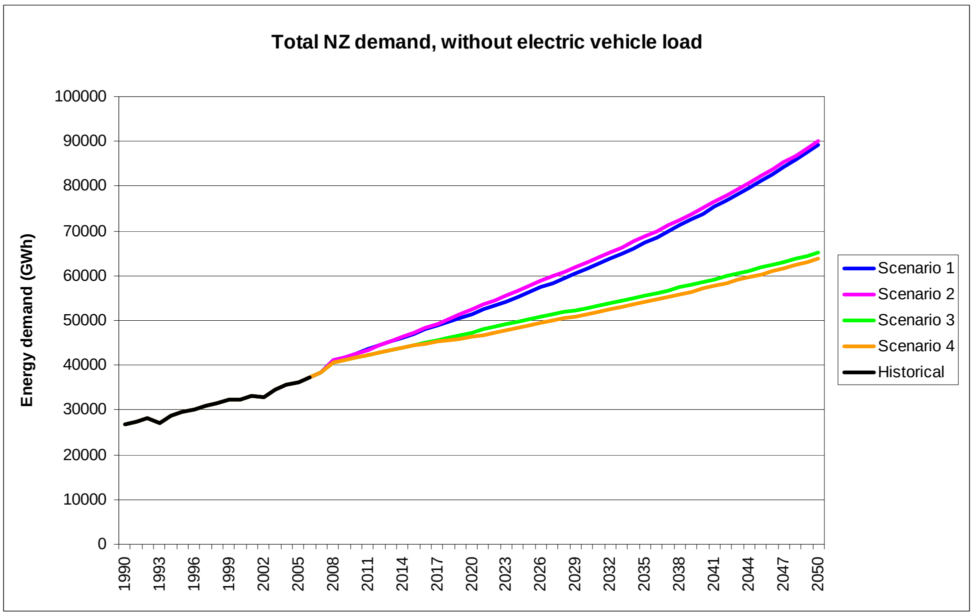
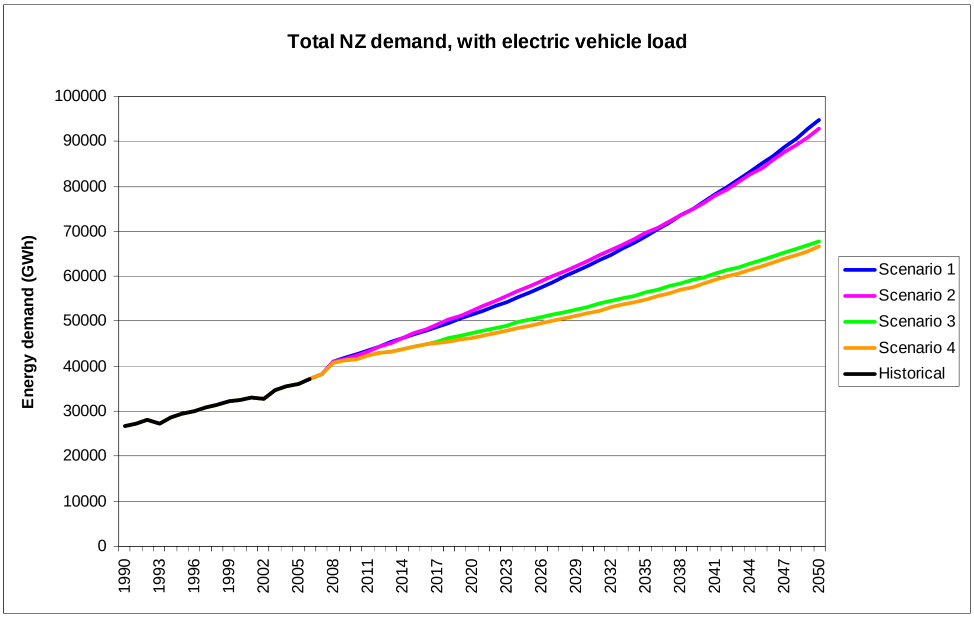


Figure 9-2 -Total New Zealand energy demand including electric vehicle load



It can be seen that demand is close to tripling for Scenarios 1 and 2 while the two low demand scenarios less than double the energy demand.

Figure 9-3 - Total New Zealand peak demand

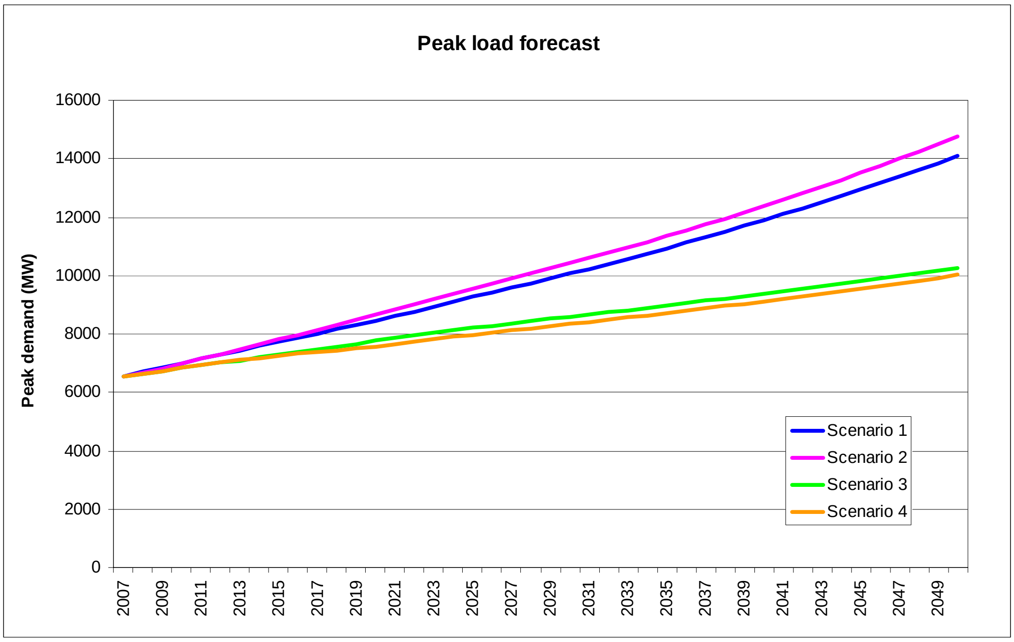


Figure 9-3 shows the peak load forecast, which is assumed to be unchanged by the additional load from the electric vehicles implying these are charged during off-peak hours. As seen, Scenarios 1 and 2 double the peak demand compared with the current level while scenarios 3 and 4 only adds another 50% to the peak load. This will lead to significant lower costs of generation, transmission and distribution compared with the two former scenarios.

9.2 Scenario generation

The figures show the generation capacity built in each scenario by technology type. It is shown both in installed capacity and as firm capacity, the latter being the capacity that is assumed being available at peak load conditions with “almost certainty”. For wind power, this amount is significantly less that the installed capacity. A peak contribution factor of 0.2 has been assumed. This is consistent with the assumptions made by the Electricity Commission for its 2008 Statement of Opportunities, which has been used as reference for the peak contribution factors in general. For solar photovoltaic power, which was not covered in the Statement of Opportunities, Transpower as assumed a peak contribution factor of 0.3. For reference, the used values have been listed below.

Technology	Peak contribution factor
Thermal (various)	0.95
Coal generation in dry-year mode	0.50
Co-generation	0.60
Geothermal	0.90
New hydro backed by storage	0.95
New run-of-river hydro	0.65
Wind	0.20
Marine	0.30
Solar	0.30

Peak load is a major driver in the GEM model. In general, it requires enough generation, adjusted with their peak contribution numbers, to be available to meet the peak while maintaining reserves to cover for the largest contingency event.

A special case is a small block of 9 hours each quarter of the year. Here, it is assumed that no wind is available, but that some reserves may be committed to meet the peak demand. Again, this is consistent with the treatment of wind power from the Electricity Commission's 2008 Statement of Opportunities.

Figure 9-4 - Total and firm capacity built in Scenario 1 – New Norway

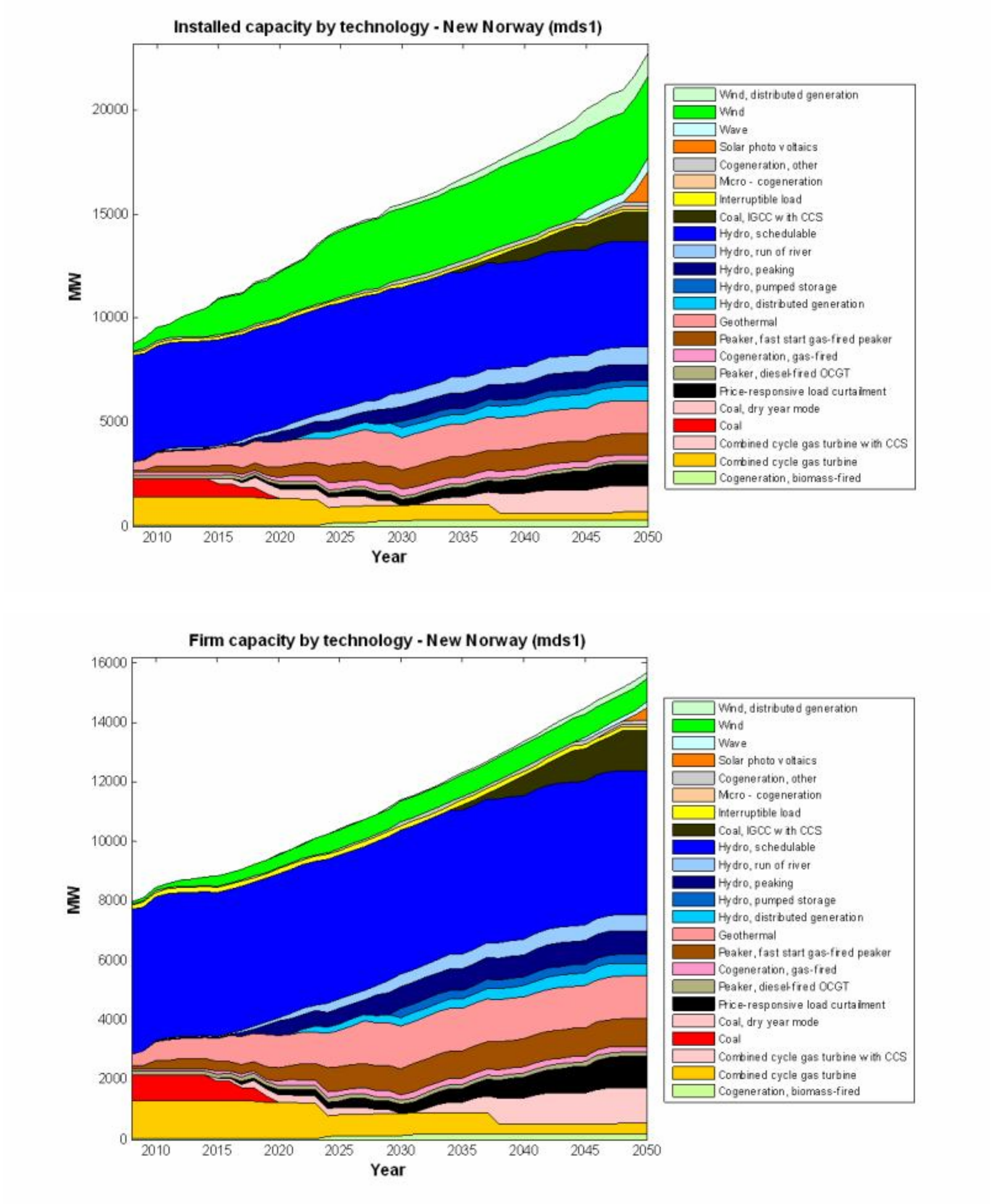


Figure 9-5 - Total and firm capacity built in Scenario 2 – Crisis recalled

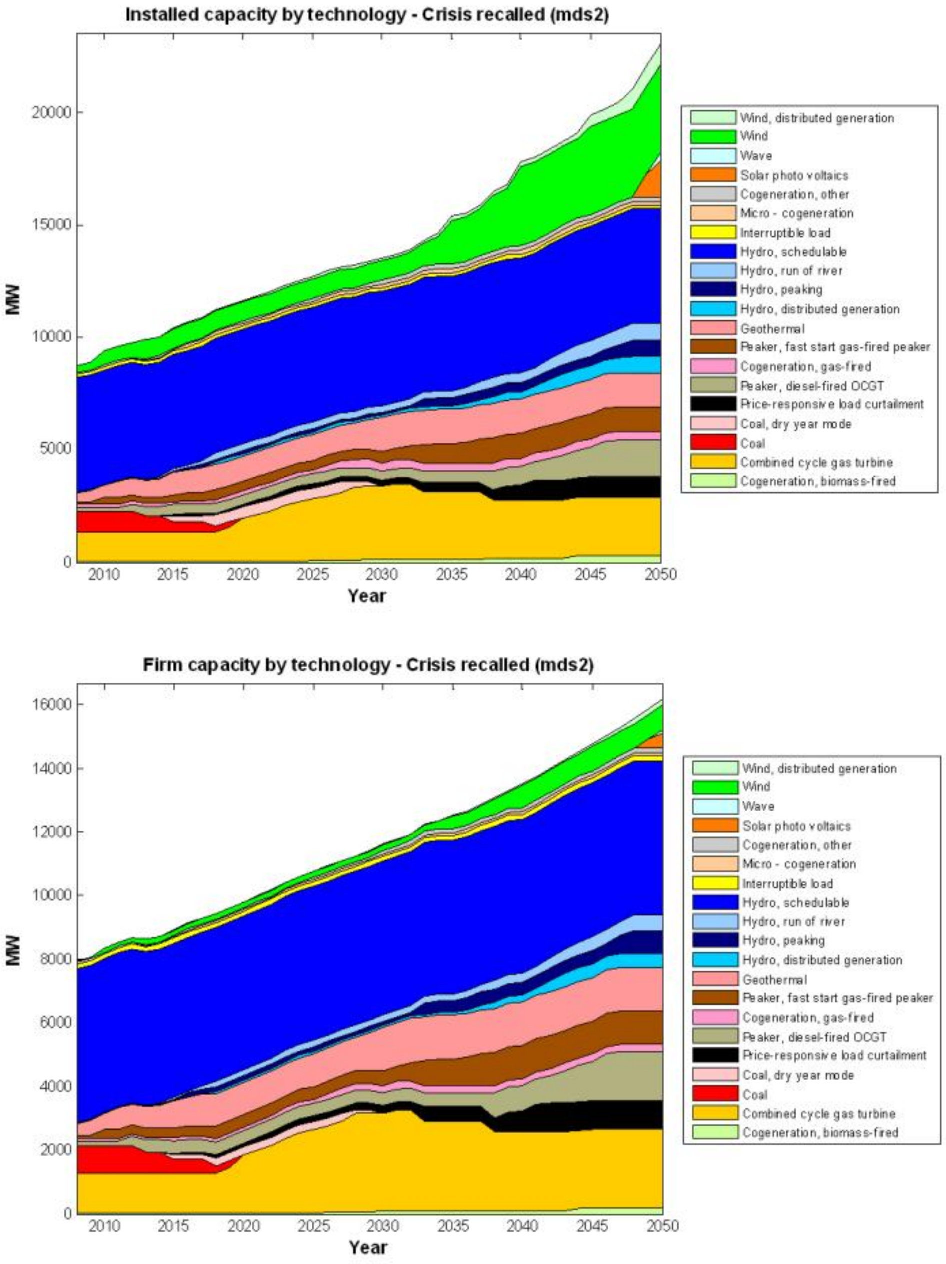
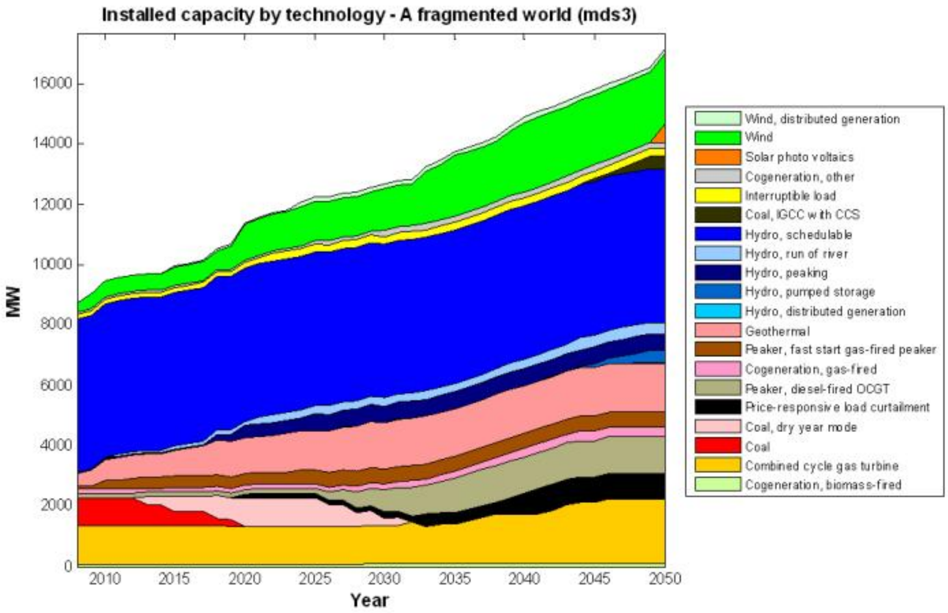


Figure 9-6 - Total and firm capacity built in Scenario 3 – Fragmented world



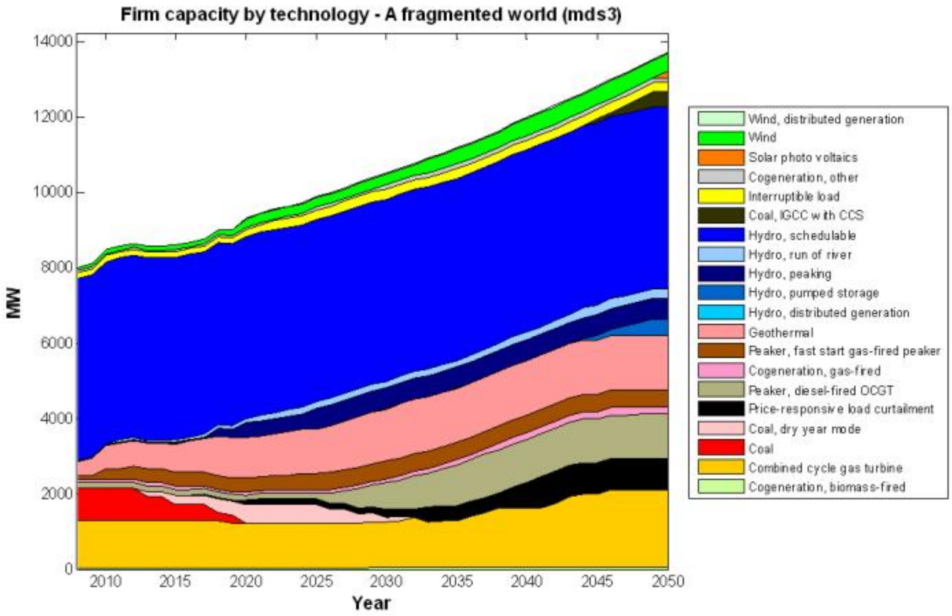
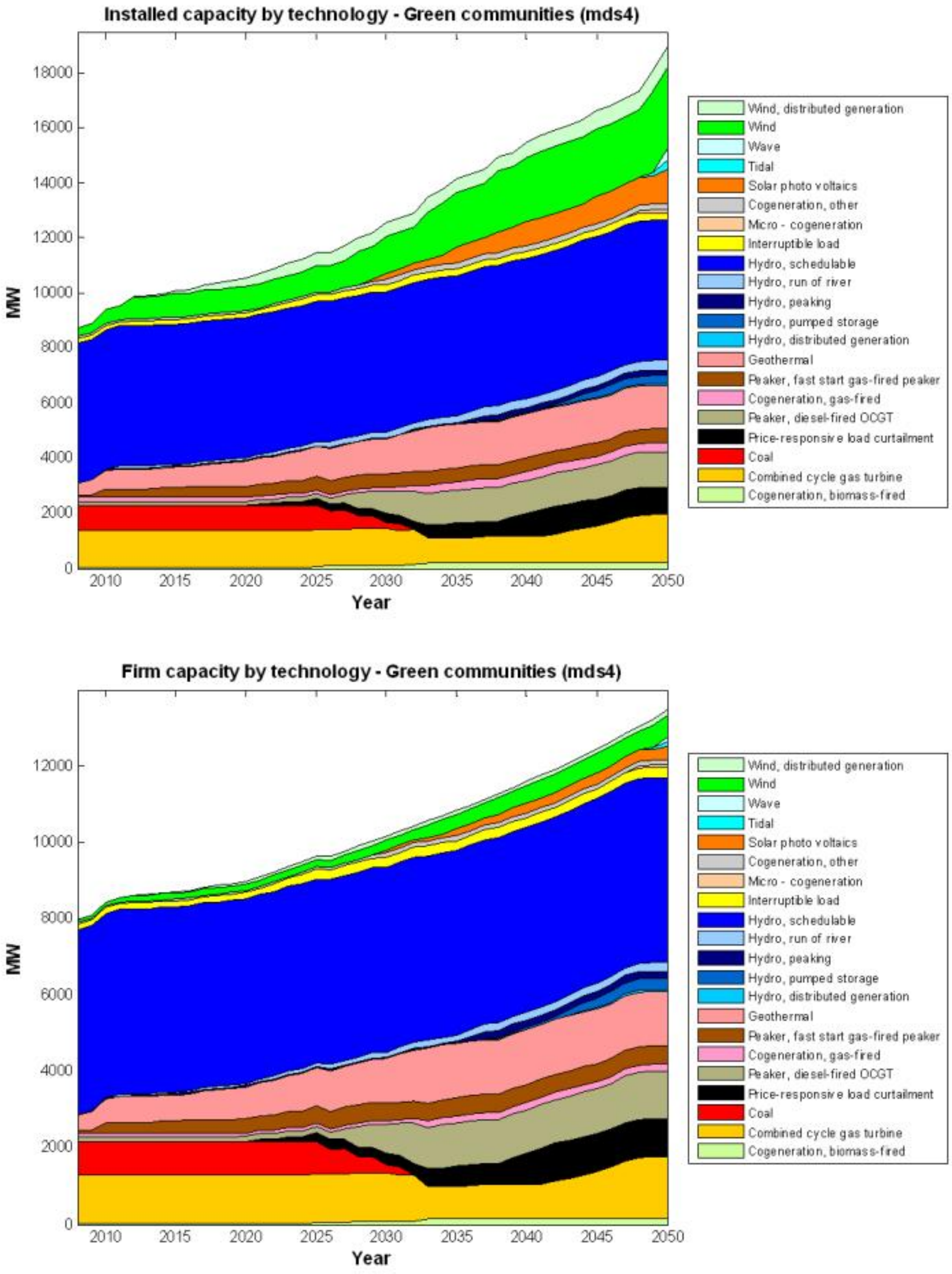


Figure 9-7 - Total and firm capacity built in Scenario 4 – Green communities



9.3 Commentary of results

The figures above illustrate how the scenarios look with the current assumptions and current modelling approach. These results are preliminary and not fully consistent with the scenario stories outlined earlier in the report. Thus, they are likely to change significantly and have mainly been included to illustrate the process of getting the results rather than the results themselves.

Questions:

9.1 Is the use of the peak contribution numbers for the capacity constraint in the GEM model appropriate?

9.2 In particular, is Transpower's assumption of a peak contribution factor of 0.3 for solar photovoltaic power reasonable?

9.3 Could it be expected that the demand for reliability as simulated by the capacity constraint in GEM will change over time, so more (or less) capacity will be required?

10 Summary of findings

This chapter is yet to be populated

Appendix A Overview of existing New Zealand scenario studies

Energy Options, Securing Supply in New Zealand

Author: New Zealand Business Council for Sustainable Development

Publication year: 2004

Scenario end year: 2021

Summary:

This report combines comprehensive economic analysis with advanced energy and electricity market analysis. It assesses scenarios for providing energy security and presents detailed projections to 2021. It has been prepared by Solid Energy, with support from the New Zealand Institute of Economic Research (NZIER) and Concept Consulting Group.

Drivers:

In the text, the following 3 drivers were mentioned:

- Availability and price of natural gas and coal
- Climate change policy
- Energy demand

Critical drivers/dimension(s) of choice:

The two dimensions: “Climate change policy” and “Energy demand’ listed above are combined to present four scenarios. Furthermore, security of supply is a main theme.

Resulting scenarios:

The above drivers are chosen as dimensions giving 4 scenarios in total. Energy demand is varied between NZIER projections in the low demand scenario (ending at around 1% growth) and a high demand scenario with 2.3% growth per annum. The high demand level is similar to the growth rates experienced by NZ over the last 10 years.

The climate change policies considered by the scenarios are a ‘Kyoto’ approach that assumes \$15/tonne of CO_2 and a ‘business-as-usual’ approach that assumes no emission taxes. The ‘Kyoto’ approach assumes carbon credits are available for renewable projects whereas the ‘business-as-usual’ approach assumes minimal credits for renewable projects.

Future currents: Electricity scenarios for New Zealand 2005-2050

Author: Parliamentary Commissioner for the Environment (PCE)

Publication year: 2005

Scenario end year: 2050

Summary:

Future currents sketches two scenarios of New Zealand in 2015, 2030 and 2050 depending on today's energy choices. These scenarios are presented through the eyes of two fictional characters.

Drivers:

The report described the following shaping factors:

Global factors:

- Rapid escalating demand for energy (China, India)
- Climate change
- Increasing energy costs
- Security of supply concerns (Middle East, Nigeria, Russia)
- New Technologies

New Zealand factors:

- Social value/identify
- Economic growth
- Political manoeuvring
- Institutional arrangements
- Education and research
- Population size

Critical drivers/dimension(s) of choice:

The scenarios vary according to:

- Climate change (unconstrained growth or not)
- New Technologies (traditional vs. smart, innovative solutions)

Resulting scenarios:

Fuelling the future, the first scenario, is strongly shaped by established ways of thinking. Building big power projects is seen as the key to a secure electricity supply.

The second scenario, *Sparking new designs*, sees huge potential in getting 'more from less' by re-thinking how we use electricity and other forms of energy. Businesses, communities and individuals are strongly encouraged to be innovative both in energy efficiency and in using more localised energy sources.

A Sustainable Energy Future for New Zealand by 2050

Author: New Zealand Business Council for Sustainable Development

Publication year: 2005

Scenario end year: 2050

A Sustainable Energy Future
for New Zealand by 2050
A BUSINESS VIEW

Summary:

The Sustainable Energy Futures – Outlook 2050 project is a business initiative using participants' combined resources to develop a better understanding of the sustainable energy options for New Zealand out to 2050. The project develops a number of scenarios which will provide future generations with comparable or greater options than we have today. Under each scenario potential solutions are suggested to help government, companies and New Zealanders make informed choices about what they want to happen.

Drivers:

Two main drivers were mentioned:

- Economic growth
- Energy demand

Critical drivers/dimension(s) of choice:

The two dimensions listed above are combined to present four scenarios. It is assumed that the linkages between the two can be broken.

Resulting scenarios:

Shielded: Security of energy supply is driver to the detriment of economic growth. Governmental intervention is required to sustain infrastructure investment and environmental restrictions are relaxed.

Conservation: Lower economic growth is accepted in order to achieve a more sustainable energy supply. Greenhouse gas emissions are highly priced and energy intensive industries decline.

Growth: The historical coupling between energy and growth is maintained. This scenario has a market focus and high energy demand.

*Transformatio*n: Energy demand and economic growth is decoupled. Energy prices are high and energy intensive industry decline. Growth is still achieved but through a service based economy. Energy growth no longer has a direct relationship to GDP.

New Zealand Energy Outlook to 2030

Author: Ministry of Economic Development

Publication year: 2006

Scenario end year: 2030

Summary:

Energy Outlook gives projections of energy supply, demand, prices, and greenhouse gas emissions. It aims to provide the background that policymakers, potential investors, stakeholders, and all New Zealanders need to understand the energy issues facing the country.

When a decision is made in the energy industry, it tends to have a long-lasting impact. A plant, a well, or a mine developed today is likely to operate for several decades. In the same way, the environmental impact of the decisions we make on energy – such as climate change – will play out over many decades.

Drivers:

There is no particular description of drivers.

Critical drivers/dimension(s) of choice:

Three scenarios are analysed – one reference case (not to be treated as the likely future but to highlight the challenges) and two alternative policy scenarios. The alternative policy scenarios are addressing policy issues around energy security, the environment and affordability. They differs from the reference scenario by alternative assumptions within:

- Energy demand (energy efficiency)
- Technology choice (renewables uptake, CCS)
- Electric vehicles

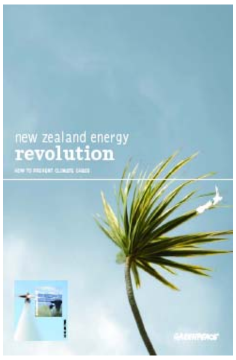
Resulting scenarios:

Reference scenario: The base case is considered a 'business-as-usual' case where oil remains the largest energy source for NZ due to its use in the transport sector.

The first alternative scenario is a *renewables scenario* that concentrates on technological advances, energy efficiency and for the transport sector, introduction of biofuels and electric vehicles.

The second alternative scenario is a *carbon capture and storage scenario* that concentrates on large scale use of coal generators combined with the use of carbon capture and storage technology.

New Zealand Energy Revolution



Author: Greenpeace Aotearoa/New Zealand, Greenpeace International, European Renewable Energy Council (EREC)

Publication year: 2007

Scenario end year: 2050

Summary:

This publication analyses two scenarios of energy use, which focus on a range of technologies that are expected to emerge in the coming years and decades. There is now universal recognition of the fact that new technologies and much greater use of some that already exist provide the most hopeful prospects for mitigation of emissions of greenhouse gases.

Drivers:

Energy demand drivers are:

- Population
- Economic development (GDP)
- Energy intensity

On the supply side, the discussion is around thermal vs. renewable generation. Nuclear and CCS (carbon capture and storage) are not considered viable options. A modest use of CHP (combined heat and power) generation can be expected to deliver heat.

Finally, electrification of transport is discussed.

Critical drivers/dimension(s) of choice:

Two scenarios are created – one business as usual and one “revolution” scenario. The revolution scenario differs by:

- Energy intensity (same population and GDP forecasts as in business as usual are used)
- 100 % renewable energy by 2030
- Electrification of transport

Resulting scenarios:

Reference scenario: This ‘business as usual’ scenario is based on a reference scenario produced by the International Energy Agency (IEA) in 2004. A continuation of current economic trends and energy policies is assumed.

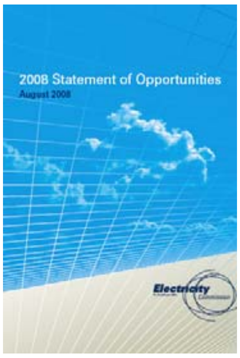
Energy revolution scenario: 100% renewable electricity generation, increased energy efficiency and 30 PJ (8.3 TWh) of electricity used for transport (electric vehicles) a year by 2050 resulting in large scale CO2 reductions from the energy sector.

2008 Statement of Opportunities

Author: Electricity Commission

Publication year: 2008

Scenario end year: 2040



Summary:

The Statement of Opportunities as published by the Electricity Commission every second year are not scenario studies per se though it has many of the same elements. Due to the requirements that the scenarios are to be used for cost/benefit analysis of new grid investments they tend towards being forecasts rather than scenarios. As a consequence hereof, they are the only scenarios that have been assigned probabilities making them likely futures rather than possible futures. Another difference is that demand and generation are treated as two separate subjects. This overview focuses on the generation scenarios, which are based on a medium demand forecast.

Still, the key drivers resemble the critical uncertainties found in other studies, which is not surprising as the Commission has adopted a similar approach for the design of the scenarios.

Drivers:

Multiple key drivers where mentioned, all of which were varied between the scenarios. See list in section below.

Critical drivers/dimension(s) of choice:

Five scenarios were created, varying assumptions around:

- Climate change policy (carbon price)
- Gas prices/availability
- Technology choice (thermal baseload ban, fate of Huntly, availability of renewables)
- Demand side (electric vehicles uptake, decommissioning of Tiwai)

Resulting scenarios:

Sustainable Path: High levels of renewable energy generation, electric vehicle uptake is rapid, new generation technologies e.g. marine, biomass and CCS are developed.

South Island Surplus: Renewable energy development, continuing gas generation in the short term, wind and hydro increase significantly in lower South Island.

Medium Renewables: Renewable generation in both islands, geothermal development is high, Tiwai assumed to be decommissioned in mid 2020’s.

Demand-side Participation: Electric vehicle uptake is high, vehicle to grid technology is implemented, new coal and lignite plants are built after 2020 and geothermal investment is high. Hydro outputs reduced due to difficulty obtaining water rights.

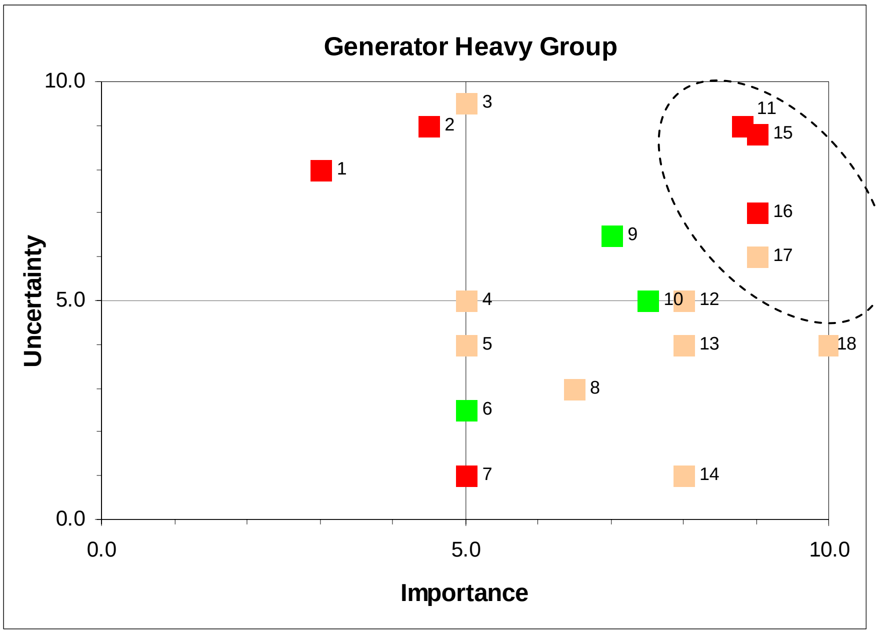
High Gas Discovery: Low gas prices, gas plants are built, demand side remains uninvolved.

Appendix B Outputs from scenario workshop

Below, the outputs from the 3 groups formed at the scenario workshop held at Transpower the 8th September 2008 is presented. Critical uncertainties are those within the circle of the figures. Some notes to the different drivers identified can be found in Appendix C.

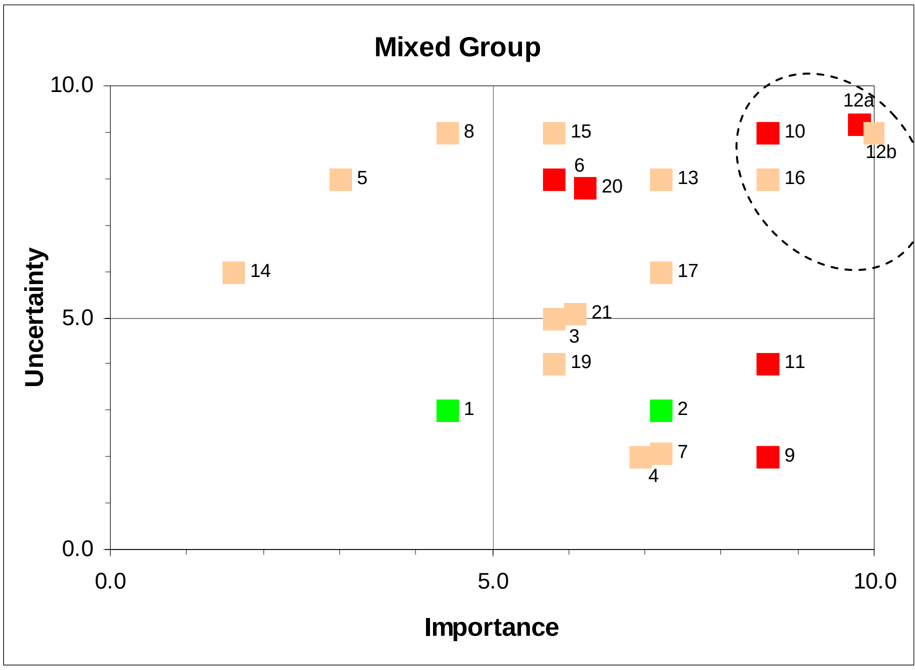
B.1 Group 1 – Generator heavy group

#	Driver	Importance	Uncertainty
1	Global Instability	3.0	8.0
2	Storage	4.5	9.0
3	Regulation	5.0	9.5
4	Nuclear	5.0	5.0
5	Changing Land Use	5.0	4.0
6	Use/Uptake of Grid Technology	5.0	2.5
7	Smoothing of peaks due to storages, smart meters etc.	5.0	1.0
8	Transmission Planning and Optionality	6.5	3.0
9	Environmental and Energy Policy	7.0	6.5
10	International Learnings and Development	7.5	5.0
11	Cost of Carbon	8.8	9.0
12	Population Growth	8.0	5.0
13	Investment Growth	8.0	4.0
14	NIMBYism	8.0	1.0
15	Climate Change	9.0	8.8
16	International Fuel Prices	9.0	7.0
17	Energy Sources/Availability (Thermal vs. Renewables)	9.0	6.0
18	Transmission Pricing Methodology	10.0	4.0



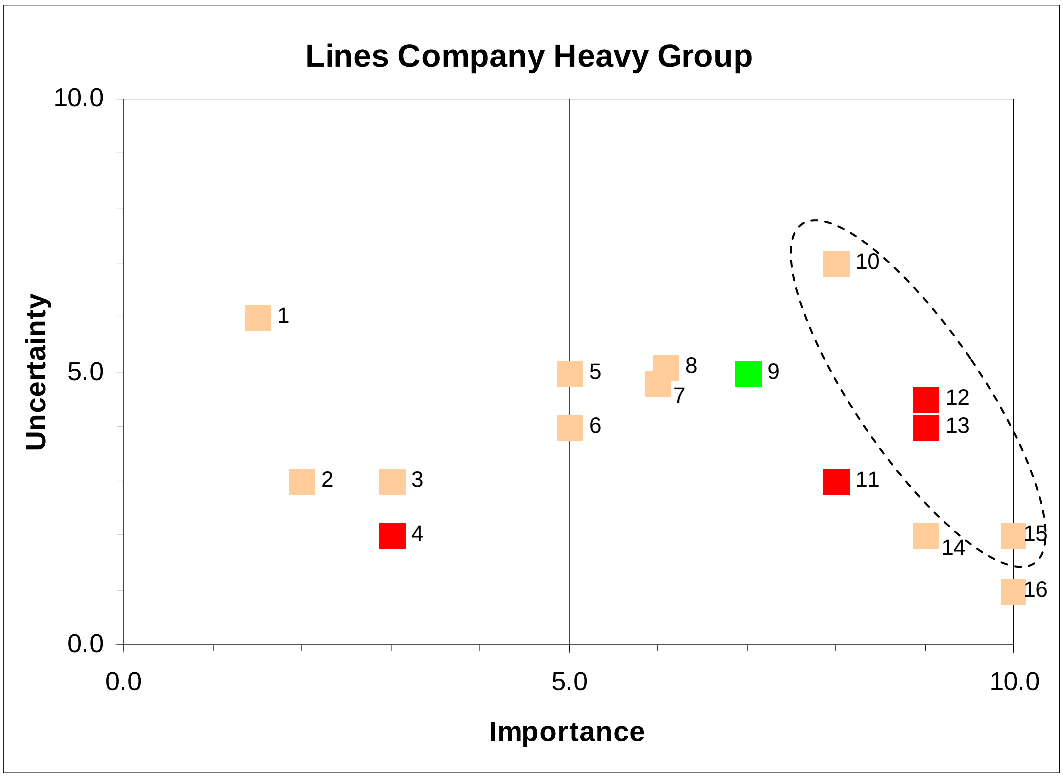
B.2 Group 2 – Mixed

#	Driver	Importance	Uncertainty
1	Energy Poverty - people can't afford to heat houses	1.6	6.0
2	Regulatory Trends	3.0	8.0
3	Planning for Energy or Transmission Services	4.4	3.0
4	National Immigration/Emigration Decisions	4.4	9.0
5	Future Residential Use - Heating, Comfort, Health	5.8	5.0
6	Global Industry Location Decisions (NZ vs. global?)	5.8	8.0
7	Institutional Issue - who is able to decide to invest	5.8	9.0
8	Transmission Enabling New Resources and Competition	5.8	4.0
9	Long term Security of Supply for Natural Gas (importing LNG)	6.0	7.8
10	Environment Regulation	6.1	5.1
11	Non-Heating Residential Load	6.9	2.0
12	Flexibility of Transmission System	7.2	3.0
13	Regional Location of Population relative to Supply	7.2	2.1
14	Consumer Price	7.2	8.0
15	Urban Form - Locational Factors, Future Industries	7.2	6.0
16	Technology - Smart Meters/Appliances, Connectivity	8.6	2.0
17	New Technology, generation and transmission	8.6	9.0
18	Energy vs. Capacity - Storage	8.6	4.0
19	More Aggressive CO_2 Policy - Carbon Cost	8.6	8.0
20a	International fuel - e.g. price, availability	9.8	9.2
20b	NZ fuel - e.g. price, local availability and consentability	10.0	9.0



B.3 Group 3 – Lines company heavy/mixed

#	Driver	Importance	Uncertainty
1	Pricing - Location, Transmission, DSM, quality, etc.	1.5	6.0
2	Heatpumps, Ecobulbs, Solar Technology	2.0	3.0
3	Space Heating - Less Coal, Heat pumps	3.0	3.0
4	Energy Efficiency Technology	3.0	2.0
5	Cost of New Generation	5.0	5.0
6	Demand Side Participation	5.0	4.0
7	Marine Generation	6.0	4.8
8	Restrictions on Water	6.1	5.1
9	Transmission Technology uptake - Losses, System Control	7.0	5.0
10	Resource Planning Requirements - becoming onerous	8.0	7.0
11	People required to Build Infrastructure	8.0	3.0
12	Peak Oil/Oil Price (Remote vs. Thermal Generation)	9.0	4.5
13	International Climate Change Negotiations, Carbon Price	9.0	4.0
14	Relax Rules around Grid Investment to enable generation	9.0	2.0
15	Government Energy Policy	10.0	2.0
16	Bi-partisan approach for commitment to infrastr. investment	10.0	1.0


Lines Company Heavy Group
Uncertainty
Importance
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Appendix C Notes from the scenario workshop

Below, the notes taken during the scenario workshop can be found. It shows some of the comments made to different topics discussed and to particular drivers identified, as listed in Appendix B.

C.1 Generation

Renewable Generation

A strong core grid is required to facilitate renewable generation investment. Future generation investment locations may be uncertain but a strong core grid will allow for fast and easy development of generation connections.

Increased renewable generation requires a more cohesive strategy for the long term future of various network components e.g. 110kV. Generators face increased uncertainty in planning if clear connection policies are not implemented.

If the cheapest generation technology results in generation located distant from load centres then timely transmission development is vitally important.

Water rights and allocation time frames (e.g. 35 years) significantly increase uncertainty for hydro investment as hydro plant has a life time of greater than the water allocation time frame.

Wind generation is likely to create volatile spot prices that will affect both generation investment planning and consumer prices.

Nuclear

Current perception is that nuclear will not be a viable technology for New Zealand for both political and technological reasons.

Technologically: Large nuclear units are not viable in NZ due to the reserve requirements that must be satisfied in order to ensure N-1 security is maintained. Small units e.g. 400MW are becoming available and may be more suitable for the NZ system but are not considered a cost effective generation technology at this time.

Politically: The NZ public is not currently in favour of nuclear generation and this stance is not envisaged to change in the near future. This viewpoint may change over time if Australia were to invest in nuclear technology.

Developing Technologies

Photovoltaic (PV): This technology has a lot of potential in enabling consumers to reduce their demand levels but must be developed further to reduce manufacturing, installation and maintenance costs. Large scale production will introduce economies of scale and reduce manufacturing prices but as demand rises resource costs will also rise potentially cancelling the savings made.

Marine: Is seen as a potential generation source with significant wave resources in NZ, particularly on the west coast of the country. Currently the technology is considered expensive with design and manufacturing in early development stages. The current state of marine generation can be compared with wind generation in the early 1990’s.

The transmission grid will need to be planned differently for marine generation as currently the NZ grid does not usually run near the coast.

C.2 Demand

Industry structure

Land use - what happens if dairying crashes? Other industries such as forestry may become dominant resulting in need for a very different energy supply and transmission system.

Restrictions on water availability and allocation will slow rural development that in turn affects regional demand growth. Some consider this a inconsequential issue over a 40+ year time horizon particularly once all land has been developed and/or all water has been allocated.

Energy efficiency and conservation

Heat pumps, ecobulbs and smart metering have only a small impact on reducing demand. Their greatest attraction, from a transmission and generation investment perspective, is their ability to delay investment although that investment will still be required albeit at a later date.

People move house every 4 years, on average, making it difficult to encourage initial investment in energy efficiency technologies such as insulation, solar hot water etc.

Demand side participation/load shaping

Demand Side Participation: will it influence peak or baseload demand? It tends to delay rather than remove the need for investment.

Need for change in retailer approach with different tariff structures to incentivise changes in energy usage.

There appears to be an assumption of general trend towards more involved consumers through smart metering, distributed generation etc. This results in increased complexity and the need for increased flexibility in operating the system. It is uncertain how this flexibility may be implemented in the current market structure.

The next development of consequence is expected to be improvements in design, availability and affordability of energy storage options. Will it be central vs. decentral technologies that will dominate?

Transport

Fuel substitution and the introduction of electric cars will increase demand but will have both benefits and drawbacks:

Benefits include:

- Facilitates connection of greater amounts of wind generation as electric cars can be used as an energy storage medium.
- Smoother demand peaks

Drawbacks:

- Increased demand
- Uncertainty about who controls the storage aspect of vehicle/grid technology.
- Grid may need upgrading to facilitate gird/vehicle control technology

Distributed generation

Some consider it unlikely that significant numbers of wind turbines will be installed in the residential sector as it will still be cheaper to buy off the grid, even with price increases.

Price/retail

The historically low levels of elasticity in the residential sector may change as prices rise. The commercial and industrial sectors see electricity as an operating cost and are likely to pass increased costs through to the consumer resulting in continuing inelasticity in demand.

Is electricity too cheap? Do we need a crisis to make people take more notice and become more aware of electricity issues?

C.3 Social/demographics

Increasingly do not want transmission lines near their properties (NIMBY). This drive generation closer to the load and makes obtaining consents for investment difficult.

There is likely to be increased competition for skills and labour but this is not seen as the largest difficulty as investors/market participants will always pay to attract people.

It seems uncertain as to how the NZ population will flatten out or decline when the global population is forecast to reach 9 billion and NZ is a desirable place to live.

C.4 Government policy

NZ Energy Strategy

Energy Efficiency:

Will only provide a small reduction in demand growth and doesn't provide a complete solution, the network will still need to be augmented.

Renewable Energy:

Regardless of outcome of coming election renewables will still be high on the political agenda.

As thermal generation costs rise, renewables will become more cost competitive.

Small scale installations (residential) are likely to increase in number. This has implications for network control (passive vs active networks). The viability of these installations is related to the economics of storage of generated energy. In poor generation conditions the grid will still be required to provide security of supply

Climate Change/Carbon Price

The introduction of a carbon price will drive technology development but will increase price uncertainty and volatility.

Carbon prices are seen as more uncertain than fuel price.

Fossil fuel availability and exploration is affected by the existence of and uncertainty surrounding carbon prices.

All parties in government have the concerns of climate change so all governments are likely to try and effect climate change legislation. The form of the legislation will change depending on the government but not that certainty that there will be legislation.

Miscellaneous

Politicians will change when people demand it but generally society is not knowledgeable of the electricity/energy industry.

C.5 Regulation

Transmission regulation

The government must provide direction and leadership to facilitate investment rather than the complex EC/Commerce Commission/Financing hurdles that currently exist.

Pricing Methodology

Transmission pricing methodology can deter a generator from being the first generator in an area, even if the transmission system has specifically been designed to facilitate generation investment because the first generator is hit with all the connection costs.

RMA issues

Resource planning/consent is likely to become more difficult and complex in the future. This may lead to small scale and lower impact investment proposals being favoured. Greater levels of small scale generation could require a grid or distribution centre level of control rather than market driven control and dispatch.

RMA must change if 90% renewables target is to be achieved. Consenting times are very long e.g. 2 years for a 15MW hydro.

If RMA costs are reduced then smaller projects will result. There are economies of scale with RMA costs, large and small projects cost the same to consent.

Difficulties of consenting with the RMA drive generation investments to easy to consent regions.

C.6 Transmission planning

General planning

There is expectation of incremental change rather than large fast moving change. The underlying physics of electricity restrict the potential for sweeping changes and developments.

All planning is undertaken with the assumption that the regulatory environment doesn’t change. This is probably an unrealistic assumption over a 40 year time frame.

Quality and Security of Supply

Demand for reliability is not going to be lower in the future.

Supply is perceived as insecure due to recent dry year events. Whether this insecurity is perception or reality is irrelevant as it is our image of having an insecure supply that influences both domestic and international investment.

Where is the balance between price and security? Who should choose this balance? Consumers or grid owner/operator?

Where investors are pushing the boundaries of technologies and investment practices the level of risk in the system increases. Historically the industry couldn’t rely on intelligence so overbuilt as compensation. With increased knowledge, skills and intelligence systems can now be pushed harder resulting in different planning assumptions.

International investment particularly in agricultural development is affected by the security of supply (or the perception of security of supply) and competition for resources in adjoining regions. NZ cannot afford to lose international investment.

Planning for more capacity is better than planning for too little, or just enough.

The near horizon (10 years) needs also to be ‘solved’ as well as the long term. Present grid needs to be brought to more reliable and robust standards to deal with the short term issues and to provide a base on which to plan for the next 40 years.

Flexibility/Optionality

Flexibility in mid term investment is important as the uncertainties of the future can change and unfold rapidly.

There is a need to work out how to make efficient investments now while still retaining flexibility for future investment and development requirements.

Transmission and generation coordination

Producing a long term transmission plan implies that transmission exists to allow the market to operate rather than transmission following a market lead. To enable such a long term plan to be useful strong leadership from Transpower, industry and government is required.

Partnership between transmission and generation can be problematic due to generation investment often being commercially sensitive. Where transmission proposals are notified publicly, it is unlikely that a partnered generation investment will want sensitive information in the public arena.

Transmission technology

FACTS, superconductors, higher voltages, smart metering: Have the potential to allow greater diversity of usage of the grid but will require much greater knowledge and skill in planning transmission investment.