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New Zealand Energy Scenarios

Navigating energy futures to 2050

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Contents

Foreword - Phil O'Reilly 5
Foreword - Dr Christoph Frei 6
Preface - Dr Rob Whitney........ 7

1. New Zealand Energy Scenarios to 2050 8
   Our WEC Trilemma Performance in 2050........ 11
2. Introduction 12
3. BEC2050 - Facing Future Challenges 13
   The WEC Approach to Scenario Development 13
   The WEC Scenarios: Jazz and Symphony 14
   Following The Leader 16
4. Scenarios for New Zealand........ 17
   New Zealand Today 17
   Decisions 22
   Uncertainty 23
   Dealing with Uncertainty 25
   New Zealand's Critical Uncertainties 29
   Scenario Quantification........ 34
   Model Inputs 35
5. Using the Scenarios........ 39
6. BEC2050 Narratives: Kayak........ 41
   Kayak Snapshot 41
   Setting the Scene: New Zealand's Place in a Jazz Rest-of-the-World Framework 42
   Our Kayak Story 42
   Our Kayak Energy Future........ 48
7. BEC2050 Narratives: Waka........ 56
   Waka Snapshot 56
   Setting the Scene: New Zealand's Place in a Symphony Rest-of-the-World Framework 56
   Our Waka Story 57
   Our Waka Energy Future 62
8. Comparative Analysis 69
9. New Zealand in a Global Context 89
10. Alternative Stories........ 93
    Tipping Points 94
    What Next? Extending the Possibilities 97
11. Appendix 1: Useful Information 100
    Abbreviations and Acronyms 100
    Units 101

General Conversion Factors for Energy 102

12. Appendix 2: List of Figures and Tables 103

Foreword by Phil O’Reilly, Chief Executive Officer of BusinessNZ

BusinessNZ’s members include major businesses and organisations operating across all spheres of energy provision, financing and use.

Their contribution to the BusinessNZ Energy Council provides invaluable insights towards energy policy-making.

This publication highlights the BusinessNZ Energy Council’s forward-looking approach.

By generating scenarios for possible energy outcomes under different economic and regulatory conditions, the BusinessNZ Energy Council is helping create and prepare for a better energy future.

I commend this work towards building a more secure, environmentally sustainable and competitive energy sector in New Zealand.

Foreword by Dr Christoph Frei, Secretary General of the World Energy Council

The World Energy Council (WEC) is the principle impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sustainable energy system for all.

With this goal in mind, in 2013, the WEC launched its ground-breaking World Energy Scenarios – Composing Energy Futures to 2050.[1] With its tradition of neutrality and its unparalleled network, including New Zealand, Brazil, Russia, India and China, developing and industrialised countries, energy producing and consuming countries, public, private sector and academia, the WEC has led an inclusive and fact-based dialogue on our global energy future.

New Zealand was at the very heart of this work, with the World Energy Scenario Study Group being chaired by Dr Rob Whitney.

And so it is only fitting that New Zealand – as one of the WEC's 'Trilemma Pack Leaders' - and one of the first countries in the world to liberalise its energy sector, to implement an emissions trading scheme including energy sources (in 2010), and to achieve eighty percent renewable electricity generation (in 2014) – should be the first WEC National Member Committee to grasp the scenario nettle and ask of itself the hard questions about its future energy challenges, choices and options.

In developing its two scenarios – Kayak and Waka – our New Zealand member committee, the BusinessNZ Energy Council (BEC) has demonstrated the power of the WEC's global out reach. It reminds us that the growing uncertainties around the future supply and demand for energy, future environmental and social contexts, geopolitics and the uptake of new technology ultimately play out in local, country-specific and sometimes unexpected ways.

As embodied in the WEC scenario development approach and now practised by the BEC, only transparency and openness of inquiry across a wide range of stakeholders will help guide us as we all seek to respond to these uncertainties in a non-ideological way. Like the WEC scenarios, Kayak and Waka are neither right nor wrong, good nor bad. They are not a roadmap, or a recipe to be followed. Instead, they seek to prepare New Zealand's energy leaders for a more diverse set of possible futures in order to ask the right questions, and to make their own better informed choices.

By taking this approach, New Zealand's scenarios can contribute towards the delivery of better, more balanced decisions across the Trilemma dimensions of energy equity, energy security and environmental sustainability, and facilitate investment – by both energy consumers and producers – in appliances and infrastructure that are resilient to a range of different possible futures.

I congratulate the BEC for this bold initiative, and will be following with interest as New Zealand determines the direction to navigate.

[1] https://www.worldenergy.org/wp-content/uploads/2013/10/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report1.pdf

Preface by Dr Rob Whitney, Emeritus Chair of the BusinessNZ Energy Council

The BEC has drawn on its unparalleled network of research, government and business organisations, including the WEC, to develop two plausible energy futures for New Zealand. In this process, we have asked ourselves: what impact would different global circumstances have on New Zealand and how would we react to the opportunities and threats that might eventuate?

It should not surprise that our choice of scenario names are water-based, given the importance of water to New Zealanders. The scenarios reflect the nature of the craft:

- **Kayak**, small and manoeuvrable and able to go with the flow of the river, an exciting and exhilarating experience.

- **Waka**, a large co-ordinated craft capable of exploring new territories and a fundamental part of New Zealand's history.

Our scenarios create a foundation on which a collective responsibility towards our future can be based. Each of our choices, on a source of energy, or a particular policy decision, will shape our domestic energy trajectory. The information they contain, and the options, choices and trade-offs they imply, create an instrument of domestic responsibility which must be exercised carefully and wisely for future generations.

This release of the Kayak and Waka scenarios is not the end but the beginning of the conversation. Scenarios are a tool which business, government, non-governmental organisations (NGOs) and others can use for planning and forward thinking. They provide us - New Zealand's energy leaders of today and tomorrow - with the long-term vision and information that will help us exert our leadership and accountability today, to those who follow.

We expect New Zealand's future to lie somewhere in between the futures painted by the Kayak and Waka stories. Rather than a template to be followed, we want New Zealand to use the scenarios to help navigate our way between them and get the best of both worlds with the markets reflecting a consensus on social equity and energy sustainability, and governments doing what only governments can do to achieve the goals. The alternative is the worst of both worlds: governments making economically sub-optimal policy decisions, and consumers focusing on short-term price signals and self-interest, thus increasing both energy poverty and atmospheric carbon dioxide (CO_2) levels.

New Zealand retains its 'pack leader' status, maintaining a top ten performance in the 2015 Trilemma Index. It is the BEC's hope that with these scenarios we can chart a course where New Zealand will continue to improve our Trilemma performance and show international leadership in delivering a balanced energy system.

Finally, I'd like to thank the project sponsors, and others involved in the development and delivery of the BEC2050 Energy Scenarios; it has been a significant undertaking of which we can all truly be proud.

1. New Zealand Energy Scenarios to 2050

Key Scenario Messages from Kayak and Waka for Policy Makers, Energy Leaders and Consumers

1. What happens globally matters to us, but we can't control it

What we can control is the quality of the decisions we make in light of the circumstances we face. This highlights the need for integrated system modelling to provide a more holistic view that can lead to a better understanding of the growing energy sector complexity and the trade-offs and impacts involved.

2. There is no such thing as 'slow energy'

The global and domestic energy sectors face unprecedented uncertainty. The degree of change in the energy sector is moving at the fastest pace it has ever moved, but the slowest it ever will. The myriad of investment signals and the speed with which relative costs are changing are having a dramatic impact on the nature and form of the entire energy-scape, impacting on both existing assets and future investments.

3. The energy sector is increasingly complex

The complexity of the energy system, both globally and domestically, is increasingly challenging our ability to identify and manage risks. The interconnectedness of international and domestic fuel markets - and sectors – outlined in scenarios reveal a hitherto unexpected depth of interrelationship. For example, the ability of the transport sector to transform will depend significantly on the price of oil and the electricity sector. Opportunities to reduce emissions in the electricity and heat sectors (on a least-cost basis) will depend on the extent of demand growth and the magnitude of the carbon price.

4. The electricity mix in 2050 will mainly be renewables, but we do not have an endless low cost supply

New Zealand will continue to increase its share of renewable energy sources and its electricity system will remain primarily renewable. But economic growth objectives may eventually come into tension with the desire to continue to invest in electricity renewables. With high demand growth and a moderate carbon price, a least-cost approach to electricity investment may see thermal generation increase towards the end of the Kayak scenario period. Only the combination of a high carbon price and targeted energy efficiency policies under Waka will see us push beyond the target of 90% renewable electricity by 2025. These measures will also have an impact on affordability.

5. Energy efficiency can play a crucial role in our future resource use

A market-led approach to energy efficiency in the Kayak scenario will have some impact on demand growth but will not stop it until perhaps the second half of the century. The total consumption of energy can decrease over the next 35 years – but hard decisions are required as it is achieved through a combination of low population and economic growth, changing behaviour (especially in the transport sector) and aggressive energy efficiency policies.

6. Transformative transport sector change is possible

Our renewable advantage presents us with opportunities for transformative change, particularly in our light transport vehicle fleet. While higher carbon prices will be a critical enabler of this transformation, the extent to which we observe increased efficiencies in alternative drivetrains (for example hybrid, battery electric vehicles [EV], hydrogen) or pursue urban intensification policies will also affect the rate of substitution away from fossil fuels.

7. Further significant reductions in energy sector emissions will be challenging, even with a high carbon price

The achievement of emission reductions appears challenging if a return 9090 levels or bellow (such as a proportionate share of the Intended Nationally Determined Contribution [INDC]) is desired, and is only likely with lower economic/population growth, high carbon prices, reduction in oil as a transport fuel and aggressive energy efficiency policies.

8. Given the magnitude of the investment required, having the right policy frameworks in place will matter

We will spend between $14.4 billion and $15.6 billion on new electricity generation assets between now and 2050 to meet demand. We need to make sure that we have the right policy frameworks and market conditions to unlock this at the right time, to achieve security and reliability and environmental sustainability.

9. Balancing the Energy Trilemma means making difficult choices with varied impacts

A wide range of options is available to business and government to help address the energy system’s growing complexity and uncertainty. Ultimately choices will need to be made to achieve balanced energy policy outcomes across the dimensions of energy security, energy equity and environmental sustainability. Adopting a Kayak ‘wait-and-see’ approach may be appropriate in some circumstances, while in others, it may not get us where we want to go. Do we, for example, introduce policies to decarbonise the transport sector or let markets play out?

10. A new consumer relationship with energy is being forged

The way consumers interact with energy is changing, and rapidly. The rise of the millennials is changing the way energy is produced and consumed. We are seeing the stronger emergence of a world in which consumers have more influence over energy outcomes - a shared world in which consumers take more control over the production and use of energy. The smart grid, electric vehicles, energy storage, and distributed forms of energy will all be a part of the paradigm shift.

Our Trilemma Performance in 2050

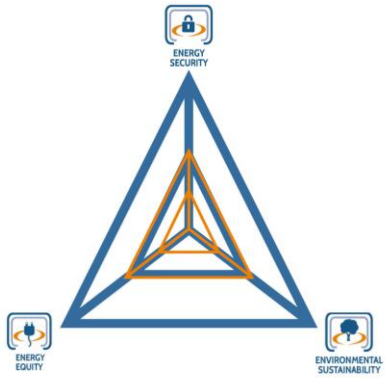
The World Energy Council's definition of energy sustainability is referred to as the "Energy Trilemma", which is a delicate balance between energy security, equity and environmental sustainability. [2] Optimising one area often means reducing performance in another. New Zealand will improve performance in all three aspects under both scenarios though there will be differences in how this is achieved.

Kayak – Energy Security

- Higher energy production.
- Greater trading of international fossil energy.
- Imported oil substituted by domestic renewable energy production.
- Greater electricity system security.

Waka – Energy Security

- Falling energy demand.
- Wider diversity of energy inputs, and less reliance on international markets.
- Intermittent and dry year electricity risk due to high renewables.
- Lower dependence on imported oil.



Kayak – Energy Equity

- Energy more affordable given higher per capita gross domestic product (GDP) growth and lower carbon prices.
- Emphasis on markets puts downward pressure on energy prices.

Kayak – Sustainability

- More emphasis on adaptation.
- Energy sustainability is led by consumer demand for low carbon energy.
- Emissions drop slowly from 2030.
- Poorer economic and social outcomes post 2050.

Waka – Energy Equity

- Energy affordability worsens with lower economic growth and high carbon impost.
- Funds directed into climate change mitigation divert from other government priorities, but targeted initiatives assist most vulnerable.
- Lower consumption challenges fixed cost recovery.

Waka - Sustainability

- More emphasis on mitigation.
- NZ adopts a range of mechanisms to meet climate change obligations on CO_2.
- Higher carbon costs and clean technology adoption achieve a significant reduction in CO_2 emissions from 2020.

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[2] The WEC defines the Energy Trilemma in the following way: **Energy Security**: the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand, **Energy Equity:** the accessibility and affordability of energy supply across the population (affordability is the relevant aspect of the energy equity dimension for New Zealand), **Environmental Sustainability:** the achievement of supply- and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.

2. Introduction

Looking at the future helps us to make better decisions today. And while we would all like to think we know what the future will hold the stark reality is that we do not. Reflecting on the changes that we have all seen, even over the last decade, reminds us that no-one has a crystal ball.

A scenario, as a tool, can help with this. But the concept of scenarios means many things to many people. They can mean a prediction of a ‘known’ future end-point or a pathway to an aspirational future result or target. Or they can be explorative about what might happen by a certain timeframe.

The BusinessNZ Energy Council (BEC) has adopted an internationally respected, independent, and tested framework used by the World Energy Council (WEC) in the development of its energy scenarios to 2050. Applying this to New Zealand, WEC’s exploratory approach has pushed the boundaries of everyone involved in the development of our scenarios. It has challenged us to move outside of our own ideological biases and anchoring and in doing so has required us to ask the right questions and importantly, to answer the questions of “how could this play out differently” and “what impact could that have”?

Consistent with the WEC approach, we have developed two scenarios – plausible, coherent and internally consistent stories of how the future of New Zealand’s energy landscape might evolve, based on a systematic analysis of those factors that will be critical to how it might do so (the “critical uncertainties”).

Rather than telling policy makers and investors what they ought to do, the report has developed two realistic scenario stories. These stories represent two different approaches to how our energy system could evolve over the next 35 years. And, through our choices made in government, businesses, families and by individuals, the path we take, whether it be Kayak, Waka or some combination, will also affect our way of life in very different ways.

Developed in conjunction with experts from across the New Zealand energy sector, and with modelling provided by the WEC’s scenario project partner, the Paul Scherrer Institute (PSI), these scenarios allow energy decision-makers to assess what is actually happening in the world now and gauge what will happen in the future including the real impact of today’s choices on tomorrow’s energy landscape.

New Zealand faces choices for the future on the nature of the economy and how to meet associated energy demands. There will be conflicting objectives as we strive to balance affordability, security and environmental sustainability. Government and business must work together to create a positive policy and investment climate that promotes new technology and innovation as well as supports energy sector developments.

3. BEC2050 – Facing Future Challenges

New Zealand's natural resource abundance provides it with opportunities and choices that are envied around the world. But the challenge we face as a country is which opportunities to seize and what choices to make to allow society to flourish, businesses to thrive on the global stage and the economy to grow in an environmentally responsible way.

The challenges are amplified as we face increasing complexity and unprecedented uncertainty in the global energy sector. In a world where new technologies foster quicker innovation and require changes in policy and investment decisions, the task of business and policy makers predicting what might happen in the future becomes harder.

The faster pace of change we are observing is due in no small part to consumers' rapidly increasing propensity to absorb new technologies and their willingness to change the relationship they have with the way energy is produced and consumed. In such an uncertain environment, our ability to predict the future beyond the next few years is seriously challenged.

In this situation, the need for useful information that will help businesses and policy-makers make informed decisions about the trade-offs around the three dimensions of energy security, energy equity and environmental sustainability, is palpable.

The BEC developed its scenarios against this backdrop. We sought to base our understanding of the future on what is actually happening in the rest of the world, combined with a range of critical uncertainties that have meaning to us here in New Zealand.

The WEC Approach to Scenario Development

The WEC faced similar issues to us when considering its energy scenarios.

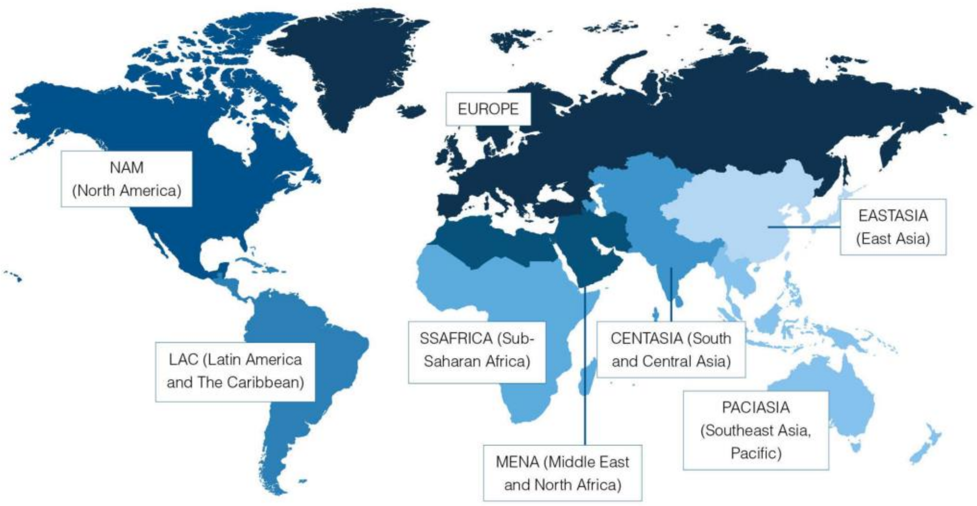
Released in 2013, the two WEC scenarios are based on a unique, bottom-up approach building on its extended global network. The WEC's approach was different from the scenario building approach that others had previously undertaken. Taking an explorative (what might be), rather than a normative (what ought to be) approach and building on its tradition of independence and neutrality, allowed it to consider wider viable future options and to integrate the critical uncertainties.

Therefore, the WEC's scenarios are not a roadmap. Instead, the WEC put together credible and pragmatic assessments of what is actually happening in the rest of the world not what the WEC would like to happen in an ideal or politically-directed world.

The explorative approach - of developing plausible, coherent and internally consistent storylines about how the future might unfold, based on a systematic analysis of critical uncertainties - provided the WEC with an anchor point to challenge and test key assumptions. It thereby strengthened the basis on which to define balanced policies and take informed investment decisions.

The WEC's *Composing Energy Futures to 2050* report is a global analysis composed of eight sub-regions where social, geopolitical and economic forces might drive different outcomes than can be seen at the global level. The eight sub-regions are shown in Figure 1 below.

Figure 1 – The WEC Eight Sub-regions



The WEC Scenarios: Jazz and Symphony

The WEC developed two scenarios typified by characteristics which comprehensively describe large parts of the world in 2050. In this exercise, the elements of the two scenarios are generalised as being applicable to the whole world: the more consumer-driven Jazz scenario and the more voter-driven Symphony scenario.

While both scenarios are 'music based', they are quite different in nature.

- **Jazz** is a style of music characterised by a strong but flexible rhythmic structure with solo and ensemble improvisations on basic tunes and chord patterns. In Jazz, musicians have freedom to take the lead and improvise; others in the band will often follow.

As an energy scenario, Jazz achieves energy equity by prioritising individual access and energy affordability through economic growth.

- A **Symphony** is a complex piece of music with a fixed structure composed to be played by a symphony orchestra. The orchestra will have a conductor and 80 or so orchestra members each with a specific role to play and score to follow.

As an energy scenario, Symphony achieves environmental sustainability through internationally co-ordinated policies and practices.

The WEC scenarios were designed to help a range of stakeholders address the "energy Trilemma" of achieving environmental sustainability, energy security, and energy equity.

The WEC then quantified the scenarios using a globally recognised energy model run by an internationally respected and independent organisation, the Paul Scherrer Institute (PSI) based in Geneva, Switzerland to develop and maintain the Global Multi-Regional MARKAL model (GMM) [3] for WEC's purposes. PSI is the largest federal research institute in Switzerland.

WEC's Jazz and Symphony scenarios are summarised in figure 2 below.

Figure 2 – WEC Scenarios Meta-Trends

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[3] The Global Multi-regional MARKAL model (GMM), is based on an underlying energy system model developed by PSI. For more information on GMM MARKAL modelling see Appendix 2 of the World Energy Scenarios: Composing Energy Futures to 2050, pages 256 to 261.

Following the Leader

The WEC approach provided the international guidance we sought in the development of some uniquely New Zealand energy scenarios. At its highest level, the WEC approach provided an independent scenario framework based on an internationally respected scenario development approach.

But while the WEC scenario development approach provided the BEC with an opportunity to leverage off it, neither the WEC's scenario narratives, nor the GMM used to quantify them, could be used straight off-the-shelf without substantial modification to reflect New Zealand's unique circumstances.

To take full advantage of the WEC approach, it was necessary to do two things:

- **Develop** a Kiwi-based approach to the project. The BEC is the first WEC National Member Committee to develop a country-specific set of scenarios within the over-arching WEC framework. The WEC's own scenario programme out-reach has so far only extended to regional scenario development (Latin America). Even then, it has not attempted a fully scaled-up WEC-like project, but has applied a lighter-touch, predominantly involving qualitative outputs. As the first of its kind, the BEC2050 Energy Scenarios Project (BEC2050) required the careful qualitative description of the New Zealand storylines with the rest-of-the-world Jazz and Symphony, and the identification of modelling parameters that were fixed or flexible in terms of our scenarios.

- **Determine** who would assist in the quantification of the New Zealand scenarios. Given the benefits arising from the relationship with the WEC and the WEC's scenario development, it was a relatively straight-forward decision to use PSI as the BEC2050 modellers.

The upshot of this is that BEC2050 is the first of its kind to leverage the global results of the WEC scenario work in a country-specific report. In addition, it has facilitated the development of a first for New Zealand: two uniquely New Zealand, globally connected, whole of energy sector scenarios.

4. Scenarios for New Zealand

The world is facing an unprecedented level of uncertainty about the future of energy systems. This is equally true for New Zealand. Moreover, New Zealand's unique geography, economy and history creates a set of uncertainties and trade-offs which are specific to us as Kiwis.

New Zealand Today

A Lucky Country

New Zealand is blessed with an abundance of natural resources, a temperate climate, plentiful water supply and fertile soils. We have the eighth largest natural capital resource wealth per capita, behind only that of the major petroleum nations.[4] Over half the country's land is pasture or arable land and more than a quarter is under forest.[5] Our coastline is the ninth longest in the world and our exclusive off-shore economic zone the fourth largest in area.[6] The high quality of our natural resources, while no longer pristine in many cases, reflects the country's relative youth and current low population pressures.

These natural and renewable resources afford New Zealand a competitive advantage in producing and exporting a wide variety of primary products. The dairy sector in particular currently stands out as a key driver of exports and economic growth.

The country also has a long-standing record of exporting the talents and ideas of its relatively highly educated workforce, with growth in services, software and hi-tech manufacturing. The economic opportunities available to New Zealanders, our relatively high standard of living and natural environment make the country a sought after destination for immigration and investment.

Figure 3 compares recent population trends. Figure 4 shows historical GDP growth and export growth over recent decades.

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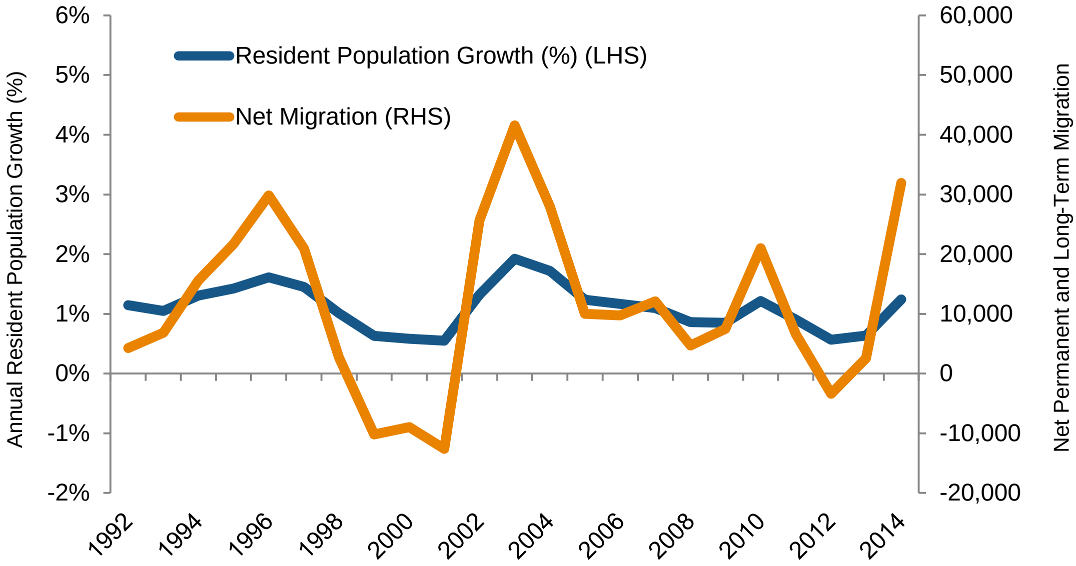
4 World Bank, 'The Changing Wealth of Nations, January 2011. http://data.worldbank.org/data-catalog/wealth-of-nations

5 New Zealand Government, 2013, "New Zealand Economic and Financial Overview 2013", http://www.treasury.govt.nz/economy/overview/2013/nzefo-13.pdf.

6 Seafood New Zealand, http://www.seafoodnewzealand.org.newzealand/our-industry/key-facts/.

Figure 3 – Annual Population Growth versus Net Migration (1992 to 2014)
Source: Statistics New Zealand



Open For Business

New Zealand's economy is currently open and ready for business. It is now recognised as one of the easiest places to do business in the world,[7] with one of the lowest levels of corruption.[8] Successive economic reforms, started in the 1980s, have liberalised labour, financial and foreign exchange markets and removed many tariffs and support mechanisms. This has transformed the economy from one of the most protected in the Organisation for Economic Co-operation and Development (OECD), to one of the most open. Despite this, New Zealand businesses face significant challenges, including sourcing skilled labour, responding to changing technologies and consumer demands and complying with regulations.[9]

Exports of goods and services account for around one-third of real expenditure gross domestic product (GDP),[10] with trade predominantly focused in the Asia-Pacific region (over 75% of export and 73% of import dollars in 2014). With an export-oriented economy, successive governments have increasingly pursued multi-track, free trade strategies to promote New Zealand exports, with a recent focus on regional trading partners. New Zealand is well-positioned under these arrangements and has a significant head-start as global markets open and liberalise. Asia in particular, with its growing and increasingly wealthy population, has been a significant source of economic opportunity. China is now New Zealand's largest trading partner for both imports and exports, with a six-fold increase in dollar exports in the last decade.[11]

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7 New Zealand has ranked 2nd in the World Bank's ease of doing business index since 2005, June 2014, http://data.worldbank.org/indicator/IC.BUS.EASE.XQ.

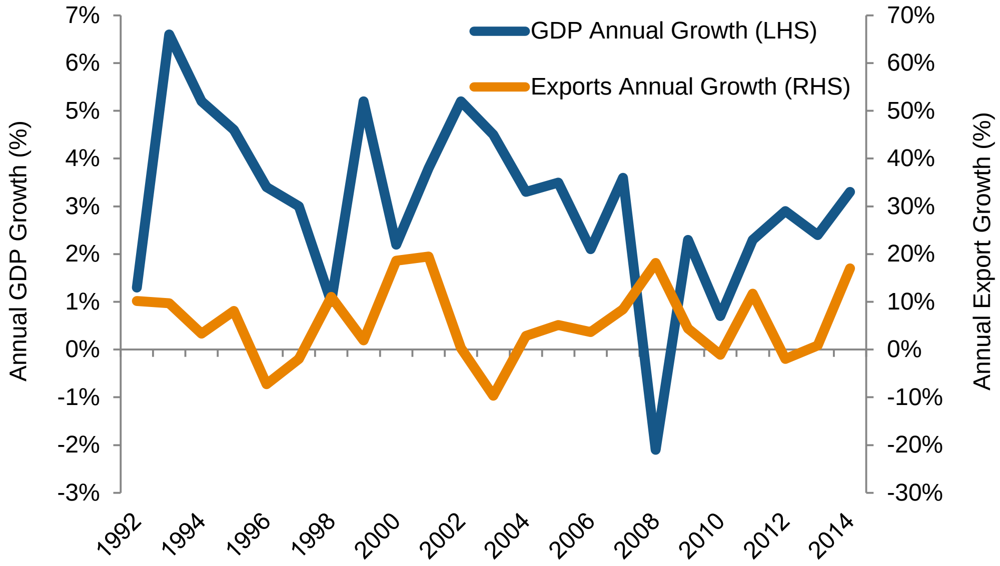
8 New Zealand was the 2nd least corrupt country in the 2014 Corruptions Perceptions Index, behind Denmark, http://www.transparency.org/cpi2014/results.

9 PwC, New Zealand CEO Survey 2015, http://www.pwc.co.nz/nz-ceo-survey-2015/.

10 New Zealand exports account for 1/3 of GDP.

11 Statistics New Zealand, 2015 Exports for Overseas Merchandise Trade (fob $NZ)

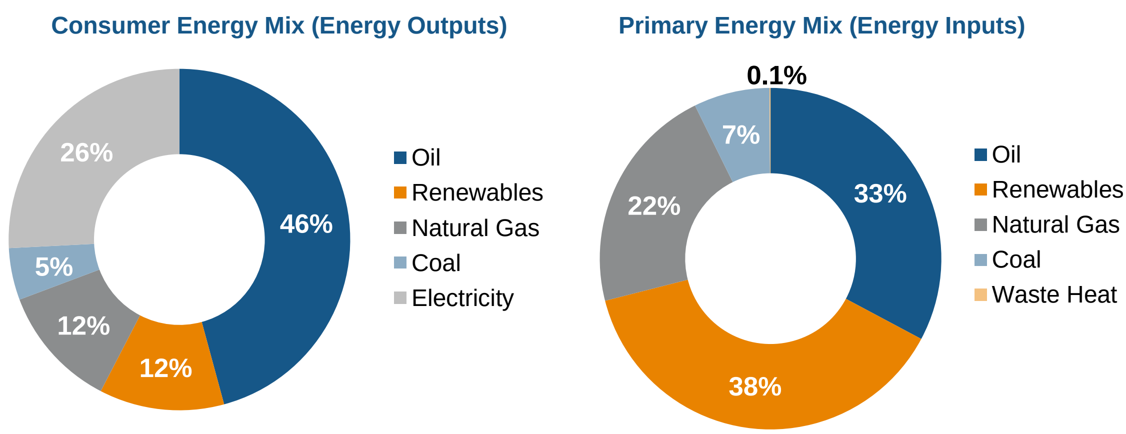
Figure 4 – Annual Growth in GDP and Exports (1992 to 2014)
Source: Statistics New Zealand



A Diverse Energy Mix

The New Zealand economy is heavily reliant on hydrocarbon-based fuel inputs, as are all post-industrial economies, with 55% of the country's total primary energy requirements being met by oil and gas and 7% by coal (Figure 5). The main engines of economic growth – the industrial, commercial and primary sectors - account for 52% of energy demand half of which is carbon-based.[12] The transport sector, dominated by the internal combustion engine (ICE), accounts for 37% of energy use and 43% of energy-related greenhouse gas emissions.[13]

Figure 5 – New Zealand's Energy Mix (2013)
Source: Ministry of Business, Innovation and Employment[14]



12 Ministry of Business, Innovation and Employment (MBIE), 14 Energy in New Zealand, Figure A.3d.

13 http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-greenhouse-gas-emissions

14 Renewables, natural gas and coal in Primary Energy are either used directly by consumers for heat – represented in the right hand chart as renewables, natural gas and coal – or transformed into electricity.

Demand for gas is met entirely from domestic production and coal mostly from indigenous sources, whereas we import over 80% of our oil needs. Domestic oil and gas reserves have expanded on the back of exploration and continued development, with most of our liquids production - of more highly-valued light-sweet crude and condensate - now being exported.[15]

At around 38% of total primary energy, New Zealand has the third highest proportion of renewable energy supply in the OECD,[16] behind Norway and Iceland. Most of this renewable energy (including from water, wind, and geothermal) is used as an input to generate electricity, with about 80% of electricity supply now generated from renewable sources.[17] Other non-electricity forms of renewable energy, including geothermal and wood-waste used for heat and steam processing, also make an important contribution to meeting our energy requirements.

The opportunities for further growth in renewables are significant. The quality and availability of our wind and geothermal resources in particular, as well as potential solar (photovoltaic and water heating), marine and bio-energy[18] resources, place the country in an enviable position to adopt more renewable energy. New Zealand also has significant non-renewable energy potential, including large frontier petroleum basins and deposits of methane hydrate, a potentially abundant fuel of the future, assuming the greenhouse gas emission risk can be mitigated.

Energy efficiency and demand-side management play an important role in balancing energy demand and supply, recognising that New Zealand's remote location limits exports of renewable electricity using current technology. For instance, in electricity, hot water load control has been used for more than 60 years to manage demand, with approximately 5% of peak load being reduced each year.[19] There have also been significant improvements over the last decade in the energy efficiency of consumer-based technology. Businesses and consumers are also increasingly experiencing the benefits of investing in improved energy efficient products, technologies and management strategies to reduce their overall energy costs. Recent government initiatives, including home insulation subsidies, ENERGY STAR™ ratings and energy efficiency standards have also contributed to overall energy efficiency gains.

Historically, New Zealand's energy intensity has declined as GDP has increased at a greater rate than total consumer energy (so that less energy is required for each unit of value added to the economy). Since 1990, there has been a 27% decrease in energy intensity, an average decrease of 1.4% per annum (see figure 6 below).[20] In recent years, the decline in energy intensity has on average been 1.7% per annum.[21] A significant contributor to this improvement is the higher growth in service industries relative to the more energy-intensive industrial sectors. Energy-intensive industries in New Zealand also face a more challenging future. Globally, heavy industry is increasingly seeking to locate in areas that co-optimise both access to natural

15 93% of indigenous production (in PJ) was exported in 2013.

16 *ibid*, 14 Energy in New Zealand, page 50.

17 http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/new-zealand-energy-quarterly

18 https://www.niwa.co.nz/our-science/energy/research-projects/all/energyscape/bioenergy_options.

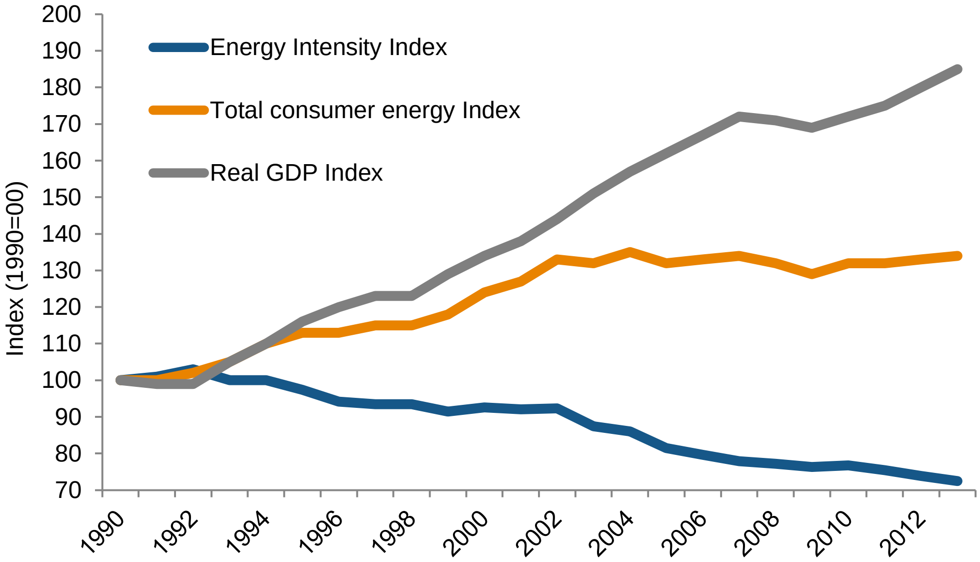
19 PwC analysis of Electricity Line Business 2012 Information Disclosures.

20 *Ibid,* 14 Energy in New Zealand, 2013 energy indicators.

21 *op cit,* 2013 energy indicators.

resources (for example, bauxite, iron ore, limestone, forestry) *and* low carbon energy. In addition, many developing countries are making significant investments in heavy industry to meet their economic development objectives. These investments use leading edge technologies and are of a scale which makes it more difficult for New Zealand to compete.

Figure 6 – New Zealand's Energy Intensity (2013)



In Pursuit of 100% Pure

New Zealand was an early mover in the adoption of more sustainable forms of economic development. It was the first country to introduce the principle of sustainability into its legislation, through the enactment of the Resource Management Act 1991 (RMA).[22] The New Zealand Emissions Trading Scheme (ETS), first legislated in 2008, was also at the forefront of such schemes at that time. It was the first scheme globally to recognise all emissions across all sectors of the economy as well as carbon sinks.

While the New Zealand ETS provides a comprehensive framework for dealing with New Zealand's unique emissions profile, its initial ambition to cover all sectors of the economy has yet to be realised. The collapse of the price of Kyoto-based emission reduction units, coupled with government decisions to extend transitional measures and delay the entry of the agriculture sector, have muted the price signal created through the New Zealand ETS. Low carbon prices have also accelerated deforestation reducing New Zealand's potential carbon sinks.

New Zealand's early leadership in the area is being overtaken by other countries, often with more pressing resource constraints, which are expending significant effort on promoting more sustainable economies. However, New Zealand consumers and businesses are increasingly conscious of their energy use and environmental footprint. Behaviour and demographics are also changing. In transport, increased urbanisation and changing attitudes towards travel (particularly by younger residents – for example, the so-called 'millennials') have contributed to a moderate reduction in

[22] Smith, Gordon "The Resource Management Act 199 1 "A Biophysical Bottom Line" vs "A More Liberal Regime"; A Dichotomy?" [1997] Canterbury Law Review 5; (1997) 6(3) Canterbury Law Review 499.

private passenger vehicle kilometres travelled (VKT) per person.[23] However, New Zealand has one of the oldest vehicle fleets in the developed world as well as one of the highest vehicle ownership rates, suggesting that achieving change in this area will be a long process.

Decisions

The New Zealand energy sector is critical if we are to meet the challenge of leveraging our natural resources in order to optimise our economic, social and cultural prosperity. It can play a greater role, with systems that reflect and support New Zealand's specific economic, environmental and cultural make-up.

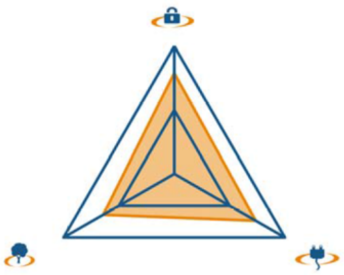
Achieving a balance in the three main pillars of the energy Trilemma requires the co-operation of government and private partners, financial institutions, and the energy sector. Together, these players must create a policy environment that encourages investment and minimises risk in a market that is seeing increasing competition and complexity. New Zealand exhibits strength in all three metrics of the Trilemma but can build on these strengths to become a world standard bearer.

New Zealand's Energy Trilemma Performance

New Zealand is considered a "Pack Leader" by the WEC, and exhibits strong, well-balanced performance in all three facets of the Energy Trilemma. By international standards, New Zealand has a strong energy performance, paired with robust and stable political and social institutions. The rankings for New Zealand in 201, 2014 and 2015 for the high-level Trilemma index dimensions are shown below - with an overall ranking of 10th out of 129 countries in the WEC 2015 index. While we have maintained a strong overall ranking over the last three years, our ranking in each individual dimension has dropped.

10 RANK NEW ZEALAND SCORE AAB

TRILEMMA BALANCE



INDEX RANKINGS AND BALANCE SCORE

	2013	2014	2015	Trend	Score
Energy performance	11	11	16	↓	
Energy security	15	16	29	↓	A
Energy equity	26	28	35	↓	A
Environmental sustainability	37	42	47	↓	B
Contextual performance	6	4	4	→	
Political strength	1	3	3	→	
Societal strength	3	6	7	↓	
Economic strength	33	12	8	↑	
Overall rank and balance score	**8**	**10**	**10**	**→**	**AAB**

KEY METRICS

Industrial sector (% of GDP)	25.5	GDP / capita (PPP, USD); GDP Group	29,609 (II)
TPEP / TPEC (net energy importer)	0.88	Energy intensity (million BTU per USD)	0.18
Emission intensity (kg CO_2 per USD)	0.30	CO_2 emissions (metric tons CO_2 per capita)	7.35
Energy affordability (USD per kWh)	0.22	Population Access to Electricity (%)	100.0

23 Pinnacleresearch, http://www.pinnacleresearch.co.nz/research/rr468living-intensified-environments.pdf.

In optimising the country's energy supply, decision-makers face the challenge of balancing a Trilemma of energy security, sustainability, and equity. Currently, the country scores highly in addressing these goals, ranking 10th in the world in 2015, but challenges remain:

- **Energy security** comes at a price and must be carefully managed and co-ordinated by sector participants and government agencies. The country continues to face energy security risks, being vulnerable to adverse domestic hydrological conditions – a function of a changing climate - and global energy markets for liquid fuels.

- **Energy sustainability** is a growing concern, as the globe grapples with how to reduce carbon emissions from the use of traditional fuels. New Zealand's energy-related greenhouse gas emissions, while small on a global scale, have increased by 32% since 1990, accounting for 39% of total emissions in 2013 (excluding emission offsets from land-use, land-use change and forestry [LULUCF]).[24] The growth in energy-related emissions is primarily from road transport emissions which increased by 69% over the same time period.

- **Energy equity** (affordability, rather than access in New Zealand's case) remains an issue for the country. Relative to other countries, New Zealand's energy affordability ranking (as measured by the WEC) has deteriorated over recent years. Energy affordability is an increasing concern for the most socially vulnerable who feel the impact of rising energy costs as a proportion of disposable income.

Uncertainty

In making these trade-offs and decisions, New Zealand faces significant uncertainty. Our fortunes as a country are intertwined with those of our major trading partners and the global economy. What we sell internationally, the technology we purchase as consumers, and the image our country has as a tourist destination and producer of food, all depend on the preferences of other global citizens. When considering the uncertainties for New Zealand, it simply does not make sense to contemplate our future in isolation from the uncertainties facing the global economy.

The energy sector must also contend with rapid technological change in how energy is both produced and consumed. Technological advances in alternative fuels, generation technologies, batteries, transportation, and energy efficiency are planting the seeds of an energy-led economic revolution comparable with that seen at the start of the industrial and digital age. New Zealand is potentially well-placed to ride this next economic wave, subject to timely and innovative policy and investment responses. However, the task for business-leaders and policy-makers of predicting what might happen during the period of transition is not easy.

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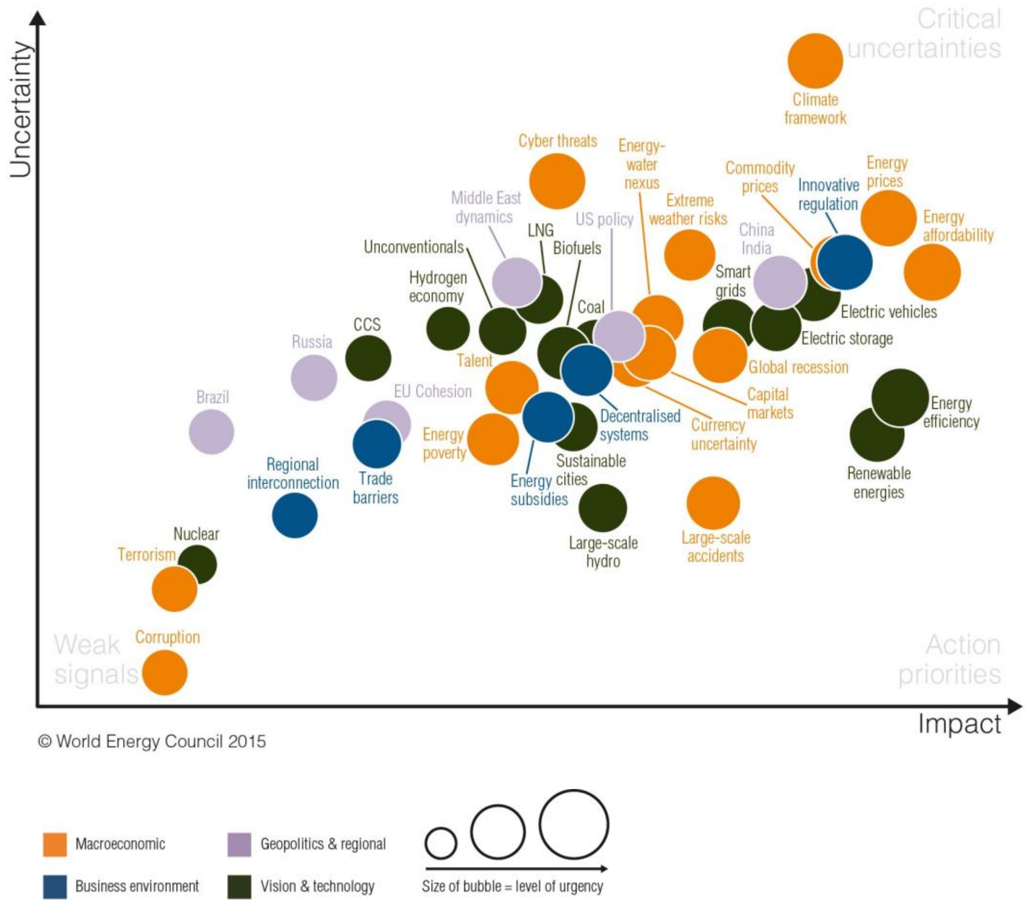
24 Ministry for the Environment (MFE), http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/ghg-inventory-1990-2013.pdf page viii.

Closer to home we face uncertainty that is domestic in origin. Almost every day we see another energy sector-related headline in the media. Possibly the most significant uncertainty manifests in the behaviour and preferences of energy consumers. What cars we choose to drive, where we choose to live, the houses we choose to build and the environmental and urban design standards we demand all have critical implications for how our energy system evolves. While these uncertainties are shared with other countries, where New Zealand ends up will uniquely reflect our Kiwi culture.

We can see the impact of these uncertainties on New Zealand decision-makers in the BEC's second annual Energy Issues Map. The Map (Figure 7) shows critical uncertainties in the minds of approximately one hundred senior New Zealand energy executives, both in terms of potential impact and perceived uncertainty.

Figure 7 – New Zealand 2014 Energy Issues Map[25]



The interconnection of New Zealand with the world is highlighted through the presence of global issues in the top right hand corner: the growth of China and India, the future climate framework, commodity prices, capital markets and the global recession. Technology – largely imported – plays a significant role through electric vehicles, storage, smart grids and energy efficiency all present in the minds of

[25] How to read the Energy Issues Map: Issues with high uncertainty and high impact ("critical uncertainties" – in the upper right corner) include those issues which will most benefit from multi-stakeholder dialogue and scenario analysis. The issues on the high-impact/low uncertainty ("need for action" – in the lower right corner) are those where immediate action finds easy consensus. The low impact/low uncertainty ones include issues of perceived lesser importance but also "weak signals" (bottom left), which may be issues that are still badly understood. The urgency of an issue is proportional to the size of its bubble.

executives. However, the uncertainty for New Zealand is not just how these technologies will evolve but also how they will be taken up by New Zealand consumers and be integrated into the New Zealand energy system.

As highlighted above, a significant local issue for New Zealand energy executives is that of energy affordability.

A set of specific uncertainties identified for this purpose is discussed in detail below. The degree of uncertainty is palpable: these are not variables which have a prospect of only minor variation. Played out over 35 years, each of these uncertainties could produce a substantially different outcome – the presence of a binding global climate agreement, or not; the compounding effects of growth in our major trading partners; the transformational potential of alternative transport on our energy system.

The BEC aims to assist decision-makers as they contemplate policy and investment decisions – many of which will have implications for decades – in this climate of uncertainty. But when we need to contemplate events that may not occur for many years, how do we provide a sensible framework?

Dealing with Uncertainty

Forecasting Approaches

Traditional forecasting approaches set out to make predictions about the future – future oil prices, discoveries, exchange rates, investments and policies. However, simple forecasting techniques often fail to inform us of the uncertainty that exists, particularly as we consider time periods decades into the future. Advanced forecasting methods help us by providing ranges of future variables. However, even these techniques do not help us understand the complex interplays between decision-makers, policy-makers, consumers and the institutional arrangements that lie behind a particular future state. And forecasting is typically a representation of the past. We observe more and more decision-makers becoming frustrated with the straight-line extrapolations that tend to occur as a result of traditional forecasting approaches.

These approaches lose even greater relevance when a number of potentially disruptive technologies are on the horizon, as is the case currently with energy systems globally. Electric vehicles, distributed generation, energy storage, home energy management systems and smart grids have the potential to fundamentally change the way we produce, distribute and consume energy. Looking at the past has limited value. Professor Clayton Christensen, who authored the seminal text on disruption[26] comments:

> *"Data is only available about the past. When we teach people that they should be data driven, and fact based, and analytical as they look into the future, in many ways we condemn them to take action only when the game is over. The only way you can look into the future – where there's no data – is to have a good theory."* [27]

When contemplating something as complex as the energy system, looking into the future has to be a pragmatic mix of historical evidence and Christensen's "theory" of the future.

[26] *The Innovator's Dilemma*, (1997), Clayton Christensen, Harvard University Press.

[27] Interview with Clayton Christensen, Harvard Business Review, March 30, 2012.

This is why we believe a scenario-based approach is most appropriate for what we are trying to achieve.

Scenarios

Futurist Peter Schwartz, who pioneered scenario planning in the 1980s, describes scenarios as:

"Stories that can help us recognise and adapt to changing aspects of our present environment. They form a method for articulating the different pathways that might exist for you tomorrow, and finding your appropriate movements down each of those possible paths."[28]

By describing a story (or narrative) of the future, we ensure that the many components of the energy system are in sync. For example, we cannot blindly assume that a carbon price is high in a particular scenario, without considering both:

- What the impacts of a high carbon price are on the rest of the energy system.
- Perhaps more importantly, what the proposed drivers of a high carbon price mean for our other assumptions about the world.

Peter Schwartz is an American futurist, innovator, author, and co-founder of the Global Business Network (GBN), an elite corporate strategy firm specialising in future-think and scenario planning.

Schwartz has written several books, on a variety of future-oriented topics. His first book, *The Art of the Long View* (Doubleday, 1991) is considered by many to be the seminal publication on scenario planning and was voted the best all time book on the future by the Association of Professional Futurists. It is used as a textbook by many business schools.

He has spent his life thinking out 10 to 20 years and helping governments and global corporations come up with how best to get there. As of October 2011, he now serves as Senior Vice President Strategic Planning for Salesforce.com.In his early career, Schwartz led the scenario team at Royal Dutch/Shell in the 1980s, where many of the scenario tools he pioneered were used to great advantage.

It is important to understand that we should not think of a forecast as a scenario – typically the second bullet point above is missed by traditional forecasting approaches. Scenarios are bottom-up in the sense that they begin with a storyline rather than being simply a variation on a set of parameters.

Further, like the WEC scenarios, the BEC scenarios are explorative in the sense that they make no pre-judgment about what the ultimate outcome of each storyline needs to be (what is known as a "normative" approach). Normative scenarios are valid, and have their place, but the explicit motivation behind both the WEC and BEC work is to explore the uncertainty we face and provide a glimpse of what contrasting variations of the future might look like in a plausible and maybe challenging manner.

Scenarios have been successfully used by major companies - Royal Dutch Shell, Motorola, and Disney[29] to name a few, as a way to provoke thinking about the future.

In order to be of practical value, our scenarios must be:

- **Plausible:** a scenario must not only be theoretically possible, but also sufficiently believable for New Zealand.

[26] *The Art of the Long View*, (1991), Peter Schwartz.

[27] "Scenario Planning", The Economist, September 2008.

- **Coherent:** within a scenario, all the parts making up the "whole" must be internally consistent.
- **Distinct:** the stories told by each scenario must be sufficiently different from one another to help people understand the nature of future uncertainty.

It is important to view the scenarios developed for the BEC2050 project not from the perspective of whether you believe they will occur, but whether it is believable that they could occur.

How are Scenarios Developed?

As stated above, scenarios must consider the interaction of the critical variables which drive the uncertainty. Hence scenario development commences with a broad consideration of what these variables are – here termed "critical uncertainties". This highlights that there are many uncertainties we will face as a country but there are uncertainties which will be most critical to the evolution of our energy system over the next 35 years.

While our focus is on the energy system, the process by which we discover the critical uncertainties must necessarily span disciplines – geo-politics, technology, the economy, politics, psychology and history. It is this broad context that drives the policies we develop, the energy we consume, and the way in which the industry chooses to satisfy demand.

It is this broad context that will guide how the different storylines will develop.

Obviously, there are innumerable potential storylines – combinations of critical uncertainties - that can result from multiple variables. This complexity has to be proactively managed –

- by considering the correlation between variables, which provides a natural grouping of outcomes (for example, the presence of a global agreement on carbon will likely tell us something about the state of geo-politics at the time), and
- through being clear about the question of interest – in this case the energy system.

Number of Storylines

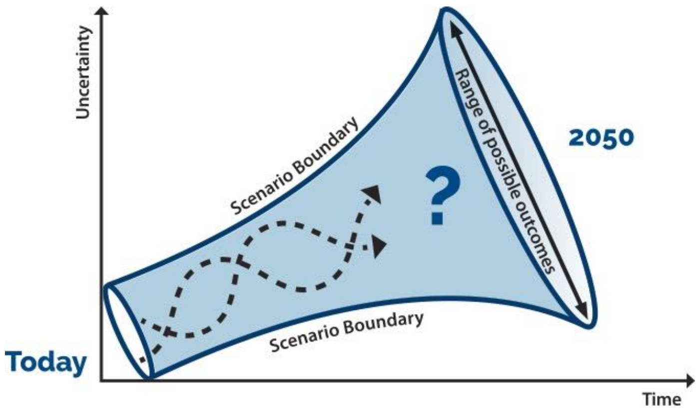
The number of storylines portrayed has to be considered. Scenario planning exercises range from two (for example, Shell's explorative New Lens scenarios – Mountains and Oceans) to multiple scenarios (for example, MBIE's eight Electricity Generation Development Scenarios [EDGS]). The WEC elected to model two storylines (Jazz and Symphony). The BEC's foundational scenario building exercise for New Zealand it set out to use these two storylines as a backdrop for what was happening in the rest-of-the-world. This does not in any way prevent us from considering additional scenarios in the future. However, it gave us the benefit of being able to leverage the comprehensive work of the WEC in developing storylines and making assumptions for all the main regions of the world.

In narrowing down to two storylines, it was challenging to maintain coherence and plausibility within each storyline, while providing enough distinction between the scenarios to provide decision-makers with sufficiently distinct narratives about the energy system.

The goal of the BEC's scenarios is to provide plausible boundaries on the evolution of New Zealand's energy system. This "funnel of uncertainty" widens as we progress into the future, where we know less and less about the future state (figure 8).

Figure 8 – Funnel of Uncertainty

Source: World Energy Council



The challenge to develop scenarios which achieve the principles of plausibility, coherence and distinction, is enormous. It is a highly disciplined process where:

- The range of views sought is a broad as possible – both from within and outside the energy sector and across government, business, civil society and academia.
- The combinations of critical uncertainties in each scenario are believable.
- Assumptions are re-checked at every iteration to ensure that internal consistency is maintained.
- The scenarios are not captured by anchoring bias, particularly that one will be a continuation of the status quo or that both are simply minor variations of what we believe will happen.

Our efforts to achieve distinct storylines, and thus test the limits of plausibility, mean that New Zealand will most likely navigate a path within the two boundaries and inevitably borrow characteristics from each scenario. The principle value of each scenario is that it allows decision-makers to test their intentions – policies, investments, and commitments – against the two edges of the funnel characterising each storyline. This provides an assessment of resilience and flexibility, and is a core part of risk management.

However, scenarios are not designed to be exact or precise forecasts. It is important to recognise that due to the interconnectedness of uncertainties, and the sheer complexity of the trade-offs involved these are not hard boundaries. Further, as outlined below, each scenario requires an assumption about the outcome of each critical uncertainty. In order to maintain plausibility and coherence, we cannot assume the most extreme value of each uncertainty. We do not believe a storyline which made somewhat heroic assumptions about each and every critical uncertainty would be useful to decision-makers.

As a result, we cannot claim that these scenarios are the most extreme imaginable. Any one of the critical uncertainties outlined below could be more extreme (as a result of, for example, a significant technology breakthrough), and point to a path beyond the “fuzzy” boundary that our scenarios imply. However, it is important that the backbone scenario is present as a reference point when discussing these tipping points (otherwise the analysis risks becoming fanciful). We discuss the impact of a range of tipping points on our scenarios in Chapter 9 Alternative Stories.

New Zealand's Critical Uncertainties

New Zealand has its own unique set of circumstances that influence its energy system. These range from its geographic isolation to its primary produce-reliant economy, to its abundant renewable electricity resources.

Many of our key uncertainties aren’t automatically aligned with the rest of the globe and actions taken in the world’s larger economies may bring about very different responses in New Zealand. For example, an international carbon price might actually benefit New Zealand due to the highly competitive nature of the farming sector and a general absence of subsidies.

Some uncertainties, both global and domestic, are important but not necessarily critical to the future of the New Zealand energy landscape.

Performing model quantification analysis with the uncertainties specifically facing New Zealand gives us a clearer picture of how the energy market will evolve.

A large group of New Zealanders working in the energy sector and related disciplines participated in three workshops set up to identify New Zealand’s critical uncertainties and the relationships between them. The group identified 19 critical uncertainties and these were grouped into the specific uncertainties of *external forces*, *domestic economy*, and *energy balance* as well as other less specific energy-related uncertainties.

- **External Forces** –

  1. **International Agreement including pricing carbon.** The approach the rest-of-the-world takes to carbon pricing and the resulting cost of carbon is a critical uncertainty for New Zealand. The nature of any international agreement about the basis on which carbon should be priced and the resulting carbon cost will be factored into on-going decision-making at a government, business and consumer level. Whether New Zealand makes a virtue of its carbon profile or not will depend on how the rest-of-the-world responds and the collective and cumulative effect of decisions made by New Zealand decision makers.

  2. **Impact of climate change on the New Zealand economy, ecology and society’s resilience.** The actual physical impact of climate change is a critical uncertainty for New Zealand. The physical impact is a different issue from the carbon price. New Zealand is a small country heavily dependent on agriculture, horticulture and aquaculture. Those activities are exposed to the geography of New Zealand with its long coast line and high weather variability.

3. **Global stability.** Global stability is a critical uncertainty for New Zealand because as a geographically isolated island nation dependent on international trade and travel, there is a wide range of events around the globe that can have a significant flow-on effect on the domestic economy.

- **Domestic Economy** –

4. **New Zealand's economic structure.** At the beginning of the 21st century New Zealand is a trade-dependent, mixed economy which broadly operates on liberalised market principles. The critical uncertainty is whether New Zealand continues to be primarily produce-based and reliant on its natural endowments as in the early part of the century or whether it will experience a more rapid uplift in the service sector, tourism, IT and other low energy-intensive industries.

5. **Governance and decision making.** We expect New Zealand decision-making will continue to be based on a mix of government policy direction and market-based outcomes. The uncertainty is whether successive governments will err towards a more light-handed or a more interventionist regime. Whichever prevails it will be driven by voters' choices and manifest itself in New Zealand's policy settings. If one critical uncertainty has to be nominated as the most important, it is this one.[30] Where we go as a nation is a result of a combination of global circumstances and the decisions we make in response to the choices or opportunities we face.

6. **Economic growth.** New Zealand's policy settings drive economic growth and, in turn, population growth. Economic growth is a critical uncertainty because the level of growth affects New Zealand's ability to make investments (in infrastructure, environmental rehabilitation, public health services, etc.) and other choices that ultimately reflect the nation's quality of life (retirement age, education, travel, etc).

7. **Population growth.** The level of population growth that occurs (or is allowed to occur) is a critical uncertainty in its own right because New Zealand has a small population in world terms and does not have an unlimited capacity to grow its population. If the population is allowed to grow strongly, the source of the population increase will also be part of this critical uncertainty.

- **Energy Balance** –

8. **Vehicle fleet transformation to non-fossil fuels.** The critical uncertainty for New Zealand's vehicle fleet is the outcome of the rate of conversion to non-fossil fuelled transportation and which fuels or technologies are adopted. New Zealand tends to be a receiver of technology advances but does have choices over fuel types and policy settings that go into the level of vehicle fleet transformation to non-fossil fuels. The outcome for this critical uncertainty is tied to other critical uncertainties - such as energy system-related technology break-throughs and the allocation of natural resources.

9. **Primary energy.** New Zealand's primary energy is a mix of oil, coal, gas and renewable sources used for transportation, commercial and industrial heat

[30] While we believe this is the most critical uncertainty, it is not the only one that creates differences between our two scenarios. For example, differences are also caused by global and domestic economic growth, carbon prices and technology changes.

processes, in buildings, agriculture, and energy transformation linked to electricity consumption. The critical uncertainty is the way New Zealand's energy needs will be served in 2050 and the eventual outcome will be the combined result of the direction a number of domestic and external critical uncertainties take.

10. **International fuel markets.** The way international oil fuel markets will evolve is a critical uncertainty for New Zealand because we are a net importer of oil products. As long as we remain an importer or exporter of crude oil, refined products, and liquefied petroleum gas (LPG), the domestic economy is exposed to the vagaries of the international market.

11. **Extracting hydrocarbons for domestic consumption.** The critical uncertainty is the choice New Zealand will make with regard to extracting the hydrocarbon resources around the country to the extent that it is economic and environmentally acceptable to do so. Future generations may wish to extract hydrocarbons and consume them internally, extract and export them, or not extract them to any great extent.

12. **Technology development, breakthroughs and adoption.** Major commercial technology advances tend to be developed in bigger markets than New Zealand, and on a larger scale. New Zealand selects from what becomes available. The critical uncertainty for New Zealand is more about what technologies are adopted internally than the breadth of possibilities that might emerge around the world. Good choices made by New Zealand have the potential to enhance its competitive advantage.

13. **Energy efficiency.** The critical uncertainty with energy efficiency is a combination of the rate efficiency improves (enabled by technology advances), the degree to which the potential for energy efficiency is realized, and the extent to which any improvements in energy efficiency translate into economic benefits.

- **Other Energy Related Critical Uncertainties** –

14. **Urban form.** The critical uncertainty is the extent to which planners and designers pursue urban density (accessible, inclusive and sustainable ways of living and thinking) or allow urban sprawl (expansion uninhibited by a priority to optimise use of space).

15. **Energy equity.** Energy equity as defined by the WEC is the level of accessibility and affordability of energy supply across the whole population. In New Zealand's case, the issue of energy equity is less about accessibility and more about affordability. The critical uncertainty is the degree to which successive governments prioritise energy affordability over other factors in New Zealand's approach to satisfying its energy needs.

16. **Community acceptance of large infrastructure development and resource utilisation.** The New Zealand public has successfully opposed a number of high profile larger scale infrastructure developments going back as far as the "Save Manapouri Campaign" in the early 1970s. The RMA (in its evolved form) provides a vehicle for such opposition to be heard. The critical uncertainty is whether the community voice will be allowed to be stronger or will become weaker in future.

17. **Nature of digital technology and security.** The critical uncertainty reflects possible outcomes across a broad range of subject areas, for example, smart-grid concepts in the power system, big data concepts and the development of a highly skilled and educated workforce and the degree to which New Zealand embraces and takes advantage of digital technology or not.

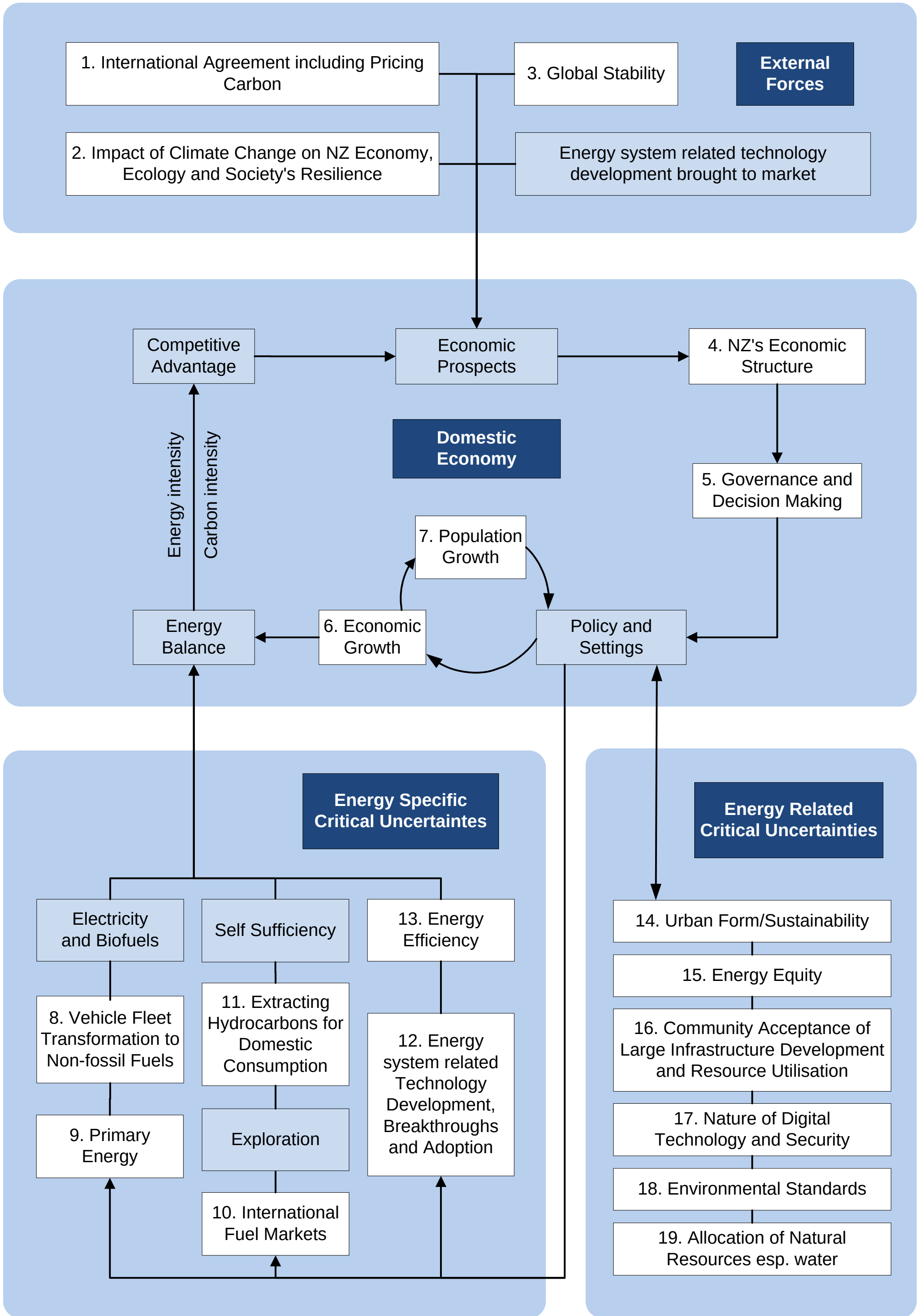
18. **Environmental standards.** The critical uncertainty is based on the notion that as there is often a trade-off between environmental standards and industrial development, whether the degree to which New Zealand society prioritises environmental standards will compromise economic growth where such a trade-off has to be made.

19. **Allocation of natural resources (especially water).** There are many situations in New Zealand where the question arises of who uses natural resources and how they are used. For example, water harnessed for purposes other than recreation may result in physical depletion (irrigation), damming (hydro generation) or pollution (industrial/agricultural waste). The critical uncertainty is how the sustainability and use of natural resources are weighed against the consequential impact on the economy. The RMA currently allows "the benefits to be derived from the use and development of renewable energy", that is, it allows economic benefits, to be taken into account, a provision that could be strengthened or weakened in the future.

The workshops developed a view of the interrelationships between the critical uncertainties as a guide for the narratives. Several elements were introduced to complete the linkages between the critical uncertainties and to make sense of them uncertainties in terms of a whole economic system. The interrelationships and the linking elements are shown in figure 9 below.

The causal relationship between the critical uncertainties is not necessarily instantaneous. The impact of decisions made or external influences might not be felt until long after the event and meanwhile other factors could have changed is an infinite number of permutations and combinations is possible. But in the first instance the eventual outcome will be dependent on how the rest-of-the-world develops. Given what the rest-of-the-world does, the New Zealand specific story will be the result of collective decisions made domestically and the cumulative effect of those decisions.

Figure 9 – Critical Uncertainties in New Zealand and the Interrelationships



Scenario Quantification

As outlined above there is significant value in the process of developing coherent, plausible and distinct storylines about the future - storylines that describe a coherent set of future economic and social drivers of the energy system. The scenario storylines cover aspects such as population, GDP, technological developments, resource availability and energy policies.

There are some outcomes of decisions made in the scenarios which are simply too complex for us to develop by logic and reason alone. Where these can be modelled using optimisation or simulation techniques, the extra step of quantification adds a further layer of richness.

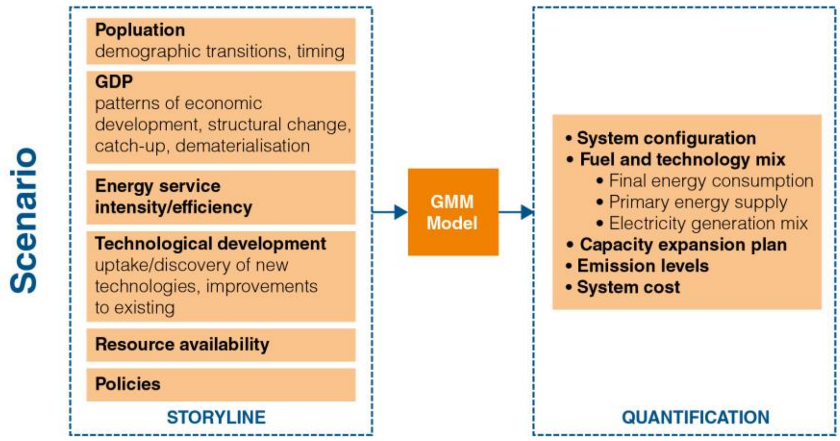
The objective of the BEC2050 project is to assess what the two storylines mean for the energy system. The modelling approach adopted from the WEC scenario work requires that:

- Specific critical uncertainties (for example, carbon price) are assigned numerical values and combined with other energy system modelling parameters (for example, energy resource availabilities and costs, which may themselves be critical uncertainties).
- These values are applied to a deterministic optimisation model which represents the approximate decisions made by consumers and producers in the energy system, over the time frame 2015-2050.

The output of the GMM model is a time series of energy extraction, production, trade and consumption decisions across the full energy value chain for each scenario. It does this for eight regions around the globe.

Figure 10 – Scenario Quantification using the GMM MARKAL Model

Source: WEC (2013)



The main advantages of using GMM are:

- It is based on a highly respected and robust modelling framework, which has been peer reviewed and applied in 77 institutions and 37 countries over the last 40 years.
- By being a multi-regional model, the evolution of New Zealand's energy system is modelled dynamically in a global context. Most importantly, trade flows of energy

commodities, (coal and oil, with the potential for liquid natural gas (LNG) can be established simultaneously with those other regions.

- Core assumptions about global parameters for example, trading partner GDP growth, have already been developed by the WEC through its scenario modelling project.

- It models the energy system in sufficient detail to add granularity to our understanding of decisions made by consumers and producers.

However, when interpreting the results, it is important to understand:

- The model is deterministic: every investment decision is made with perfect foresight regarding future outcomes of key critical uncertainties. Hence investment risk cannot be considered as part of the model.

- The model is a linear optimisation: complex dynamics such as first-mover advantage, entry deterrence, and consumer preference, must be highly simplified in order to be accounted for.

These considerations do not invalidate the modelling approach; rather they are the necessary result of making modelling tractable and are typical of many of the decision support models used worldwide in many industries. These limitations must be understood when interpreting the model output.

However, the opportunity to use a robust, internationally recognised modelling approach, in partnership with the WEC and modelling partners the PSI, gave the BEC a unique ability to quantify the potential impact of critical uncertainties on the evolution of the energy system.

Model Inputs

In order to quantify the impact of our 19 critical uncertainties, on the energy system, the linkages in figure 6 need to be integrated with the GMM model. The critical uncertainties were effectively separated into three categories (Table 1):

- Uncertainties which could take on a numerical value and be entered into the GMM model as an input parameter.

- Uncertainties which could not be quantified but help inform the likely value of input parameters.

- Outputs or outcomes of the modelling.

Table 1: Categories of Critical Uncertainties

Context for Inputs	Input Parameters	Outcomes
Impact of climate change on New Zealand's economy	International agreement including carbon prices*	Vehicle fleet transformation to fossil fuels
Economic structure	Global stability*	Primary energy
Governance and decision making	Economic growth	International fuel markets*
Urban form/sustainability	Population growth	Extracting hydrocarbons and use domestically
Community acceptance of large infrastructure	Energy system technology breakthroughs*	Energy system technology adoption
Environmental standards		Energy efficiency
Allocation of natural resources (water)		Energy equity
The nature of digital technology and security		

Note: * denotes inputs adopted directly from the WEC scenarios.

The Use of WEC Inputs

An important consideration in integrating New Zealand into a global model (developed by the PSI) is ensuring that the modelling parameters are sufficiently relevant to New Zealand.

Clearly, assumptions describing economic and population growth, energy resource availability, and energy consumption (transport, heat and electricity) are all unique to New Zealand. Further, New Zealand's energy resources have capital and operating costs that are specific to New Zealand. These values have been derived for New Zealand by the BEC and entered into the modelling. More detail on the assumptions used is provided below.

For the vast majority of other parameters relating to technology, we adopt the values assumed by the WEC in its 2050 scenario study. This is appropriate, given that - other than the specific situations outlined above - New Zealand is largely a technology taker.

Below we present the assumptions developed for the BEC2050 project. All figures are in $NZD using an exchange rate of $NZD1.00/$USD0.65 and all figures are real with base-year 2010.[31]

[31] Real figures removes the effects of underlying inflation, and hence must be referenced to a particular base year (in this case 2010).

Table 2: BEC2050 Model Inputs and Assumptions

	Kayak	Waka
Population	Higher population growth - Increasing at 0.9% per annum; 6.1m by 2050	Lower population growth - Increasing at 0.6% per annum; 5.5m by 2050
GDP	Higher GDP growth at 2.1% per annum	Lower GDP growth at 1.6% per annum
	Per capita GDP increasing at 1.3% per annum	Per capita GDP increasing at 1.0% per annum
Carbon Prices	Rising to $60/tCO_2$ in 2050	Rising to $115/tCO_2$ in 2050
Oil and Gas Exploration	5% reduction in exploration costs against global exploration costs	Global exploration costs
Coal	Coal-to-liquids (CTL) without Carbon Dioxide Capture and Storage (CCS) constrained out	Constrained to current coal production.
Transportation	3% reduction in motorisation in light vehicle fleet	5% reduction in motorisation in light vehicle fleet
	Constant VKT/car of 12,000	VKT/car reducing to 9,800 by 2050
	LNG/LPG as light fleet fuel constrained	LNG/LPG as light fleet fuel constrained
		5% reduction in total light fleet passenger kilometres travelled through a switch to alternative modes
Electricity Generation	MBIE EGDS	MBIE EGDS
	Large scale hydro deployment constrained	Unconstrained deployment
Solar Photovoltaic (PV)	$4/Watt installed and 13%-15% solar efficiency	$4/Watt installed and 13%-15% solar efficiency
	50% real cost reduction over horizon, but faster than Waka in mid-years	50% real cost reduction over horizon, slower than Kayak in mid-years

	Kayak	Waka
Electric Vehicle Battery Costs	$460/kWh in 2010 falling to $160/kWh by 2050; faster reduction in earlier years than Waka	$460/kWh in 2010 falling to $160/kWh by 2050; slower reduction in earlier years than Kayak
Energy Efficiency	Energy efficiency uptake driven by price and expected technological development	Policies introduced to encourage uptake of high efficiency appliances; reduction in use of coal boilers, etc
Biofuels Subsidy		20% price subsidy

5. Using the Scenarios

The BEC has developed

- A **Kayak** scenario in which markets drive supply chain decisions and innovation, with business and consumers making informed decisions in their own interests based on price and quality (including environmental quality).

and

- A **Waka** scenario in which changing global circumstances and heightened environmental awareness drive business, consumers and government to make decisions in the national interest.

These scenarios deliberately describe clear boundary conditions for where New Zealand could find itself in 2050 but will not, in reality, reflect the bright-line distinctions we have attributed to each of them. The scenarios are deliberately meant to challenge New Zealand's future.

In being so designed, the scenarios provide a basis for making long-term planning and investment decisions. They are intended to give stakeholders from government and business a means of testing policy and investment decisions against each scenario, and understanding the trade-offs associated with their decisions. As they are equally plausible, they allow for the testing of decisions – what would each scenario trigger us to do as an organisation or nation but are they robust and resilient to either situation eventuating? Or are they dependent upon one of the scenarios coming true?

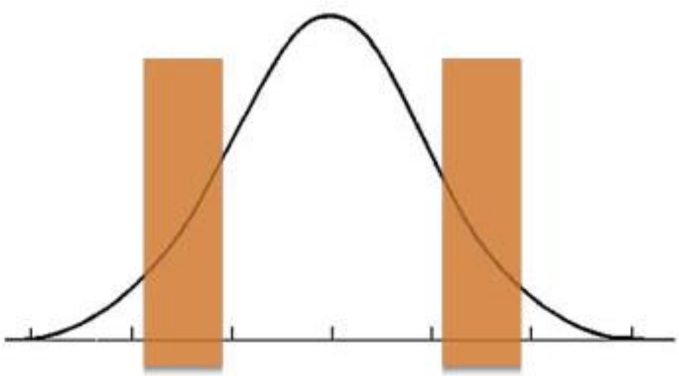
The world is littered with examples of what happens when governments or businesses place too much emphasis on a particular outcome becoming reality. One can see how Transpower in the 1990s over-weighed the future likelihood that the importance of the national grid would diminish as a future dominated by distributed generation would unfold. A decade of under-investment with a subsequent decade of substantial catch-up investment was the result.

While the scenarios are characterised as two edges or extremes, the true result will lie somewhere in between. We do not, of course, know how reality will play out. How the world and New Zealand interacts and reacts in, for example, a $60/t or $115/t carbon scenario requires complex real life decisions. Whether or how fast a certain technology emerges will be the result of a complex range of factors. We do not know the answer. By their very nature, scenarios in general are "grey" because both governments and markets are capable of making good and bad decisions.

The scenarios are not a pathway or a bundle of initiatives from which the "desirable" elements can be chosen as if they are a "pick-and-mix" option list. You might like markets but also want the more rapid electric vehicle (EV) uptake. The benefit of each scenario is that it embodies a unique and coherent mix of economic, environmental, cultural and social institutions and behaviour. To cherry-pick elements from the scenarios undermines the value of the integrated storylines and they become predictions. To be analytically robust, choosing a particular critical uncertainty to underpin the storyline requires a new internally coherent, plausible and distinct story to be told, along with its accompanying institutions and behaviour.

The scenarios and their results can be compared to the standard deviations of a bell-curve as shown in figure 11 below. The scenarios, and their modelling results are reflected in the “tails” of the curve. We suggest that both scenarios are equally likely. But in reality, investors and consumers will attach their own weightings and make their own judgments. The decisions they make will almost inevitably result in a future that navigates a course between the edges.

Figure 11 –The Edges of the Scenarios as ‘Standard Deviations’



Users of these scenarios will bring to them their own views on such factors as risk, market behaviour, and political/societal pressure that will, in practice, see the clarity of the sometimes sharp distinctions between our stories and modelling results begin to blur.

This does not diminish the usefulness of what we have done, rather it places it into context – decision-makers must inevitably apply their judgment to these matters and our goal is to help inform that judgment.

In charting such a course away from the edges, will we get the best of both worlds with the markets reflecting a citizens’ consensus on social equity and energy sustainability, and governments doing what only governments can do to achieve the goals? The alternative is the worst of both worlds: governments making economically sub-optimal policy decisions and consumers focusing on short-term price signals and self-interest, thus increasing both energy poverty and atmospheric CO_2 levels. Our model can only make a "correct" decision; reality will play out differently.

Therefore, while each of the scenarios has its own internal logic, neither scenario is intended to be superior to the other, neither is “right” or “wrong”, and there will be winners and losers, successes and failures in both cases. By the same token, neither of the scenarios is absolutely good or bad in all the three dimensions of the Energy Trilemma. But importantly, neither do the scenarios require a “magic wand”. They are deliberately intended to stretch but not break the bounds of plausibility.

6. BEC2050 Narratives: Kayak

At the heart of this scenario – markets drive supply chain decisions and innovation, with business and consumers making informed decisions in their own interests based on price and quality (including environmental quality).

Kayak Snapshot

Kayak defines New Zealand's experience to 2050 under a rest-of-the-world Jazz scenario. In Kayak, consumers and suppliers determine outcomes through market forces, while government focuses on establishing strong competitive frameworks relying on the pursuit of least cost energy supply.

Free trade and higher global economic growth drive an export expansion in our traditional primary sectors, as well as in services and high-tech manufacturing. New Zealand's "clean and green"[32] image and economic opportunities draw people to the country, resulting in higher net immigration and a vibrant domestic economy. Growth is concentrated in increasingly sprawling cities as well as regional hub towns.

A global deal on climate change is agreed but international commitments on reducing emissions are weak, lacking breadth and depth. Carbon markets develop but are fragmented across ad-hoc regional and national schemes. Consumer preferences for renewable-sourced energy and environmentally friendly goods and services go some way towards filling this void, which sees market-led action across a wider front where this is commercially viable.

At the global level, a lack of co-ordination on climate change and relatively low carbon price results in missed mitigation opportunities. Economic growth that is achieved in the short term is therefore effectively borrowed from younger generations who will face higher costs of adaption, social and cultural change, and significant economic volatility post 2050.

Development and adoption of technology within global energy markets is determined by price and access to supply, but our abundant renewable energy resources allow for more sustainable economic growth. Technology has the greatest impact on the land transport sector through the uptake of more efficient internal combustion engines (ICEs), non-plug in hybrids, and bio-diesel.

[32] Referring to New Zealand's relative low levels of pollution and environmental degradation, and outstanding natural features.

Setting the Scene: New Zealand's Place in a rest-of-the-world Jazz Framework

Greater Global Growth and Integration

Global average annual GDP growth to 2050 is 3.5% per annum. This reflects a strong focus on growth across world markets. The global population grows to 8.7 billion by 2050, which while substantial, reflects a moderation in fertility rates driven by higher incomes and higher education levels. Of direct relevance to New Zealand is the growth in Asia, with the main engines of growth in the region being China and India.

Trade liberalisation progresses in the absence of material carbon prices or widespread adoption thereof, and there is significant progress in reducing international trade barriers (primarily through the World Trade Organisation [WTO]), including for environmental goods and services. Trade activities between countries increase on the back of sustained demand growth, especially from China, India and Brazil. New Zealand governments continue to pursue high-quality multi-track trade agreements, to secure better terms of trade for our exports. These seek to further liberalise capital and labour markets, resulting in an expansion of foreign direct investment and trade in services.

A Weak Agreement on Climate Change

In a Jazz world, governments broker a global climate change deal but it is not comprehensive and has weak commitments on emissions targets and obligations. While there are short-term economic gains arising from this decision, these are at the expense of longer term economic and social development which will be influenced by the high cost of climate change.

Carbon markets do grow, albeit slowly, from the bottom up, based on national, bilateral, and regional initiatives. As local markets develop, opportunities to integrate with larger markets are pursued to increase liquidity and homogeneity of carbon pricing. The initial focus is on merging with the markets of our most important trading partners.[33] However, in the absence of a comprehensive global framework, the patchwork of arrangements that emerges is ad-hoc and fragmented. Carbon markets are therefore not universally accepted and not all trade-competitors face a price on carbon.

By 2050, carbon prices in New Zealand reach \$60/tCO_2 (\$2010 real).

Our Kayak Story

Government Facilitates Markets

In the absence of a persuasive global mandate to address climate change, New Zealand governments turn towards markets to drive the uptake of new low-carbon and energy-efficient technology. There are no direct or indirect support mechanisms for these technologies apart from the modest carbon price. Instead, government policy focuses on reducing barriers to the private sector and on further liberalising markets to drive competition and more cost-reflective pricing. All energy sources, like all commodities, must compete on price, quality and supply.

[33] For example, China, which expects to establish a national ETS, becoming the world's biggest by 2016.

In electricity, the current framework underpinning competitive electricity markets is strengthened with a continued focus on removing competition barriers and distortions to efficient investment in new technologies. This drives further innovation and competition, placing greater downward pressure on prices.

Markets and technology improvements deliver more affordable energy over time, which when combined with rising national incomes (discussed below) results in improvements to energy affordability.

The principle of sustainability remains enshrined through the RMA but legislation is developed to ensure that economic benefits are more readily taken into account. New Zealand develops its existing ETS to best position our exports, with exemptions for agriculture and transitional features removed only where international competitors and export markets make similar commitments.

Demographic and Social Change

While population growth has moderated globally in a rest-of-the-world Jazz scenario, increasing economic integration sees capital and labour flow more freely from the Asia-Pacific region. New Zealand becomes a more desirable place to live and invest (relative to other Asia-Pacific countries suffering from pollution and over-crowding) with perceptions of the country as non-corrupt and safe, with a high standard of living and outstanding natural features. This is driven by:

- Our increasing growth rate in per capita GDP.
- An open stance toward immigration, which seeks to address shortages of skilled labour in key high “value-added” sectors.
- Migrants and returning expats favouring New Zealand as a desirable place to live.

Immigrants are predominantly young and wealthy students, professional couples, and families arriving from across the Asia-Pacific region. This moderates the impact of our aging population and reinforces New Zealand’s ethnic diversity with growth in Pacific and Asian ethnic groups. Maori and Pacific ethnic groups also grow as a result of higher fertility rates, with overall fertility rates reaching 2.3 children per woman by 2050. The wealth and investment brought into the country by migrants creates new jobs and economic opportunities.

New Zealand’s population grows to 5 million in 2025 and 6.1 million by 2050.[34] This equates to an average rate of population growth of 0.9%, slightly down on historical growth of 1.1% since 1992.[35]

Immigrants largely seek out work in New Zealand’s main urban centres, which provide important social connections. To accommodate this growing urban population and to alleviate resulting housing pressures, cities open up greenfield land on the urban fringe for development. This urban sprawl makes public transport less effective and puts pressure on already constrained roading, water, sewerage and storm water networks. Increases in rates and charges are inevitable to cover development costs.

[34] Based on Statistics New Zealand, 2014 10th and 90th percentile population projections to 2068.

[35] Statistics New Zealand, 2014 population estimates.

The focus remains on private vehicles as the primary means of transport but vehicle ownership rates from private vehicles reduce due to the changing attitudes of migrants and millennials (that is, “Generation Y”).

The current trend of rural population decline continues across heartland New Zealand. However, this is offset by an increasing demand for skilled labour, management and entrepreneurs to support the primary sector export expansion. Wealthy rural support towns grow to support this workforce and have an increasing importance in the rural economy.

A Vibrant Domestic Economy

Asian markets dominate our exports in 2050, while Australia, North America and the European Union (EU) continue to be significant export markets. The rapidly growing nations in East Asia continue to drive towards a more protein-oriented diet, underpinned by an expanding and more wealthy middle class, increasing the demand for major exports such as meat and dairy products. The agricultural sector expands on the back of this development and there is a move up the value chain to meet rising demand for premium goods from more wealthy consumers.

New Zealand’s international competitive advantage continues to be driven by demand for products from its traditional highly-efficient agricultural sector. This is supplemented by a growing services sector and hi-tech manufacturing. However, in a highly competitive international environment, New Zealand businesses must compete vigorously on price, quality, and reliability. In the face of such stiff competition, particularly from low wage economies, exporters focus their limited resources on moving up the value chain to produce premium goods and services. In pursuing higher margins, exporters seek to drive efficiency and innovation into production processes, while new products and services are brought to market on the back of local research and development (for example, agriculture research, biomedical, and information technology and systems). Significant investments in technology and capital goods are made to support these initiatives.

The country’s open, non-corrupt way of doing business allows us to move quickly and aggressively into newly liberalised markets, through marketing our intellectual property and top talent in specialist areas. Our experience with operating high levels of renewables generation leads to opportunities to export our expertise. Similarly, our productive primary sector provides opportunities to export our knowledge and experience to developing countries where this experience is highly valued, particularly in Asia. These opportunities provide us with a foothold to move into investing in overseas markets and further up the supply chain, where it is strategic to do so.

We remain reliant on imports used as inputs to production, including capital equipment, petroleum and raw materials. Imports are supported by our liberal approach to trade and by 2050 all goods and services crossing our borders are free of economic tariffs (excluding, for example, social tariffs, such as on alcohol and tobacco).

Growth in exports, services and immigration fuel a vibrant domestic economy in which businesses thrive. Employment and demand for skilled labour rises. The retail and commercial sectors grow on the back of rising consumer wealth (from immigration, wage growth, and export profits). However, the retail sector struggles to achieve scale on e-commerce platforms against global firms, focusing instead on niche and premium offerings. The tourism sector expands on the back of a more highly-integrated global economy as well as from international linkages from migrants and foreign students.

As owners of substantial amounts of natural resources, the Maori economy flourishes in this heightened economic environment. Maori iwi and hapu groups that are able to commercialise their assets (worth $36.9bn in 2010[36]) and interests are well placed, particularly where they are custodians of:

- Renewable resources that can be used for energy generation (that is, water, land and sea).
- Agricultural, forestry and fisheries assets.
- Urban land that can be developed.
- Outstanding natural features of interest to tourists.

Domestic GDP growth averages 2.1% per annum supported by a combination of factors, including:

- Increasing demand from wealthier Asian economies for our exports.
- Domestic population growth on the back of our open immigration policies.
- Competitive energy prices.
- Liberalised foreign direct investment (FDI) and labour markets providing additional opportunities to invest for local (outward) and foreign businesses (inward).

GDP per capita increases at 1.3% per annum, with economic growth and wealth centred in the cities and rural hub-towns. Economic volatility increases at the end of the period as the costs and impacts of climate change bear down. These effects progressively erode the natural resource stocks that underpin the economy and become a drag on economic growth and development post 2050. The high historic rates of economic growth are not sustainable in the longer term as the post 2050 impact of climate change is realised.

Environmental

Consumer Driven Sustainability

In the absence of concerted global efforts by governments to mitigate climate change, businesses and consumers take the lead.

Consumers focus their attention on the broader environmental footprint of products, such as water use, animal welfare and greenhouse gas emissions. Notably, the buying power of millennials starts to have a significant influence on commercial service product offerings. This generation is more likely to:

- Pay for responsibly made products.
- Work for companies that care about their environmental impact.
- Use public transport and bicycles.

[36] BERL and TPK, 2011, "The Asset Base, Income Expenditure, and GDP of the 2010 Maori Economy" http://www.tpk.govt.nz/_documents/taskforce/met-rep-assetbaseincexpend-2011.pdf.

- Support environmental initiatives and policies.[37]

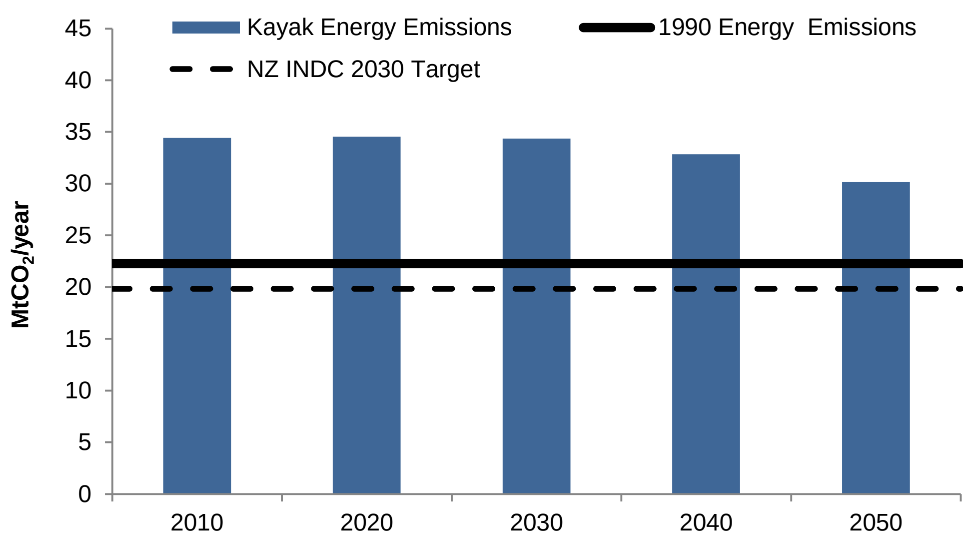
As the consumer voice is heard, investors are forced to consider the environmental effects of their investment decisions, which increasingly influence shareholder returns. New Zealand exporters, being at the start of a global supply chain, are also required to be accountable for the breadth of their impact on the environment (for example, food miles, carbon content labelling) to meet consumer demand.

Consumer demand drives growth in services and products from organisations which are able to operate sustainably and responsibly and disclose information about their performance. For instance, the dairy sector, while initially exempt from carbon charges on ruminant methane emissions, must manage consumer interests on a range of sustainability measures. These sectors respond by investing in research and development and environment-friendly practices and technologies which form part of the overall sustainability story presented to consumers.

Ultimately, however, action by businesses and consumers do not reach the step change many think is required to avoid substantial climate change-related economic and environmental damage.

Without a strong, co-ordinated global impetus to mitigate climate change, New Zealand's energy emissions are held constant until 2030, in part due to the impact of a moderate carbon price and in part due to the consumer-led response to climate change. After 2030, substitution of oil and gas with renewables energy and electric vehicles begins the process of reducing energy-related emissions later in the period (figure 12 below).

Figure 12 – Energy Related Carbon Emissions (million tonnes of CO_2 per year)



Water – Food – Energy Nexus

Decisions over water use, food production and energy generation are inextricably linked and become more important as economic and environmental pressures grow.

37 Pew Research, 2014, "Millennials Most Sustainability-Conscious Generation Yet, But Don't Call Them 'Environmentalists'", http://www.sustainablebrands.com/news_and_views/stakeholder_trends_insights/aarthi_rayapura/millennials_most_sustainability_conscious.

Irrigation is used extensively to increase agricultural yields and to facilitate new dairy conversions, herd management practices and land being opened up to pasture. More frequent droughts as well as demand for water from irrigation and a growing population place greater pressure on water resources and water quality. This reinforces consumer signals to innovate, both on and off-farm.

To address these pressures, water markets develop, with access quota rights openly traded amongst participants. This develops slowly, due to central government reluctance to intervene to reconcile tensions between water consumers, iwi and other interested parties. Consumer and supplier preferences also provide the impetus to progress initiatives that address water quality concerns and drive more efficient water use practices.

New small hydro projects proceed where there are synergies with irrigation schemes. However, there are few opportunities for new large-scale hydro generation to proceed, due to increasing costs (for example, for water use) and a growing social intolerance of large scale hydro (that is, due to adverse effects on lakes, rivers and local communities), which make it more difficult to gain resource consents.

Adaptation

The failure at a global level to mitigate the worst effects of climate change (through global emissions reductions) results in rising temperatures and sea levels over the long-term. This increases the risks of serious and continued damage to the country's economic prosperity and way of life, which today's younger generation must pay for.

The worst effects of climate change do not crystallise until after 2050 (beyond the end of the Kayak scenario). Nevertheless, New Zealand needs to make significant preparations to adapt to meet this challenge, particularly in relation to coastal infrastructure and urban developments and to adapt to the impact of changing weather on the horticultural and pastoral sectors.

For instance, the country's major population centres, being situated near the coast, are prone to rising sea levels, with many homes and businesses at risk of being forced to move inland from low-lying areas. Adaptation is planned for where it is considered economic (in the low-lying economic centres of Auckland, Wellington, Tauranga, etc), is funded privately by household and corporate investments and publicly through rates and general taxes. The agricultural sector is also likely to be severely affected through an increasing prevalence of droughts, storms, and floods, either constraining future export production and GDP growth or resulting in significant adaptation costs.

While adaptation costs are likely to occur post-2050, major adaptation planning is initiated later in the period as fear of the impacts of climate change grows. This is driven by observations of the impact of climate change in more vulnerable regions of the world (for example, low-lying areas). In later years, this fear also prompts an increasing number of climate-conscientious consumers and corporates to voluntarily off-set their carbon emissions and adopt cleaner technologies.

Regardless of these modest efforts, the world is already committed to some level of climate change on account of historical greenhouse gas emissions. Some of these impacts will happen pre-2050 regardless of efforts to curb emissions in the short to medium term. For example, the "time spent in drought in eastern and northern New Zealand is projected to double or triple by 2040", and "the days with 'very high' and 'extreme' fire danger in some locations are estimated to increase by up to 400% by

2040."[38] The impact on GDP prior to 2050 is relatively low at the national level. However, the economy does start to butt-up against resource constraints as natural resource stocks are eroded. There are winners and losers, with some regions benefiting from possible temperature and weather changes (making them more productive) while other regions suffer from lower levels of productivity, exacerbating regional decline.

Our Kayak Energy Future

Energy Intensity

New Zealand's energy intensity continues to decrease at recent historical rates (that is, 1.7% per annum). This reflects:

- Greater growth in the service/commercial sector, relative to the industrial sector (which traditionally has a high energy intensity).
- Energy efficiency investments in the industrial and primary sectors (ie agricultural, forestry, and fishing) where this is commercially sensible.
- Growing consumer demand for energy efficient products and vehicles.
- A move up the value chain which, while usually associated with greater energy use, is more than offset by the higher GDP value and energy efficiency improvements. In the case of dairy, higher valueadded products typically use less energy to produce (that is, cheese, UHT, etc).

Energy system-related technology breakthroughs and adoption occur on an evolutionary basis. Increasing consumer-led initiatives (for example, technologies that help manage consumers' costs) drive incremental technology deployment, as does the drive for a more robust, secure and efficient power system.

Cumulative energy efficiency improvements reduce energy consumption by 231PJ[39] over the next 35 years. This equates to a 25% reduction in 2050 consumer energy demand.

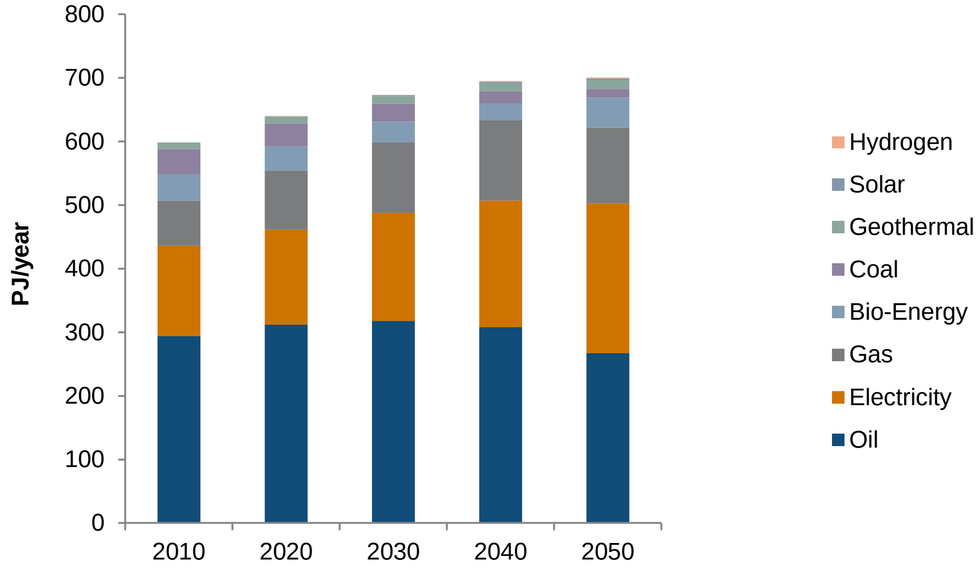
Energy Mix

Energy demand increases 0.5% per annum on average between 2010 and 2040, to nearly 700PJ, where it remains constant to 2050.

[38] IPCC Fifth Assessment Report, Chapter 25.

[39] In line with international convention, the majority of our charts use the peta-joule (PJ) as the unit of measurement of energy. One PJ is equivalent to the annual electricity consumption of around 25,000 households, or the energy contained in 170,000 barrels of oil or the electricity generated by a small (40-50 MW) hydro-power plant in one year.

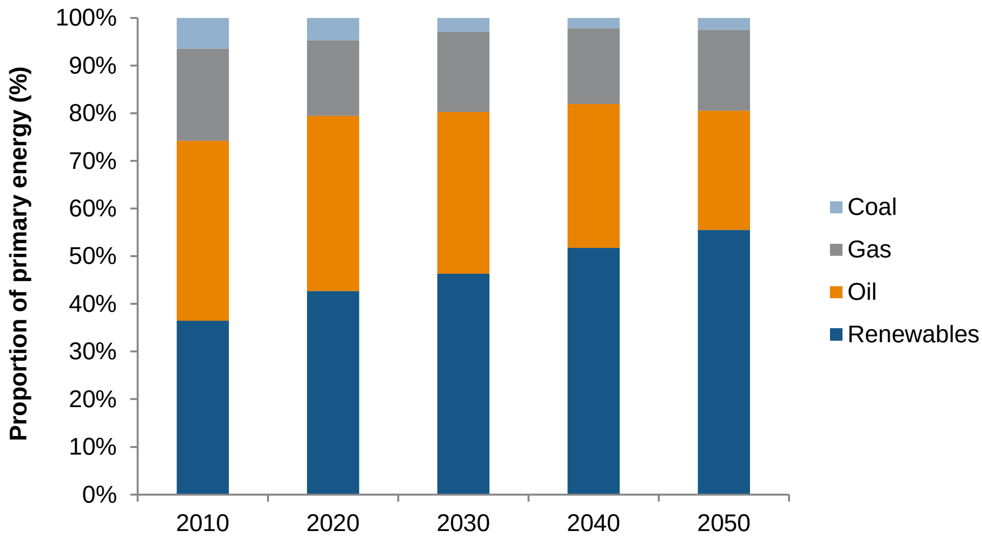
Figure 13 – Total Consumer Energy[40] (Energy Output – PJ/year)



New Zealand's fuel mix highlights a declining reliance on fossil fuels (in particular, for oil and coal). Consumption of oil peaks in 2030. Its contribution diminishes thereafter, being increasingly substituted by electricity, hydrogen and biofuels (each supported through a growing base of renewables). Gas consumption grows albeit remaining constant as a proportion of total supply. Coal demand declines throughout the period, representing only 2% of consumer energy by 2050.

Overall, hydrocarbons remain an important primary fuel source with oil, gas and coal still comprising 45% of primary energy inputs in 2050.

Figure 14 – Total Primary Energy Proportions (Energy Inputs)



[40] The 2010 Total Consumer Energy figures provided by the PSI for New Zealand are based on the IEA Statistics for NZ. However, the PSIs figures differ from MBIE's figures as reported in their "Energy in New Zealand" publication, for two main reasons. Firstly, the PSI includes oil in aviation and marine bunkers (approximately 46PJ) and fuel used in blast furnaces (13.5PJ) in their consumer energy figures. Secondly, they allow the model a 4% deviation from actual statistics in order to obtain a feasible solution in the first year.

Despite continued government support for exploration, there are limited new oil reserves discovered and brought to market. Domestic oil production reduces significantly as a result, from 115PJ in 2010 to 16PJ in 2050. Net oil imports increase initially to meet domestic demand for oil but both demand and imports peak in 2030 as oil is displaced by other fuels.

Domestic gas production remains constant over the period at approximately 160PJ, but is insufficient to meet demand for gas in later years. An LNG terminal is constructed in the late 2040s to address this supply imbalance, supporting a further 35PJ of gas demand. The business case for this investment is supported by an oversupply of gas in world markets, which in turn results in relatively cheap gas and investments in LNG shipping and terminal capacity.

Annual coal (including lignite) production increases by 115% by 2050 to 257PJ. This is almost exclusively exported to meet global demand for steel and power generation (mainly in developing countries). International demand for coal is driven by coal-fired power generation combined with CCS, which becomes more economic and is adopted globally. In New Zealand, with our relatively cheap renewables, coal power generation with CCS is initially less economic. However, by the mid-2040s most cheap renewables are exploited and advances in technology make it possible to develop coal-fired generation with CCS.

Early versions of the Kayak baseline scenario saw CTL introduced early in the forecast period. This solely reflected the relative economics of various technologies in a rest-of-the-world Jazz/ NZ Kayak world. CTL does not appear in Waka. While we accept that it may be economic to invest in CTL in the future, this would need to be accompanied by CCS to address investor uncertainty over oil and carbon prices (given the large amount of associated emissions) and broader social concerns. For this reason the BEC decided to constrain CTL in the final Kayak baseline scenario but the impact on the Kayak scenario if CTL had not been constrained is shown in the following box.

Kayak Tipping Point: Coal to Liquids without Carbon Capture and Storage (CCS)

CTL becomes economic relatively early in the forecast period and is used to produce first methanol, then petrol and diesel, for use in transport and other applications.

Refining capacity progressively expands from 2030 and by 2050 CTL accounts for 28% of all refined fuels. CTL fuels compete directly with oil refined fuels as well as biofuels. This results in slightly lower production of petrol and diesel at Marsden Point. However, biofuels are unable to compete and are completely eliminated from the energy mix, due to the relative economics of source inputs and economies of scale.

Bio-diesel is therefore not used in transport. Cheaper CTL-based fuels also crowd out the uptake of EVs, although this is offset by greater uptake of hybrid vehicles able to use CTL refined fuels. The reduction in EV uptake reduces electricity generation output by 4% but total liquid fuel use (that is, CTL and oil refined) increases by 16%. There is no change in the use of ICEs.

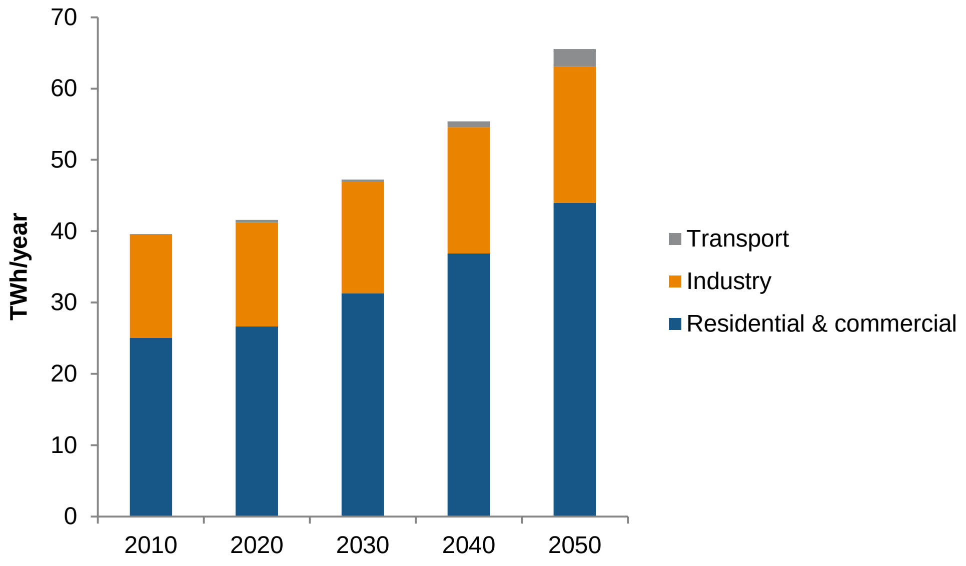
Domestic coal production and imports are on average 29% and 5% higher over the period with CTL, when compared with the Kayak baseline. The profile of domestic oil production is affected by CTL but on average is unchanged over the period. However, oil imports reduce by 3% (relative to Kayak baseline) in response to a declining demand for oil as a fuel feedstock. Overall, New Zealand's net hydrocarbon imports fall by 12% between 2010 and 2050 as oil imports are reduced.

An additional 7 million tonnes of CO_2 are emitted in the CTL refining process. Overall the CTL investment decision adds 19 million tonnes of CO_2 to energy emissions (compared with the baseline Kayak), including from increased transport-related carbon emissions.

Electricity

Electricity demand increases on the back of GDP growth, with consumption dominated by the traditional industrial and residential/commercial sectors.

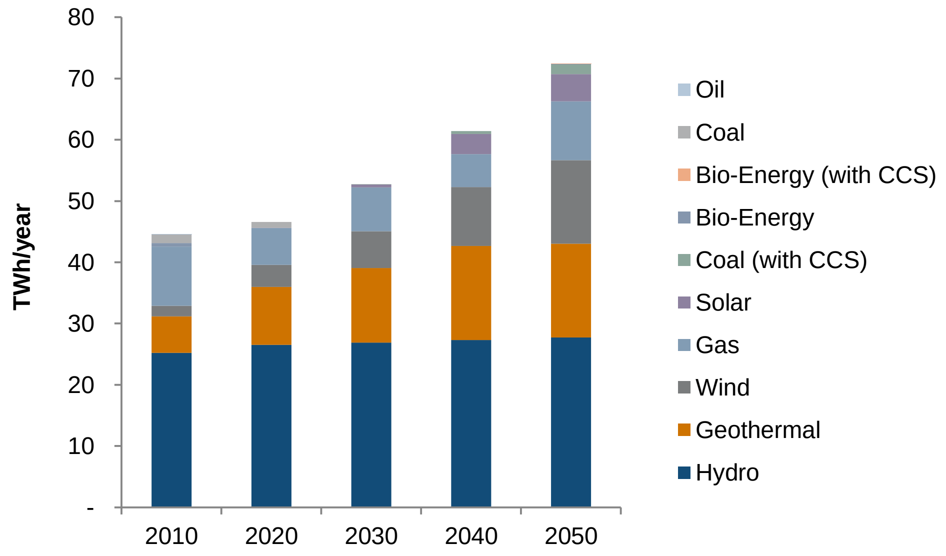
Figure 15 – Electricity Consumption by Sector (TWh/year)



Demand growth is highest in the residential sector (for example, where population growth manifests itself more directly) and the industrial sector (for example, largely due to irrigation and agricultural demand). Electric vehicle uptake is modest at first, but by 2050 comprises 4% of electricity demand.

Electricity generation increases by 63% between 2010 and 2050 to 72,000 GWhs to meet demand.

Figure 16 – Electricity Generation by Type (TWh[41]/year)



[41] With electricity production, we do not use the conventional unit of energy (PJ) but instead revert to TWh (tera-watt hour). To put this into context, 1TWh of electricity is approximately equivalent to the annual consumption of 130,000 households, roughly ¾ of the number of households in the Greater Wellington region. A 150 MW hydro power plant operating for around 6500 hours in a year will generate 1 TWh of electricity.

New Zealand's electricity mix is driven by the relative economics of each conversion technology and its fuel. Thermal gas-fired generation is less competitive with renewables until 2040 due to the increasing influence of carbon prices, with several plants closing over this period. However, gas makes a comeback in the final decade as relatively cheap renewable resources are exhausted and cheap imported gas comes on stream through the new LNG terminal.

Growth in production is achieved through continued growth in geothermal capacity, increasing levels of wind penetration, and incremental net hydro additions. This continues recent trends in New Zealand, where these renewable sources of electricity dominate recent additions to the country's generation portfolio.

Uptake of solar also starts to accelerate from 2040 to 2050, with roof-top solar on around 1 million homes and contributing 6% of supply by 2050. Solar PV uptake is heavily reliant on technology costs decreasing at a global level and is naturally lower in New Zealand due to lower overall levels of solar efficiency (due to lower sunlight intensity and sunlight hours from our more southerly latitude). Evolutionary technology developments and cost reductions in batteries also increase the viability of solar PV, given the need to meet residential night and winter peaks.

As discussed, hydro generation operates collaboratively with irrigation, with new small-scale hydro commissioned where synergies exist. Other forms of renewable generation also become relatively more economic (for example, wind technology costs are expected to fall over time).

Coal-fired generation is eliminated from the generation fleet in the 2020s, but makes a return in the 2040s with 450MW of coal-fired generation and CCS being developed as this technology matures. [42] The plants store over 1.2Mt of carbon dioxide per annum in underground geological structures (for example, disused gas fields and mines).

Renewable penetration reaches 91% by 2020 but falls back to 84% by 2050 with the introduction of gas and coal with CCS.

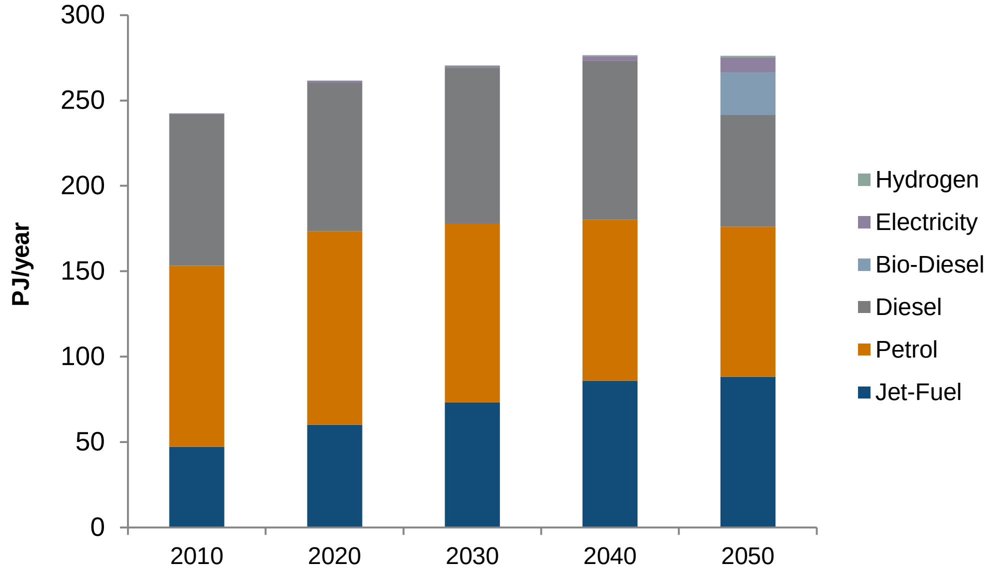
Transport

Urbanisation and the different travel behaviour of migrants and millennials reduce vehicle ownership rates 3% by 2050. However, population growth overrides this effect and total vehicle kilometres travelled per annum increases by 57% by 2050.

Despite this, there is an overall decline in land-based fuel use as diesel and petrol ICE vehicles become more efficient and hybrid vehicles are introduced en masse to the light vehicle fleet. This contributes to a 16% fall in energy consumption for personal car use. However, at the same time there is a 17% increase in energy consumed for other land transport uses including freight, reflecting increased use of public transport (spurred by a more dense urban form and changing travel behaviour) and heavy transport (to support economic growth).

[42] After the modelling had been completed and Genesis Energy announced the retirement of its remaining two Rankine units by the end of 2018. For further information on the impact on this announcement see footnote 54.

Figure 17 – Fuels in all Transport (PJ/year)

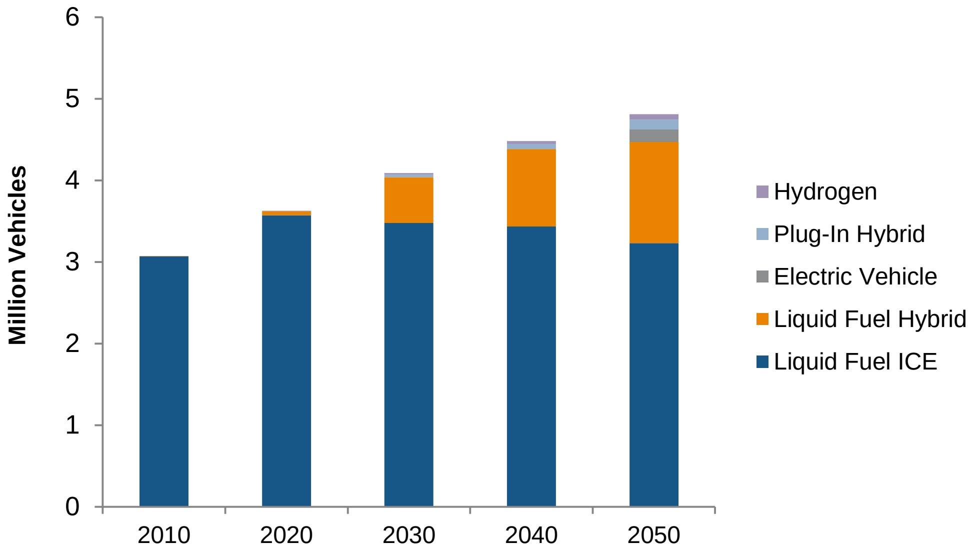


The consumption of jet fuels increases by 87% between 2010 and 2050. This reflects the higher level of international travel but is partially offset by engine efficiency improvements. In particular, the number of flights grows to support immigration, foreign students, exports of fresh food (for example, fresh fish and vegetables), and tourism, which expands due to an increasing demand from wealthy Asian tourists.

New Zealand continues to be reliant on imported fuels to meet the bulk of its transportation energy requirements. The country is exposed to volatility in world fuel markets both in terms of imports (due to higher use of transport fuels) and exports.

As discussed above, the light vehicle transport fleet remains dominated by ICE and non-plug-in hybrid vehicles, which are powered by more efficient power trains. The uptake of hybrids and other non-ICE vehicles (both new and second hand) compounds quickly across the period but is relatively modest in aggregate. This leads to small increases in vehicle fleet efficiency. Late in the period there is a modest uptake of electric and hydrogen vehicles.

Figure 18 – Technology Mix of Cars (millions of vehicles)



Alternative fuels represent 13% of total fuel use in transport by 2050, with bio-diesel comprising 9% of total fuel use, electricity 3%, and hydrogen 0.3%. The low uptake of EVs partly reflects the expiry of the exemption from road user charges in 2020. In the absence of such subsidies or incentives, the cost of alternative fuel sources struggles to compete against more efficient ICEs and non-plug-in hybrids.

In the baseline scenario, Kayak assumes battery costs are \$460/kWh in 2010, falling to \$160/kWh by 2050. We have modelled two alternative assumptions using updated costings, what we believe are now more plausible for future battery storage costs, given recent developments since the WEC report was first released. These results are outlined here in comparison with the baseline Kayak scenario results.

Kayak Tipping Point: Battery Technology Advances

Incremental improvements in battery costs drive uptake of hybrids

In this scenario, we assume that battery costs are currently 20% lower than the baseline assumption of $460/kWh. This reflects our view of current international battery costs. They still reduce to $160/kWh by 2050.

This improves the economics of hybrids and EVs over time relative to traditional ICE vehicles, enticing many consumers to purchase battery powered vehicles of some form. Hybrids stand out as the most cost effective technology and, by 2050, 54% of all vehicle kilometres travelled are from non-plugin hybrids, with 3% from EVs (57% in total compared to 31% in the baseline Kayak). However, petrol and diesel (including bio-diesel) still accounts for 95% of land transport fuel use (bio-diesel is 11%). The relative efficiency of battery powered vehicles decreases total energy consumption for the light vehicle fleet by 13% and for total surface transport by 6% (when compared with the baseline Kayak).

Transport accounts for 3% of electricity consumption (4% in the baseline Kayak) in 2050 as a result of a lower uptake of plug-in vehicles relative to non plug-in hybrids. Electricity generation output increases by 60% to 2050, compared with 63% in the baseline Kayak, with gas and (to a lesser extent) solar providing swing capacity to charge EV batteries.

Advances in battery technologies drive uptake of EVs from 2030

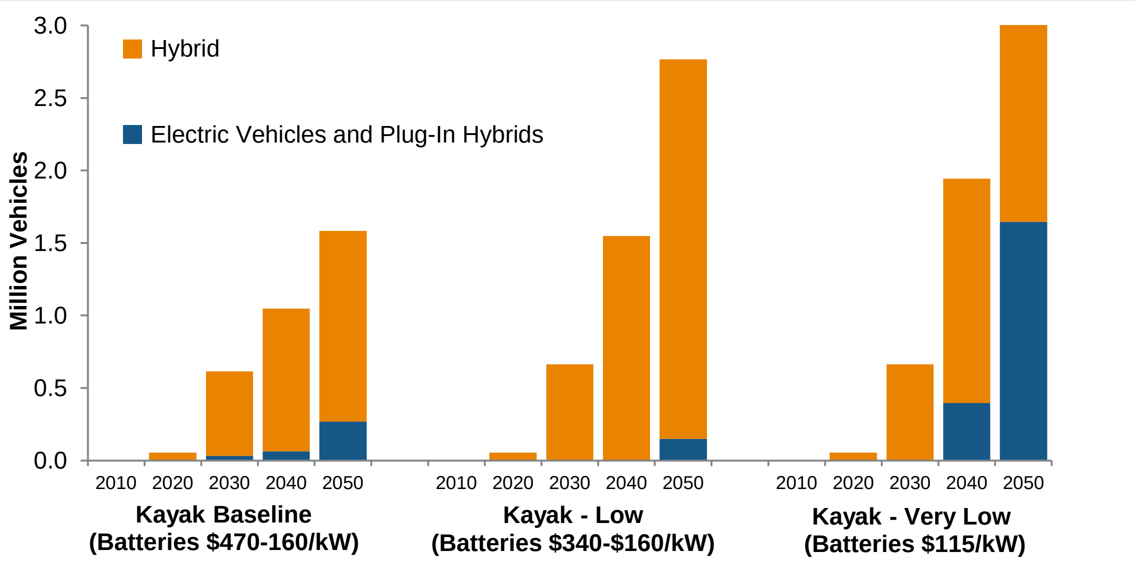
Significant research and development investment in battery storage yields technology breakthroughs which reduce the cost of battery storage capacity to $115/kWh in 2020.

These breakthroughs trigger major changes in the transport sector. Traditional ICE vehicles, as well as alternative fuels (particularly bio-diesel) struggle to compete against EVs and hybrids, both in terms of vehicle costs and fuel costs. By the 2040s, EVs are the dominant technology and begin to displace hybrids. In 2050, 66% of all vehicles are in battery powered vehicles. This reverses the vehicle fleet mix in Kayak, compared to the Kayak baseline scenario where 67% of vehicles are traditional ICEs.

Despite this, petrol and diesel still account for over 150PJ, or 90% of land transport fuel use (compared with 153PJ and 81% in Kayak). The higher proportion of oil-based fuels reflects a reduction in total energy consumption associated with EVs due to the relative mechanical efficiency of using electricity for transport purposes when compared with liquid fuels. When compared with Kayak, this improvement in efficiency reduces total energy consumption for personal cars by 23% and total surface transport by 11%.

Transport accounts for 7% of electricity consumption (4% in baseline Kayak). Electricity generation output increases by 67% to 2050, compared with 63% in Kayak, with gas and solar providing much of the incremental generation capacity.

Uptake of EVs and Hybrids



7. BEC2050 Narratives: Waka

At the heart of this scenario – changing global circumstances and heightened environmental awareness drive business, consumers and government to make decisions in the national interest.

Waka Snapshot

Waka defines New Zealand's experience to 2050 under a rest-of-the-world Symphony scenario. In Waka, government makes decisions in the national interest, particularly to meet the country's environmental commitments.

Global leaders unanimously agree that climate change is the defining problem of our time and a comprehensive global deal on climate change is agreed based on strong emissions reduction commitments. New Zealand's emissions are reduced in an effort to mitigate the worst effects of climate change, with significant adaptation costs avoided post 2050.

Lower overall rates of economic growth are observed internationally due to governments around the world looking to protect their national interests. But greater government involvement in economic decision-making does not always deliver the best results. In this environment, New Zealand's exports are less attractive due to the lower levels of wealth in our key export markets and the tyranny of distance we face, where high carbon prices add to freight costs for our exports relative to these of other countries'. Trade is therefore focused towards our closest trading partners with the lowest trade barriers.

New Zealand's "clean green" image still draws people to the country but increasingly other countries catch up in offering more sustainable forms of living as they adapt in a high carbon-priced world.

Development and adoption of technology within global energy markets is supported by government initiatives. Technology change is greatest in transport through the uptake of alternative vehicles, public transport and ride and car sharing. The electricity sector also approaches near 100% renewable. Biofuel projects target production of bio-diesel and bio jet-fuels.

Setting the Scene: New Zealand's Place in a rest-of-the-world Symphony Framework

A Comprehensive Climate Change Deal

There is a high level of international co-operation on addressing climate change. Global leaders agree a comprehensive deal based on strong emissions reduction commitments and carbon markets to come into force before 2020. Different countries choose to meet their obligations through different mechanisms, including carbon markets but also through carbon taxes and various policy instruments (quotas, energy efficiency, clean technology, and renewables obligations).

Developing countries are afforded an effective carbon cost benefit of approximately $NZD8/t$CO_2$ to accommodate their development needs. The value of carbon sinks (that is, forestry) grows to off-set carbon emissions from the production of necessities, such as food and raw materials.

Sustainable Global Economic Growth

Global average annual GDP growth to 2050 is 3.1% per annum. Levels of growth reflect the population accepting the upfront cost to protect and manage the global environment.

The world population grows to 9.3 billion by 2050, reflecting increasing fertility rates. Of direct relevance to New Zealand is the population growth across Asia which drives increasing volume-based demand for our produce. Asia also has one of the highest economic growth rates across the world in both relative and absolute terms and the emerging middle class across this region continues to drive towards a more protein oriented diet. Globally this is tempered by a trend towards less protein rich diets (relative to now), with animal proteins viewed as less sustainable to produce due to the high input costs of land, energy and carbon.

On the back of high carbon costs, international trade agreements place increasing emphasis on the free flow of sustainably produced goods and services. However, the imposition of subsidies and trade barriers to protect national interests introduces inefficiencies and sub-optimal allocations of resources globally, meaning global growth does not meet its full potential.

Higher transportation costs (due to higher carbon-related costs) make it tougher to compete in distant export markets for high volume, low value products. Regional trading clusters therefore develop, fragmenting global trade. The early establishment of free trade agreements with Australian and Asian export markets consolidates New Zealand's presence in the Asia-Pacific region. Trade expands as these markets seek more trade from countries with favourable terms, influenced by the carbon content within the production and freight chain.

Our Waka Story

Government Mandate for a Zero Carbon Future

In this world, markets struggle to provide the strategic long-term direction to transition to a low carbon economy (for example, reach 100% renewable), especially as the effects of high carbon costs start to bite and other countries (both trade partners and competitors) aggressively pursue self-interest. New Zealand businesses see increasing benefit in enhancing the country's clean green image to serve consumer preferences for sustainable goods and services. Consumers and businesses therefore give a mandate to the government to enable and co-ordinate efforts towards a zero carbon future.

Governance and decision-making become more hands-on as a result, with climate change mitigation strategies prioritised to meet New Zealand's international obligations. These include a cap placed on national emissions. Decisions are made on the economy and society to ensure opportunities are taken and emerging risks in a high-carbon cost world are managed to the country's benefit. The government increases its focus on energy sustainability in order to maximise global opportunities in a carbon constrained world. Economic and environmental objectives are balanced by managing the country's energy and industrial mix in a more hands-on manner.

The government decides to abandon the current ETS early, instead preferring to adopt a range of fiscal measures and policy settings to meet its international obligations. Government reinvests the proceeds from various fiscal measures in the form of supports and incentives for low carbon technologies and carbon sinks (for example, forestry). Carbon exemptions are allocated to certain emitters of high strategic importance to the country, to help them transition to a low carbon future. Agriculture sector emissions are included in national emission caps on the basis that they are included in the carbon commitments of our key trading partners.

The government makes strategic choices aimed at increasing the level of the country's renewables in the primary energy mix and reducing reliance on high carbon fuels and related technologies. Specific energy policy and regulatory interventions include:

- Incentives to increase the proportion of renewables in the energy supply mix based on:
    - an aspirational goal of 100% renewable electricity by 2050 including greater facilitation of large hydro projects through the consenting process
    - targeted subsidisation of biofuels (for example, a 20% subsidy on biofuels)
    - electrification of the national vehicle fleet through extending the current exemption on road user charges to 2030
    - support for greater use of renewable heat (that is, from geothermal, biomass and solar thermal) and waste heat byproducts (co-generation)
- Removal of any incentives and protections for low-value, high carbon emitting sectors.
- Higher energy efficiency targets, supported by targeted use of regulation, standards and incentives to adopt more energy efficient technology.
- Increased support mechanisms and incentives for research, development and education, across a range of initiatives and technologies, including low carbon, information and communication technology (ICT), transport and smart grids.

The sustainability provisions of the RMA are strengthened to take a more aggressive approach to ensuring a low carbon future that preserves New Zealand's environmental foundations for future generations. In response, local authorities adopt more sustainable forms of planning, targeted at dense urban form.

The implied cost of carbon emissions under these arrangements reaches $NZD115/t$CO_2$ (2010 real) by 2050.

Energy affordability (particularly in transport) deteriorates as energy prices rise due to the high carbon price. The government seeks to address this with fuel poverty initiatives for the most socially vulnerable.

Demographic and Social Change

While there is significant international co-operation on climate change, the global economy is more fragmented and differentiated due to costs associated with climate change policies. This limits international travel and heavy freight to distant countries and focuses our social and cultural ties towards our closest neighbours in the Asia/Pacific.

New Zealand is still seen as a desirable place to live given its natural features and high standards of living and migrants and returning expats favour New Zealand as a destination. However, increasingly other countries pursue green living strategies, which make New Zealand relatively less attractive on the global stage due to our distance.

The government also seeks to manage the impact of population growth on the country's resources and living standards. It is more selective in its immigration policy focusing on highly skilled and relatively wealthy migrants. New Zealand's population grows to 4.9 million in 2025 and 5.5 million by 2050. This equates to a rate of growth of 0.5% per annum, compared with historical rates of 1.1% since 1992.

New Zealand's cities capture most of the population growth as they provide work opportunities as well as social connections. Local and central government policies actively support the creation of sustainable cities. These promote dense urban development as well as self-sustaining communities that support local retail and commercial sectors within residential areas. This is supported by integrated public transport systems and greater uptake of ride share and car share schemes. As a result, car ownership reduces and average annual VKT per person drops. The agglomeration benefits of dense urban living result in more affordable living as well as economic growth in urban centres.

Rural population decline continues due to a high carbon charge and focus on sustainable development, which limits agricultural intensification and rural economic development. Urban centres also provide relatively more attractive wages and higher living standards.

The population grows older given typically young working couple and family immigration is insufficient to offset the aging population, while many young New Zealanders leave for overseas opportunities. Fertility rates also fall to 1.4 children per woman by 2050 further increasing the average age of the population.

A Sustainably Managed Domestic Economy

The high cost associated with carbon emissions has significant implications for New Zealand's economic structure. This is manifested through increasing costs across the economy, particularly through fossil fuels used for transport and thermal heating, and process heat sector participants. In particular, a high carbon impost on fuels increases the cost of exporting goods to our target markets. The pastoral sector also faces a significant challenge in reducing and offsetting emissions, particularly in dairy farming (methane) which is resolved through low emission technology advances and through carbon offsets. Our agricultural sector exports become more expensive as a result, and the implied cost disadvantage relative to China, Africa, the Middle East and North Africa ($NZD8/tCO2-e differential) exacerbates the problem further.

Despite these concerns, New Zealand's agriculture production is efficient on a global scale and we respond by increasing production to make a meaningful contribution to feeding a growing world population. This drives demand for our primary produce exports. Horticultural exports include wine, kiwifruit and other high value products such as avocadoes, berryfruit, summerfruit and olive oil. The pastoral sector continues to support the export of dairy products, venison, sheep, beef and wool, while our long coastline and exclusive economic zone provide access to a wide range of aquaculture and fisheries.

Before it was abandoned, the ETS had given New Zealand businesses exposure to managing and accounting for greenhouse gas emissions. With the inclusion of agriculture and carbon sinks (that is, LULUCF impacts) in the global agreement, New Zealand benefits from its relatively emissions efficient agricultural production.

Our fast growing plantation forests provide a valuable supply of timber exports and wood biomass and receive generous subsidies from government as carbon sinks. The resulting wave of new forestry plantations crowds out dairy conversions on marginal land and holds back GDP growth in the short term, given forestry profits are made later in the investment cycle when trees are harvested.

Primary sector commodities continue to account for around half of total goods exported. This is supplemented by growth in the service sectors and in low carbon manufacturing, which increasingly substitutes for imports that face high carbon costs on freight. Overall, exports of goods and services account for around one third of real expenditure GDP.

While the country is heavily reliant on exports of commodity-based products, we are equally reliant on imports of capital equipment and raw materials for industry. There is less importing of goods for subsequent export, as more of these activities are undertaken in lower cost markets prior to export. Our key trade partners and competitors subsidise their marginal industries in sensitive sectors (for example, agriculture), increasing the cost of imports to New Zealand whilst creating price resistance for our own exports to foreign markets.

The New Zealand economy benefits from rapid and large incentivisation of renewable and low carbon technologies at a global level (that is, generation technologies, smart grids, batteries, energy efficiency, and vehicles). It also enjoys the benefits from favourable environmental outcomes as a result of reduced carbon and particulate emissions, and strengthened environmental standards. Our largely renewable electricity supply provides a low carbon base, favouring electricity intensive businesses that can co-optimise production with local access to raw material inputs.

The guardianship (kaitiaki) role that many iwi and hapu groups have in regards to the sky, land and sea, becomes more important in an environment of sustainable resource management. These groups increasingly work with government and business to progress shared environmental interests and are also able to commercialise and facilitate access to geothermal, water and marine resources for renewables generation.

Average annual economic growth is 1.6% over the period. GDP per capita increases at 1% per annum as a result, compared with recent growth rates of between 2-3%.

Environmental

Sustainability

The relatively high carbon cost focuses attention on reducing or offsetting greenhouse gas emissions, particularly in the agriculture, transport and energy sectors. Within this environment there is growing pressure to address other environmental, animal welfare, and conservation impacts. The targeted suite of policy measures adopted by the government to address these issues (discussed above) enhances New Zealand's natural environment.

Water – Food – Energy Nexus

Water plays an important role in supporting agricultural exports, through use in irrigating horticultural lands and pastures. However, growth in irrigation is limited due to increasing constraints placed on water supply, access and quality:

- Conversions of pasture and barren land to forestry significantly reduce the supply of water flowing into river catchments as trees soak up more rainfall (recent studies show water yields decreased by 30%-80% due to afforestation).[43]
- Hydro power generation is prioritised under the RMA, given the renewable electricity target is of national interest. This creates greater demand for water storage. However, hydro's non-consumptive use of water upstream means irrigation downstream is typically only constrained due to the timing of water release and during dry periods when storage is important for security of supply. Investment in a range of both small and large hydro projects factors in use of further irrigation.
- Water quality becomes more important due to heightened environmental awareness. Adverse effects on river catchments are resolved through enhancements to the RMA National Policy Statement for Freshwater Management[44] which directs councils to place further limits on water quality standards and minimum water levels. This tightens the parameters of use for water, constraining irrigation and therefore agricultural production.

Mitigation

Under a strong global climate agreement that mandates concerted action, the country will face lower longer-term climate change risk. In particular, the high carbon impost elicits responses focused on reducing global greenhouse gas emissions and therefore the risk of global warming.

Given New Zealand's highly renewable electricity profile, the impact of high carbon costs is somewhat muted, except where producers are unable to transition to electricity supply. Nevertheless, reduced carbon and particulate emissions result due to the lower consumption of fossil-based fuels. New Zealand's greenhouse gas emissions from the energy sector are nearly halved by 2050, from 34 $MtCO_2$/year in 2010 to 18 $MtCO_2$/year in 2050.

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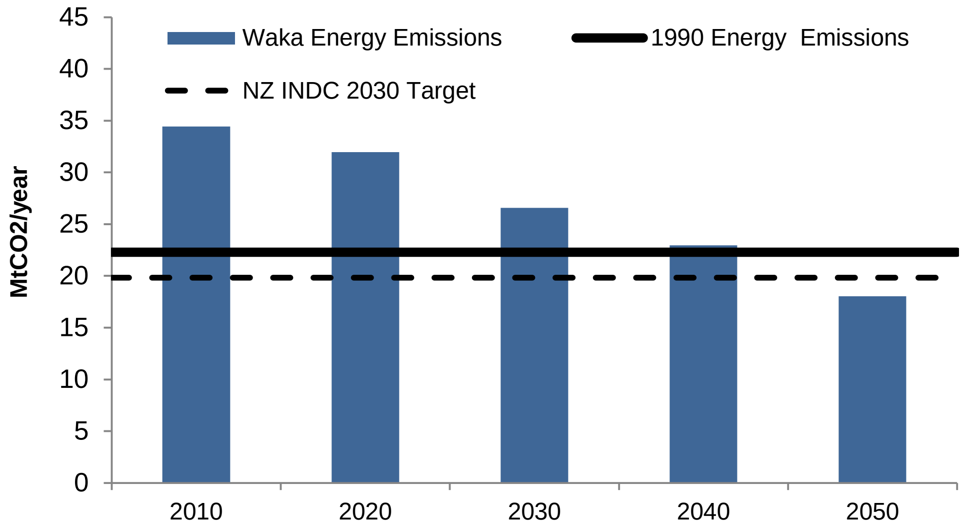
[43] Tim Davie and Barry Fahey, "Forestry and water yield: the New Zealand example", *The New Zealand Journal of Forestry* 49(4):38.

[44] http://www.mfe.govt.nz/fresh-water/national-policy-statement/about-nps.

Figure 19 – Energy-Related Carbon Emissions (million tonnes of CO_2 per year)



However, the world is already committed to some level of climate change due to historical emissions. Some of these impacts will happen pre-2050 regardless of efforts to curb emissions in the short to medium term (for example, greater exposure to droughts, wild fires and extreme weather). New Zealand will, therefore, still need to adapt to a changing climate. With successful planning, the costs of weather-related events is modest.

The government sponsors adaptation initiatives, particularly in relation to coastal infrastructure, and infrastructure required to support changing weather impacts on agricultural and pastoral sectors. The regions of the country and the commodities they support will be affected in different ways. Some will benefit from temperature and weather changes, making them more productive, whereas other regions are likely to suffer from lower levels of productivity due to drought and extreme weather.

Our Waka Energy Future

Energy Intensity

In Waka, New Zealand's energy intensity decreases on average by 1.9% per annum to 2050, a larger rate of decrease than recent historical trends. Energy intensity decreases more quickly as a result of growth in the services and commercial sectors, relative to the industrial sector which has high energy intensity. Some heavy industry may be forced to consider curtailing production due to higher transport costs for heavy goods (arising from the carbon charge), despite efforts to improve the energy efficiency of production. This will lead to incremental improvements through lower energy intensity over the period. The energy intensity of the agricultural, forestry and fishing sectors remains largely unchanged due to energy efficiency savings.

Energy intensity also reduces due to incentives on businesses and consumers to improve energy efficiency under the ETS. Globally there is a high tolerance for top down mandated energy efficiency and conservation policies and directives. The New Zealand Government, with a focus on energy efficiency and conservation programmes, also invokes proactive energy efficiency policies and initiatives.
The primary areas where energy efficiency improvements are likely to come from include:

- Transformation of the vehicle fleet towards non-fossil fuels (for example, due to the improved efficiency of electric vehicles).
- Decarbonisation of thermal energy (that is, process heat coal boilers), incentivised by high carbon prices.
- The transition to electricity renewables and more efficient appliances (for example, bans on inefficient light bulbs and appliances).

New Zealand will be a beneficiary of overseas technology developments in all these areas. Energy system-related technology breakthroughs and adoption will occur on a revolutionary basis, as overseas governments incentivise investment in energy efficient technologies.

Energy efficiency standards are applied to a larger number of products and tightened with minimum standards on increasing efficiency. Some low efficiency technologies are banned altogether. While mandated efficiency standards increase the price of some capital equipment and appliances, the uptake of energy efficiency initiatives in buildings and industry increase as a result of the higher carbon prices and energy savings which generate a better return on investment.

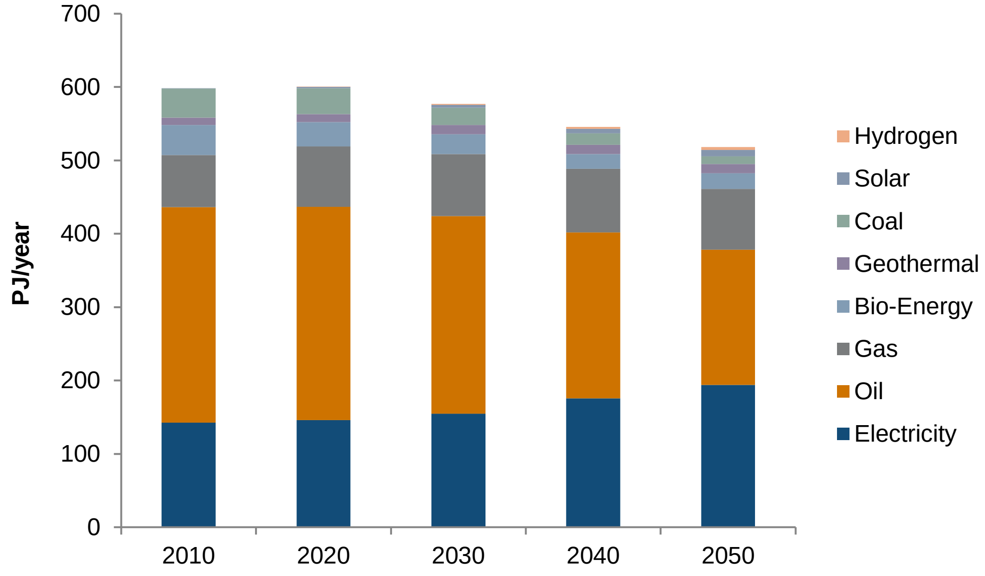
Cumulative energy efficiency improvements reduce energy consumption by 197PJ over the next 35 years. This equates to a 28% reduction in 2050 consumer energy demand.

Energy Mix

Government policy incentivises a shift in New Zealand's energy mix towards renewable sources. The country's consumer energy mix is driven by the relative economics of each conversion technology and the carbon content of its fuel. Climate-related externalities are better reflected by a carbon charge, reinforced by government interventions, and thermal and renewable energy compete on their economic merits.

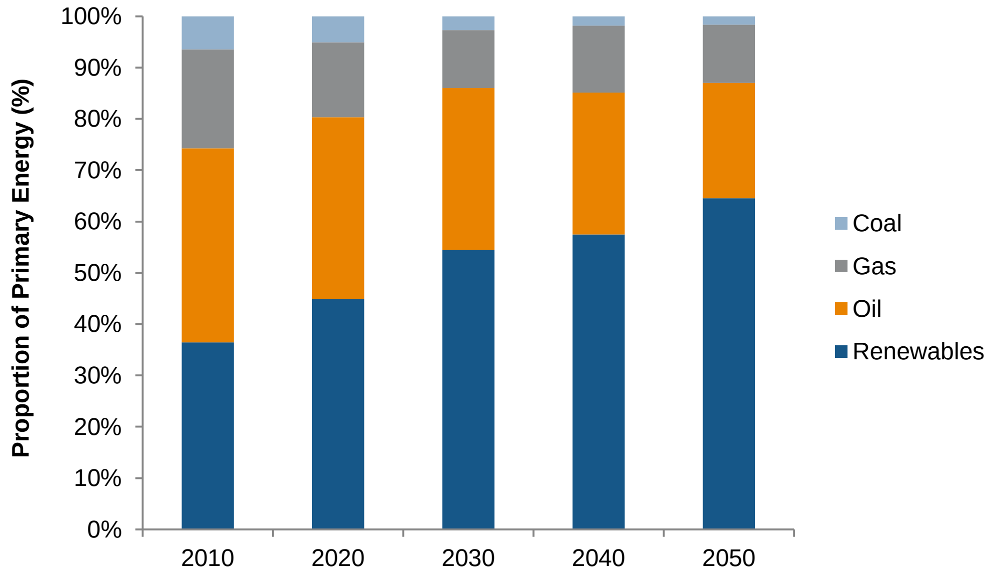
Consumer energy decreases from 2010 to 2050 by 13% to 520PJ, as highlighted in the graph below, driven primarily by behaviour change and electrification in the transport sector, and efficiency.

Figure 20 – Total Consumer Energy by Fuel Type (Energy Output – PJ/year)



The graph highlights the diminishing contribution of oil and coal, which is substituted with a growing proportion of renewables (65% of energy inputs in 2050) is predominantly consumed in the form of electricity. Despite our substantial lignite resources, CTL is uneconomic due to a high CO_2 price. Gas consumption remains constant over the period.

Figure 21 – Total Primary Energy Mix (PJ/year)



Domestic annual gas production decreases by 51% over the period to 2050, and oil production by 94%. This reduction of domestic oil and gas production is offset by an increase in the energy supply from domestic renewable sources. Also, imported LNG (via a new LNG terminal developed in the late 2030s) is substituted for falling domestic gas production principally due to the improved relativity between the international price of gas and the cost of continued exploration and extraction in New Zealand. Domestic coal demand decreases by 73% but coal production remains constant to support a steady demand for coal exports for steel. Opposition to new greenfield coal mine projects means that production is capped at present levels.

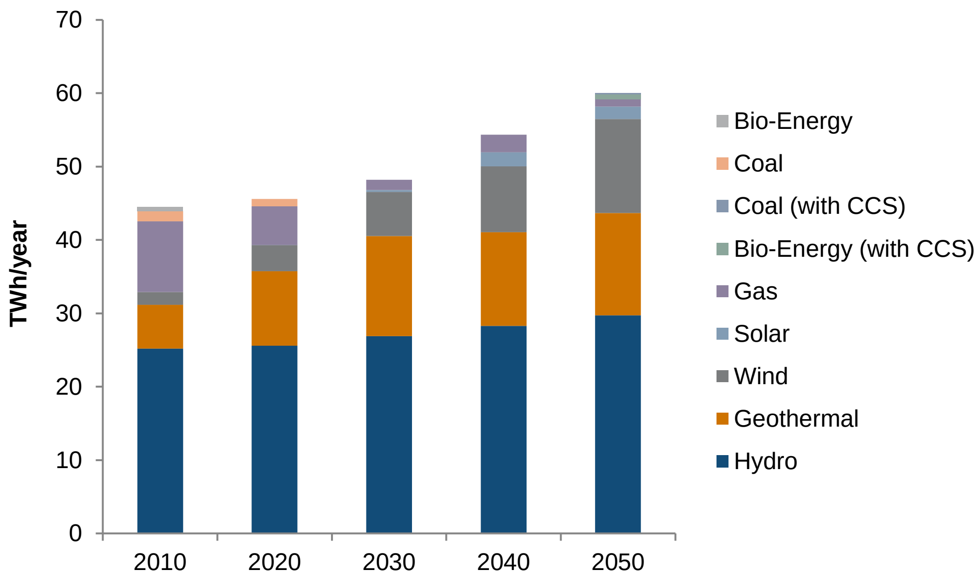
The make-up of fuel consumed highlights the declining use of fossil fuels (in particular oil-based fuels for transportation which decreases by 31%). These declines are more than offset by increasing reliance on electricity production, which increases by 45%. Higher energy prices (through the higher carbon charge) put pressure on the continued use of fossil fuels as the primary fuel source for the vehicle fleet. However, demand for aviation fuel increases due to economic and world population growth.

Government support for bio-fuels and research and development in emerging renewable energy technologies (for example, deep geothermal, tidal/wave power systems) does not contribute significantly to supply investments. These more expensive energy sources can't compete in an environment of declining energy demand.

Electricity

Electricity production increases by 35% over the period from 2010 to 2050.

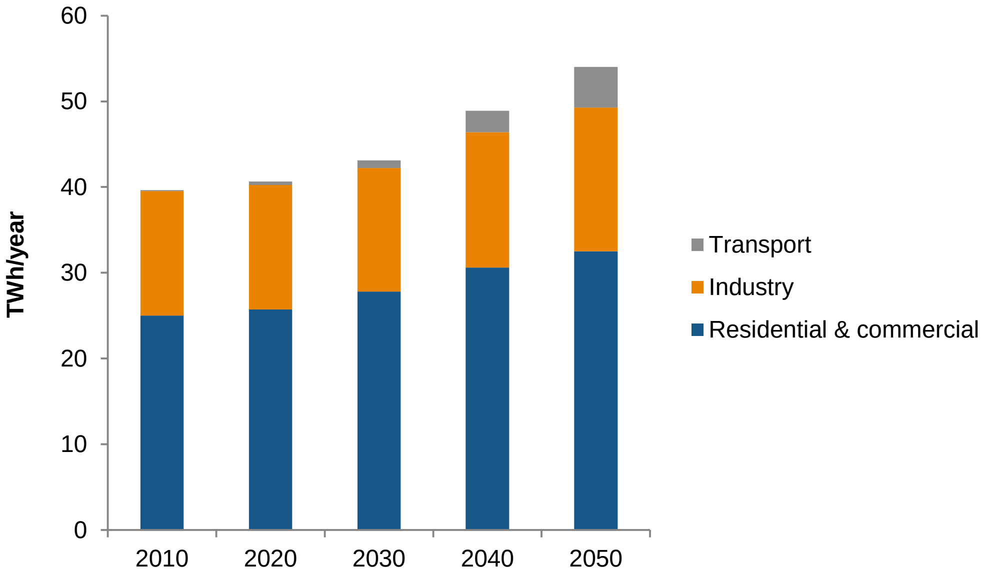
Figure 22 – Electricity Generation by Type (TWh/year)



This growth is driven by:

- Increased economic activity and population growth. The relative increase in industrial consumption is lower than that of the residential and commercial sectors.
- Significant displacement of fossil fuel energy in the economy, particularly in transport, where electric vehicle uptake accounts for 9% of electricity consumption by 2050, and in domestic and process heating using modern electro-technologies.

Figure 23 – Electricity Consumption by Sector (TWh/year)



Increasing demand is partially offset by improvements in energy efficiency.

The development of new electricity generation largely depends upon the carbon content of generation, as factored in by the higher carbon charge which influences relative generation costs. Gas-fired generation is all but gone by 2050 due to these costs.

Growth in demand is met through continued growth in geothermal capacity, greater uptake of distributed solar, increasing levels of wind penetration, and incremental net hydro additions. This continues recent trends in New Zealand, where these renewable sources of electricity dominate investment in the country's generation portfolio. Renewables penetration of electricity generation reaches 86% by 2020 and 98% by 2050, just falling short of the aspiration of 100%. This high uptake is driven by:

- The increasing cost-competitiveness of renewable energy sources relative to thermal-based generation sources (excluding bioenergy), which are unable to compete due to the higher carbon costs imposed on them.
- The ease with which renewables projects are consented and re-consented.
- Reductions in the costs and increasing electrical efficiency of new renewable generation capacity.
- Direct intervention, through providing a 20% subsidy on biofuels.

PV capacity reaches 1.3GW by 2050, but only contributes 3% of generation output due to New Zealand's lower overall solar efficiency. Solar penetration increases from 2040 as technology costs decrease but growth is moderated domestically by high large-scale renewables penetration.

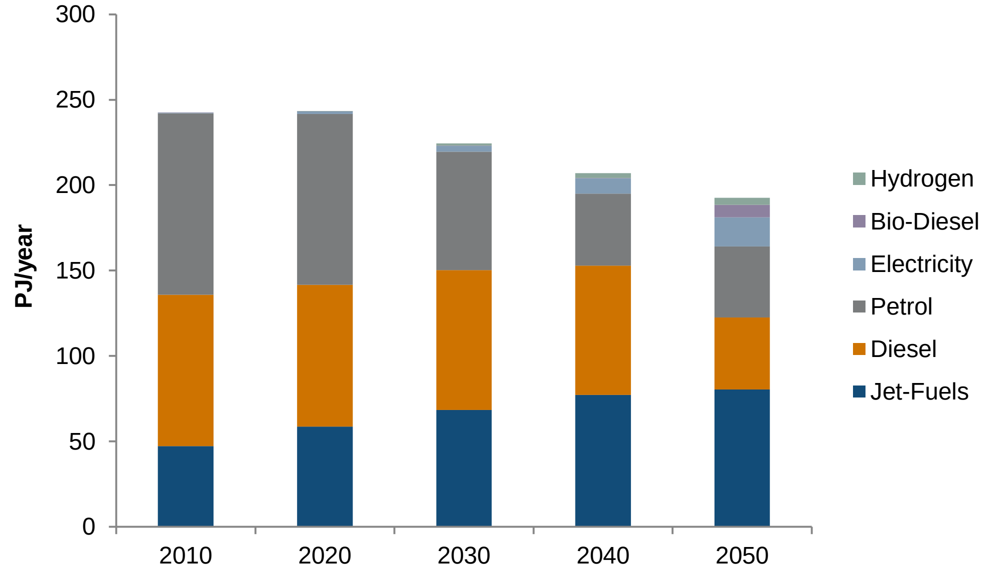
This high level of renewables initially creates challenges for security of supply which are overcome by:

- Maintaining flexible gas and biomass capacity, although operating at very low load factors to respond to hydro variations.
- Adopting new power demand management systems and technologies.
- Demand-side management markets.
- Use of improved battery and hydrogen fuel cell storage to meet peak demand (when non-renewables are currently most often called upon to meet demand).
- Advanced system operations, including smart grid initiatives.
- Cost-reflective tariffs facilitated through smart meters.

Transport

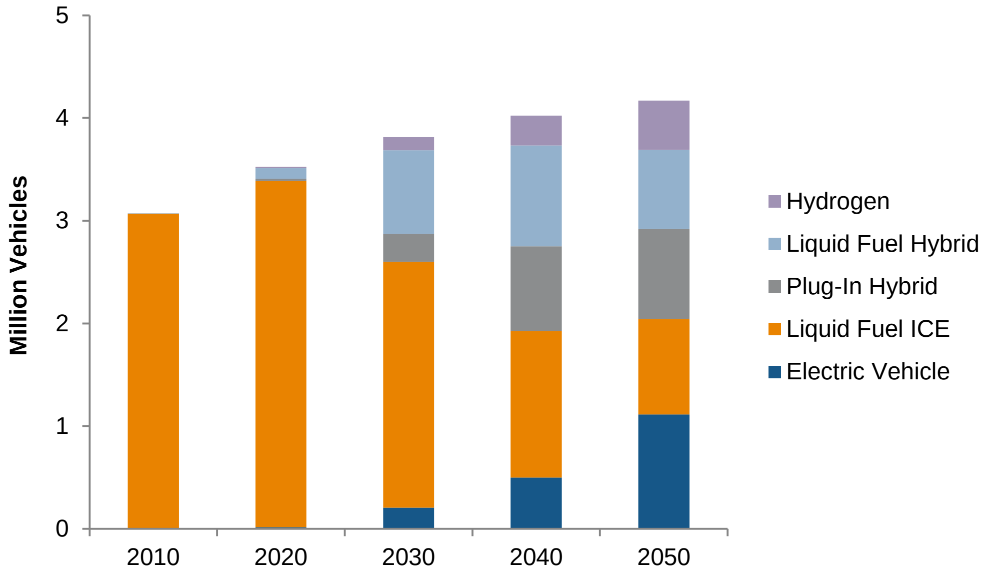
Vehicle kilometres travelled (VKT) per capita in the light fleet reduce by 20% to 9,800km by 2050 due to increased use of public transport, ride share, tele-commuting and car sharing schemes, but also as a result of urban planning targeting density and economically self-sufficient communities to encourage non-motorised transport. Rates of car ownership also decrease by 5% as inner city living becomes more prevalent. When coupled with an increasing population base (partially offset by an aging population), this leads to a higher level of total VKT travelled. However this is not reflected in total fuel use, which decreases 21% from 243PJ in 2010 to 193PJ in 2050, reflecting the increasing efficiency of the transport sector and greater use of alternative fuels.

Figure 24 – Fuels in all Transport (PJ/year)



The use of traditional hydrocarbon-based fuels in transport steadily decreases by 31% from 2010 to 2050. Imported fuels (diesel and petrol) reduce from 79% of transport consumption to 43% by 2050.

Figure 25 – Technology Mix of Cars (millions of vehicles)



Alternative fuels comprise 28% of land-based fuel use in transport by 2050 but 78% of the light vehicle fleet (biodiesel comprising 4% of total fuel use, electricity 9% and hydrogen 2%). Growth in alternative vehicles is slow at first but exponential uptake occurs from 2030. Hydrogen and biofuels become more viable for heavy road transport but require government subsidisation to establish themselves in the New Zealand market.

Utilising domestic feedstock options for biofuels and hydrogen also helps the country to enhance its fuel self-sufficiency.

Hybrids, EVs and plug-in hybrid electric vehicles (PHEVs) are widely available at economic prices on the back of revolutionary global technology developments. New Zealand benefits from the early adoption of these vehicles and uptake reaches 66% by 2050. The light vehicle fleet is largely transformed to electric vehicles which, with the country's renewable electricity base, further reduce the carbon intensity of the economy. These technological developments become viable for both private and public transport – substantial substitution occurs in New Zealand by 2050.

The consumption of jet fuels increases 70% by 2050, arising from the growth in the global population, particularly in Asia.

8. Comparative Analysis

The following compares the energy outcomes modelled under the Kayak and Waka scenarios. It does not move in depth into either scenario; its primary purpose is to highlight the key differences and tradeoffs between the scenarios. Key areas of focus include:

- Primary energy.
- Hydrocarbons.
- Electricity demand and supply.
- Transportation energy use.
- Carbon emissions.

Key PSI modelling inputs are provided for reference in Chapter 4.

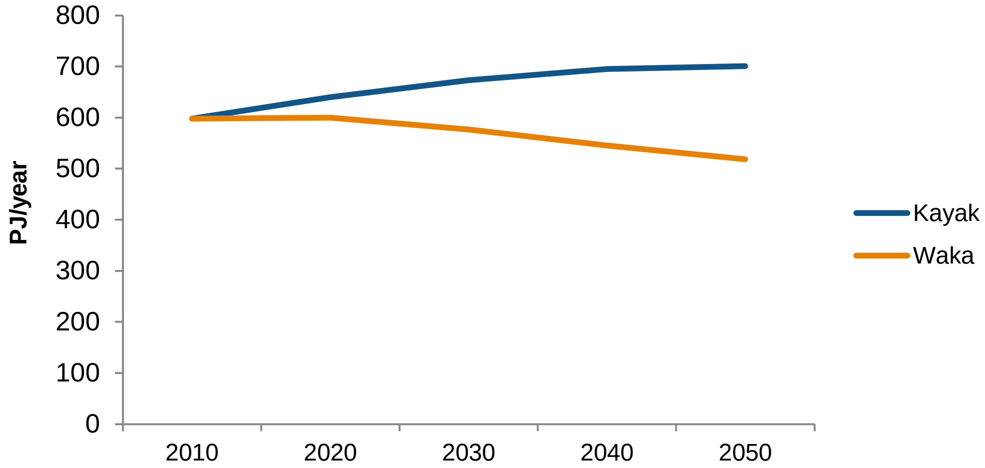
Output from the GMM model used to represent the Kayak and Waka scenarios allows a vast set of analytical enquiries to be undertaken. This chapter provides a selection of the key insights and observations that we believe are pertinent to New Zealand's key energy policy and investment decisions. However, more granular data is available for analysis.

We recommend that the reader re-cap on the discussion of the GMM model provided in Chapter 4 before interpreting the outputs reported in this chapter.

Total Consumer Energy – Overview

In the GMM model, demand is driven by the combined effects of population and economic growth and the selection of different and/or new consumption technologies (which, in turn, may be more efficient). These technologies are selected by the model at the optimal time, based on capital and operating costs.

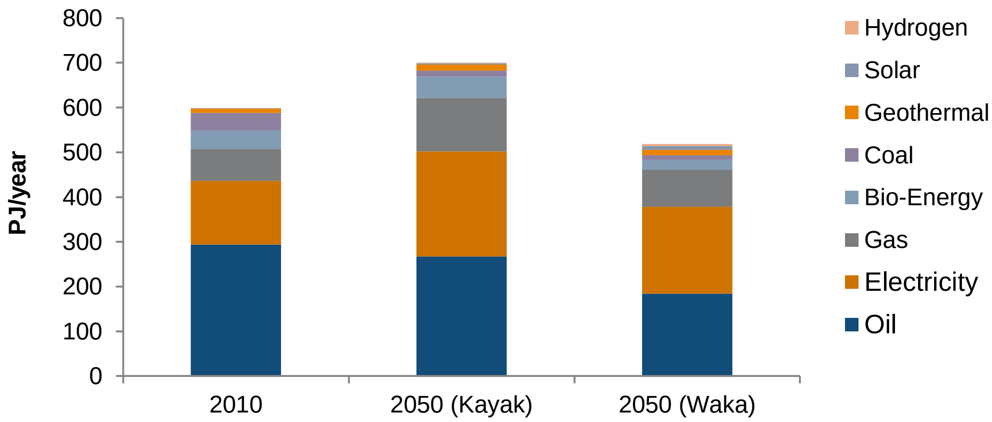
Figure 26 - Total Consumer Energy (2010 to 2050)[45]



The increase of energy consumption in Kayak (compound annual growth rate (CAGR) 0.4%) is due to stronger economic growth and population growth. In Waka (-0.4% CAGR) the weaker economic and population growth is more than offset by a reduction in use of the transport fleet, greater use of electricity as a transport fuel (more “efficient” as a use of primary energy), and more aggressive energy efficiency policies.

As a result, New Zealand’s energy intensity reduces at 1.8% per annum in Kayak, and 2.0% per annum in Waka. Both of these rates are faster than experienced over the last 10 years (1.7%).

Figure 27 - Total Consumer Energy by Fuel Type in 2010 versus Kayak and Waka Scenarios in 2050



[45] See footnote 40 for a reconciliation of modelled numbers with MBIE statistics.

Figure 27 shows the make-up of consumer energy at the start of the modelling period (2010), and at the end of the modelling period (2050) under each scenario. While each of the following key components is expanded on in the sections that follow, we briefly comment on their effects on overall energy consumption here:

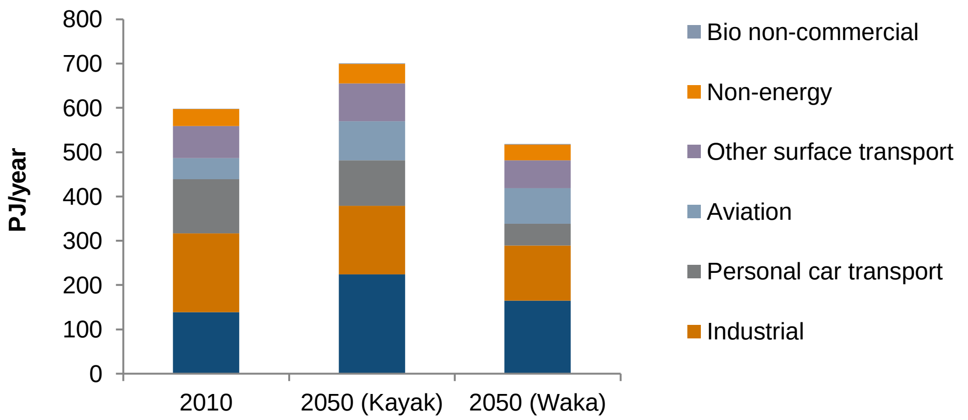
- Oil declines from 50% of total consumer energy to 38% (Kayak) and 36% (Waka) of our energy consumption, driven in both scenarios by the switch in transport from pure ICEVs to alternative transport, but more aggressive in Waka due to a higher rollout of electric vehicles and the reduction in the distance driven by owners of private vehicles.

- Electricity rises from 24% of total consumer energy to 34% (Kayak) and 37% (Waka). Hence we are using electricity to meet more of our energy services and again, the stronger role in Waka reflects the more dominant role of electricity in the transport sector. Gas consumption grows 20% under Kayak, but declines 40% in Waka. Consumption by the industrial sector increases in both scenarios while its role in the electricity sector remains relatively constant (after declining through the middle decades). Consumption by the industrial sector increases.

- Coal declines as a form of primary energy in both scenarios. Even with the lower carbon prices in Kayak, coal still only makes up 2% of total consumer energy in 2050 (compared with 7% today), roughly the same percentage as Waka. While the final carbon price in Kayak ($60/t CO_2) is approximately half that of Waka ($115/t CO_2), it still appears sufficient to significantly disincentivise the use of coal, even with the availability of CCS as an option. Note that, in Kayak, the Coal + CCS electricity generation plant represents about half the total domestic use of coal in 2050.

- Solar grows both as an energy source for electricity generation and as a source of direct heat (mainly for water heating). By the end of the modelling period, it represents ~3% of total fuel consumption in both scenarios but with quite different mixes in terms of the form of usage.

Figure 28 - Total Fuel Consumption by Sector[46] (2010 versus Kayak and Waka 2050)



[46] Most of the sector headings here are relatively self-explanatory. However, for clarity, "Non-energy" relates to where neither the raw energy source used to produce the product nor the product itself is combusted, for example, the conversion of natural gas into methanol or urea. Other surface transport includes the heavy vehicle fleet and shipping. Bio non-commercial is the use of bio-energy (for example, wood) for residential consumption for heating.

Industrial Sector

Industrial energy consumption falls under both scenarios but more aggressively in Waka. This is due to the combination of the higher carbon price (raising the cost of both coal and gas as direct fuel and increasing transportation costs for raw material imports and product exports) and more stringent efficiency policies which are partly targeted at the industrial sector. However, in 2050 the direct use of coal (primarily industrial) in Waka (10PJ) is not substantially lower than Kayak (13PJ), in both cases significant reductions from the current level (~40PJ).

The declining use of coal features as a specific policy initiative in Waka, targeted at coal boilers. This drives a substitution away from coal to gas for heat or perhaps the closure of some industrial sites altogether. Gas has a lower carbon impost and, given the likely underlying coal and gas prices at the time, will probably be an economic choice for industrial consumers anyway. But recall that GMM does not model New Zealand geographically; hence the transition from coal to gas as a form of heat does not recognise the difference between the North and South Islands in terms of gas distribution. Therefore, the lack of a significant (and secure) distribution infrastructure in the South Island will be a key consideration if this fuel transition is considered desirable.

The overall declining trend in industrial energy consumption is concentrated in GMM's thermal category (heat for industrial processes plus HVAC[47]). Specific energy consumption partly counters the thermal trend growing 15% in Kayak and 4% in Waka, reflecting the growing role of electric motors, computers and other electronics driven by underlying economic growth and the changing nature of technology and industrial sector participants. As a result, electricity grows as a proportion of industrial energy consumption from 30% in 2010, to 44% in 2050 under the Kayak scenario, and to nearly half of industrial energy consumption under Waka.

Residential and Commercial Sector

As with the industrial sector, consumption of energy for residential and commercial appliances, lighting and electronics grows under both scenarios. Residential and commercial thermal energy (space and water heating, refrigeration) also grows under Kayak – the higher efficiency of new technologies is clearly outpaced by economic and population growth. However the specific energy efficiency policies (labelling and banning of inefficient heating technologies) under Waka are stronger and drive this sector's thermal consumption down.

Transport

Road transport fuel usage shows the most dramatic differences between the scenarios – under Kayak, with low carbon prices and consistent travel behaviour, fuel consumption is relatively flat despite the growing use of hybrids (although there are offsetting effects between the light and heavy fleet). Under Waka however, the combination of carbon prices, travel behaviour change and the transition to electricity (as a more efficient usage of primary energy) sees dramatic reductions in personal car fuel usage (-2.3% CAGR) as well as heavy fleet usage (-0.4% CAGR).

In GMM, New Zealand's use of aviation fuels is driven purely by population and economic growth. Hence the difference between the two scenarios reflects these parameters. Aviation consumption includes both domestic and international travel and reflects the fact that for most purposes (especially business), travel between New Zealand's main centres will continue to be dominated by air travel. Given New

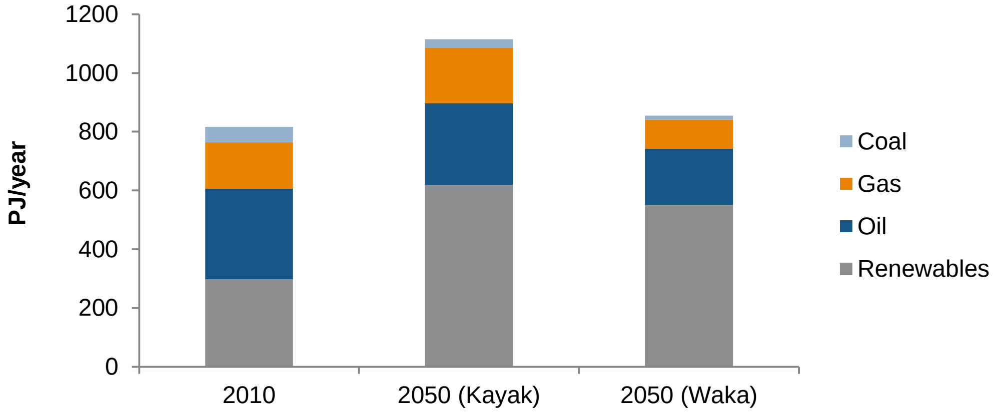
[47] Heating, ventilation and air conditioning.

Zealand's geographic isolation, international travel for freight will remain strong under both scenarios.

Renewables in Primary Energy Supply

In 2010, renewable energy made up 36% of our total primary energy supply (TPES). By 2050 renewable energy makes up 55% in Kayak, and nearly 65% in Waka, primarily reflecting the expansion of renewables in the electricity sector[48].

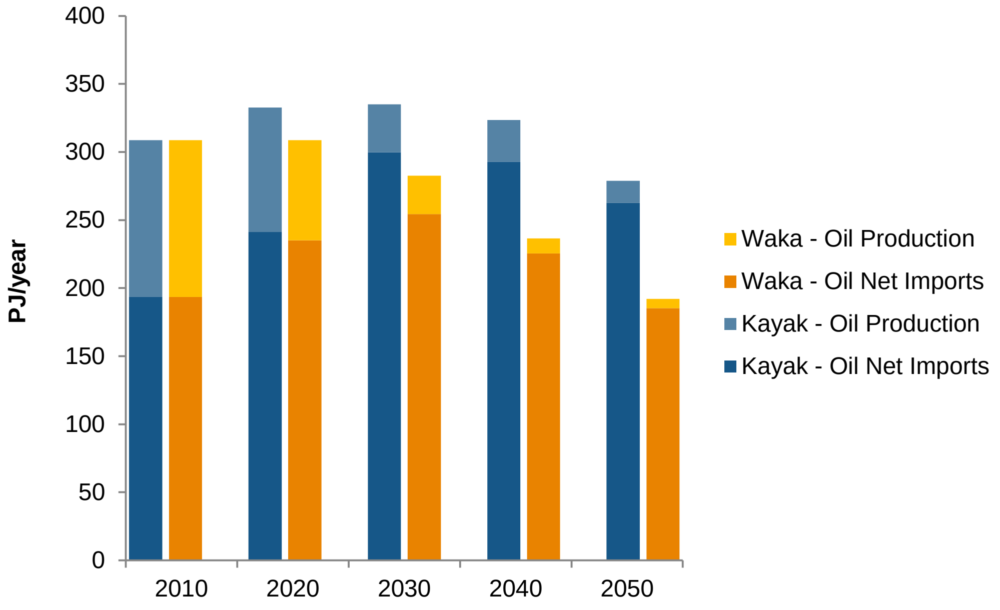
Figure 29 – Total Primary Energy Supply (2010 versus Kayak and Waka 2050)



[48] Here we use the International Energy Agency (IEA) (and MBIE) efficiency value for geothermal (15%). Hence the increasing role of geothermal in New Zealand expands the primary energy supply by a factor of 6 over the geothermal electricity actually produced by the generation plant.

Total Primary Energy - Hydrocarbons

Figure 30 - Production and Importation of Oil



The pattern of overall oil consumption reflects the transport trends in each scenario. While oil consumption increases initially under Kayak, it eventually declines to a point 10% lower than current consumption as more efficient drive trains grow in the transport fleet. In Waka, this downward trend begins much earlier (after 2020) and oil consumption drops 37% over 40 years.

Domestic oil production declines consistently in both scenarios, leading to increased imports initially. By 2050, New Zealand increases its relative reliance on imports (that is, as a proportion of total oil consumption) in both scenarios. Oil imports are lower than today in Waka, while absolute imports increase in Kayak. The above figure only shows net imports, but New Zealand continues to export small amounts of oil.

Figure 31 - Depletion of New Zealand's Oil Resources (2010 versus Kayak and Waka 2050)

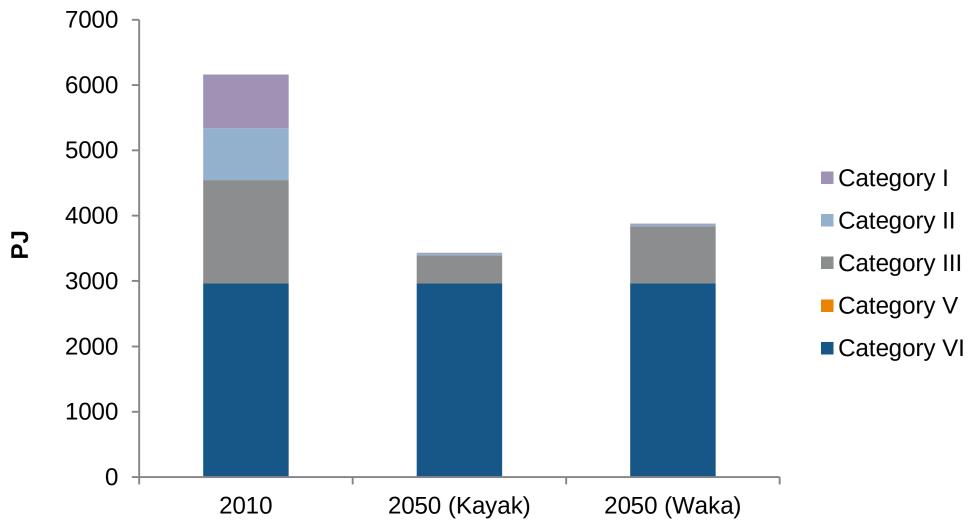
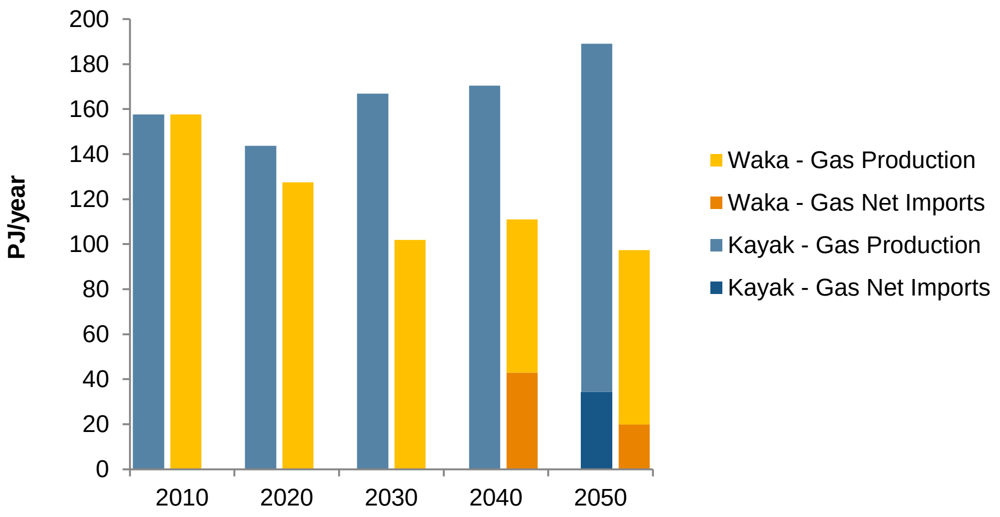


Figure 31 shows that our domestic production of oil exhausts Category I Reserves, but also consumes Category II and III resources. Note that GMM assumes that Category II and III are conventional resources, whereas Categories IV and above are unconventional. Neither scenario makes use of unconventional oil resources including hydraulic fracturing (fracking) that remains uncertain for future development of oil and gas extraction in New Zealand.

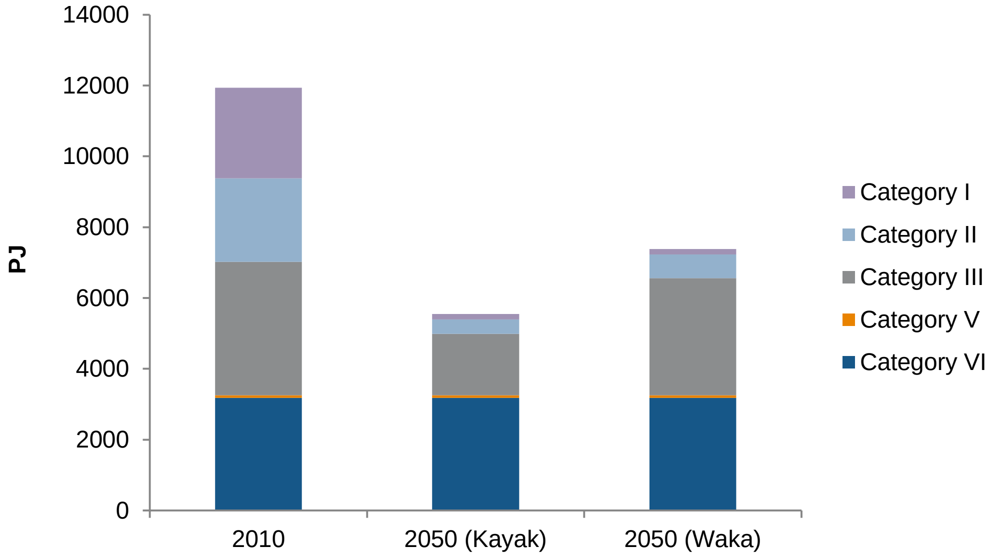
Figure 32 - Production and Net Importation of Gas Products (2010 versus Kayak and Waka 2050)



As discussed above, gas usage is shared across electricity and industrial usage. In Kayak, this initially equal share shifts in favour of industrial usage as electricity usage declines and industrial usage increases. Under Waka, however, industrial usage stays relatively constant and the use for electricity consumption declines.

The increase in usage of gas industrially in Kayak reflects its relative carbon advantage over coal, even with a modest carbon price whereas in Waka, the higher carbon price constrains gas consumption in the industrial sector.

Figure 33 - Depletion of New Zealand's Gas Resources (2010 versus Kayak and Waka 2050)



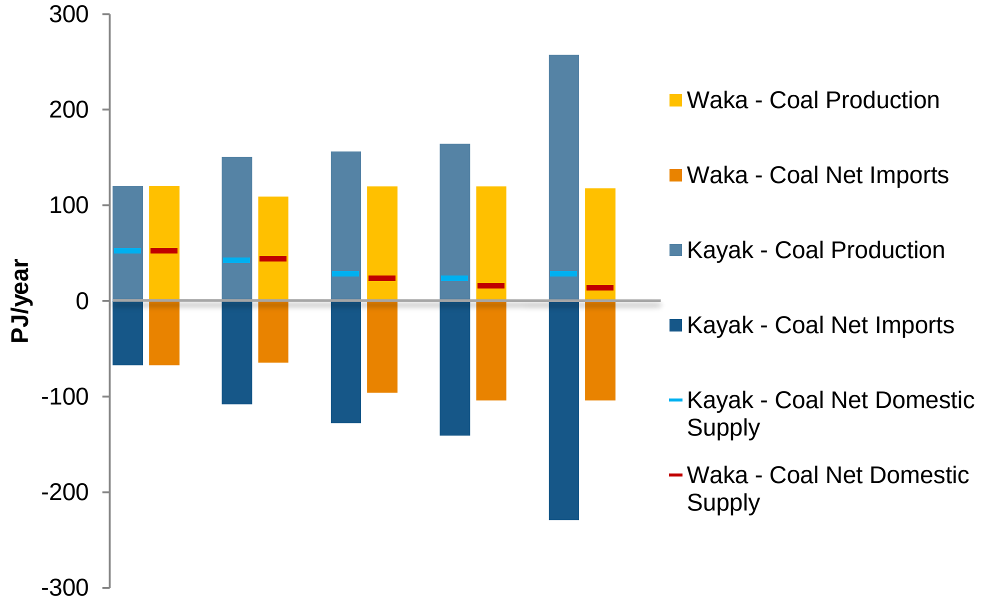
Domestic gas production stays relatively constant throughout Kayak, reflecting consistent discoveries of conventional Category I-III reserves and resources (at a marginally lower exploration cost than Waka), although at the end of the modelling horizon (2050) we see a small substitution for imported LNG. This is likely to reflect the increased cost of domestic exploration relative to the global price of gas. This price differential is clearly sufficient to warrant the expense of an LNG terminal, which we have modelled based on the publicly reported Gasbridge costs.[49]

However, in Waka, gas production declines (with the relatively higher cost of exploration compared with Kayak) and little of the Category III resources are extracted. LNG becomes economic earlier than in Kayak, likely the consequence low international gas prices with the lower demand for gas generally. However, the level of imports is of a similar order of magnitude to Kayak; in fact, higher initially (2040), probably reflecting the attractiveness of gas as a fuel prior to the doubling in carbon price observed in 2050. Note that the carbon price in Waka in 2040 is equal to the carbon price in Kayak in 2050.

[49] \$600m for approximately 85PJ/year. Our modelling suggests that LNG imports would be at most 50% of that. The extent to which the Gasbridge figures can be scaled to this lower capacity is both a function of the fixed versus variable investment costs but also future technology trends for gas transport and regasification facilities. However even an approximate scaling of these costs suggests that the investor would only require a capital recovery (in the form of an annuity) of between NZD\$30m – NZD\$50m, depending on the risk-weighted cost of capital (in turn a function of the tenure of contracts). This implies a differential between domestic costs, and international costs, of ~\$1-\$2/GJ.

COAL

Figure 34 - Production and Net Importation of Coal



Coal production gradually increases over Kayak but flatlines in Waka. The growth story in Kayak is underpinned by strong export demand as domestic consumption declines with increasing carbon prices, with coal use in the industrial and electricity sectors declining. At the end of the modelling horizon, coal production increases significantly, again primarily driven by international demand but also ~15PJ required for the 460MW coal with CCS electricity generation plant.

The Waka story is also an export story. Exports increase as a result of flatlining local production (reflecting our storyline that in a carbon-constrained world, few new coal mines would be opened up) and declining local use in a high-carbon price world. Coal is eliminated from the electricity supply chain in the 2020s and industrial use drops by 65% over the modelling horizon.[50]

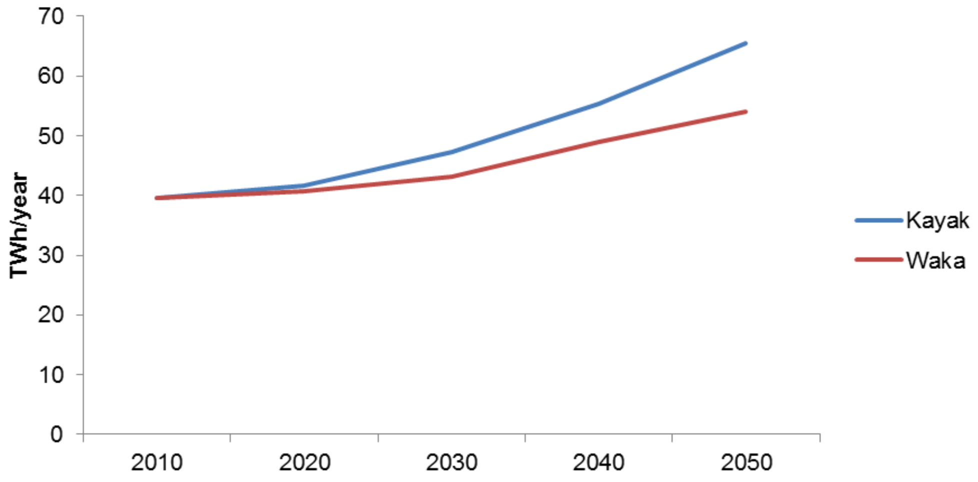
The global demand for our coal exports is underpinned by global growth in coal as a form of electricity generation in both scenarios. The rest-of-world Symphony scenario makes significant use of coal with CCS, especially in developing countries, to offset emissions growth.[51]

[50] See footnote 54 for a discussion of the impact of Genesis Energy's recent announcement to retire its two Rankine coal-fired units.

[51] In the rest-of-world Jazz scenario, global coal generation doubles between now and 2050; in rest-of-world Symphony, it increases approximately 30%.

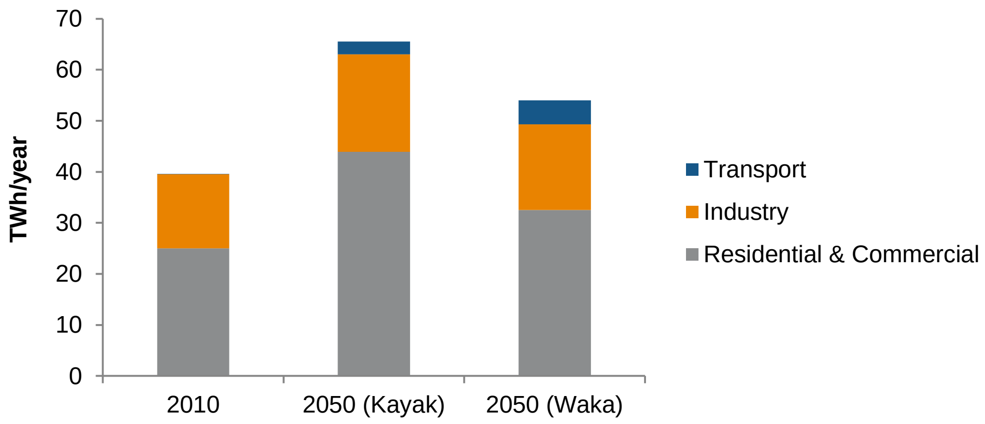
Electricity - Demand

Figure 35 - Total Electricity Demand



Electricity demand, in total, grows by 1.3% CAGR in Kayak, and 0.8% in Waka.

Figure 36 - Electricity Demand by Sector (2010 versus Kayak and Waka 2050)



Growth in electricity demand, in both scenarios, is dominated by growth in the residential and commercial sectors. In Kayak, this grows by 1.4% CAGR, compared with only 0.6% CAGR in Waka.

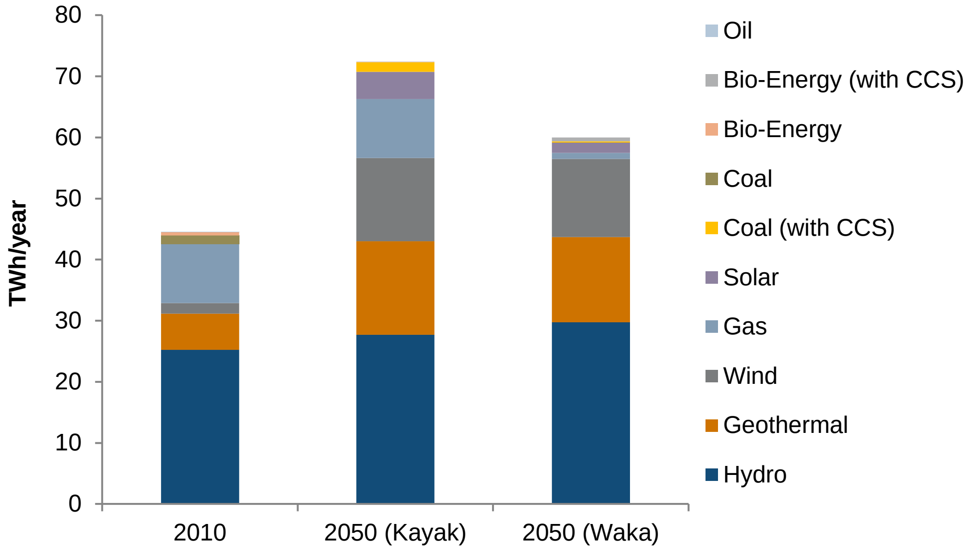
As discussed above, electricity grows in its share of overall industrial energy usage. In both the industrial and residential sector, more efficient heating (and cooling) technologies offset the natural underlying growth driven by population and economic growth. As a result, industrial electricity consumption grows by 31% in Kayak and 16% in Waka. As a growth rate, this is much slower than overall electricity demand in each scenario, reflecting the continuing economic transition from an industrialised economy to a service-based one, as well as the integration of higher levels of energy efficiency in the industrial sector.

The residential and commercial sectors dominate overall growth in total electricity demand. These sectors grow at 1.4% in Kayak and 0.7% in Waka, with growth rates underpinned particularly by the non-thermal consumption (especially electronics and appliances). Electronics, lighting and whiteware experience an efficiency improvement equivalent to 16% of their consumption in each scenario. However, in heating, air conditioning and refrigeration appliances experience more than twice that efficiency – 32% in Kayak and 35% in Waka. Some of our energy efficiency policies in Waka specifically target heating.

Growth in transport-related electricity demand is small in both scenarios, reflecting the high efficiency of electricity as a transport fuel. Even under Waka, where nearly 2 million light vehicles are powered by electricity in one way or another, transport only accounts for 9% of overall electricity demand. Recharging of some EVs occur off-peak, limiting the need for additional generation capacity.

Electricity - Generation Supply

Figure 37 - Electricity Supply by Generation Type (2010 versus Kayak and Waka 2050)



Both Kayak and Waka scenarios increase their proportion of renewable generation from current levels of around 80%,[52] in Kayak to 85% in 2050, in Waka to 98% in 2050. Both scenarios invest heavily in wind and geothermal (both to meet growing demand, as well as replacing end-of-life plant), with capacity in these technologies expanded by over 4GW in both scenarios, dominated by wind. However total geothermal production in both continues to exceed wind throughout the period.

Consistent with government facilitation in Waka, this scenario also sees 750MW of net hydro additions[53] (compared with only 300MW in Kayak).

The two remaining Huntly Coal units are assumed to be removed from service between 2020 and 2030. This is primarily driven by end of economic life and eliminates coal from the electricity supply chain at that point.[54] However, coal returns in Kayak in 2050 in the form of a 450MW plant fitted with carbon capture and storage (CCS) to manage emissions. The re-emergence of coal in Kayak is (like solar) driven largely by a more aggressive growth in demand and is clearly competitive with

[52] Ministry of Business, Innovation and Employment; “Energy in New Zealand 2015”.

[53] Most of the current hydro plants were modelled as having their end-of-life outside the modelling period. Further, the capacity additions in Kayak were all less than 90MW each, although in Waka, some of the hydro projects were closer to 250MW. This is consistent with the Waka storyline where a government would facilitate development of a technology that was both renewable and flexible enough to manage short-term fluctuations in solar and wind.

[54] On 5th August 2015, after this modelling had been completed, Genesis Energy announced that it intended to retire the two remaining Rankine units by 2018, a few years earlier than modelled for the project. Further, on 17 August 2015 Contact announced that its Otahuhu combined-cycle gas turbine (CCGT) would close immediately. Since GMM models in decadal time steps, this may have brought forward investment in approximately 2TWh of (most likely) renewable generation, increasing the renewable proportion in 2020 to around 87%. However, we note that if you assume the current stock of thermal power stations remains in order to manage New Zealand’s hydro-risk exposure, this would require the building of a further 14,000GWh of renewables to move past 90%. This also means that demand would have to grow by a further 14,000GWh by 2025.

next-tier renewables, gas and solar.[55] In Waka, despite having a higher carbon price, renewable geothermal, wind, hydro and solar are sufficient to manage the lower growth path of that scenario.

Gas generation capacity increases in Kayak but decreases in Waka. This results primarily from the difference in carbon prices. We note also that the gas plant in Waka is run at much lower load factors in the 2030-2050 period, primarily as flexible firming plant to manage the high degree of renewables (see below).

In Waka, a 200MW biomass integrated gasification combined cycle (IGCC) plant with CCS is constructed to assist with the intermittency of renewable generation.[56]

Solar expands more aggressively under Kayak than Waka. This is partly a result of the higher growth behind the Kayak scenario which requires 12TWh more electricity in 2050 and hence higher investment in generation plant. Further, under Kayak, solar follows a more aggressive cost reduction trajectory (although reaching the same point as Waka in 2050), reaching a point close to competitive with grid-based generation.[57] We emphasise that, despite the elevated role of government in the Waka scenario, our storyline does not subsidise solar. Solar reaches 3.4TWh generation by 2050 under Kayak (6% of total generation share) and 1.7TWh (3% share) under Waka. We assume that solar is predominantly installed by households; the figures imply household penetration rates of 42% and 16% respectively,[58] a respectable proportion given that preference of residential installation is likely to be in owner-occupied houses (~60% of the housing stock).

[55] We note that WEC assumes that Coal IGCC with CCS follows a slightly faster technology improvement curve in Kayak than Waka, with Kayak being 3% lower capital cost in 2050. That said, we observe that there is little global investment in Coal with CCS in this scenario, suggesting that NZ is aggressively moving up a steep part of the electricity supply curve at that point.

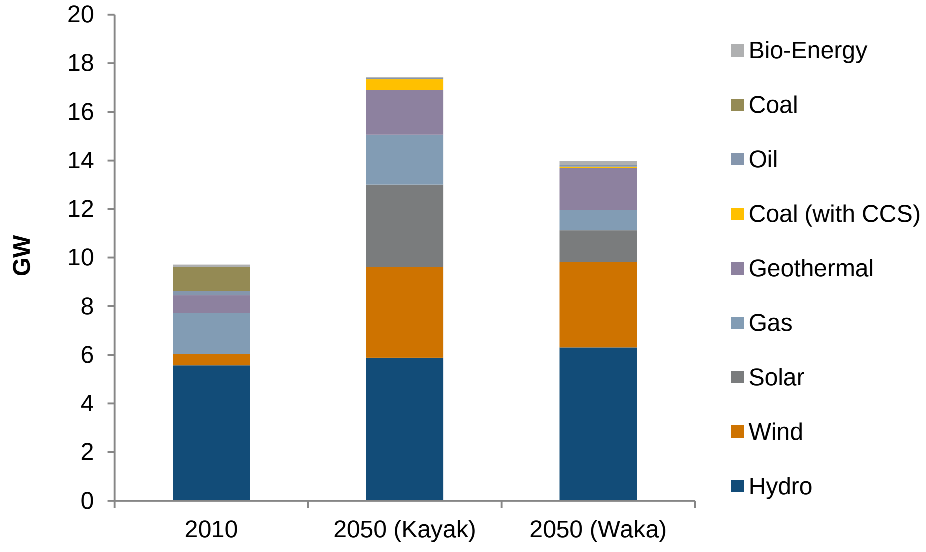
[56] Integrated gasification combined cycle, where biomass is converted into syngas ($CO + H_2$) and then run through a gas turbine and steam turbine combination.

[57] Transmission and distribution costs are modelled as $NZD66/MWh. One of the limitations of the GMM model is that transmission and distribution costs cannot be differentiated by residential, commercial and industrial, hence only an average transmission and distribution cost is possible. Also, this does not allow us to model a fixed/variable structure as inherent in most electricity tariffs. However, even if we were able to do this, it would require us to take a position on the fixed versus variable rate structure that lines companies will adopt, and assume that structure persists for the next 35 years. Clearly, this would be problematic. We feel $NZD66/MWh is a plausible compromise, effectively implying that, irrespective of the fixed charges on customers' bills, residential and commercial solar customers will be able to offset 6.6c/kWh of consumption charges on top of the wholesale energy component of their bill.

[58] This assumes a yield of 15% (a in-built modelling assumption) and an average installation size of 4kW (a post-modelling assumption). At the time of writing, the average residential solar installation in New Zealand is around 3.5kW, hence we are assuming that improvements in stationary battery technology and costs result in average installation size increasing. Of course, there is a range of potential scenarios even in this sub-storyline which would impact on the household penetration rates presented above.

Renewables Proportion and Security of Supply in Waka

Figure 38 – Installed Generation Capacity (2010 versus Kayak and Waka 2050)



As shown in Figure 38 in Kayak, the proportion of renewable electricity increases marginally from its current level to 85%. However, we observe that in 2040 it reached over 90%, before falling back to 85% with the introduction of coal + CCS (not renewable, but zero emissions).

Waka reaches a very high level of renewable penetration (98%), which includes nearly 30TWh of hydropower (50% of total generation). Around 4.8GW of variable solar and wind generation capacity is reached. This, of course, has significant security implications. We are comfortable that a combination of grid-scale batteries and a highly flexible hydro system (which reaches 6.3GW of installed capacity by 2050) can manage the intra-day variations of wind and solar.

The main issue for New Zealand is the 3-4TWh variation in hydropower outputs due to inflow variations that occur from season to season (usually from late summer and autumn, through to winter). The model preserved a significant amount of flexible gas capacity (1.1GW of natural gas plus 0.2GW, of bioenergy IGCC) which, in the "average" hydrological year modelled by GMM, is only required to generate 1.8TWh, a load factor of less than 20%. However, this capacity can scale up to produce over 3TWh over a 4-month period if hydro conditions require it. Combined with a modest[59] medium-term response from industrial demand-side management (DSM) participants, 98% renewable electricity is technically feasible with high reliability.

However, this does not consider the commercial implications of maintaining 1.1GW of gas plant with low load factors, and the flexible fuel contracts required to provide sufficient security. It is unlikely that this can be achieved within current market design. Consistent with the Waka storyline, we assume that a policy measure would be required to underwrite such contracts, and/or a move to a form of capacity market, in

[59] As outlined above, to maintain current security levels we would probably need at least 4TWh of hydro-firming "response". Also, assuming that 1100MW of stand-by gas plant can run reliably for 4 months is ambitious and the 4TWh shortfall in hydro inflows may manifest over a shorter period than 4 months. Thus at least 2TWh of demand-side reductions – equivalent to a ~10% reduction in industrial consumption, or 230MW baseload – would be necessary to be maintain security levels with this plant configuration.

order to make this commercially feasible, as well as a more formal approach to rewarding demand-side response by industrial consumers.

Transport

Light Fleet

In 2050 the total distance driven by the light fleet is 56% higher under Kayak, and 10% higher under Waka. This significant difference between scenarios is driven by a number of factors:

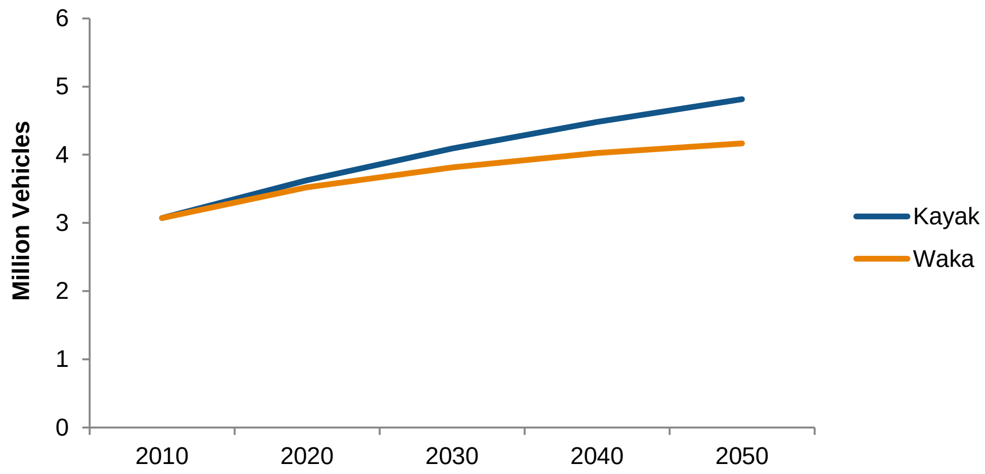
- Probably the most substantial cause relates to the difference in assumed vehicle kilometers travelled (VKT) per car; under Kayak, each car continues to travel on average 12,000km per annum whereas under Waka, this gradually decreases 20% to 9,800km by 2050.

- Our scenarios assume that our motorisation rate (cars per head of population) drops 3% under Kayak and 5% under Waka. With fewer cars on the road, our total kilometres travelled (and thus fuel consumed) decreases.

- We also assume that the total distance covered by private cars decreases 5% under the Waka scenario, as people switch to alternative modes including public transport, walking and cycling.

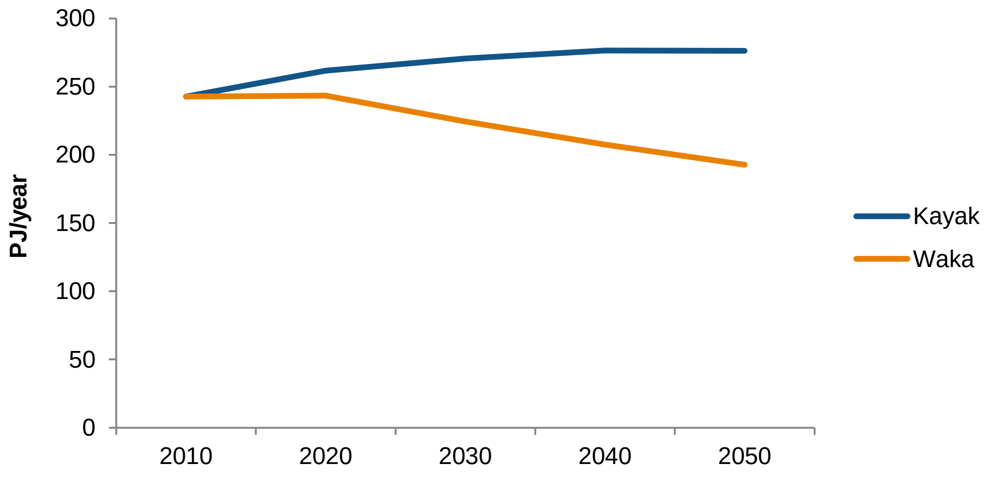
All up, these changes result in a 27% lower VKT per capita in light duty vehicles under Waka than under Kayak (Figure 39). The remaining difference reflects the difference in population growth assumptions.

Figure 39 – Number of Vehicles in the Light Fleet



Despite private cars covering greater distances in aggregate under both scenarios and growth in heavy fleet as a result of economic growth, our overall consumption of transport fuels grows only by 14% (0.6% CAGR) under Kayak while dropping 20% (-0.6% CAGR) under Waka. This reflects overall increased fuel efficiency in the vehicle fleet (light and heavy).

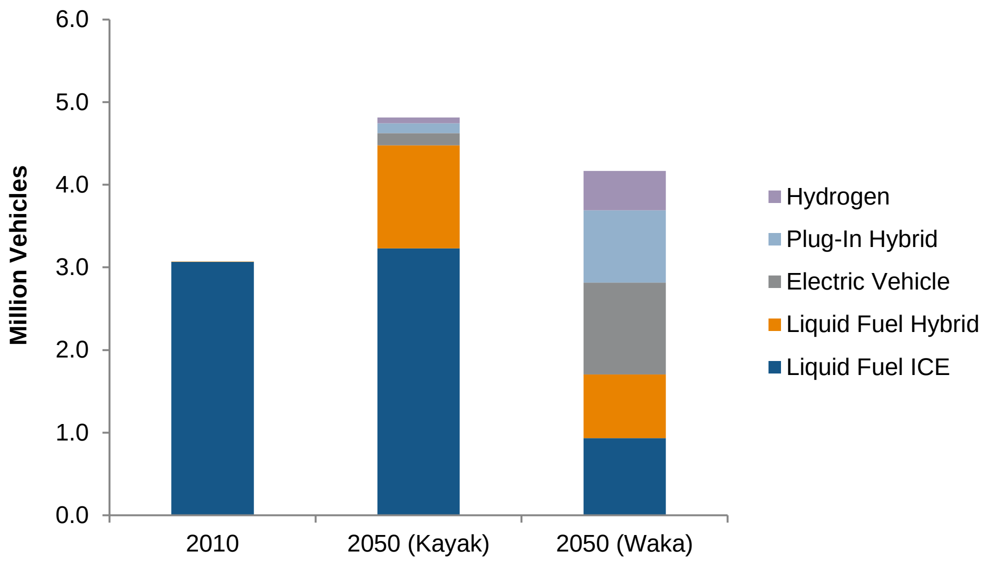
Figure 40 – Total Transport Sector Fuel Use to 2050



Fuel efficiency in the light fleet contributes additional reductions in light fleet fuel usage in both scenarios (44% and 59% in Kayak and Waka respectively).

Both scenarios see the introduction of hydrogen, biofuels and electricity fuels into the mix – making up 33% of the overall fleet in 2050 under Kayak and 78% in Waka.

Figure 41 - Technology Mix of Light Fleet (2010 versus Kayak and Waka 2050)



The Kayak scenario is dominated by ICE hybrid vehicles (1.2 million vehicles) with a relatively small penetration of electric vehicles (250,000 EVs and PHEVs). This reflects the relative attractiveness of oil products as a fuel, compared with electricity. The focus is on improving the efficient use of petrol and diesel by better engine and vehicle designs to reduce fuel consumption.

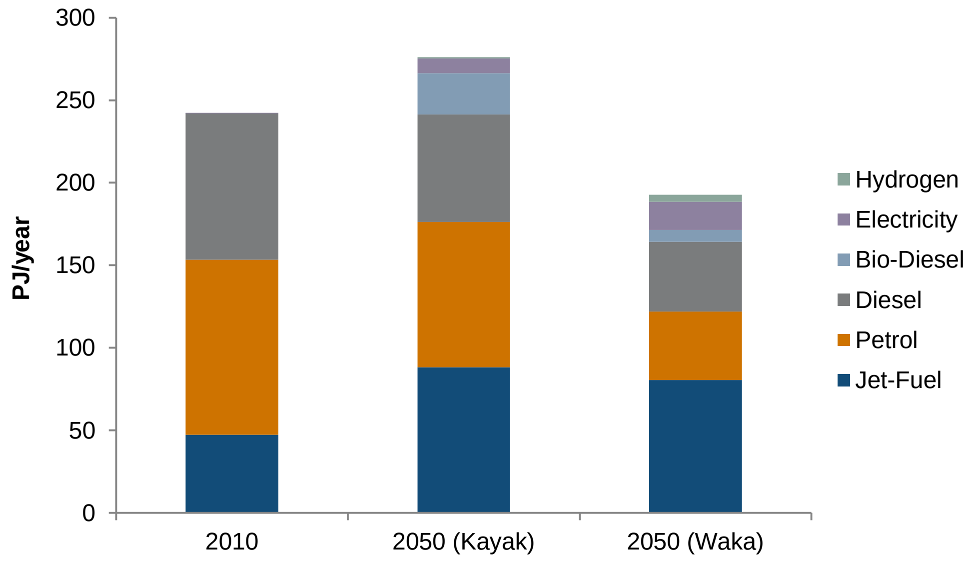
In Waka, it is clear that the relativity of the electricity price improves partly as a result of the impact of the carbon price on oil derivatives but also reflecting the lower marginal cost of electricity in later years arising from the lower electricity growth path observed in Waka.

By the end of the Waka horizon, half of the total 4 million light fleet vehicles are EVs or PHEVs, with traditional ICEs, hybrids and hydrogen-fuelled vehicles equally sharing the rest of the fleet.

Recall that an underlying assumption of both scenarios is that the light fleet would not have the option of compressed natural gas (CNG) as a transport fuel (but it would be available to other surface transport).

The efficiency improvements observed in the heavy fleet are much less dramatic than in the light fleet. This reflects the significant impact electricity has on light fleet fuel efficiency (since electricity is not assumed to have a significant penetration of the heavy fleet, other than trains and buses).

Figure 42 - Transport Sector Fuel Use by Type (2010 versus Kayak and Waka 2050)



Above we can see the impact of the significant change in light fleet transport behaviour and fuel efficiency on petrol consumption and, to a lesser extent, diesel consumption. Petrol and diesel consumption together drop by 20% and 56% respectively in Kayak and Waka, underscoring the reducing reliance on oil products as transport fuels.

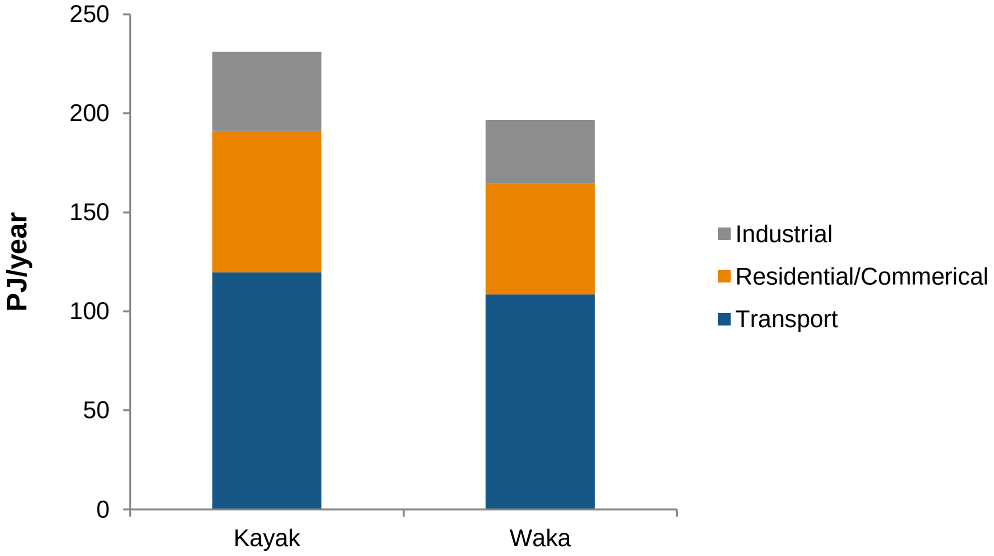
Biofuels (without subsidies) support the overall growing needs of the heavy vehicle fleet in Kayak but do not appear to the same extent in Waka, despite being subsidised. This reflects the lower growth of heavy fleet demand in Waka, as a result of lower economic growth.

Reflecting our reliance as a country on domestic and (more intensively) international air travel, jet fuel consumption grows under both scenarios.

Energy Efficiency

The GMM model allows us some insight into energy efficiency improvements in each scenario. GMM models energy demand in the form of “useful energy” (a proxy for the underlying task that energy is used for, e.g., driving a km, or heating a square metre of a house); hence by comparing these with actual fuels consumed we can measure the impact of the model’s technology choices. However, it is important to note that these measures of efficiency do not reflect changing behaviour (e.g., reducing the use of a vehicle). Any behaviour change assumptions are built into the first order estimates of useful energy.

Figure 43 - Reduction in Total Consumer Energy Demand Due to Energy Efficiency Measures in 2050



Due to Kayak having higher overall energy demand, the absolute amount of energy demand reduction due to efficiency is greater than in Waka. However, once normalised for the growth in energy, relative energy efficiency improvements in Waka (28%) are higher than in Kayak (25%), reflecting the efficiency policies imposed under that scenario.

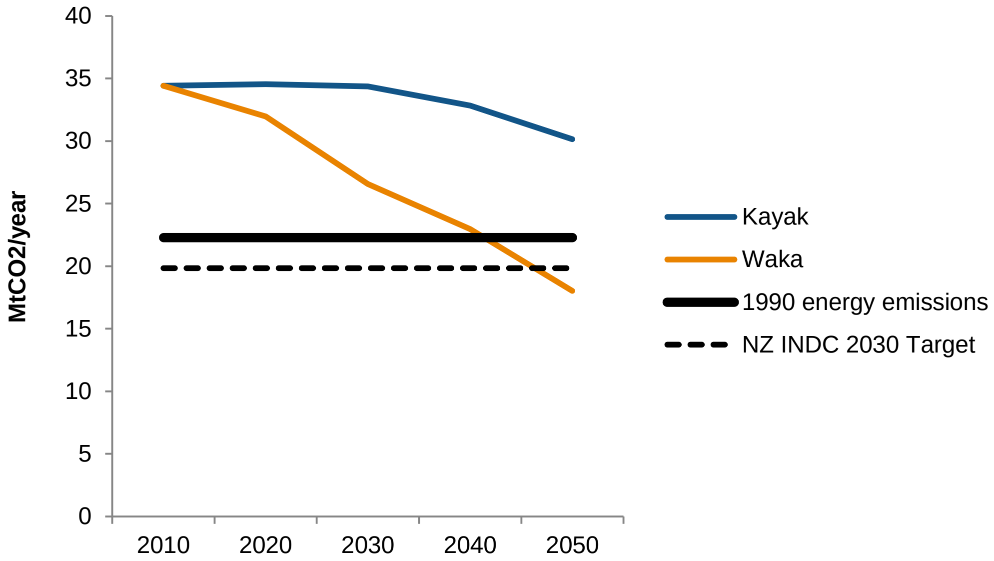
Unsurprisingly, the majority of the efficiency in both scenarios arises from the transport sector; most critically the light duty fleet.

Table 3: Reduction in Demand through Energy Efficiency (%)

	Kayak	Waka
Light Vehicle Fleet	47	64
Residential/Commercial Thermal	32	35
Industry Thermal	26	28

Energy Related Carbon Emissions (Gross)

Figure 44 – Total Energy Related Carbon Emissions to 2050[60]



Gross energy sector CO_2 emissions[61] drop under both scenarios but much more significantly under Waka, reflecting the higher carbon price driving mitigation. Under Waka, our emissions are 12Mt lower than under Kayak. New Zealand's emissions intensity (the number of tonnes of carbon dioxide per $ of GDP) drops dramatically in both scenarios to 63% of 2010 levels in Kayak, and 73% in Waka.

The additional emissions reductions in Waka arise primarily from converting 50% of the private vehicle fleet to electricity, which, by 2050, results in almost zero emissions. We estimate that this conversion alone is worth 5Mt, over 40% of the difference in emission reductions between the two scenarios.

The continued presence of electricity sector fossil fuels (albeit some with CCS) in Kayak and the higher industrial use of gas explain the majority of the remaining difference.

The New Zealand government announced its economy-wide Intended Nationally Determined Contribution (INDC) on 7 July 2015.[62] Assuming this target was applied at the energy sector level (and ignoring carbon sequestration or purchasing of overseas carbon credits), as the figure above shows, we are some distance off New Zealand's INDC of an 11.2% reduction below 1990 levels by 2030. To achieve this target in the energy sector (again, ignoring carbon sequestration), an additional 6Mt of emissions reductions would be required by 2030. The GMM modelling results suggest that this would require, in 2030, 1.2m electric vehicles replacing ICE light fleet vehicles.

[60] New Zealand 1990 energy emissions are based on CO_2 emissions only (Excluding LULUCF) to align with model outputs

[61] Gross emissions exclude any carbon sinks such as forestry and land use change.

[62] http://www.beehive.govt.nz/release/climate-change-target-announced

9. New Zealand in a Global Context

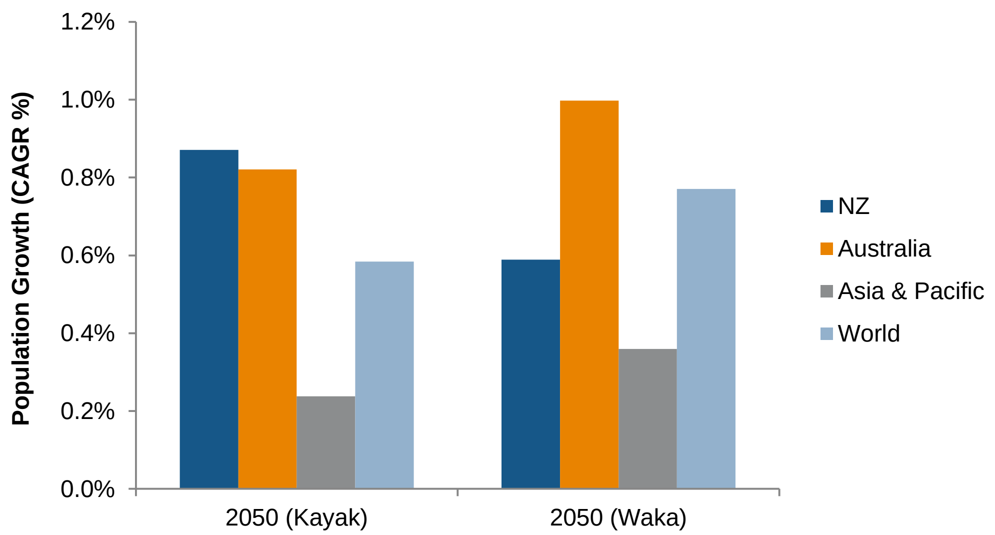
New Zealand's Kayak and Waka scenarios can be compared with the Jazz and Symphony rest-of-the-world outcomes for Australia, the wider Asia-Pacific region and the whole world. Since the only parameter values that were changed for the New Zealand modelling related to New Zealand-specific factors, we can directly compare the results of our modelling with the results obtained by the WEC. This would not have been the case had we changed global parameters, for example the carbon price. The results show that New Zealand stands out in the Asia-Pacific region as a leader in the adoption of renewable technologies and management of energy issues.

Australian data is extracted from the WEC's rest-of-the-world Jazz/Symphony scenario data for the combined Australia-New Zealand region by removing New Zealand Kayak/Waka outcomes. Asia-Pacific represents the combined data for the WEC's South & Central Asia, East Asia, Southeast Asia and Pacific regions.

Overview

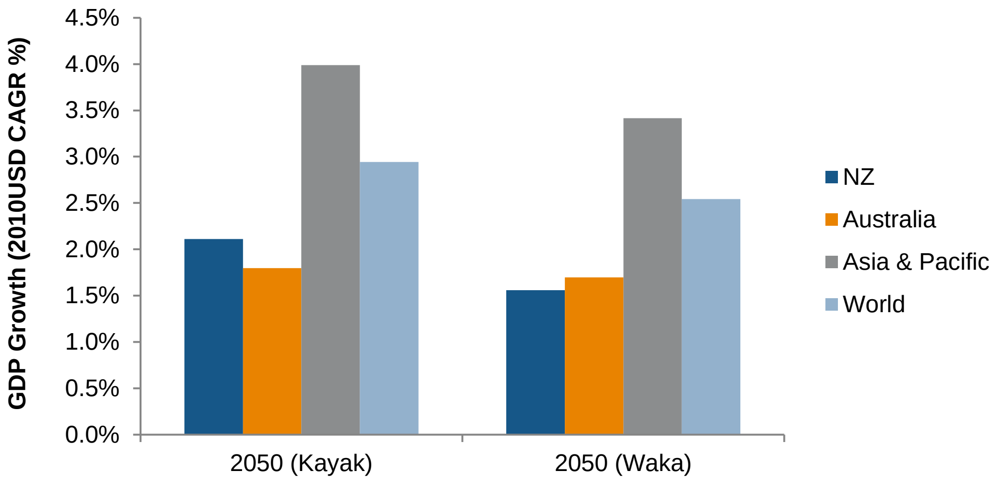
While the expected population growth in the Asia-Pacific region is moderate compared with global averages, it is significant in absolute terms (that is, representing a quarter of the global population increase in the rest-of-the-world Symphony). This creates pressure on Australia and New Zealand to absorb more migrants from across the region. In Kayak, New Zealand targets wealthy and highly skilled migrants and has similar rates of population growth to Australia. In Waka, New Zealand is more selective, reducing our population growth relative to Australia.

Figure 45 - Population Growth



Both the New Zealand and Australian economies benefit from their proximity to the growing Asian economies and population base. This generates similar levels of economic growth for both countries under each scenario. The economic fortunes of both Australia and New Zealand are driven by the primary sector. In Australia, economic growth is driven by exporting minerals and resources (including regionally valuable energy inputs, such as coal), whereas New Zealand's focus is on agricultural exports.

Figure 46 – Real GDP Growth

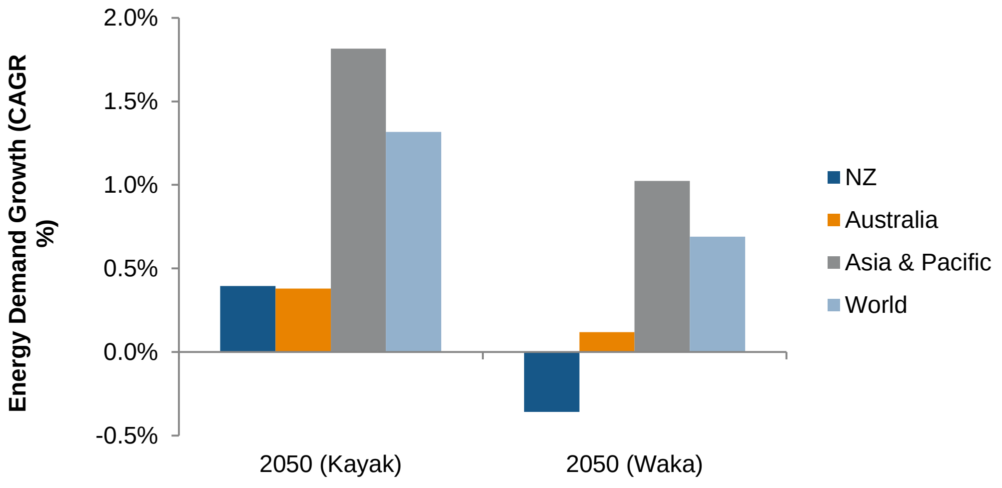


Energy

In the market-dominated rest-of-the-world Jazz scenario, the growing Asian economies consume twice the amount of energy in 2050 than they did in 2010, accounting for nearly 50% of total global energy demand. New Zealand and Australia have much lower rates of energy growth.

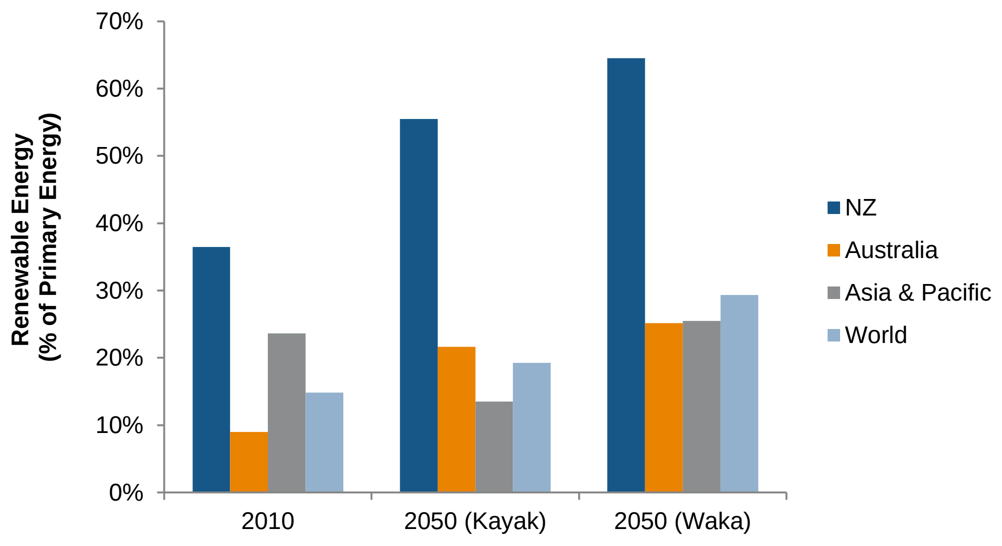
The world and the Asia-Pacific region are able to moderate growth in energy demand between 2010 and 2050 in the rest-of-the-world Symphony in pursuit of their climate commitments. However, New Zealand stands out as being able to reduce its overall energy demand compared with 2010 levels, partly due to lower population and economic growth and partly due to its policy settings and adoption of low emission technology. Australia is close to achieving this too, with relatively flat demand growth. Asian countries (particularly China and India) have significant difficulties in balancing the energy needs of their growing populations and economies.

Figure 47 – Energy Demand Growth



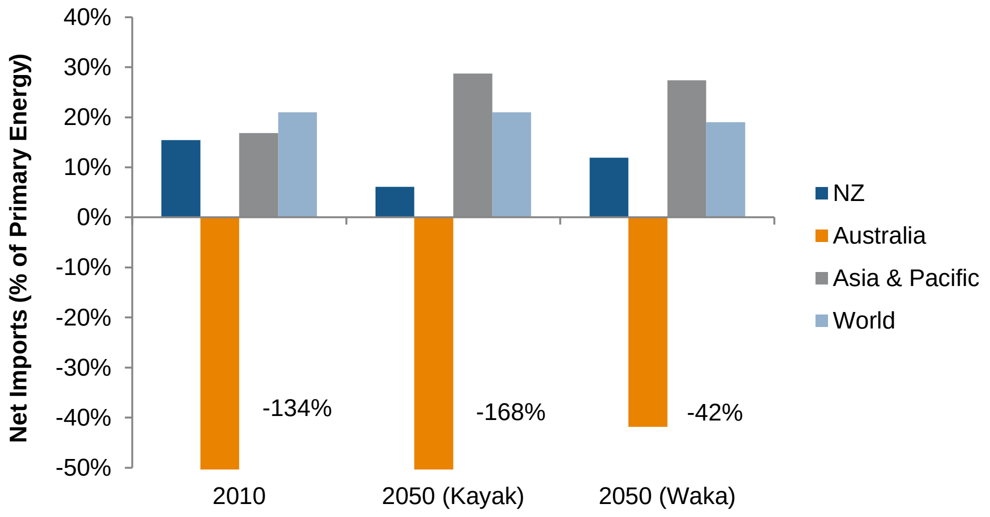
Fossil fuels still play a crucial role in the global and Asia-Pacific energy mix in 2050. Asia remains heavily dependent on coal in a rest-of-the-world Jazz scenario but moves towards gas, nuclear and a higher proportion of renewables in the rest-of-the-world Symphony. Australia is able to achieve rates of renewable energy in the rest-of-the-world Jazz and Symphony scenarios at least similar to those currently seen in New Zealand. Again, New Zealand stands out in both a rest-of-the-world Jazz and Symphony world by outperforming its peers in the move to clean renewable energy sources.

Figure 48 – Share of Renewable Energy in Primary Energy Supply



Australia continues to be a significant exporter of energy inputs in the rest-of-the-world Jazz and (to a lesser extent), the rest-of-the-world Symphony scenarios and must respond to rising demand for its coal and gas exports from Asia in the rest-of-the-world Jazz. New Zealand's reliance on energy imports is unchanged in Waka (similar to the global average) but falls in Kayak, partly due to expanding coal exports to Asia.

Figure 49 – Share of Net Imports in Primary Energy Supply

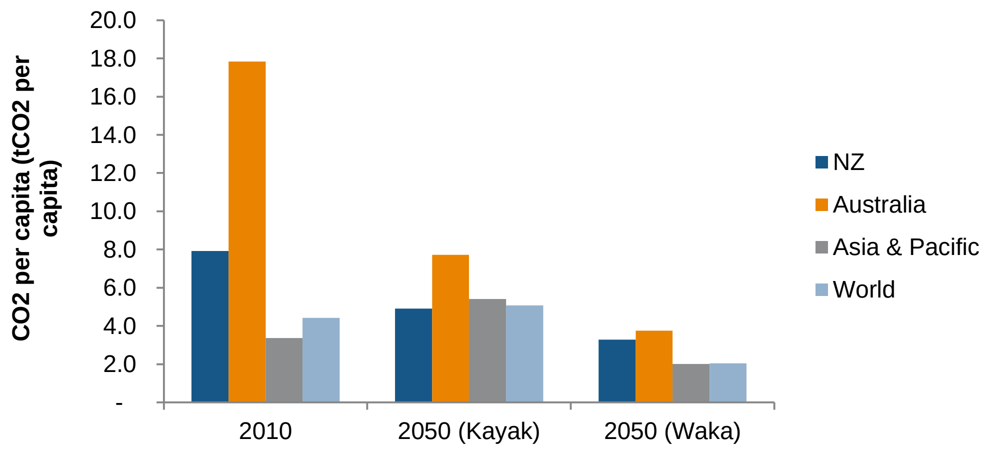


Emissions

While the WEC scenarios indicate that the global economy is not on track to meet its 450ppm emissions target, the world and Asia-Pacific economies are nevertheless able to significantly decarbonise in both rest-of-the-world scenarios. Carbon emissions per unit of GDP and per capita fall significantly. New Zealand and Australia are able to reduce their carbon emissions to similar relative levels. Australia, in particular, reduces emissions by nearly 70% compared with 48% for New Zealand. However, New Zealand is coming off a lower overall emissions' base, reflecting our abundance of renewable energy and climate change efforts achieved to date.

Despite significant improvements, the Asia-Pacific region accounts for approximately a half of the world's energy-related carbon emissions in 2050 under rest-of-the-world Jazz and Symphony sceanrios, partly due to the reliance on fossil fuels.

Figure 50 – Energy-Related Carbon Emissions per capita



10. Alternative Stories

What we have sought to do in this scenario development exercise is lay out two distinct and credible storylines that are plausible. Other than in this regard, we do not lay claim to having any particular insight into how the future will unfold. Others have alternative views that may be thought of as plausible or simply start from a different anchor point or baseline. Examples of such scenarios or future outlooks are Jonathan Porritt's The World We Made, Greenpeace's The Energy [R]evolution 2012, and Tony Seba's Clean Disruption of Energy & Transportation. The box below highlights the key themes of each of these three future outlooks as taken directly from the respective author's work.

Jonathan Porritt's The World We Made. Part history, part personal memoir, Alex's story charts the key events, technology breakthroughs and lifestyle revolutions that make the world what it is in 2050.

- A world in which 90% of our energy comes from renewable sources, and 30% of our electricity from solar power.
- A world in which standard IT devices are computing at the same rate as the human brain and everyone loves their robots.
- A world in which nanotechnology, 3D printing and biomimicry have transformed manufacturing.
- A world in which personal genomics allow everyone to manage their own health, live longer and healthier, and die when they want to.
- A world in which there are still rich and poor but the rich are poorer but happier and the poor are richer in so many ways.

Greenpeace's The Energy [R]evolution. To make the energy [r]evolution real and to avoid dangerous climate change, Greenpeace, the Global Wind Energy Council and the European Renewable Energy Council demand that the following policies and actions are implemented in the energy sector:

- Phase out all subsidies for fossil fuels and nuclear energy.
- Internalise the external (social and environmental) costs of energy production through "cap and trade" emissions trading.
- Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
- Establish legally binding targets for renewable energy and combined heat and power generation.
- Reform electricity markets by guaranteeing priority access to the grid for renewable power generators.
- Provide defined and stable returns for investors, for example by feed-in tariff programmes.
- Implement better labelling and disclosure mechanisms to provide more environmental product information.
- Increase research and development budgets for renewable energy and energy efficiency.

Tony Seba's Clean Disruption of Energy & Transportation. The industrial age of energy and transportation will be over by 2030. Maybe before. Exponentially improving technologies such as solar, electric vehicles, and autonomous (self-driving) cars will disrupt and sweep away the energy and transportation industries as we know them.

- The mass migration from ICE (gasoline) cars to Electric Vehicles will start ~2017-2018.
- All new cars will be EVs by 2030.
- Oil will be obsolete by 2030.
  - Car-as-a-service will change the concept of individual car ownership.
  - Up to 80% fewer cars on the road.
- Disruption of the auto industry.
- Disruption of the car insurance industry.
- Up to 80% parking and highway space will be redundant.
- An opportunity to re-design cities.

Tipping Points

The BEC2050 Energy Scenarios are based around the identification of 19 critical uncertainties by a cross-sector group during an intensive set of three workshops. Consistent with the development of other, alternative 'stories' as outlined above, there could be other high-impact, but low probability events around which scenarios could be developed and modelled.

Alternatively, there could be parameters which we have modelled but which could be more extreme - for example, the costs of disruptive technologies. We did this for battery costs but there are other factors for which this could have also been done.

Consistent with maintaining a fine balance between scenarios that are plausible, yet credible, there are some parameters or events that would massively skew the scenario to which it is associated in either a positive or negative way, or that are unpredictable enough to call the plausibility of the scenarios into question. Instead we have treated these as "tipping points".

Tipping points are treated differently to the critical uncertainties around which we have constructed our two scenarios. This is because their inclusion in the scenarios is sufficiently speculative as to timing and impact that it would undermine their credibility and plausibility.

Therefore, the purpose of this section is to outline the tipping points that we think could materially shift the nature and outcomes of the narratives. In doing so, we have assumed that each tipping point has happened, so we can focus our attention on providing a brief outline of the potential impact on each of our two scenario storylines. We have not attempted to model these events, though they could be modelled.

1. International Economic Crisis

The Euro is dragged under by Greek debt, the US defaults on its debt or the debt cannot be refinanced, or there is an economic crisis in Asia (for example, the balkanisation of China and/or nuclear conflicts in the Indian subcontinent resulting in the collapse of the Asian markets).

	Kayak	Waka
Assumptions	The WEC assumes higher global economic volatility under Jazz than Symphony, but didn't assume economic crises or any consequential impacts on trade despite growing regional tensions. Future economic growth shifts to developing countries in particular Asia.	
Impacts	Will have an impact on GDP growth because of a higher dependence on global trade, with China and Asia being key markets.	Nationalistic policies will give some protection against global events.

2. Middle East and North Africa ('MENA') 'Winter'

Crises in MENA created by tensions in the Middle East finally boiling over lead to another major oil shock.

	Kayak	Waka
Assumptions	The WEC Scenarios make no provision for international supply interruptions	
Impacts	We are going to be more dependent on imports for transport. Electricity would not be severely impacted. Industrial heat is provided from indigenous fuels. A MENA Winter makes our oil and gas resources more valuable and prospective.	Our shift to renewable electricity, electric vehicles and biofuels will give us good energy security. Industrial heat is provided from indigenous fuels.

3. Major Technology Advances

Smart grids, small scale generation, low cost energy storage, electric vehicles, IT advances, energy efficiency and big data all come together with novel market solutions to bring about a paradigm shift in energy transmission, distribution, supply and demand.

	Kayak	Waka
Assumptions	The cost of small-scale, distributed generation, electric vehicles and energy efficiency follow plausible pathways. WEC do not assume any step change in the cost of these technologies or the impact on the energy supply chain of energy storage, IT advances or "big-data". Jazz relies on the market to deliver new technologies whereas Symphony can foster new technologies.	
Impacts	Our innovative markets, ability to take new technologies off the shelf and our high renewables could give us a head start. Reliance on markets makes access to energy easier with innovative pricing and supply models.	The Government could be looking to be the second "cab-off-the rank", to take advantage of overseas technology subsidies, in order to achieve even higher levels of renewable penetration, although technology choices may not always be the best.

4. Big Oil/Gas Finds

Technology advances in the exploration, extraction of gas and oil including satellite based exploration, fracking, floating LNG platforms plus a push from the market and government and a big dose of luck mean we get a big oil and/or gas find, another Maui.

	Kayak	Waka
Assumptions	Increased global demand for oil and gas will drive more exploration in Jazz than in Symphony. Kayak assumes a 5% reduction in exploration costs relative to Waka.	
Impacts	Higher demand both globally and domestically encourages the oil	We may be lucky but exploration is less likely to

	majors to explore offshore basins. This will increase the likelihood of new discoveries in New Zealand's various sedimentary basins. This could alter New Zealand's supply and demand balance, increasing the country's net self-sufficiency. In the event of large-scale finds the benefits from additional discoveries are most likely realised through exporting more hydrocarbons, benefiting GDP rather than an increase in domestic gas use.	be facilitated in in New Zealand. LNG demand is lower so we may look at "Think Big" again, not to synfuels, rather to low carbon fuels such as methanol hydrogen, or electricity all with CCS.

5. Clean Coal Comes of Age

Technology advances in the utilisation of coal including CTL, CCS, fuel cells and hydrogen, mean a low carbon fossil fuel economy is affordable.

	Kayak	Waka
Assumptions	Coal is a major fuel in both WEC scenarios. The WEC identifies CCS as being one of the key uncertainties moving to 2050, with it becoming important in Symphony with higher carbon prices.	
Impacts	Clean coal power generation technologies advance. A major CTL or coal to hydrogen project based on our lignite resources is viable. CCS for this type of project is more affordable than for coal to electricity. CTL would be a major regional economic boost.	CTL in Waka is unlikely but CCS would need to be part of the project which, with higher carbon prices, would be more affordable than Kayak.

6. Climate Solutions

Dramatic and unforeseen changes occurring at a much faster rate than expected and media coverage of weather events lead to an international resolve from governments, businesses and consumers to move rapidly to a minimum carbon economy.

	Kayak	Waka
Assumptions	A much slower rise in carbon prices in Jazz (rising to $USD38 in 2050), than in Symphony (rising to $USD75 in 2050) with commensurate projections for the adoption of existing and new low carbon technologies and practices. Both scenarios fail to achieve the 450ppm global target.	
Impacts	With a genuine and higher, more aggressive cost of carbon embedded into global market prices, New Zealand uses its early adoption of a carbon price to its trade advantage, especially as the most carbon efficient producer of agricultural products. But concerns remain that both globally and domestically the action is too little too late.	New Zealand is, under Waka, already firmly on the pathway to significantly reduce its emissions as part of a strong global agreement. New Zealand's high renewable electricity sector gives it an advantage.

7. Climate Change Impacts on Energy Sector

Climate change impacts change energy demand patterns and put renewable energy supply at risk. Cooling water for thermal power could also be affected.

	Kayak	Waka
Assumptions	The WEC assumes the impacts of climate change to be after 2050. In New Zealand, we assume that the yield from renewable energy (for example, wind, solar and hydro) is unchanged through the time horizon under either scenario and we have not modelled any impact of climate change or energy demand patterns (such as from the increased use of air conditioners).	
Impacts	Annual average peak electricity demand reduces by 1-2% for every 1^{o}C of warming. Peak electricity demand increases in summer in the Auckland megacity as air conditioning use increases. Electricity systems are more robust because of thermal generation to cover dry years and extreme wind shut downs but prices could increase. Higher emissions result.	Wind power generation would benefit from projected increases in mean westerly winds but faces increased risk of damage and shutdown during extreme winds. New Zealand's predominantly hydroelectric power generation is also vulnerable to precipitation variability. Increasing winter precipitation and snow melt, and a shift from snowfall to rainfall will reduce this but there could be an increase in dry years.

What Next? Extending the Possibilities

Looking Beyond Project Completion

The BEC is convinced that, by publishing its New Zealand Energy Scenarios to 2050, a dialogue can be started among its members, policy-makers and industry leaders to explore strategies that help to ensure the provision of sustainable and affordable energy for the greater benefit of all.

The Scenarios provide a working platform from which further analysis can be both scaled-up – to better understand New Zealand's role in the global energy context – or down – to better understand how global and domestic trends might impact on a sector or even a firm. Either way, our scenarios:

- Can be applied at all levels including long-term policy development, industry decision-making, energy research and education.
- Will allow the key assumptions that are taken to shape the energy of tomorrow to be tested.
- Can be used to assess which are likely to be the most dynamic areas and real game-changers of tomorrow.
- Could be used for planning purposes, training programmes, or to "deep-dive" into the detail on a range of topical and important energy sector issues.

These scenarios are therefore likely to change the way energy decision makers consider the choices they make in understanding the real impact of their actions in the long term.

The BEC is working in parallel with the WEC Global Scenarios programme which is currently developing new energy scenarios out to 2060. There is good interaction between the two programmes, both of which are exploratory scenarios using the WEC Energy Trilemma metric. A future project will update BEC2050 after the WEC has finished its new 2060 Scenarios, to be launched at the WEC World Energy Congress in Istanbul next October 2016.

While the BEC will be discussing a range of potential project extensions with interested stakeholders, some further potential areas of further work could be:

- The implications for climate change responses. This could involve assessing the carbon "gap" between various targets and what can be achieved at certain carbon price levels, and/or extending the modelling beyond partial equilibrium to general equilibrium modelling, to better capture economy-wide impacts.[63]
- Future transport technology options. This could involve modelling more aggressive uptake of new transport technologies.
- Renewable electricity targets. This could involve working through in more detail the costs and benefits associated with achieving certain targets by certain dates.
- Greater uptake of disruptive technologies. This could involve modelling a world in which there is more aggressive cost reductions across a range of technologies, both fossil fuel (such as CCS, CTL) and smart grid-related.
- Exploring some of the tipping points identified earlier in the report. In some cases it will be a simple assessment of their impact on Kayak and Waka, in other cases we may want to model the impacts on New Zealand.
- Developing and modelling a 'Goldilocks Scenario'. This could be something which takes from both Kayak and Waka to achieve a balanced Energy Trilemma solution for New Zealand.

The BEC encourages the users of these scenarios to leverage off the rich platform now provided and engage in further fruitful investigation into these and other areas. The BEC believes that regardless of the issues investigated further, the on-going use of a common platform – the WEC and BEC scenarios – and the ability to compare the impact of different inputs across a common assumption set will create a powerful and common vocabulary for discussing different views of the future.

[63] MARKAL GMM is a partial equilibrium, not a computable general equilibrium (CGE) model. As such, it is incapable of fully modelling the economic and fiscal impacts of the scenarios. Extending the GMM with a CGE model would allow for additional insights to be revealed.

Concluding Thoughts

The BEC has built two exploratory scenarios which describe New Zealand's economy in 2050. The scenarios are meant to challenge us but still remain achievable. We do not intend one scenario to be better than the other. There will be things that succeed in both scenarios and there will be failures as well. As a result, there will certainly be winners and losers within each scenario. Either way, the BEC will continue to provide decision-makers with a neutral fact-based tool that they will be able to use to measure the potential future impact of their choices.

11. Appendix 1: Useful Information

This appendix provides general information on units and conversation factors for energy units, abbreviations and acronyms.

Abbreviations and Acronyms

CAGR	compound annual growth rate
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CNG	compressed natural gas
CO_2	carbon dioxide
CTL	coal-to-liquid
ETS	Emissions Trading Scheme
EU	European Union
EV	electric vehicle
FDI	foreign direct investment
GDP	gross domestic product
GMM	global multi-regional MARKAL model
ICE	internal combustion engine
ICT	information and communication technology
IGCC	integrated gasification combined cycle
INDC	Intended Nationally Determined Contributions
LNG	liquid natural gas
LPG	liquefied petroleum gas
LULUCF	land-use, land-use change and forestry
MARKAL	market allocation modelling framework
MENA	Middle East and North Africa
NGOs	non-governmental organisations
OECD	Organisation for Economic Co-operation and Development
PHEVs	plug-in-hybrid electric vehicles
PV	photovoltaic
TPES	total primary energy supply
USD	US Dollar

WTO	World Trade Organisation

Units

Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
Emissions	ppm	parts per million (by volume)
	CO_2-e	carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
Energy	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal unites
	Gcal	gigacalorie (1 calorie x 10^9)
	TJ	terajoule (1 joule x 10^{12})
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	bcm	billion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
Monetary	$ million	1 NZ dollar x 10^6
	$ billion	1 NZ dollar x 10^9
Oil	b/d	barrel per day
	mb/d	million barrels per day
Power	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)

General Conversion Factors for Energy

Convert to:	**TJ**	**Gcal**	**Mtoe**	**MBtu**	**GWh**
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11 630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-8}	3 412	1

Note: There is no generally accepted definition of boe; typically the conversion factors used vary from 7.15 to 7.35 boe per toe.

12. Appendix 2: List of Figures and Tables

Figures

Figure 1 – The WEC Eight Sub-Regions ... 14
Figure 2 – WEC Scenarios Meta-trends ... 15
Figure 3 – Annual Population Growth versus Net Migration (1992 to 2014) ... 18
Figure 4 – Annual Growth in GDP and Exports (1992 to 2014) ... 19
Figure 5 – New Zealand's Energy Mix (2013) ... 19
Figure 6 – New Zealand's Energy Intensity (2013) ... 21
Figure 7 – New Zealand 2014 Energy Issues Map ... 24
Figure 8 – Funnel of Uncertainty ... 28
Figure 9 – Critical Uncertainties in New Zealand and the Interrelationships ... 33
Figure 10 – Scenario Quantification using the GMM MARKAL Model ... 34
Figure 11 – The Edges of the Scenarios as Standard Deviations ... 40
Figure 12 – Energy Related Carbon Emissions (million tonnes of CO_2 per year) ... 46
Figure 13 – Total Consumer Energy (Energy Output – PJ/year) ... 49
Figure 14 – Total Primary Energy Proportions (Energy Inputs) ... 49
Figure 15 – Electricity Consumption by Sector (TWh/year) ... 51
Figure 16 – Electricity Generation by Type (TWh/year) ... 51
Figure 17 – Fuels in all Transport (PJ/year) ... 53
Figure 18 – Technology Mix of Cars (millions of vehicles) ... 54
Figure 19 – Energy-Related Carbon Emissions (million tonnes of CO_2 per year) ... 62
Figure 20 – Total Consumer Energy by Fuel Type (Energy Output – PJ/year) ... 64
Figure 21 – Total Primary Energy Mix (PJ/year) ... 64
Figure 22 – Electricity Generation by Type (TWh/year) ... 65
Figure 23 – Electricity Consumption by Sector (TWh/year) ... 66
Figure 24 – Fuels in all Transport (PJ/year) ... 67
Figure 25 – Technology Mix of Cars (millions of vehicles) ... 68
Figure 26 – Total Consumer Energy (2010 to 2050) ... 70
Figure 27 – Total Consumer Energy by Fuel Type in 2010 versus Kayak and Waka Scenarios in 2050 ... 70
Figure 28 – Totel Fuel Consumption by Sector (2010 versus Kayak and Waka 2050) ... 71
Figure 29 – Total Primary Energy Supply (2010 versus Kayak and Waka 2050) ... 73

Figure 30 – Production and Importation of Oil ... 74
Figure 31 – Depletion of New Zealand's Oil Resources (2010 versus Kayak and Waka 2050) ... 75
Figure 32 – Production and Net Importation of Gas Products (2010 versus Kayak and Waka 2050) ... 75
Figure 33 – Depletion of New Zealand's Gas Resources (2010 versus Kayak and Waka 2050) ... 76
Figure 34 – Production and Net Importation of Coal ... 77
Figure 35 – Total Electricity Demand ... 78
Figure 36 – Electricity Demand by Sector (2010 versus Kayak and Waka 2050) ... 78
Figure 37 – Electricity Supply by Generation Type (2010 versus Kayak and Waka 2050) ... 80
Figure 38 – Installed Generation Capacity (2010 versus Kayak and Waka 2050) ... 82
Figure 39 – Number of Vehicles in the Light Fleet ... 84
Figure 40 – Total Transport Fuel Use to 2050 ... 85
Figure 41 – Technology Mix of Light Fleet (2010 versus Kayak and Waka 2050) ... 85
Figure 42 – Transport Sector Fuel Use by Type (2010 versus Kayak and Waka 2050) ... 86
Figure 43 – Reduction in Total Consumer Energy Demand Due to Energy Efficiency Measures in 2050 ... 87
Figure 44 – Total Energy Related Carbon Emissions to 2050 ... 88
Figure 45 – Population Growth ... 89
Figure 46 – Real GDP Growth ... 90
Figure 47 – Energy Demand Growth ... 91
Figure 48 – Share of Renewable Energy in Primary Energy Supply ... 91
Figure 49 – Share of Net Imports in Primary Energy Supply (%) ... 92
Figure 50 – Energy-Related Carbon Emissions per capita ... 92

Tables

Table 1 – Categories of Critical Uncertainties ... 36
Table 2 – BEC2050 Model Inputs and Assumptions ... 37
Table 3 – Reduction in Demand through Energy Efficiency ... 87

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The BusinessNZ Energy Council is a group of New Zealand organisations taking on a leading role in creating a sustainable energy future for New Zealand. The BEC is the New Zealand Member Committee of the World Energy Council (WEC). All BEC members are automatically members of the WEC.
Participation from members is very important to the BEC and its membership with and contributions to the WEC. Participation allows members to engage with both the BEC and the WEC programmes, help direct the outcomes of the programmes and by mutual exchange increase the value of their respective activities.
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The World Energy Council (WEC) is the principal impartial network of leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit. Formed in 1923, the WEC is the UN-accredited global energy body, representing the entire energy spectrum, with more than 3000 member organisations located in over 90 countries and drawn from governments, private and state corporations, academia, NGOs and energy-related stakeholders. The WEC informs global, regional and national energy strategies by hosting high-level events, publishing authoritative studies, and working through its extensive member network to facilitate the world's energy policy dialogue.

Further details at **www.worldenergy.org** and **@WECouncil**

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