

# NEW ZEALAND ENERGY SCENARIOS

Navigating our flight path to 2060



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The individuals and organisations that contributed to this report are not responsible for any opinions or judgements it contains. All errors and omissions are solely the responsibility of the BusinessNZ Energy Council.

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## **FOREWORD BY DR. ANGELA WILKINSON, SECRETARY-GENERAL OF THE WORLD ENERGY COUNCIL**

The energy sector has entered a new era of broader innovation and unprecedented disruption, which we call The Grand Transition. The World Energy Council (the 'Council') has been developing global energy scenarios for almost two decades to equip energy leaders with a powerful tool for preparing in unpredictable times and to support decision making under deep uncertainty. We regularly validate and refresh our global exploratory energy scenarios and invest in their use. Recently we launched our ground-breaking 2019 World Energy Scenarios 'Exploring Innovation Pathways to 2040' which provide new storylines of the innovation turning points in three plausible global energy futures.

I am delighted that New Zealand continues to invest in its energy scenario heritage in these turbulent times of transition. In addition to helping to build our worldwide energy scenarios, the new BusinessNZ Energy Council (the 'BEC') has developed a series of nationally focussed scenarios.

On a local level, the BEC gathers new insights on the energy issues that are most exercising the minds of our entire global community – for example, accelerating deeper and affordable decarbonisation, enhancing productive energy access, and, rethinking energy security as dynamic resilience in an era of broadening geopolitics, cyber insecurity and global environmental risks. By working together to look at shifting global-to-local-to-global dynamics, we are able to appreciate and anticipate the ongoing shift from commodity to consumer-centric energy systems and to support energy leaders in preparing for new consumer logics, and shifting social norms (e.g., travel avoidance in a new mobility paradigm).

The emergence of new people power is driving demand for new energy services, and, in turn, social cohesion and trust are the key enablers or constraints on successful managed energy transition. Realising the synergies between social-technological-business developments, which are emerging interfaces of energy and adjacent sectors, is at the centre of our whole systems approach and the work of BEC, as it looks to assess the direction in which the New Zealand energy sector will take flight in its new scenarios – Tūi and Kea.

The development of coherent, plausible and distinct stories following an informed and yet impartial, non-ideological process is not a trivial exercise. The challenges of translating wise narratives into meaningful numbers is more complex than ever. Yet it is better to be prepared for alternative futures than to be precisely wrong about THE future.

The fullest added value to New Zealand will be gained by using the BEC's Tūi and Kea scenarios to move bolder and smarter together -- to effectively engage the many and more diverse stakeholders in energy system transition in a social learning process of collaborative innovation.

In a sustained drive to impact, our New Zealand member committee uses its national scenarios in combination with other tools in our unique Energy Transition Leaders Toolkit, including our annual Energy Issues Monitor and Energy Trilemma Index. As such, it deserves recognition as a forerunner in our global network community, which extends to nearly 100 countries and over 3000 organisations. It is a leading example of moving bolder and smarter to deliver the benefit of sustainable energy for all.

I congratulate the BEC, and its members on their innovative collaboration. I wish them continued success in using the new Tūi and Kea energy scenarios for the benefit of New Zealand and our global community.



## PREFACE BY THE HON. DAVID CAYGILL, CHAIR OF THE BUSINESSNZ ENERGY COUNCIL

Our well-being and prosperity depend upon access to reliable, affordable, secure and sustainable energy. At the same time we live in a world where energy systems are changing fast, shaped by many factors and diverse actors.

This speed of change and its growing complexity have reinforced our decision, taken at the time we launched in 2015 our ground-breaking BEC2050 scenarios – *Kayak* and *Waka* – to refresh our future energy stories at regular intervals. This report fulfils that promise.

We have worked with public and private sector investors and the Paul Scherrer Institute from Switzerland who developed our own whole-of-energy sector model. We commenced BEC2060 in 2018 with a series of public workshops before the project really took flight. And what a journey it has been.

While only just evident then, we have truly entered a new energy era, which promises zero emissions energy abundance and the benefits of reliable, affordable energy for all. It is a lofty target to aim at. To succeed, we need to avoid the risks of fragmented bottom-up innovation and top-down ideological polarisation, which characterises much of the global energy dialogues.

As we undertook our refresh, we asked: how do we set our flight-path confident that we are well positioned to avoid the risks and seize the opportunities?

For a country known for its flightless birds, indeed we are colloquially known as kiwis, we consistently demonstrate our ability to soar above the detail and discern the key elements of what might happen. The scenarios we have developed reflect this ability in different ways:

- **Tūi** are territorial and competitive, resulting in a lively and vibrant forest environment. As mainly nectar feeders, their specialised energy needs limit them to specific habitats and ways of living, but provide benefits to others through pollination and seed dispersal.
- **Kea** are known for their intelligence and curiosity, both vital to their survival in a harsh mountain environment. Kea can solve logical puzzles, such as pushing and pulling things in a certain order to get to food, and will work together to achieve a certain objective.

Our continued development and use of explorative scenarios provide an inclusive and strategic framework enabling big picture thinking and deeper assumptions, choices and options. We trust that our two scenarios will help to guide leadership decisions through rapidly changing energy realities and provide a common platform to realise the importance and benefits of a collaborative approach by energy transition leaders, within and beyond the energy sector.

I thank the project sponsors, and others involved in the development and delivery of the BEC2060 energy scenarios. This has been a substantial endeavour and one of which we can all truly be proud.

## INTRODUCTION

In 2015, the BEC adopted an internationally respected, independent, and tested framework used by the Council in conjunction with its modeller, the Swiss-based Paul Scherrer Institute (the 'PSI') in the development of its energy scenarios to 2050.

The two scenarios - 'Kayak' and 'Waka' – helped reset the domestic energy sector conversation about how to move forward.

As promised, the BEC has now built on and extended this analytical platform and prepared two new scenarios of New Zealand's energy future to 2060. Like 'Kayak' and 'Waka' these have been developed by a broad cross-section of New Zealanders from both within and outside the energy sector. Their role was to test and help us determine the set of uncertainties around which our stories would be based.

We quickly realised that BEC2060 would not be a 'refresh' of 'Kayak' and 'Waka' but a rewrite. The context within which our work is nested – both global and domestic – has moved substantially since 2015. New Zealand, like the rest of the world, faces rapidly changing patterns of energy use, blurring boundaries between previously isolated elements of the sector, emerging disruptive technologies and the challenge of living sustainably.

And this time around we had better tools to help us in our work. With our whole of energy sector model built for New Zealand by PSI, BEC2060 has a unique contribution to make to the dialogue we must now have about the challenges and risks we face about how we need to manage the country, our businesses and our lives.

'Tūi' and 'Kea' are the result. These unique stories about New Zealand's energy future and the modelling insights they provide give us - New Zealand's energy leaders of today and tomorrow - the long-term vision and information that will help us exert our leadership and accountability today, to those who follow.

But even this next chapter, to 2060, is not closed-ended. Due to the high level of uncertainty about the future of the energy system, and the pace at which energy technology costs are falling, we will pivot our modelling capability away from lengthy one-off scenario rewrites towards regular modelling as new information comes to hand. With this promise, the BEC will become the source of the most up-to-date hard data on our energy future.

## OUR SCENARIO STORIES AT A GLANCE

Our stories about the future lie at the very heart of our work. Our task, in conjunction with the input of a wide range of public and private sector stakeholders, has been to craft two plausible, coherent and distinct stories about what the future might look like then model the resulting energy sector.

While we developed two stories for BEC2050, we commenced BEC2060 with an openness to telling more than two. The Council, in its scenario refresh in 2016 developed a third scenario – ‘Hard Rock’ and we have previously taken our lead from them. However, we decided to retain two stories. In our search for sufficient distinction we found that a third story, based on BEC2060’s ‘critical uncertainties’, would simply be a derivative of the other two. Developing a third story on this basis would undermine the overall efficacy of what we set out to achieve and the insights available to be drawn from it.

### The Basis for our Stories

Based on what we learnt from BEC2050, we have built our new scenarios – ‘Tūi’ and ‘Kea’ – from the ground up. This was influenced by three factors being:

- the massive amount of change in the sector since 2014/15, driven by rapidly declining technology costs, and the sentiment surrounding how the sector might respond to the main challenges and opportunities;
- a desire (underpinned by the availability of our own unique model) to tell a uniquely New Zealand story that could respond in ways that were different from what is happening in the rest of the world. This allowed us to focus on the pathways and their respective challenges and opportunities, as opposed to the end point; and
- a shift from the simple divide between the options of government action or reliance on markets to one more evenly based on how policy makers, investors and consumers might react to the challenges and opportunities each pathway presented.

We have developed our new stories around the expectation that they will endure for a number of years, while the input assumptions we use around technology costs, carbon prices, etc will change more regularly with new modelling outputs being presented.

### Our Two New Stories

We developed our two new stories on this basis. For this evolution of our scenarios we have chosen scenario names based on New Zealand birds and their characteristics which match the scenarios. Our scenarios reflect the nature of the bird:

- in Tūi the global community takes some action on climate change. New Zealand society does not generally have a common view on what is the most important issue of the day. As a result, New Zealand is a slow follower on climate change responses, protecting some businesses from the full force a carbon prices, and deliberately taking a ‘wait and see’ approach to how other countries develop climate policy, and how technology costs might change. Governments do what they can to meet international emission reduction commitments but otherwise, New Zealand focuses on delivering economic prosperity and individual wellbeing by leveraging more

aggressively off its comparative advantages. Adoption of low emissions technology is a purely commercial, competitive response; and

- in Kea New Zealand adopts the position that the economy cannot remain internationally competitive with its current emissions intensity and takes an international and domestic leadership stance in lowering emissions, choosing to undergo an early and aggressive economic transformation. This leadership stance is strongly supported by business and the wider community and sees New Zealand acting earlier than the global community. Where possible, the early adoption of low emissions technology is supported, and wider policy strongly encourages the reduction of emissions.



## **BEC2060 KEY MESSAGES**

### **1. A changing society and economy**

Whichever pathway we are on the New Zealand's economy and energy system will look considerably different to today. There will be less reliance on primary produce with greater emphasis on service industries. Policy makers, investors and consumers all have important roles in shaping what this future might look like. Collectively we need to develop an understanding of what we will be selling to the rest of the world by 2040 or beyond, that they want to buy, that will retain if not enhance our prosperity and wellbeing as a nation. Energy will be an enabler of this new society and economy, not a cause of it.

### **2. Renewables are the greatest opportunity to decarbonise, but it's not exclusively an electricity story**

The biggest opportunity to decarbonise is to leverage New Zealand's significant renewable electricity resources and convert much of the transport fleet and industrial heat to electricity. This opportunity needs to be carefully managed as electricity extends its reach to a much larger section of the economy, and we need to be careful not to neglect the opportunity for biofuels and hydrogen to deliver low-emissions outcomes to sections of the economy facing tougher decarbonisation paths (for example, aviation and marine), or energy efficiency.

### **3. Energy security becomes more important in a renewable world**

Careful investment in the resilience of our electricity system is required to ensure the wider economic reach of electricity is not compromised by the very problem it is trying to fix. Climate change will bring a stormier, windier future. While renewables are now more affordable, a big question is how to make them secure when they are heavily reliant on weather patterns.

### **4. A technology race ensues**

The race for technology is finely balanced, and we must be wary of 'betting the house' on a given technology. Electricity is favoured in the heavy transport fleet, but purchase costs for hydrogen need only to fall by a small amount to become economic. Robust trialling, piloting, and clear policy frameworks will level the playing field for technology development.

### **5. More forward-thinking solutions are needed**

Policy makers, businesses and investors need to turn their focus to innovation and R&D in order to commercialise solutions. As a major tourist destination, New Zealand is susceptible to global reactions to the emissions impact of air travel. Despite very high carbon prices, solutions to emissions in aviation (and marine) are not obvious. While some potential low-carbon technologies are appearing for these sectors, they are nascent at best. Net zero carbon targets for the economy need to be paired with an accelerated commitment to investigating and trialling solutions to these 'sticky' emissions.

## **6. The dangers of siloed thinking demand better information**

Siloed thinking risks unintended consequences and poorly allocated resources. Interconnectivity between electricity and transport markets will emerge very soon, and throughout the economy the carbon price is binding decisions together. This drives greater complexity than the historical siloed approach, and greater co-ordination will be needed to soften the silos, to deliver better policy outcomes and alignment in the energy sector. A much greater degree of transparency in markets, as well as a heightened awareness of the behavioural impacts of this interconnectivity, is heralded.

## **7. Balance is required between stable policy and investment frameworks and adaptive ones**




We know that reality will be different to the stories told in Kea and Tūi, and this highlights the risk when forming policy and making strategic business decisions. What happens if the early investment in Kea is not rewarded or the doubling-down in Tūi results in higher, not lower, long term growth? Over the next 40 years, hundreds of billions of dollars will be expended by governments, businesses and individuals on capital, operating and fuel costs in both scenarios. The cost of change includes the risk that, having incurred considerable cost in the pursuit of either direction, governments may have to change tack later if the strategy isn't working for New Zealand. Governments need to strike a balance between making long term policy and investment decisions and decisions that are resilient and adaptive to the rapidly moving energy system.

## **8. Quicker insights are required**

The pace at which innovation and the development and execution of new business models in the energy sector is occurring has never been faster. As a result, large scale, infrequent scenario development processes rapidly lose their relevance, especially as the costs of new and emerging technologies fall. Policy makers, businesses and consumers need more timely analysis and delivery of insights. In order to fill this growing gap, the BEC, in conjunction with its members, will look to leverage off the unique capability that resides in its TIMES-NZ model to look at particular issues and assumptions and to refresh its on-line results, possibly quarterly, increasing the rapidity with which we can translate emerging trends into insights.

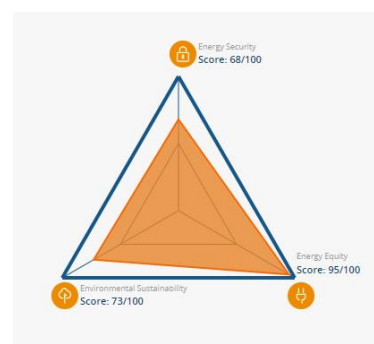
## THE ENERGY TRILEMMA

The World Energy Council's Energy Trilemma ranks countries on their ability to provide sustainable energy through three dimensions: energy security, energy equity and environmental sustainability. The ranking measures overall performance in achieving a sustainable mix of policies and the balance grade highlights how well a country manages the trade-offs of the Trilemma with 'A' being the best.

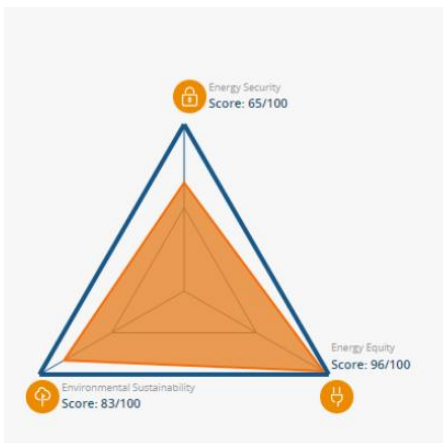
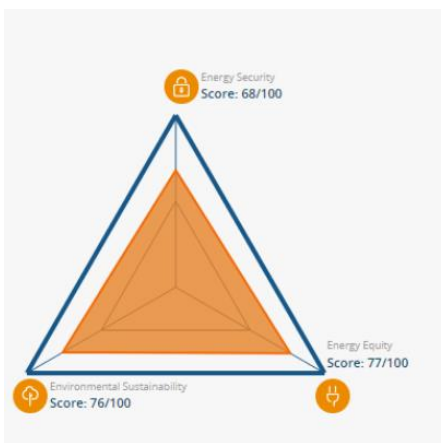
Index rank	Country name	Balance grade	Trilemma score	 Energy security rank	 Energy equity rank	 Environmental sustainability rank
1	<u>Switzerland</u>	AAA	85.8	11	11	1
2	<u>Sweden</u>	AAA	85.2	1	40	3
3	<u>Denmark</u>	AAA	84.7	2	28	2
4	<u>United Kingdom</u>	AAA	81.5	28	19	6
5	<u>Finland</u>	AAA	81.1	3	33	28
6	<u>France</u>	AAA	80.8	27	29	4
7	<u>Austria</u>	AAA	80.7	18	22	16
8	<u>Luxembourg</u>	BAA	80.4	56	1	8
9	<u>Germany</u>	AAA	79.4	16	30	23
<b>10</b>	<b><u>New Zealand</u></b>	<b>AAA</b>	<b>79.4</b>	<b>20</b>	<b>26</b>	<b>29</b>
11	<u>Norway</u>	CAA	79.3	73	20	5
12	<u>Slovenia</u>	AAA	79.2	9	39	17
13	<u>Canada</u>	AAC	78.0	5	21	67
14	<u>Netherlands</u>	BAB	77.8	39	8	43
15	<u>United States</u>	AAB	77.5	17	14	54
16	<u>Czech Republic</u>	AAB	77.4	10	36	40
17	<u>Uruguay</u>	ABA	77.2	15	46	11
18	<u>Spain</u>	BAA	77.0	36	37	18
19	<u>Hungary</u>	AAB	76.8	12	35	33
20	<u>Italy</u>	BAA	76.8	37	23	20

### New Zealand's Energy Balance Today

Today, New Zealand is the only non-European country to rank consistently in the top 10, reflecting strong policies for energy transition and stable growth in sustainability driven by generation from renewables. However, reduction in fossil fuel stocks, and a slight upturn in import dependence since the late 2000s represent fluctuations in energy security. Energy equity (including energy affordability) remains stable in a context of social change.



## New Zealand's Energy Trilemma Performance in 2060

Kea 2060	Tūi 2060
	
<b>Energy Security</b> <ul style="list-style-type: none"> <li>- Lower diversity of energy supply</li> <li>- Energy self-sufficiency 92%</li> <li>- Lower import dependence:</li> <li>- Net imports primary energy supply 10%</li> <li>- Oil product net import 100PJ</li> <li>- LNG net import 0PJ</li> <li>- Coal net import 0PJ</li> <li>- Domestic gas production 35PJ</li> </ul>	<b>Energy Security</b> <ul style="list-style-type: none"> <li>- Higher diversity of energy supply</li> <li>- Energy self-sufficiency 87%</li> <li>- Higher import dependence:</li> <li>- Net imports primary energy supply 14%</li> <li>- Oil product net import 170PJ</li> <li>- LNG net import 54PJ</li> <li>- Coal net import 0PJ</li> <li>- Domestic gas production 0PJ</li> </ul>
<b>Energy Equity</b> <ul style="list-style-type: none"> <li>- GDP per capita 152,757\$/person</li> <li>- Carbon price \$205/t</li> <li>- Electricity price \$100/MWh</li> <li>- Diesel and Petrol price \$37.42/GJ</li> <li>- Natural gas price \$9.45/GJ</li> <li>- Total energy consumption 600PJ</li> <li>- Energy savings through energy efficiency 800PJ</li> </ul>	<b>Energy Equity</b> <ul style="list-style-type: none"> <li>- GDP per capita 122,749\$/person</li> <li>- Carbon price \$130/t</li> <li>- Electricity price \$220/MWh</li> <li>- Diesel and petrol price \$32.15/GJ</li> <li>- Natural gas price \$20.98/GJ</li> <li>- Total energy consumption 720PJ</li> <li>- Energy savings through energy efficiency 600PJ</li> </ul>
<b>Environmental Sustainability</b> <ul style="list-style-type: none"> <li>- Energy intensity 0.6MJ/\$GDP</li> <li>- Energy sector carbon emission 10Mt/pa</li> <li>- Energy carbon emission intensity 0.01kg/\$GDP</li> <li>- Renewables in energy 88%</li> <li>- Renewables in electricity 95%</li> <li>- Electrification 50%</li> </ul>	<b>Environmental Sustainability</b> <ul style="list-style-type: none"> <li>- Energy intensity 0.9MJ/\$GDP</li> <li>- Energy sector carbon emission 17Mt/pa</li> <li>- Energy carbon emission intensity 0.02kg/\$GDP</li> <li>- Renewables in energy 83%</li> <li>- Renewables in electricity 90%</li> <li>- Electrification 50%</li> </ul>

We recognise that a 2060 energy trilemma assessment seems too distant to be meaningful. However, this timeframe gives policy and investment decision makers time to achieve the best of both worlds and balance New Zealand's energy market performance.

## WHAT WE HAVE DONE, HOW AND WHY

### Our Approach

The purpose of our original BEC2050 work in 2015 was to undertake explorative analysis of potential futures to help government leaders, businesses and individuals better understand that there is more than one possible future pathway and to identify the uncertainties before they arise in order to manage their impact.

BEC2050 outlined two plausible, integrated, and distinct energy sector futures to help New Zealand think about how the future energy mix might look, and the range of trade-offs and choices it might need to make along the way. 'Waka' and 'Kayak' sought to help us all make more resilient, durable decisions today, about the future.

The release of 'Kayak' and 'Waka' was just the beginning of the conversation. The plan was to regularly refresh this work to accommodate new information.

Since the release of BEC2050, the energy sector has seen a proliferation of 'scenarios' to the point where the landscape is now crowded but none of them have been similarly explorative. We have future stories from Vivid Economics (for the cross-party GLOBE-NZ group of parliamentarians), the Productivity Commission, the Interim Climate Change Committee, Transpower, Westpac and others. All of these play a valuable role in filling an information deficit.

Yet despite this our work remains relatively unique in approach for a number of reasons, and in so being, retains a number of advantages over the work undertaken by others.

But first it is worthwhile unravelling the uses associated with the term 'scenarios', as it actually covers many different methods. We distinguish three main approaches that commonly use the term 'scenario', being:

- explorative scenarios: these are generally explicit about societal and political elements in addition to techno-economic elements. Explorative scenarios focus on forming robust input assumptions, and allowing the future to be told through the modelling of decisions based on these inputs, rather than focusing the outcomes on the achievement of a particular objective (see 'normative scenarios' below). They tend to describe new and alternative energy futures that are already emerging and that are shaped by factors beyond the direct control and influence of any one system actor. Examples are the Council's World Energy Scenarios 2060, the BEC2050 energy scenarios, and the Electricity Demand and Generation Supply Scenarios by the Ministry of Business, Innovation and Employment ('MBIE');
- outlooks: these tend to focus on techno-economic elements. These evidence-based predictions aim to establish a baseline or base case that can be used to evaluate the costs and benefits of additional and/or new policy options. Outlooks are also commonly referred to as conditional predictions, baseline scenarios, or policy scenarios. Examples are the IEA's Current Policies scenario and the work of the Interim Climate Change Committee; and
- normative scenarios: these focus on achieving a specific goal aligned to a global vision agenda – for example, avoiding climate change (UNFCCC Agenda) or achieving universal development (UNSDG Agenda). These goal-based pathways are developed by back-casting to inform detailed technology and policy roadmaps. As such, normative exercises are less open to unexpected outcomes as part of the input

definition is constraining the output. Examples are the Shell Sky scenario and the Productivity Commission scenarios.

Each, has its advantages and disadvantages and these often depend upon the context in which they are used, or the intended purpose of use. We continue to be convinced of the merits of developing plausible, explorative scenarios as the most effective analytical tool to help policy makers and investors understand and manage complex uncertainties and the trade-offs they imply. In doing so, we can avoid being captured by anchoring bias, particularly one that is a continuation of the status quo or some deviation from it that we believe will or should happen. Normative outlooks or predictions are especially prone to this.

In particular, we also remain convinced that an approach that brings together the two elements often found in isolation in others' work or combined but in ad hoc, inconsistent ways – a coherent and plausible storyline and its quantification – allows for greater insights to be drawn.

The energy supply chain is becoming increasingly interconnected – these interconnections will drive the incentives for consumption and investment. An approach that assumes a single pathway (even with sensitivities) and fails to recognise the interactions of the many components of the energy system, or impeding uncertainties will miss the mark. Instead, scenarios that provide a glimpse of what contrasting variations of the future might look like will provide greater insight. This is amplified when a number of potentially disruptive technologies are on the horizon that can fundamentally change what energy we produce, and how we produce, distribute and consume it.

### **Creating our New Stories**

As noted earlier, the development of stories that are plausible, coherent and distinct lies at the very heart of our work. The attainment of these three guiding principles forms a substantial analytical challenge especially at a time of rapid change and growing complexity.

Our core task is to explore - in a plausible and perhaps challenging manner – the uncertainties we face and the variables that drive them, and provide a coherent and integrated way of thinking about how they might coalesce into a story about the future. It is worthwhile pointing out that there is no point trying to tell stories around what we know as these automatically form the platform on which all future stories are developed.

### **Uncertainties Are All Around Us**

Uncertainty can be both global and domestic in origin. Our fortunes as a country are intertwined with those of our major trading partners and the global economy. What we sell and what we purchase, and how we are perceived as a country all depend on the preferences of other global citizens. And technological advances are planting the seeds of an energy-led economic revolution comparable to that seen at the start of the industrial and digital age.

The uncertainties for New Zealand are not just about how new technologies will evolve but also how they will be taken up by New Zealand consumers and integrated into the New Zealand energy system.

While BEC2050 scenarios were inextricably tied to the global economy due to the use of the Council's model as the basis of our work, the availability of our own TIMES-NZ model allowed us the freedom to think about the interconnections of New Zealand with the rest of the world, but not be tied to trends in global economic variables such as growth paths.

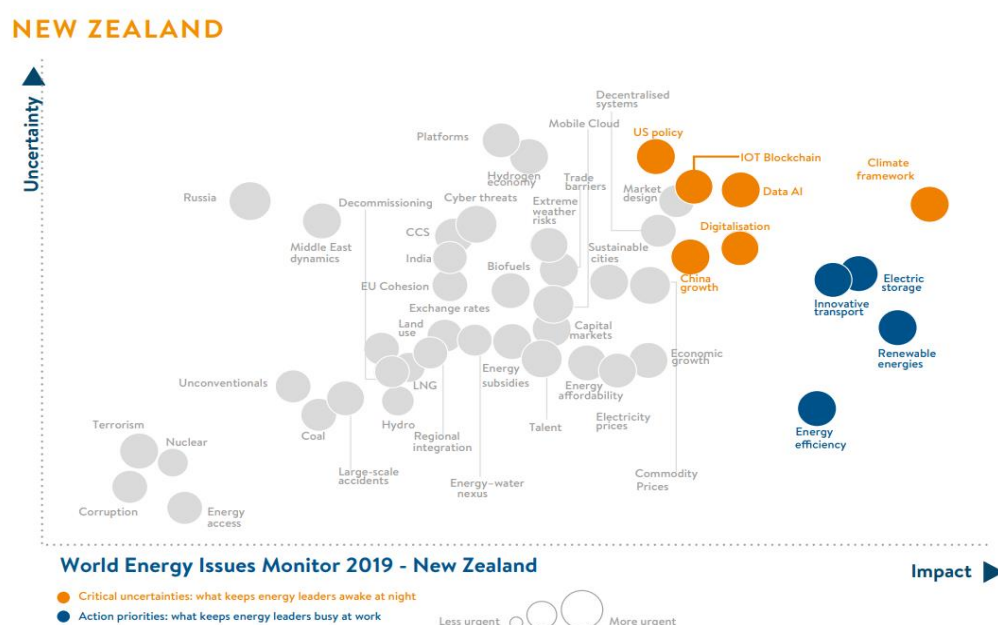


This allowed us to think more closely about the nature of our domestic growth trajectories, and tell a more nuanced, sophisticated pair of distinctly different stories. Rather than assuming that key underlying drivers (for example, economic and population growth) remained constant through time, our stories could now have an 'arc', where we explore how choices made in the early years had different consequences for the country in later years. These stories, changing through time, are inextricably connected to the cars we choose to drive, the houses we choose to build, and the businesses we choose to grow, or discard.

We can see the impact of these and other uncertainties on New Zealand decision-makers in the BEC's sixth annual Energy Issues Map. The Council produces the World Energy Issues Monitor each year through a global survey of energy leaders. It assesses 42 issues and highlights critical uncertainties and action priorities. Critical uncertainties have high uncertainty and high impact, while action priorities are those with high impact and low uncertainty.

Figure 1 below highlights the critical uncertainties and action priorities in New Zealand, the major issues include climate change, emerging technologies, energy efficiency and electric storage. Uses for artificial intelligence, the internet of things and blockchain in the energy sector were highlighted in the Energy Issues Monitor. These innovations will further disrupt the energy sector and are increasingly in the spotlight as ways to increase energy efficiency.

**Figure 1 – New Zealand Energy Issues Monitor 2019**



Source: World Energy Council

These and a number of other critical uncertainties were considered in a series of narrative workshops whose participants came from across the public and private sectors, as well as non-governmental organisations. These workshops identified a large number of critical uncertainties facing the energy sector as we head to 2060.

### Thinking About Uncertainty Through Time

Our BEC2050 scenarios differentiated largely on whether governments were mandated by society to intervene, or whether markets would be relied upon. This led to a simplistic representation of the future, characterised by a widening 'funnel of uncertainty' through time.

BEC2060 makes a significant departure from BEC2050 by anchoring its two narratives around the critical decision as to whether New Zealand leads or follows the rest of the world in response to the challenge of global warming. While it is true that, generally, uncertainty still grows the further we peer into the future, the nature of our stories centres on the plausible future consequences of this critical decision and commitment now – does it pay off, or would future governments have to take corrective action having taken one or other path?

This is a more nuanced view of uncertainty. It is still true that uncertainty around exogenous factors (for example, technology) grows the further we look, but the characteristics of future uncertainty are shaped by how the stories characterise the payoff to each critical decision. In practical terms this means how much effort will be put into New Zealand's response in each scenario, the cost of the response and when that cost is realised, and how the economy will respond compared with our trading partners. So some of our future uncertainty is derived exogenously; some is created by the decisions we represent in the scenarios.

### The Choice of 2040 as a 'Point of Inflection'

Whether, in either scenario, the decisions made in the immediate decade 'pay-off', or whether governments would be likely to correct the path they are on, won't be known until well into the scenario period. Our narratives argue that the period in which the payoff can be fully assessed as being realised or not is around 2040. We chose this point because:

- we did not want the point of inflection in our story arcs to be confused with being a commentary on existing policy targets (for example, 2035, 2050);
- the period needed to be far enough out to begin to be free from the inertia of long-life energy investment decisions (for example, power stations); and
- it represented a half-way point in the scenario period.

We stress that 2040 was a pragmatic choice for modelling parameters (which must be specified 5-yearly). In reality, the threads of success or failure may be apparent earlier, and/or the ability to change course will be slowed by (geo)political, economic and societal inertia.

We also note that with respect to the inflection point of 2040:

- progress, especially with respect to technology, is moving as fast as it ever has but as slow as it ever will. This unprecedented pace of change means that while the long-term trends are critical, the nearer term story-telling and modelling results are relatively more clear; and
- policy makers and investors are reacting to problems now and in the next 5 – 10 years and so need near term trend information to inform these decisions.

### Strategic Risk of Policy Choices

The narratives (and the modelling) represent a particular payoff in each scenario, in this post-2040 world. In Tūi, having enjoyed high growth to that point, the country starts to experience international carbon-intensity related headwinds, and struggles to pursue a late focus on decarbonisation. Kea's heavily (and somewhat painfully) decarbonised economy enjoys spectacular success on the international stage, and enjoys a return to economic growth.

We see from the modelling late in the period (that is 2040 – 2060) outcomes based on our current assessment of technology and technology costs. These outcomes for each scenario provide a basis for a conversation about the merits of one or other path. Like many of the underlying assumptions about the future, the adopted assumptions are just one characterisation of the potential outcome of the early period policy choices. Inside each scenario, the uncertainty associated with taking either of the paths is a strategic risk, for example:

- the cost of correcting the course if the path taken turns out to be less rewarding than expected, or
- the benefits of the course do not outweigh the costs already incurred.

The ultimate payoff could be measured in GDP, GDP per capita or a range of wellness indicators. The risk could be dimensioned as some function of the range of payoffs that might emerge. This assessment is not part of BEC2060's scope at this point, but, later in this document, we return to the issue of strategic risk management, especially around the post-2040 world.

### **Differentiating the Narratives Based on the Key Critical Uncertainties**

The breadth and nature of our project participants allowed us to build on our tradition of independence and neutrality in our assessment of the critical uncertainties and the relationships between them.

Our post-workshops task was to take the participants views of the critical uncertainties and the interrelationships between them and weave them into two plausible, coherent, and distinct stories. We did this with the support of our project sponsors from across the public and private sectors.

While there is an infinite number of permutations and combinations, especially given the relationship between New Zealand and the rest-of-the-world, the core of the New Zealand-specific story will be the result of the quality of decisions made domestically and the cumulative effect of those decisions.

We decided that four critical uncertainties differentiated the two narratives, and essentially acted as anchors for them:

1. the way New Zealand – as a society - makes decisions in the future, being either more cohesive or more individualistic:

The community may wish to protect the freedom of individuals to act as they see fit or may look to make greater use of the tools of central and local government.

2. domestic acceptance as to whether climate change is one of a number of issues or the most important issue to be addressed:

This critical uncertainty distinguishes between a cultural shift in society leading to a full commitment to respond to the climate change challenge at one end of the spectrum and a society that resists prioritising climate change issues over other important issues facing the economy at the other.

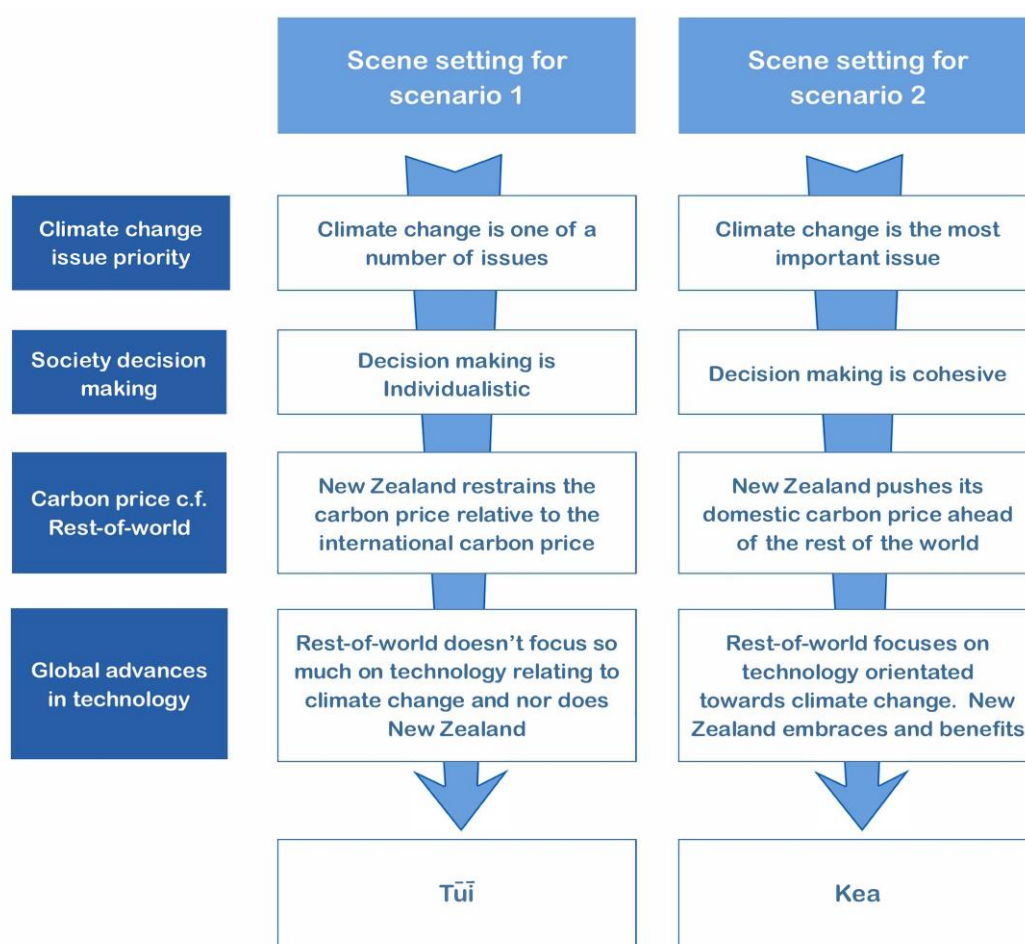
- the level of actual or implied price of carbon relative to the rest of the world:

One mechanism that New Zealand uses to signal its intent in respect to climate change is the stringency with which it limits GHG emissions domestically relative to the rest of the world (which may be wholly or partially expressed through the carbon price).

- the degree to which technology is available to address energy balance and emissions domestically:

This critical uncertainty picks up on the idea that globally technology development may or may not be targeted at the climate change challenge and that New Zealand, in turn, may or may not be a high adopter of technologies that target GHG emissions.

**Figure 2 - The Combinations of Dichotomies for the Anchor Critical Uncertainties that Define the Narratives**



This characterisation of the core critical uncertainties provided us with the backbone of our stories and their overall nature and shape. The narratives that emerged from theme were quantified using the BEC2060 TIMES-NZ model.<sup>1</sup>

## Our Model

A key strength of our work is our ability to illuminate New Zealand's key energy sector scenario differences and drivers by quantification. This allows us to ensure that the many interconnections within the energy system are respected, and gives us the ability to make transparent what would otherwise be complex and opaque.

One of the key lessons from BEC2050 was the desirability to have direct access to our own model in order to provide us with easier and more rapid access to modelling capability than relying on PSI in Switzerland, which we had done for BEC2050. This goal was made a reality with investments from a range of public and private organisations.

The quality of the modelling resource available to us was also lifted. This time around, our stories are quantified using a model known as 'TIMES' – an integrated energy-systems model.<sup>2</sup> TIMES is a technology rich, bottom-up model, used for the exploration of possible energy futures based on contrasted scenarios. It is an advanced version of the MARKAL modelling family on which we relied for our BEC2050 modelling.<sup>3</sup>

TIMES is a linear program optimisation, meaning that it minimises the total discounted costs, through time, of meeting all energy service demand. This modelling approach has several advantages.

- TIMES is an integrated energy-systems model, meaning that it simultaneously models all components of the energy system, ensuring any interdependencies are reflected – the impact of gas exploration and supply, or the impact in changes in freight transport technology, on electricity generation, and the consequential impact on electricity costs for what technologies residential consumers may choose to buy. This way we can always trust that the results from the TIMES model are internally consistent at every point in time
- as much as possible, TIMES requires the services demanded of the energy system as inputs, not simply forecasts of energy demand.<sup>4</sup> The services are expressed as, for example, vehicle kilometres travelled and the space required for heating and lighting, or the demand for heat at an industrial site. It is then up to the model to determine which are the optimal technologies to use to supply these service demands – which

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<sup>1</sup> The BEC2060 TIMES model is based on the Council's scenario model developed by PSI. This is the version of the model produced for BEC for the purpose of modelling these narratives. See below for more detail in the TIMES-NZ model specification.

<sup>2</sup> The TIMES model uses the IEA-ETSAP methodology. The Energy Technology Systems Analysis Programme (ETSAP) is one of the longest running Technology Collaboration Programme of the International Energy Agency (IEA). ETSAP currently has as contracting parties 20 countries, the European Commission and two private sector sponsors. See <https://iea-etsap.org/>.

<sup>3</sup> MARKAL is a numerical model used to carry out economic analysis of different energy related systems at the country level to represent its evolution over a period of usually of 40–50 years. The word **MARKAL** was generated by concatenating two words (MARKet and ALlocation). MARKAL is also based on the IEA-ETSAP methodology (see previous footnote). TIMES is a more advanced version of the methodology.

<sup>4</sup> In the current model specification, this is true of the residential and commercial sector, and the road-based vehicle system. Enabling this feature in agriculture, industrial and the remainder of the transport system is the subject of a model enhancement which is underway.

type of car, or which type of heating device. Simultaneously, it determines the optimal fuel for those energy-consuming technologies which will be procured and delivered.

While this relieves us of having to form specific forecasts for energy demand, it does require us to provide the model with forecasts of service demand. The BEC2060 project used inputs from a variety of sources – using two of the Ministry of Transport’s (the ‘MoT’s’) transport outlook scenarios to form projections of the need for passenger and freight transport,<sup>5</sup> using sub-sectoral GDP forecasts to project the future service demand from the commercial, agriculture and industrial sector, and population to form the basis of the residential service demand projections. Combined, these core inputs formed the fundamentals of our modelling and results (for more on this see the next section); and

- a feature only available to linear programming optimization models is that TIMES produces a rich array of economic information as part of its solution. Rather than simply tell us what the optimal quantities of different fuels and technologies are for each scenario, it also tells us what the implied commodity prices are, and how far away technologies are (economically) from becoming ‘optimal’. In our view, this has been a missing piece of the dialogue in so many scenario-based discussions. Not only can TIMES tell us the optimal commodity prices associated with the solution at every point in time, it can also provide information about how far it was from finding a different solution – for example, if hydrogen trucks didn’t appear, and electric trucks did, the model can tell us how far away hydrogen trucks were from appearing, which, in itself, gives us some insight into the sensitivity of the scenario to the relative costs of hydrogen and electricity technologies for freight. The precise estimates of energy demand and supply become decreasingly useful the further into the future we peer; but knowledge of how the relative economics of different technologies are playing out is far more useful.<sup>6</sup>

In Figure 3 we illustrate the components and structure of the TIMES model as it stands today. However, we note that many components of the model will undergo continual improvement and modification. For example, work has already begun on those elements of sectoral demand (shown below) for which the model used for BEC2060 was constrained in terms of choice of consumer technologies.

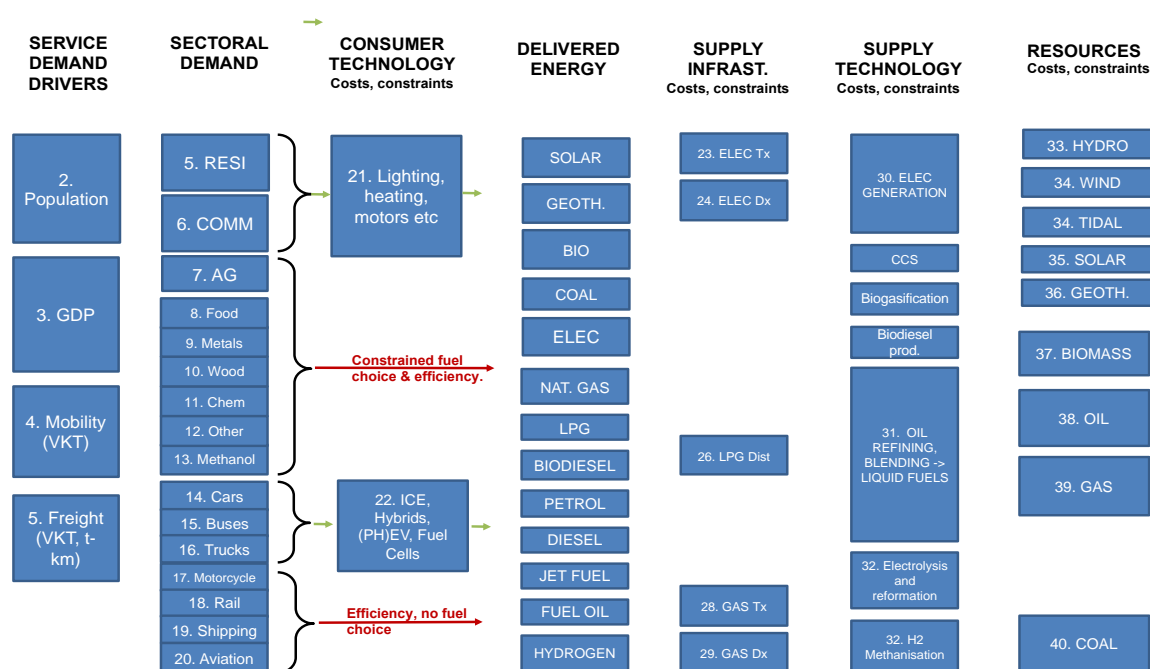
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<sup>5</sup> MoT’s scenario data was calibrated to BEC2060’s population and GDP projections.

<sup>6</sup> We stress that this is more than just comparing the relative long-run marginal costs of different technologies (which implicitly assumes all technologies provide an identical service); a linear program provides information on the net value of the technology, i.e., its long run value to the energy system as a whole, minus its cost.



**Figure 3 - The Structure of TIMES-NZ**



Finally, as with any model, we need to remember the limitation of TIMES. Models are just machines that have very limited capacity to mirror the nuance of human decision making. The reason we use models is that it is very difficult for us to use our mental powers of deduction and reasoning to reconcile the many interconnected parts of the energy system, as that system undergoes change. However, the capacity of the model to represent the systemic effects requires a trade-off with modelling tractability.

With TIMES, one of these trade-offs is that it is a linear model. Practically speaking, this means that if the model sees some technology as 'optimal' – even only fractionally more economic than another technology - it will try to maximise the use of that technology. TIMES has a high degree of sophistication in it which ameliorates this to some extent, but we need to remember that it is the natural tendency of any linear model.

## WHERE OUR STORIES COMMENCE

The global energy sector sits on the verge of a historic transformation, driven by technological progress and evolving political, economic and environmental issues.

Energy technology innovation is playing a central role in this transformation of the energy sector. Solar photovoltaic, wind energy, energy storage, unconventional oil and gas resources, and the electrification of transport are now realities that are changing the energy sector. The confluence of falling technology costs for energy supply options, the emergence of new technologies for managing energy demand and a shift in focus to reducing GHG emissions from energy use have created a level of uncertainty about the future of energy systems in every country around the globe. As a result of cost reductions and improvements in technology, we are now seeing new business models and regulatory responses evolve.

This applies equally in New Zealand even though it is ranked amongst the leading countries in the world for electricity and energy produced from high levels of renewable sources. That being said, New Zealand's geography, economy and resources create a unique set of uncertainties and trade-offs for New Zealanders.

In developing the BEC2060 scenarios narratives and modelling assumptions, it is important to understand the specific features of the current New Zealand economy in the context of its competitiveness along with the key drivers affecting the energy industry.

### Climate Change

Climate change is a serious threat to New Zealand, and the rest of the world. The Paris Agreement marked a landmark deal in the two-decade old global climate effort. Core elements of the Paris Agreement include commitments on emissions, adaptation, finance and transparency, and steps to promote carbon trading. The participating countries agreed on a long-term mitigation goal of keeping global warming well below 2°C. Countries will co-operate on enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change. Sharing information, good practices, experiences, and lessons learned in relation to adaptation actions. The Agreement has been approved by 195 countries and will take effect from 2020.

Sustainability is a growing concern around the world and the reduction of carbon emissions has become a greater priority globally. The current New Zealand Government aims to support decarbonisation by targeting 100% electricity generation from renewable sources, in a normal hydrological year, by 2035. A Climate Change Commission will set carbon budgets and the legislated goal is to be a net zero carbon economy by 2050.

### Our Energy System

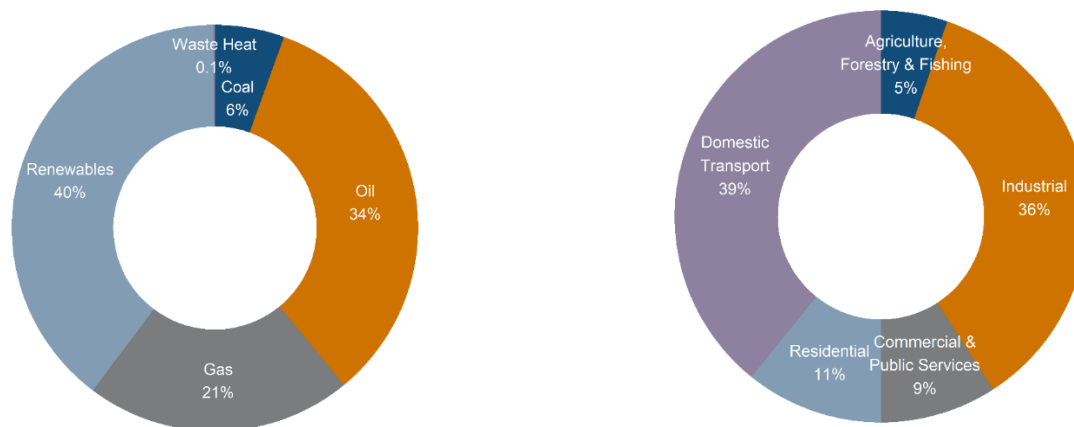
In 2017, New Zealand had the fourth highest proportion of renewable energy in the Organisation for Economic Co-operation and Development (OECD) countries after Iceland, Norway and Sweden. 52% of New Zealand's indigenous energy production comes from hydro, geothermal and other renewables and 85% of New Zealand's electricity generation comes from renewable sources.<sup>7</sup>

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<sup>7</sup> Ministry of Business, Innovation, and Employment – Energy in New Zealand, 2018.

Currently, 55% of the New Zealand's total primary energy requirements are met by oil and gas and 6% by coal (as shown in Figure 4). New Zealand imports the majority of its oil needs, while coal and gas demands are met predominantly through indigenous production. Renewables, such as geothermal and hydro, contribute 40% to our total energy supply with the majority of this used to generate electricity.

**Figure 4 – New Zealand's Energy Supply (2017)    Figure 5 – Energy Demand by Sector (2017)**

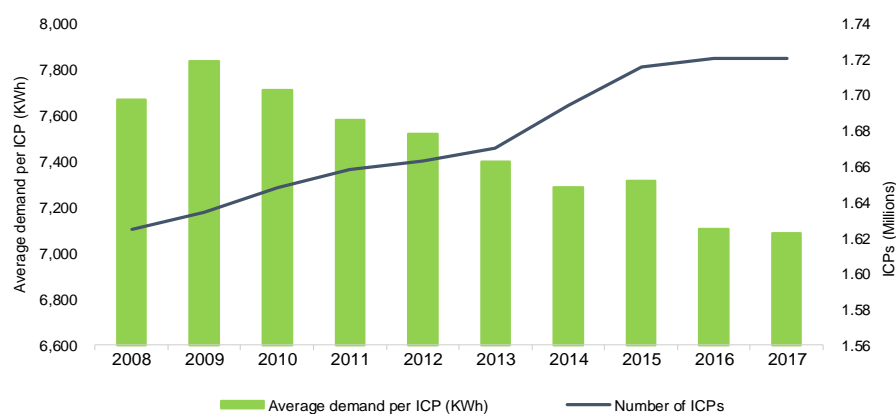


Source: Ministry of Business, Innovation & Employment

Figure 5 shows the industrial, commercial and primary sectors account for 50% of energy demand and the domestic transport sector accounts for 39% of energy use.<sup>8</sup>

Figure 6 sets out the historical residential demand per installation control point (ICP) – an acceptable proxy for the number of households in New Zealand. Since 2009, annual average household demand has steadily reduced from 7,800 through to ~7,100 kWh in 2017. Figure 6 also illustrates the continued reduction of electricity intensity in the residential sector, that is, there is a relatively consistent reduction in annual average demand, even though the number of connections increases over the same period.

**Figure 6 – Annual Electricity Consumption (Residential)**



Source: Deloitte analysis, MBIE

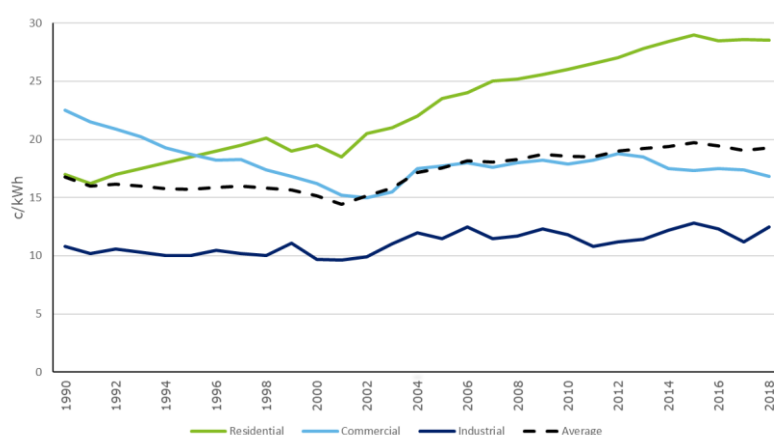
<sup>8</sup> Ministry of Business, Innovation, and Employment – Energy in New Zealand, 2018.

## Energy Affordability

In New Zealand, customer affordability – particularly for the most vulnerable - has come into sharp relief as a genuine societal and political expectation of the electricity (and wider energy) system. Policy measures to address customer affordability are leading policy changes in the New Zealand energy system at the time of writing. We think it is important to reflect that focus in the context of where our stories start.

Relative to other countries, New Zealand's energy affordability ranking (as measured by the Council) remains stable and well-managed in a context of social change. Despite this, 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. Residential electricity retail prices have increased over the last approximately 30 years. The recent Electricity Price Review (the 'EPR') Report found that large increases in electricity prices for residential customers have not been matched by similar increases in electricity prices for other consumer types, shown in Figure 7.

**Figure 7 – Average electricity prices (1990 to 2018)**



Source: Electricity Price Review – First Report

From 1990, residential prices rose steeply, while commercial prices kept falling, and industrial prices stayed relatively flat. The EPR report noted specifically:

- residential consumer prices rose at an average rate of 2.1% a year, and by 2018 were 79% higher than in 1990. Since 2015 they have been relatively flat;
- commercial prices dropped at an average rate of 1% a year, and by 2018 were 24% lower than in 1990; and
- industrial prices rose at an average rate of 0.6%, and by 2018 were 18% higher than in 1990.

There are many explanations for this. Some of the price divergence is due to cost differences. For example, residential consumers require more infrastructure to get electricity to their homes, and they tend to use proportionately more electricity at peak times. By comparison, 46% of industrial demand is met by direct connection to the transmission grid and therefore does not incur any distribution charges.

The EPR report found that as new technology continues to develop which offers consumers choices, there is an increasing chance they will look to disconnect from the grid.

## **Our Core Modelling Inputs**

As noted above, the TIMES model required us to provide it with forecasts of service demand. This involves the forming of a number of robust input assumptions in order to calculate the model results.

Our approach is to develop the narratives and, in doing, so, identify commensurate economic, social, carbon and energy-related inputs that would lead to the distinct outcomes modeled for the two scenarios. As required by the model, we have, below, developed GDP, population and growth components, and carbon prices for each narrative to inform the energy sector that we would end up with under each scenario.

The narratives developed here are two plausible stories of the future that are located at the more pronounced end of the spectrum for the critical uncertainties identified below. They are not predictions or forecasts; rather they illustrate two possible pathways.

### The Economy

New Zealand is a good place to do business. It ranks first out of 190 countries for ease of doing business,<sup>9</sup> second out of 153 nations for business friendliness,<sup>10</sup> and 3<sup>rd</sup> out of 186 countries for economic freedom.<sup>11</sup> Respect for property rights and the exercise of the rule of law are broadly cherished attributes and the country's desirability as a location to live and work features strongly amongst those who seek a high standard quality of life.

But our economic growth is currently in a challenging phase, with slower population growth and some sectors that helped the economy get to the peak in the cycle in 2016 (construction and tourism) currently at capacity. Figure 8 below shows New Zealand's GDP growth from 1994 to 2018.

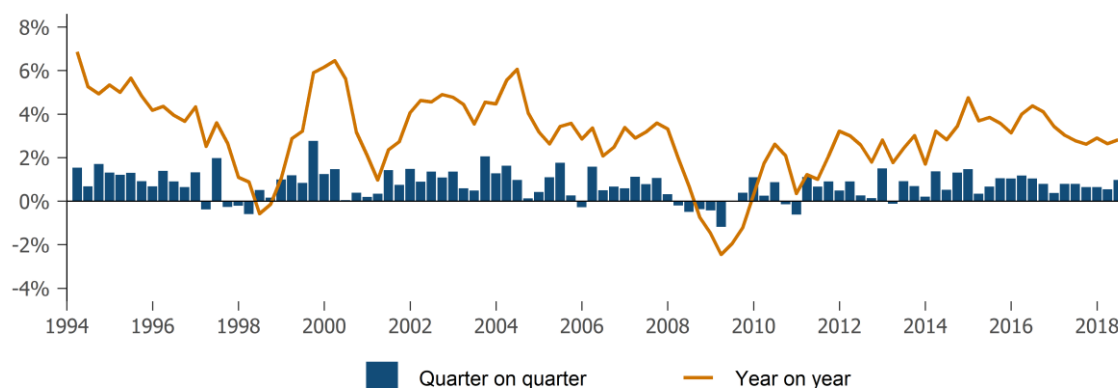
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<sup>9</sup> IFC World Bank, Doing Business Report 2019.

<sup>10</sup> Forbes Best Countries for Business List 2017.

<sup>11</sup> Index of Economic Freedom, The Heritage Foundation 2019.

**Figure 8 – New Zealand GDP growth (1994 to 2018)**

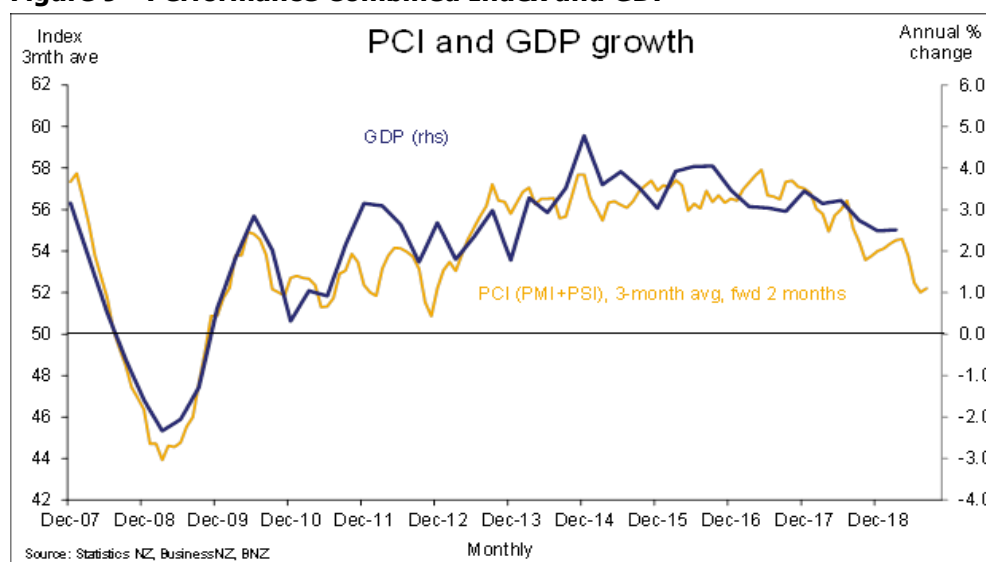


Source: Deloitte analysis, StatisticsNZ

The largest risk to growth outlook comes from offshore. The global economy has a large influence on New Zealand and our country must not be looked at in isolation. New Zealand's close proximity to Asia along with the rise of the middle class in emerging economies and the ongoing shift towards consumption-driven growth in China means that Asia represents a significant opportunity to New Zealand. However, the apparent cooling between Wellington and Beijing, and concerns over a slowing in Chinese economic growth represent a threat to this opportunity.

The possibility of future troubled economic waters is reinforced by Figure 9. This shows a combined performance of manufacturing and services index as correlated with GDP growth.

**Figure 9 - Performance Combined Index and GDP**

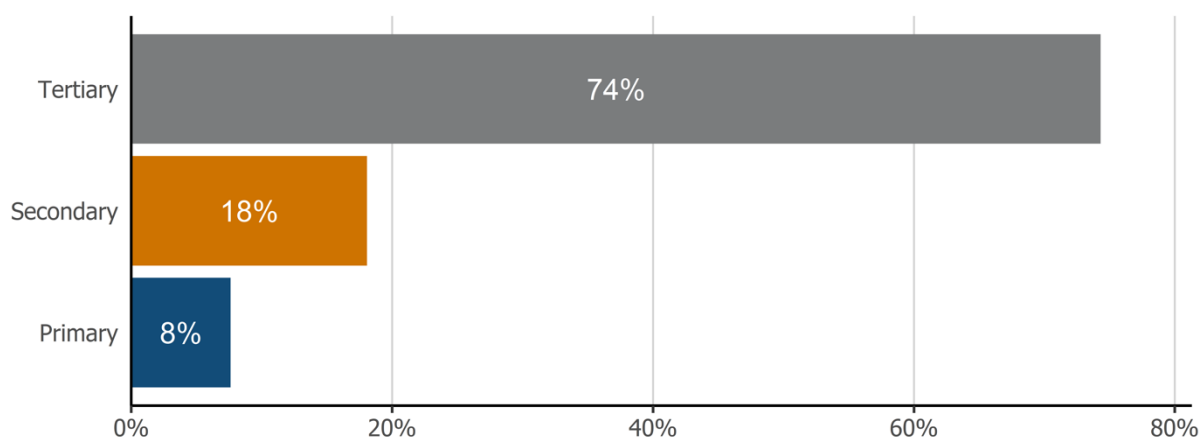


The PCI is generally characterised as a 'lead indicator' of growth trends. In light of the strong evident correlation between the combined indices and GDP, this graph tells a story of New Zealand's fortune as measured by GDP. The PCI seems to be saying that at the time of writing economic activity may be slowing. In terms of our stories this end point trend presents both challenges and opportunities and has influenced our growth stories.

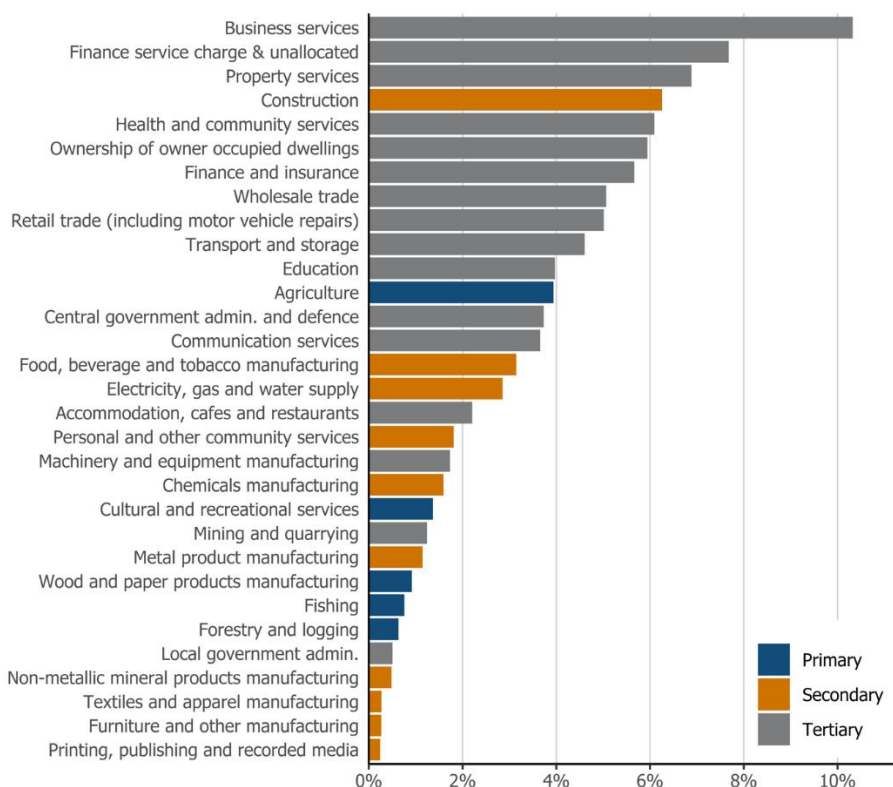


A significant part of GDP in New Zealand comes from the tertiary industry, with approximately 23% of total GDP coming from business, property and finance services. The primary industry contributes approximately 8% to GDP, with over half of this coming from agriculture which makes up 4.0% of total GDP. A breakdown of New Zealand's GDP is shown in Figures 10 a and b below.

**Figure 10 a – Industry Shares of GDP (September 2018)**



**Figure 10 b – Industry Shares of GDP (September 2018)**



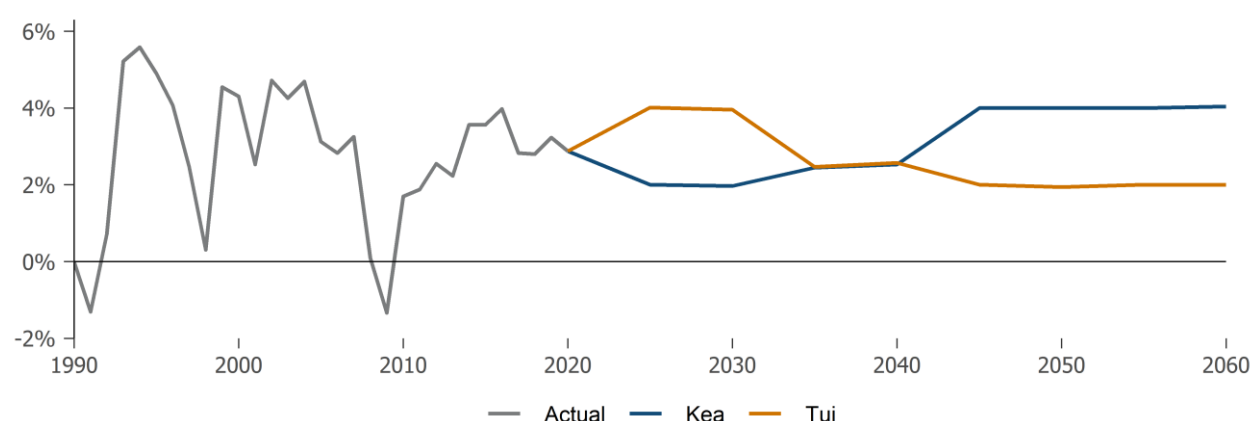
Source: Deloitte analysis based on NZIER data

## Tūi and Kea: Economic Growth

Figure 11 shows the gross GDP paths of the two scenarios and illustrates the two different scenarios that the narratives are based on, as well as the historic actual trend.

GDP growth is often used to indicate the performance of an economy and is well understood even though economic health and well-being are not solely captured by GDP. Critically, for scenarios focused on the energy system, GDP (along with population) is a key driver of the demand for energy services, and thus is a core component of our quantification of the scenarios.

**Figure 11 - GDP Actual 1990 – 2018, Tūi and Kea 2020 – 2060**



### What's Going On?

The two narratives are essentially two strongly different economic paths governments might take to provide for a sustainable economy in the long term. A response to the global challenge of decarbonisation will have to be made with a long-term view in mind because neither of our scenarios is risk free or cost free.

In Tūi, New Zealand continues to capitalise on its natural assets and the pursuit of GDP growth which is an economic model that has served us well historically. It remains relatively committed to its international emissions targets but balances that with protecting its key wealth-generating sectors from the full effect of international carbon prices. The underlying philosophy is that a wealthier country, combined with a wait-and-see approach to global technology, policy evolution, and societal expectations will provide a more resilient economy in the long run. This, of course, is based on the assumption that we can actually adapt later as the global response becomes clearer.

Tūi is characterised by strong growth in the early part of the period. Midway through the scenario period wealth has grown but the rest of the world has moved ahead, perceiving that New Zealand has failed to take commensurate action on achieving its climate targets. As New Zealand has followed a defensive position, it is near the 'back of the pack' vis decarbonisation; albeit wealthier as a country.

New Zealand becomes less desirable as a trading partner, and – to some extent – as a tourist destination. The world starts to be more selective about how it buys from New Zealand, especially since New Zealand has consistently lagged behind at this point. New Zealand has to modernise its economy to better reflect a world that is more orientated

towards climate change than the early part of the period. However, the domestic political inertia resulting from two decades of conservative policy-making is such that New Zealand can't adapt as quick as hoped. Trying to catch up to the rest of the world costs New Zealand dearly. The growth of economic well-being in the Tūi scenario tapers off after 2040.

In Kea, New Zealand takes the risk of transforming the economy with the climate change challenge being the catalyst. Kea is characterised by difficult structural change through to 2040, where economic growth suffers as a result of widespread unemployment and other socioeconomic impacts of economic transformation. New Zealand pursues global leadership in this transition. While generating international respect, initially this does not translate into economic benefits. But after a decade of change, New Zealand begins to return to better growth with a new low-emissions economy and improving productivity resulting from the transformation.

The economy eventually picks up and enjoys a trade renaissance. Population expands and the commensurate productivity improvement delivers strong growth at the end of the scenario period. Economic well-being in the Kea scenario, as measured by GDP, rises above Tūi before the end of the period, and New Zealand pushes beyond its Paris targets pursuing net zero carbon emissions by 2050.

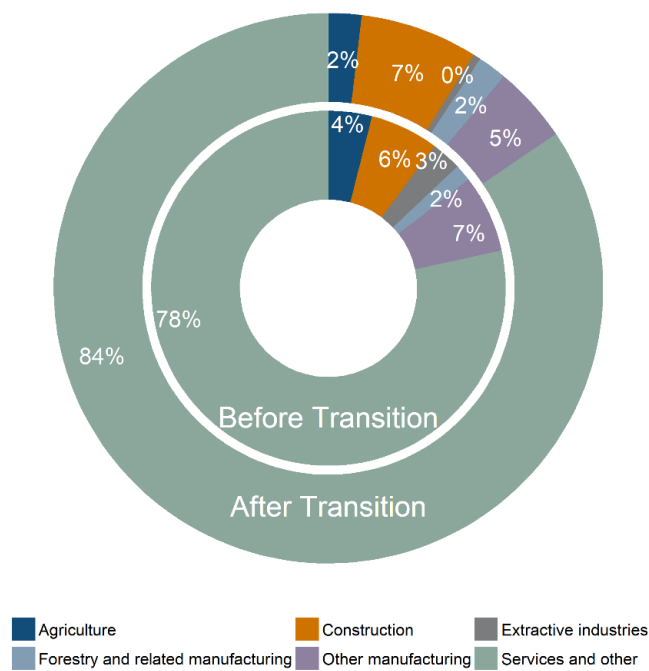
### The Sectoral Story

Figure 12 breaks down GDP into sectoral trends. Given the nuanced GDP trends for Tūi and Kea, the outcomes are essentially timing-related, that is, these shifts happen early in Kea (during the transformation), and later in Tūi (as it tries to adapt). Aside from the timing issue, Figure 12 illustrates the changing growth rates and the way the sectoral splits might change through the forecast period in an economy that is decarbonising (whether that is aggressively or passively).

Agriculture and extractive industries suffer compared with construction and services which thrive. The forestry and timber processing sector is the only traditional sector which maintains a presence in the new economy, as it has been most able to transition its fuel sources to renewables.

Forestry also benefits from the speed at which decarbonisation proceeds. Where decarbonisation becomes too hard or too expensive (e.g. aviation jet fuel, very high temperature process heat or some marine bunker fuel requirements), offsetting becomes a necessity thus benefiting the forestry sector.

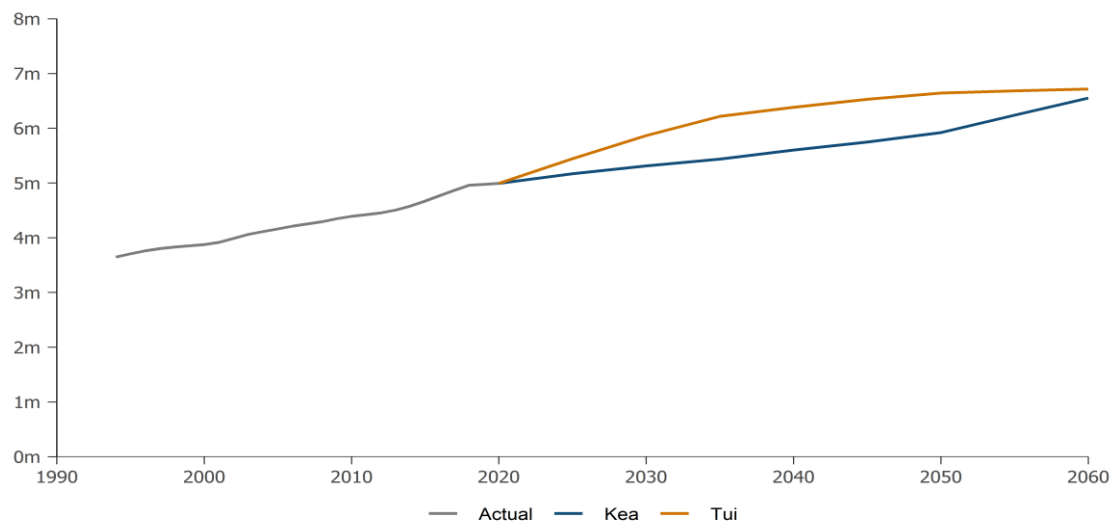
**Figure 12 – Sectoral Growth Trend Break-down**



## Tūi and Kea: Population

Population growth is also a key driver of the demand for energy services, and thus is another core component of our quantification of the scenarios. The graph below shows the population trajectories for the two BEC2060 scenarios.

**Figure 13 - Population Growth Actual 1994 – 2018, Tūi and Kea 2020 - 2060**



## What's Going On?

In both scenarios, population growth is primarily driven by immigration.

Under Tūi, due to the continued growth in the New Zealand economy, migrants are initially attracted to the wealth generation prospects in New Zealand. At the same time, governments are open to immigration, seeing it as a way to continue fuelling economic growth, and hoping for increasing productivity as well. In the first part of the scenario period, immigration and thus population growth, is growing strongly at 1.2%. However, as New Zealand's international reputation begins to be eclipsed by other countries who are making greater strides to reduce emissions and providing more liveable cities, immigration – and thus population growth – wanes.

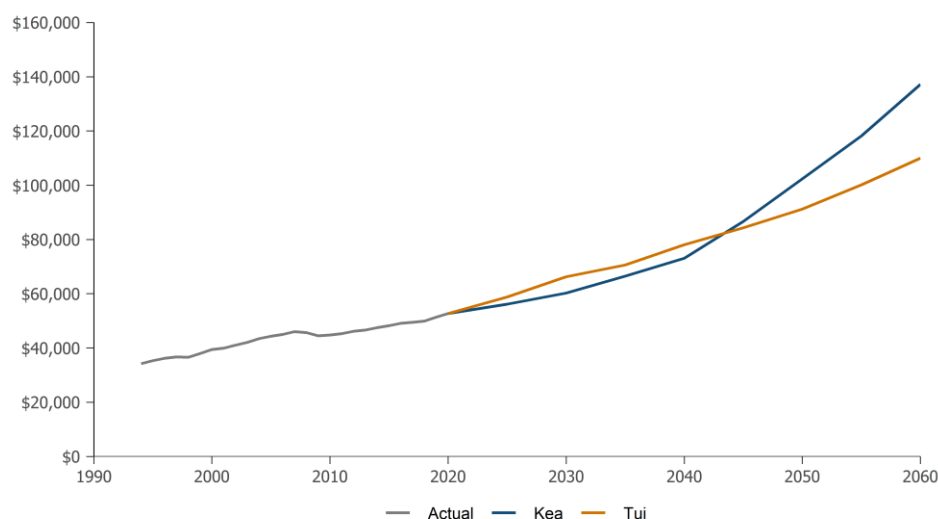
In the Kea scenario, population grows at only 0.6% p.a. during the period of transformation 2021 – 2040. Most of this growth has been in the major cities, fuelled by the prospect of service sector and technology jobs. Some rural areas suffer as a result of being left behind by the transforming economy.

Immigration in the early years of the Kea transformation will be limited by widespread unemployment in primary industries dampening New Zealand's attractiveness. Moreover, governments will actively limit immigration to those with the skills to contribute positively to the economic transition away from dependence on fossil fuels and towards very low (net-zero) emissions. Later in the scenario period, as the transition is nearly complete, future governments are more receptive to wider immigration, and the world-leading economy is highly attractive to people offshore who want to play a part. As a result, net population grows at around 0.8% during the economic boom later in the period.

### **Tūi and Kea: GDP per capita**

Wealth per capita tells us how much discretionary income households and businesses – and governments – have. If we are wealthier as consumers and businesses, we may be less inclined to save money by being more efficient but on the other hand, we can afford to invest in capital-heavy technology (like electric trucks).

**Figure 14 – GDP per capita Actual 1994 – 2018, Tūi and Kea 2020 - 2060**



## What's Going On?

By 2040 Tūi has grown the economy significantly, leveraging the advantages of automation, robotics and other technology advances in manufacturing. Thus productivity has increased much faster than Kea, which has struggled. This sees its GDP per capita exceed that of Kea.

The wealthier Tūi population makes decisions which often contradict each other: the greater wealth makes them more able to afford capital-heavy technology (like electric vehicles), but many parts of the population feel less inclined to do so as a result of the climate challenge. Electric vehicles are seen as desirable as well as economic; but for some industries, moving away from fossil fuels still fails to make the cut as there is no collective desire to accept slower payback periods.

Similarly, the prospect of urban intensification, and using more public, active and shared travel simply holds no attraction for people who can more easily afford to travel by themselves from further afield.

By 2040, the Tūi population is nearly 7% wealthier (in real terms) than Kea. The challenge is that another 2 decades of individualistic consumerism have passed, and sprawling cities have locked in an even greater transport emissions challenge. Continued use of fossil fuelled boilers and motors in industry will have to wait another capital cycle to reach replacement. Wealth growth slows as the government attempts to course-correct.

In Kea the period of transition sees some growth in wealth and incomes as manufacturing is automated, but is weighed down by workers displaced from 'old' economy jobs losing incomes. Society is broadly (although not exclusively) committed to the challenge of climate change, and decision makers are willing to tolerate slower paybacks on investments which facilitate the switch to low-emissions living. But, even with that motivation, lower wages and salaries make this hard. Growth comparable to the early years of Tūi only resumes in earnest as the country emerges from the first 20 years and a trade-fuelled economy enjoys its global leadership. In this scenario the green economy becomes a reality and international trade benefits from the stance New Zealand has taken to aggressive decarbonisation.

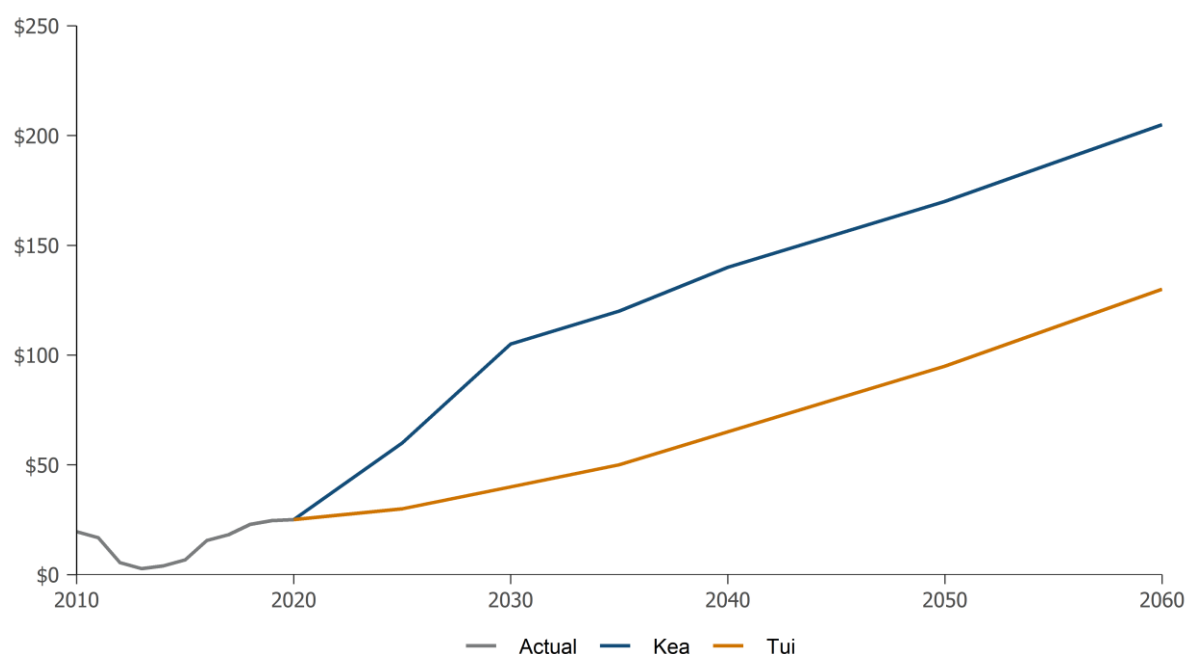
Simultaneously, society's acceptance of more intensive neighbourhoods connected by highly efficient public/active transport systems lowers the cost of infrastructure to service growth; industry is better placed to leverage continued technological advancement and, as a result, New Zealand becomes a more skilled, efficient and technologically advanced society.



## Tūi and Kea: Carbon Prices

Figure 15 below shows the carbon prices used in the Tūi and Kea scenarios. The assumed international carbon price trajectories are based loosely around the Council's 'Modern Jazz' and 'Unfinished Symphony' scenarios as they reference global prices in Tūi and Kea respectively, but 'spread' the prices to reflect how New Zealand positions itself relative to the rest of the world.

**Figure 15 – Carbon Prices Actual 2010 – 2019, Tūi and Kea 2020 - 2060**



### What's Going On?

In Tūi, global efforts to combat climate change are, on average slower than they are in Kea; hence our scenarios tend to mirror this global narrative. However, we introduce an additional distinction: in the ambitious world, Kea attempts to be a leader; in the conservative world, Tūi is content to be even more conservative; a follower.

More specifically, in Tūi, steps are taken to ensure that it lags the international carbon price, reflecting the effort to protect strategic wealth-generating industries from the full effect of the carbon price. In Kea the carbon price is allowed to run ahead of the international carbon price for the duration of the scenario period, as the country aims to accelerate the path to net zero emissions, in order to adopt a globally leading position.

Under Tūi, New Zealand is not as ambitious or solely focused as Kea about reducing GHG emissions.

Meeting New Zealand's GHG emissions targets relies primarily on the emissions trading scheme for Tūi, although with the carbon price effectively allowed to lag the international price to protect current economic market structures and industries, the full cost of emissions is not necessarily reflected in the carbon price. Some protection is afforded to industries which are heavily export-exposed, implying that the true carbon price in the New Zealand economy lags behind the global price, consistent with our defensive position. The risk in this scenario is that New Zealand may fall behind on meeting its Paris Agreement targets.

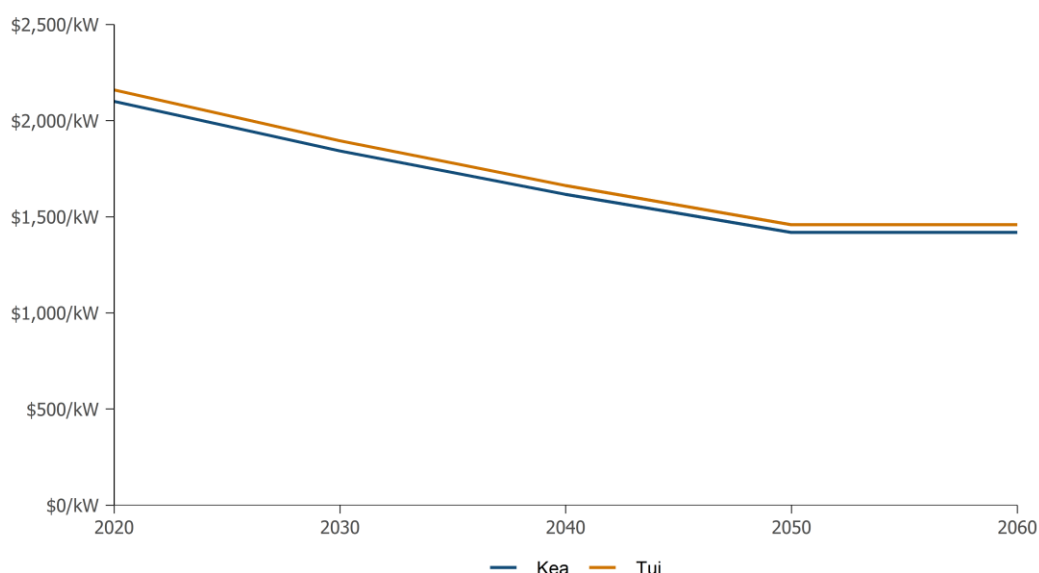
Under Kea, consistent with the global leadership aspiration, the domestic carbon price is allowed to run ahead of the global price of carbon (which itself is rising rapidly) as policy settings constrain the supply of carbon units. Access to international units is also severely constrained. Over time, carbon prices rise to levels required for significant emissions reductions to be incentivised – in excess of NZD\$200/t. New Zealand phases down free allocation of carbon credits for energy-intensive, trade-exposed (EITE) industries and takes bold moves to reduce GHG emissions in agriculture.

### Tūi and Kea: Technology Costs

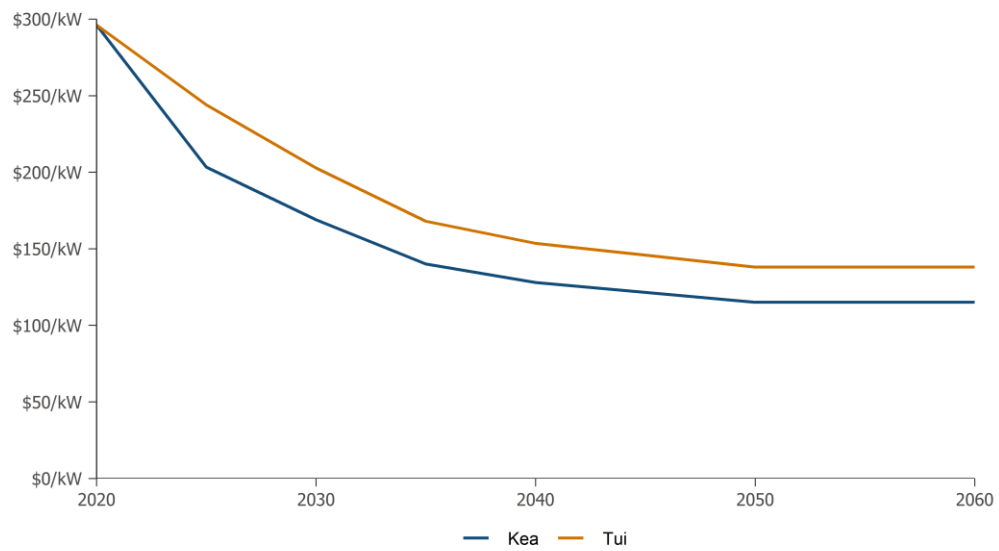
New Zealand is, and will predominantly remain a technology taker, although the nature of its economy and energy system mean there are numerous opportunities to tailor and evolve international technology developments to suit the country. The costs of New Zealand's energy technology are therefore largely determined by the pace and speed of research and development, and commercial investment offshore. In light of the narrative that in Kea the rest-of-the-world focuses on technology orientated towards climate change and New Zealand is an early adopter, and that in Tūi, the rest-of-the-world doesn't focus specifically on climate change technologies, the technology costs faced by New Zealand reflect this.

Our model inputs incorporate this only in a selection of technology costs, however. In Kea, electric and hydrogen vehicle costs, battery costs and hydrogen electrolyzers all outpace Tūi as a result of significant domestic and global investment in research and development, and commercialisation. Solar and wind costs are broadly similar in both scenarios, as these technologies are close to maturity today.

**Figure 16 – Wind Power Costs Tūi and Kea 2020 - 2060**



**Figure 17 – Lithium Ion Battery Costs Tūi and Kea 2020 - 2060**



## BEC2060 NARRATIVES: TŪĪ

### Leverage New Zealand's Traditional Comparative Advantages

*New Zealand society does not generally share a common view on what is the most important issue of the day. As a result, governments do what they have to do to meet international emissions commitments but otherwise, New Zealand focuses on delivering economic prosperity and wellbeing by leveraging off our natural advantages.*

In this scenario the economy maintains a predominantly market-led approach to decision making. Individuals make their own choices in most matters rather than having priorities determined by government. Government intervenes where there are market failures, and acts to buffer sectors of the economy which are traditional wealth generators from the full effects of the carbon price.

New Zealand has relied on its long-standing comparative advantages with primary production a significant source of its income. This position has been supported by an ongoing push for efficiency with farming practices and innovation. Processing of short life products (such as milk or meat) takes place onshore and exports are dominated by low value bulk commodities as has been the case for over a century with increasing efforts to move up the value supply chain. Growth in dairy in particular has been limited due to environmental limits. Energy fuel demand from the agriculture sector continues to be based on a similar mix as it has been in the period leading up to 2020, with modest improvements in energy efficiency (0.5% per annum).

In this setting some other large industrial players have remained in the economy due to being shielded from the full cost of carbon. Tourism continues to be an important contributor to GDP. Overall, this mode of production is land, water, energy and carbon-intensive.

Lack of consensus by New Zealand communities on the major issues of the day makes it harder for governments to act decisively on climate issues until at some point the imperative to catch up with the rest of the world can no longer be ignored. The inertia behind a predominantly market-led approach means that the country faces strong headwinds as New Zealand falls further behind international approaches to climate change, and it becomes harder to find markets for its now relatively carbon-intensive export products. Growth suffers as a result and eventually governments are forced to attempt aggressive decarbonisation, but a lack of consensus means this can only be done in a piecemeal way.

### The Tūi World in 2040

There is still no consensus on the imperative to drive down emissions. Technology advances and reducing costs for many technologies, combined with the cost of carbon flowing through to consumers, have driven some decisions but parts of society continue to use fossil fuels even where they may have a choice.

- implied carbon prices have reached \$60/t, lagging most countries in the rest of the world as a result of government action to buffer some industries;
- the economy has continued to grow a little over 3% per annum over the 20-year period driven by the traditional mix of commercial/services sector, industry and agriculture;

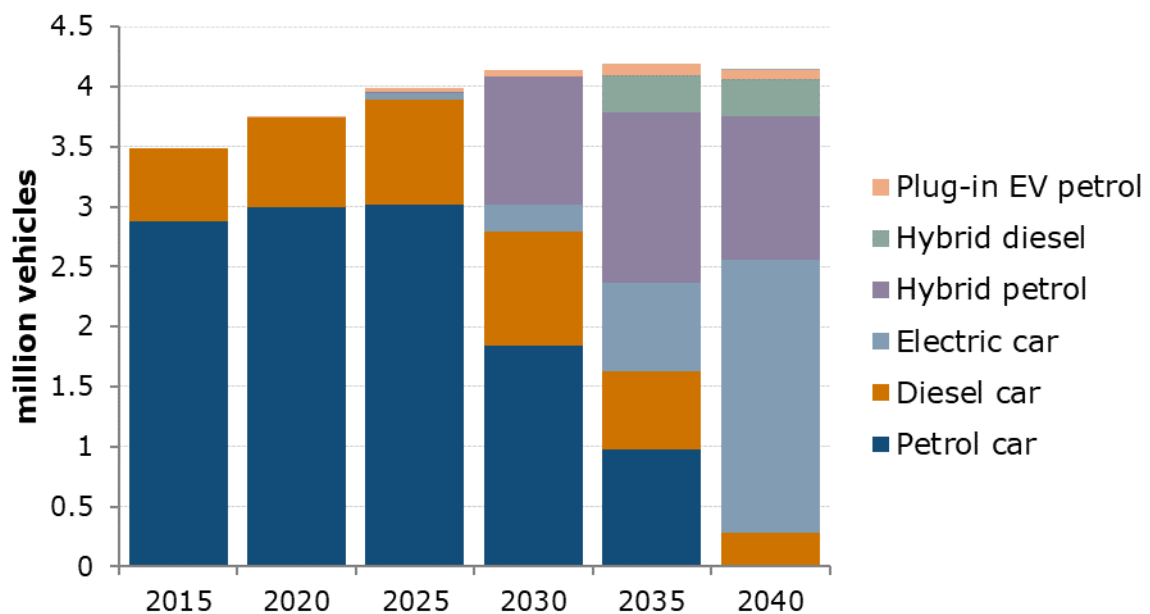
- population has grown a little over 1% through selective immigration, reaching 6.4m. Most of this growth has been through immigration during the boom years of 2020-2035;
- wealth per capita has reached \$86,000 per person; and
- technological change has seen incremental reductions in the cost of electric vehicles, wind and solar.

Transport has historically been one of New Zealand's largest users of fossil fuels. In 2040 many of the cars and trucks being driven are different but some individuals and businesses, and public transport providers, do not yet see a positive benefit in changing to these new alternative fuels.

The light duty vehicle fleet has grown around 20% since 2020, as major cities have continued to spread making the need for individual vehicular transport as pressing as ever.

In 2020 transport was the biggest emitter and now, in 2040, the cost of petrol and diesel, along with the cost of, and relative availability of, alternatives sees quite a different mix of vehicles - a mix of purely electric cars, hybrids and a small number of ICE vehicles. Transport is no longer the largest emitter, but fossil fuels are still involved in the drivetrain of 40% of the light fleet.

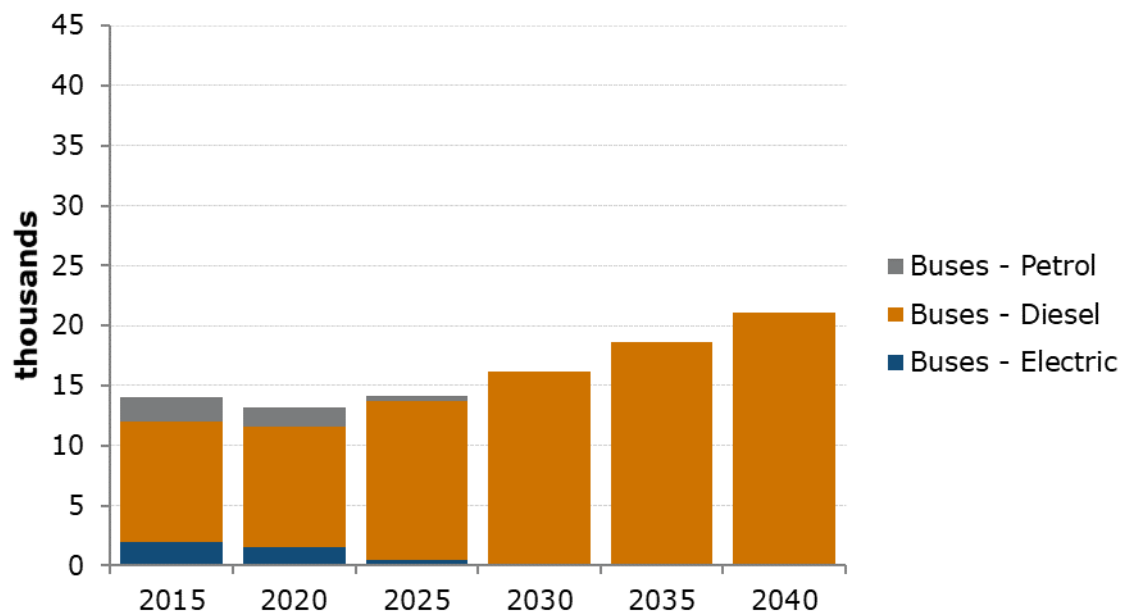
**Figure 18 - Car Fleet – Tūi**



The use of public transport has increased modestly in line with population growth, but uptake has been limited due to the continued dominance of the private car as a mode of transport. There has been a lack of clear direction on public transport from regional and central government, and bus operators have taken a very conservative stance on bus fleet turnover due to fears of low utilisation. In this context, the lower cost of purchasing and operating diesel buses, compared with lower carbon alternatives, as well as a lack of clear

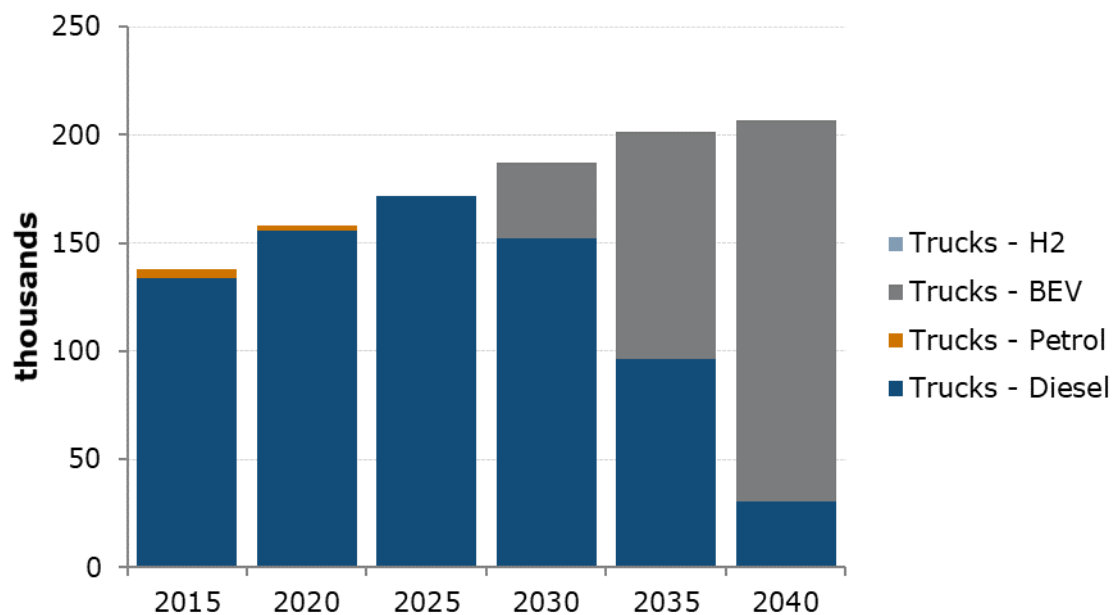
direction on enabling public transport, has seen diesel remain the fuel of choice for public transport.

**Figure 19 - Heavy Bus Fleet – Tūi**



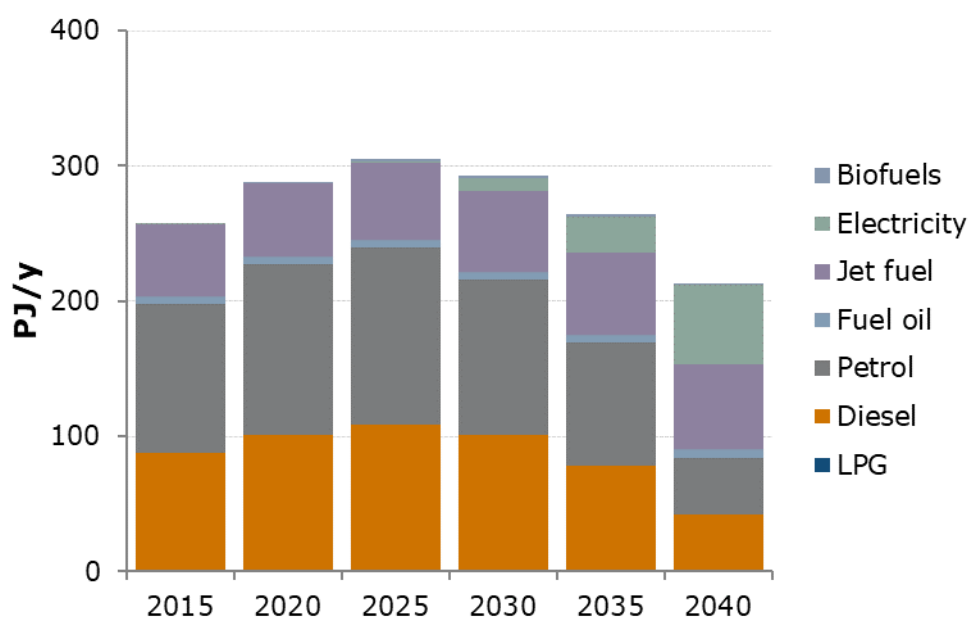
However, high economic growth has driven a significant increase in road freight, and this has been sufficient to give freight operators the incentive to commit to electricity as a fuel. The price of electric trucks has come down sufficiently and the technology is proven to be reliable for trucking. A near complete fleet transformation has taken place.

**Figure 20 - Truck Fleet – Tūi**



In terms of overall fuel mix for transport Figure 21 shows the overall decline in fuel use and the change in the mix.

**Figure 21 - Fuels in Transport – Tūi<sup>12</sup>**



The fuel with the largest share in the overall transport consumption is now jet fuel (slightly ahead of electricity), with the majority use by international passengers, five times domestic jet fuel consumption. Jet fuel consumption has grown in line with tourism, with a modest 1% annual efficiency improvement as a result of newer, better engines. But no obvious low-emissions alternatives have come to commercial fruition.

Some sectors of society (individuals and businesses) have struggled to fund the up-front costs associated with transitioning to new, lower emissions technologies, and government programmes have not helped. So, the willingness of consumers and businesses to pay for more efficient technologies or low-carbon fuels has been based on cost, budget constraints, and the preference for quick payback periods. Consumers and businesses have only switched to emerging technologies where they are the least cost solutions to their needs.

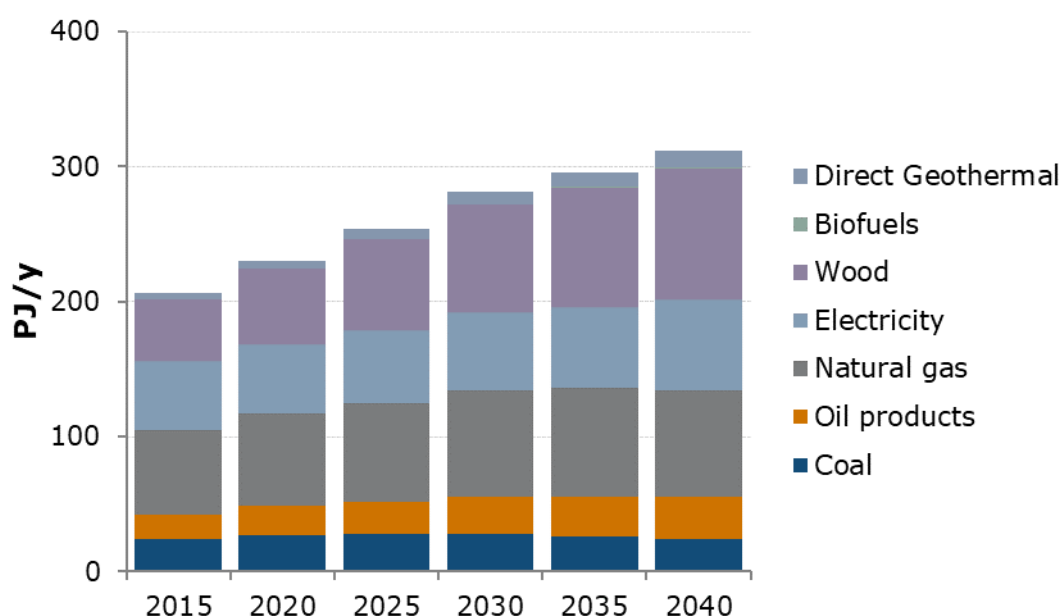
It was well understood in 2020 that the second highest potential to contribute to reducing emissions was industrial process heat. In 2040 a portion has switched away from a dependence on fossil fuels but the bulk of fossil fuel use (especially natural gas for process heat) remains.

Large industrial businesses have tended to remain with their traditional fuels, and, like households and other businesses, have been focused on quick paybacks and least cost. Being shielded from the full effect of carbon prices has prolonged the role of fossil fuels. That said, coal use has been capped with the carbon price reaching levels where natural gas or biomass are seen as economic alternatives for some businesses to meet continued growth in output. It is in industry that we now see the greatest presence of natural gas, which underpins ongoing gas exploration.

<sup>12</sup> The BEC2060 modelling was baselined on 2015 data, and growth rates applied thereafter. In most cases, this has provided plausible estimates for 2020. However, in the case of jetfuel, demand increased significantly immediately after 2015, due to a range of drivers (the cost of jetfuel, tourist numbers, and increasing international competition for NZ-bound flights, for example); noting that this steep increase has abated more recently. We will re-baseline jetfuel demand in 2020.



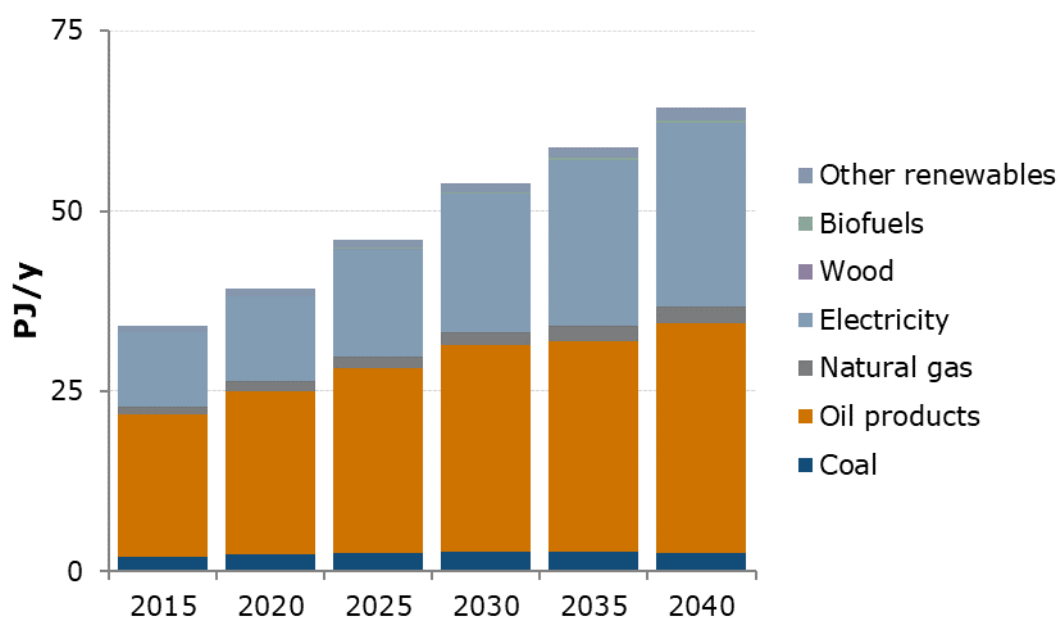
**Figure 22 - Fuels in Industry – Tūi**



The composition of GDP changes slowly but the focus on our historical comparative advantages is evident. The fuels used to produce GDP change but largely in response to the carbon price rather than any major shift in societal preferences.

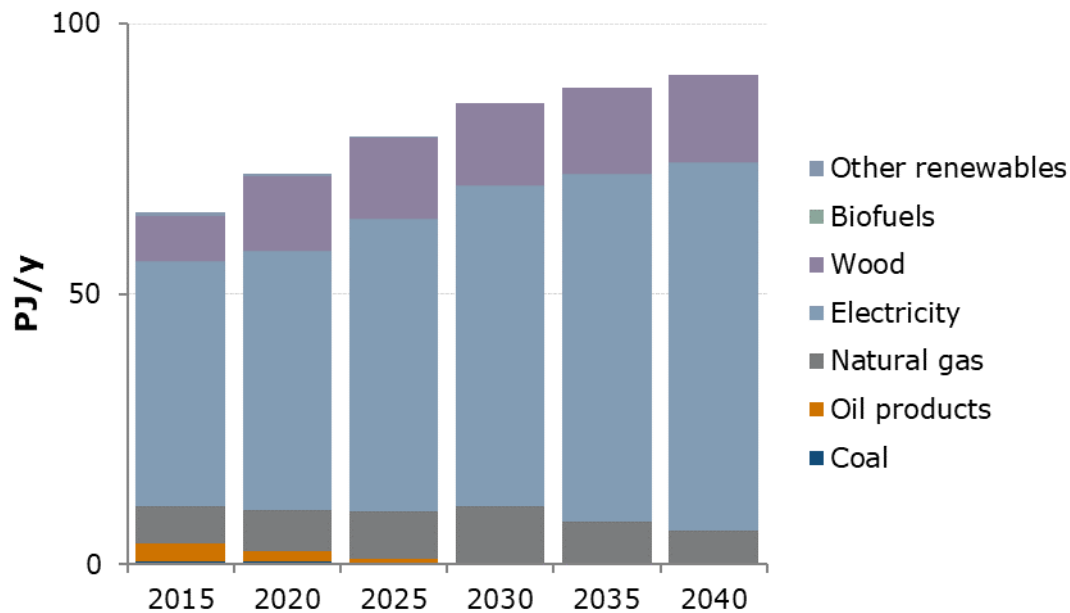
Agriculture, for example, has seen electricity become more competitive as a fuel, primarily as it starts to face the challenge of maintaining a low-carbon presence in markets for traditional exports. However, agriculture increases its overall use of fossil fuels even though much of the growth in agriculture (including forestry & fishing) has utilised low carbon electricity. There is potentially an implication here for land use or, more likely, there must be an increase in the energy intensity of agriculture. This is the only way to reconcile it to current land available to land-based agriculture in New Zealand.

**Figure 23 Fuels in Agriculture – Tūi**

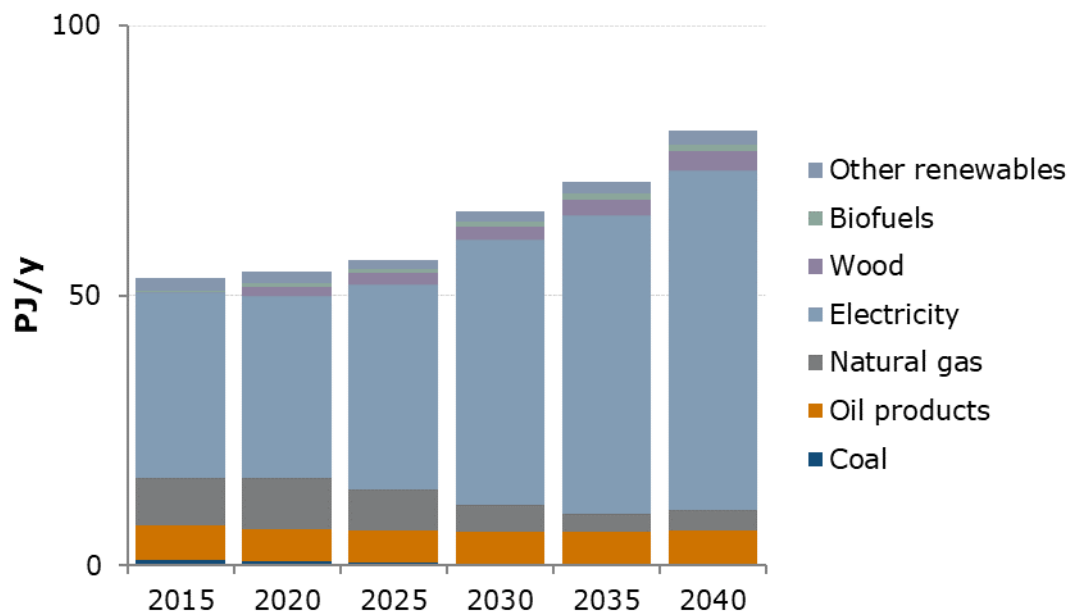


Most of the community has stopped using fossil fuels in their homes and businesses, but some natural gas usage remains, despite the cost, for heating and cooking. By 2040, many consumers have installed small scale solar generation and batteries (see later section on electricity).

**Figure 24 Fuels in Residential – Tūi**



**Figure 25 - Fuels in Commercial – Tūi**



## Overall

In 2040, electricity is the dominant form of energy consumption in the economy, more than double its share twenty years previously. This has been most noticeable in the transport

fleet, as discussed above. Fossil fuel use (gas, oil and coal) has fallen 32% to 387 PJ p.a. since 2020.

Total energy consumption is shown to climb from 660PJ (including a share of international aviation) per annum in 2015 to 800 PJ in 2040. With coal and gas frozen at historical levels, the rise is met through an increase in renewable energy being deployed primarily in electricity generation (but also biomass) which supports, in turn, the electrification of transport and industrial process heat in particular.

**Figure 26 - Total Fuel Consumption by Fuel Type – Tūi**

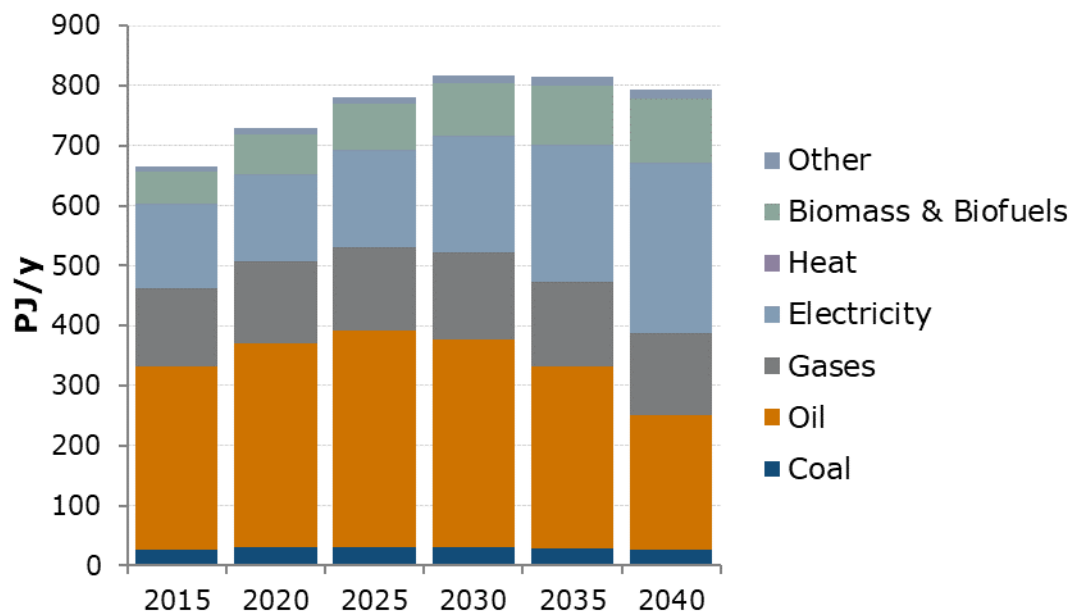
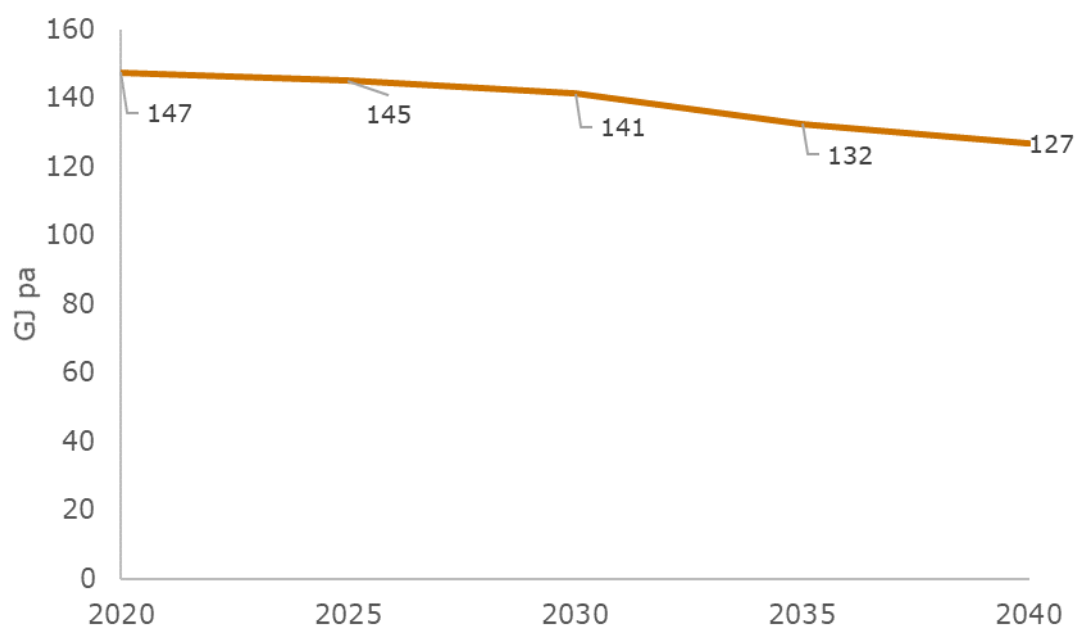


Figure 27 shows that energy consumption per capita has declined by nearly 20% since 2020.

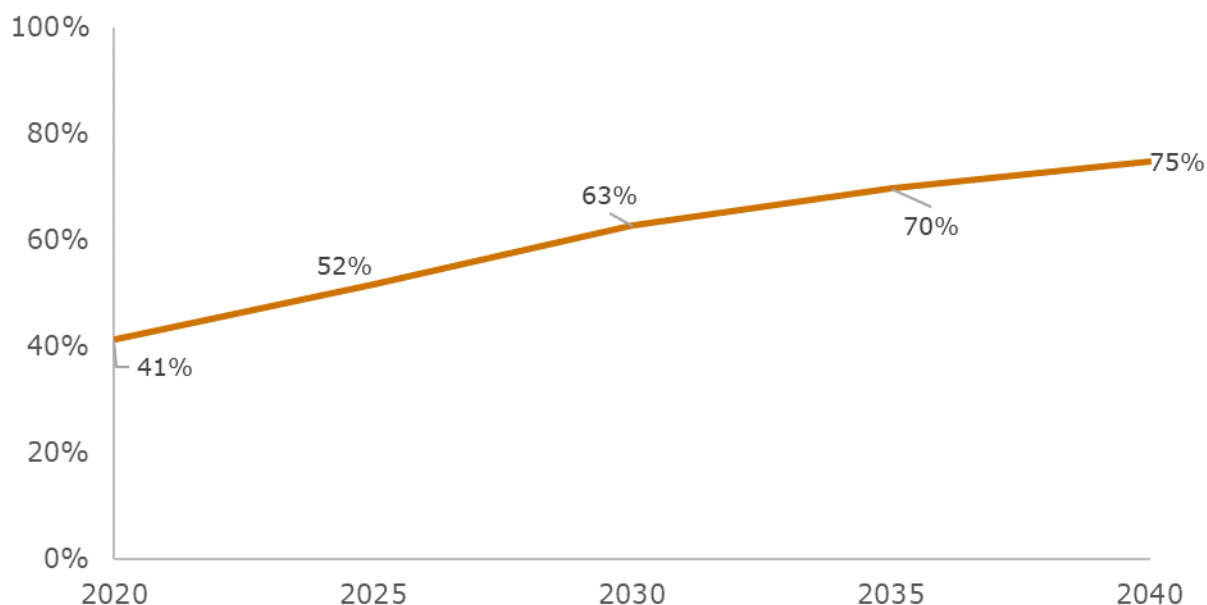
**Figure 27 - Final Energy Consumption Per Capita - Tūi**



Per capita energy consumption declines as a result of consumers making conscious decisions both with asset purchases and consumptive behaviour.

The upshot of the energy and economic growth pictures painted above is shown in Figure 28 below. New Zealand has reached 75% renewable energy in the economy.

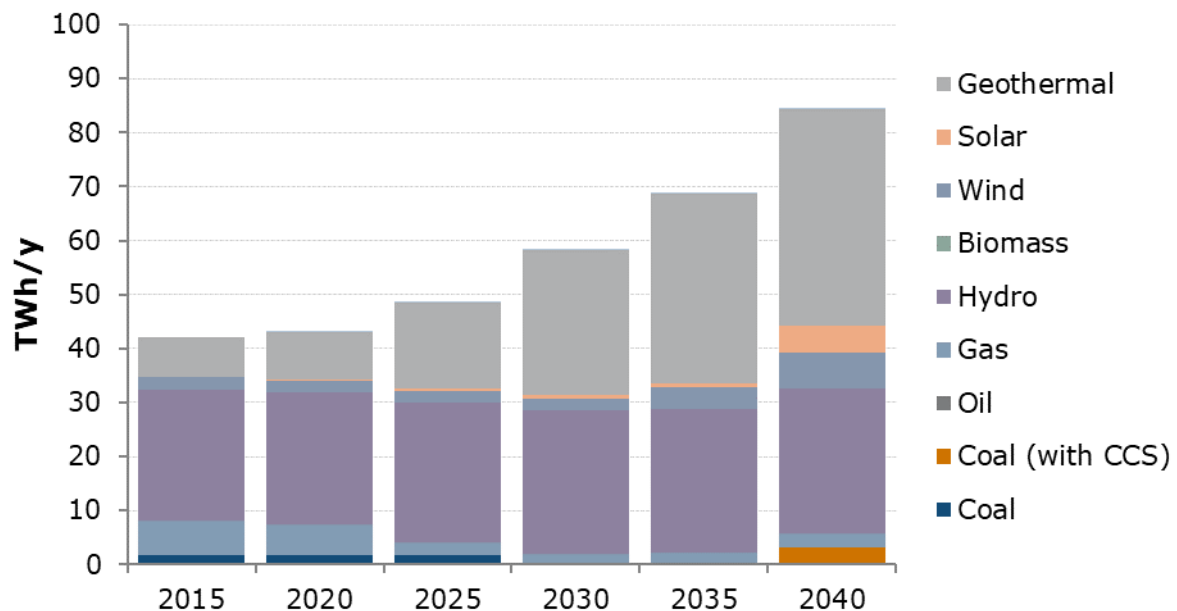
**Figure 28 - Renewables Proportion in Energy – Tūī**



### **The Role of Electricity**

To the extent electrification of the transport fleet and industrial/agricultural applications have taken place, total electricity demand has increased. The Huntly Rankines were decommissioned a decade ago, and more generally, fossil fuel usage (coal and gas) has been displaced in the market by renewables. However the gas capacity in 2020 has remained, and indeed increased, in order to maintain a secure supply (even though it may have to be served by liquified natural gas ('LNG') in the absence of any other viable alternative). With the pressure on demand, even a small trial carbon capture and storage ('CCS') coal plant has recently been commissioned with a view to expansion over coming years. But the growth in demand for secure, reliable electricity has been met generally through geothermal, with more variable sources such as wind and solar having only recently see significant investment. Investors in geothermal are indicating that further geothermal expansion is looking harder, and more costly, and the market is expecting future increases in demand to be met from wind and solar, with their attendant security challenges. However, fleets of network-connected batteries, totalling 1.4GW, are already being used to manage daily wind and solar variations.

**Figure 29 - Electricity Generation – Tūi**



**Figure 30 - Electricity Capacity – Tūi**

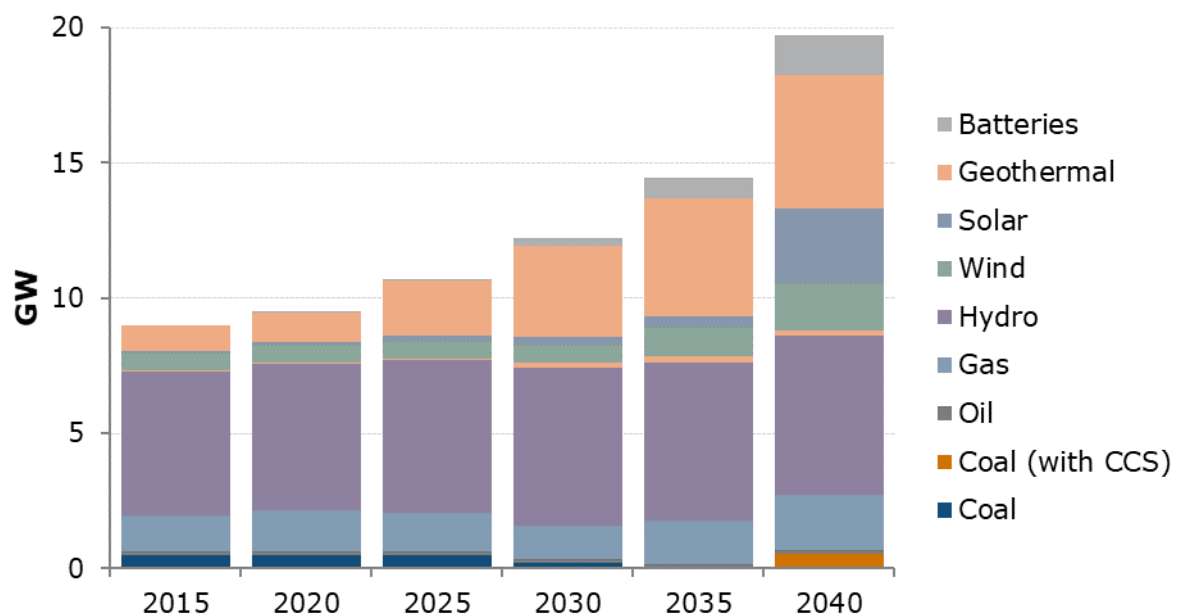
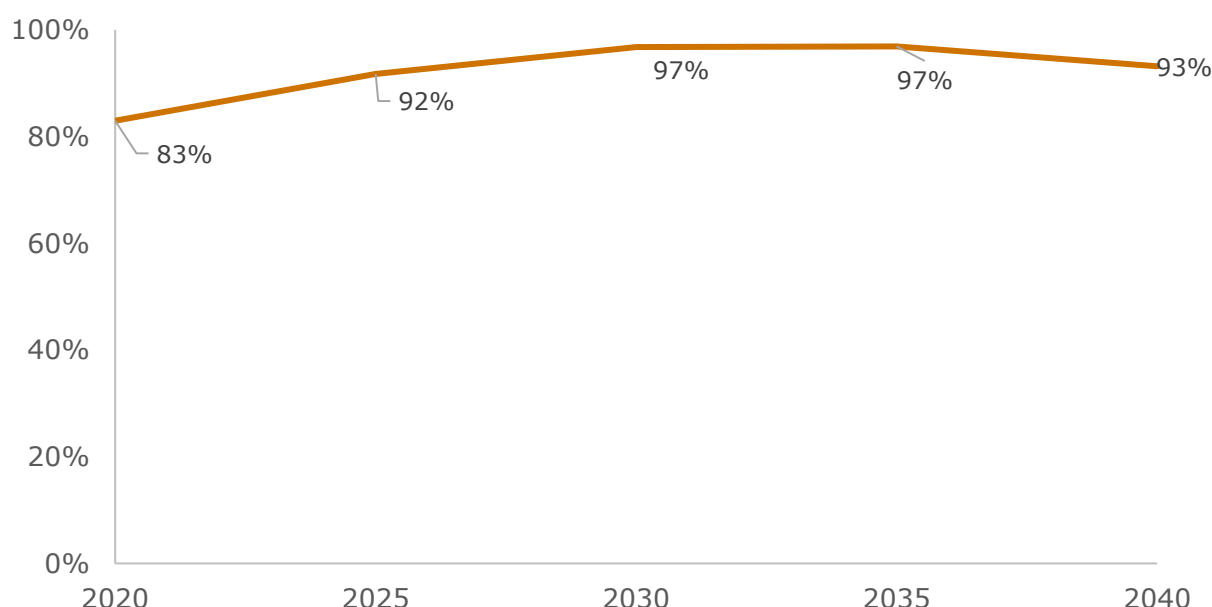


Figure 29 and Figure 30 tell the story about how consumed electricity is powered and how provision is made to provide for a secure grid regardless of the conditions that emerge over time.

In terms of renewable electricity production, Figure 31 shows fossil fuel generation making a comeback by 2040 with renewables falling to 93%.

**Figure 31 - Renewables Proportion in Electricity – Tūi**

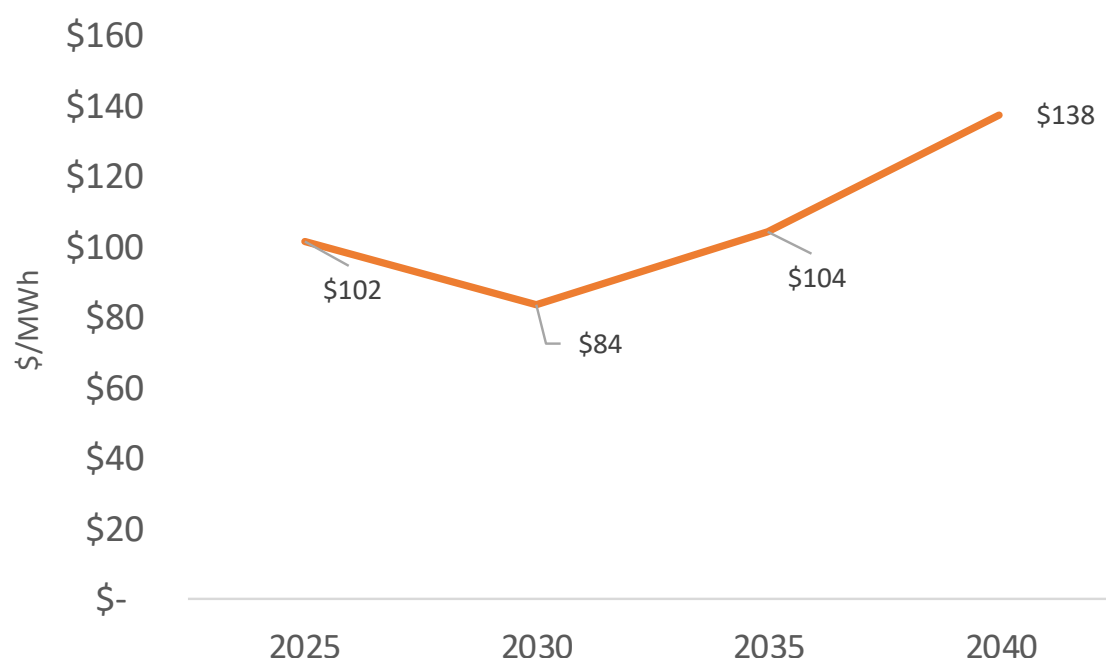


The decline in the renewable proportion of electricity supply in 2040 reflects the fact that investors can no longer see the expansion of renewable electricity as the way to meet rapidly growing demand. The construction of a gas and coal/CCS plant in 2040 reflects growing pressure on security of supply, and that thermal plant is the most economic option to fill this need. In reality, the security of supply challenge will be amplified by the effects of climate change precisely because so much supply is weather dependent.

Figure 32 shows the implications of the high rate of building renewables in the early part of the period and the re-emergence of fossil fuels, albeit in small volumes, required to maintain a secure system.<sup>13</sup> The initial lowering of prices in 2030 is caused by significant southward flow from the North to the South Island (probably driven by industrial and agricultural demand growth in the South Island while generation build is principally geothermal in the North Island).

<sup>13</sup> For the purposes of BEC2060 we have relied upon long-run marginal cost (LRMC) of generation technology available at the time as a proxy for wholesale electricity prices. In reality, annual wholesale prices will be the combined product of investment decision, behavioural decisions, and annual hydrology. That is annual wholesale prices rarely equal LRMC.

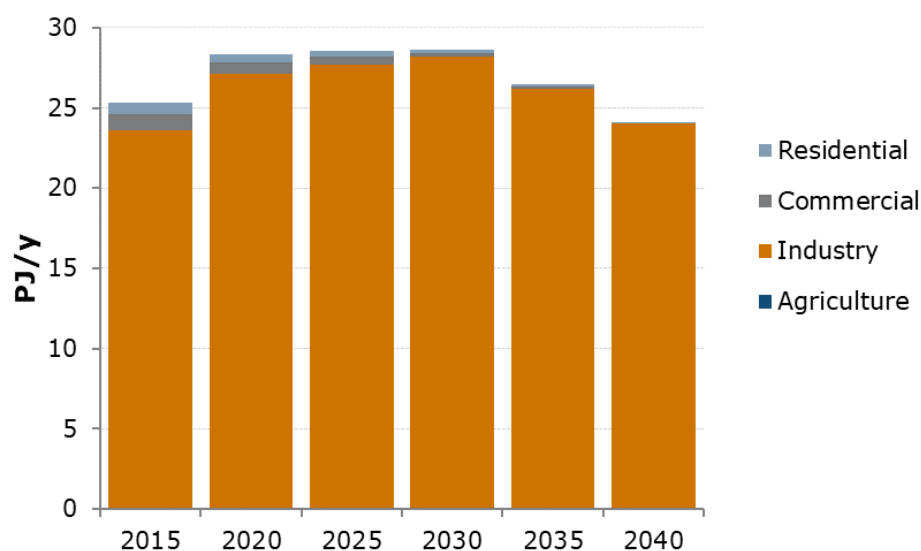
**Figure 32 - Electricity Prices – Tūi<sup>14</sup>**



## Resources Sector

Coal retains a role in industry through to 2040 although it is completely displaced for residential and commercial uses.

**Figure 33 - Coal Consumption by Sector – Tūi**

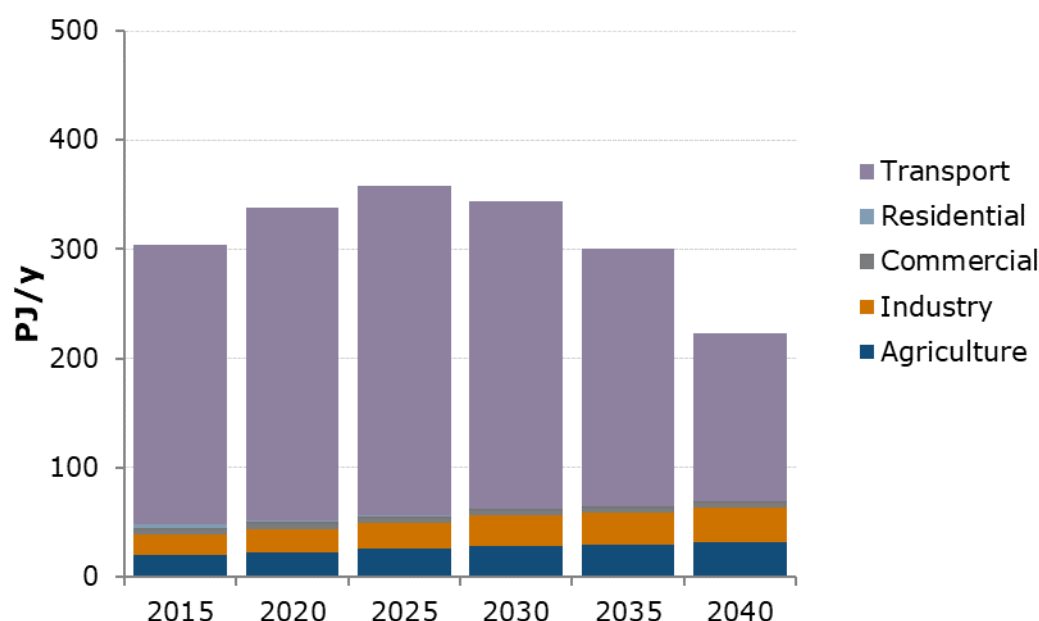


Oil use has been displaced by increases in electricity use but security of supply in electricity continues to be met with the use of gas and other fossil fuel-based supply chains. Governments understand that a fully renewable and secure supply would be more much more expensive than continuing to accommodate gas use.

<sup>14</sup> For the purpose of showcasing the ability to model outcomes between islands, this graph illustrates North Island prices only, and shows a suppression of North Island prices relative to South Island.

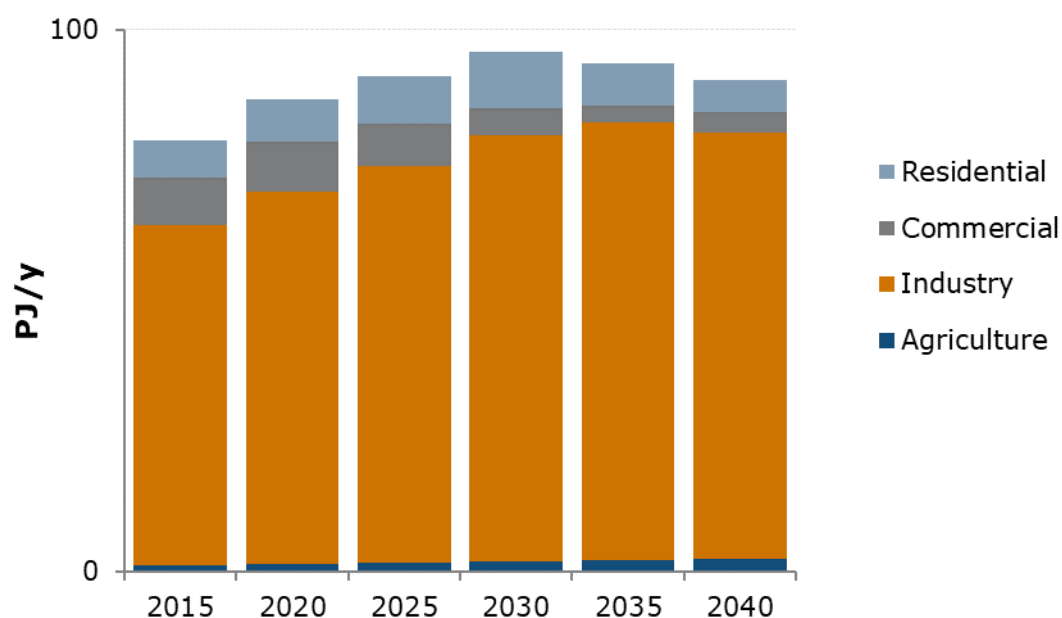


**Figure 34 - Oil Consumption by Sector – Tūi**



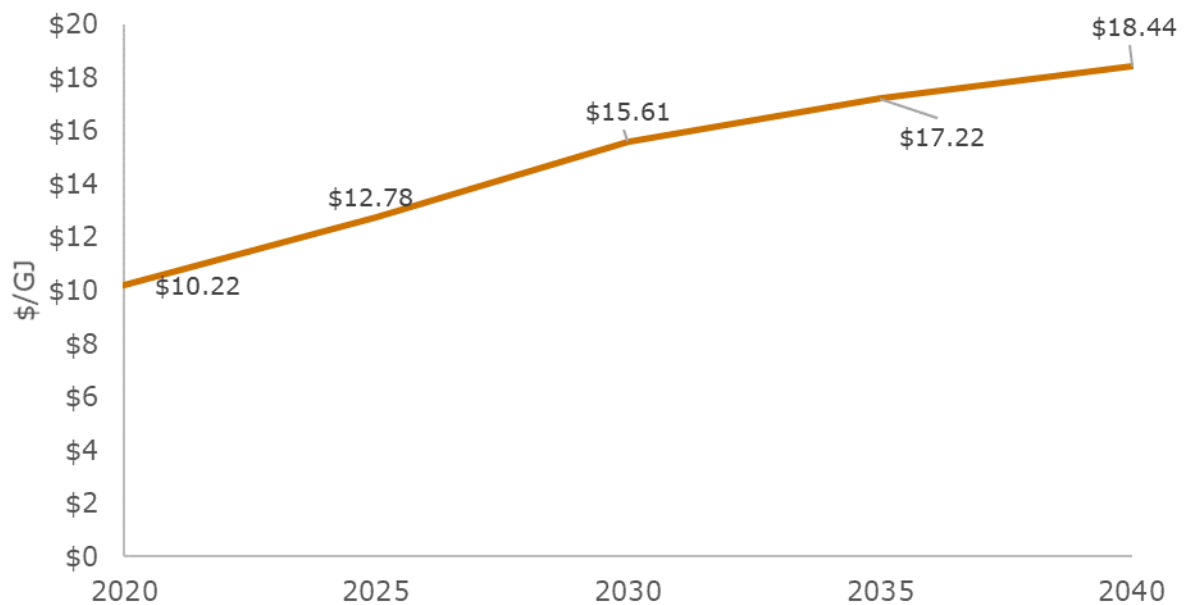
Domestic natural gas reserves are almost exhausted, making imminent LNG importation highly likely as fuel supply changes struggle to adapt to renewables.

**Figure 35 - Gas Consumption by Sector – Tūi**



Due to the continued profitable use of natural gas, including Methanex, 2P and 2C reservoirs have been almost fully depleted, and exploration has yielded only an additional 700PJ of onshore resources. Figure 36 shows how natural gas prices are responding by rising rapidly as the prospect of importing LNG from the international market (at prices of around NZD20/GJ) becomes closer to reality.

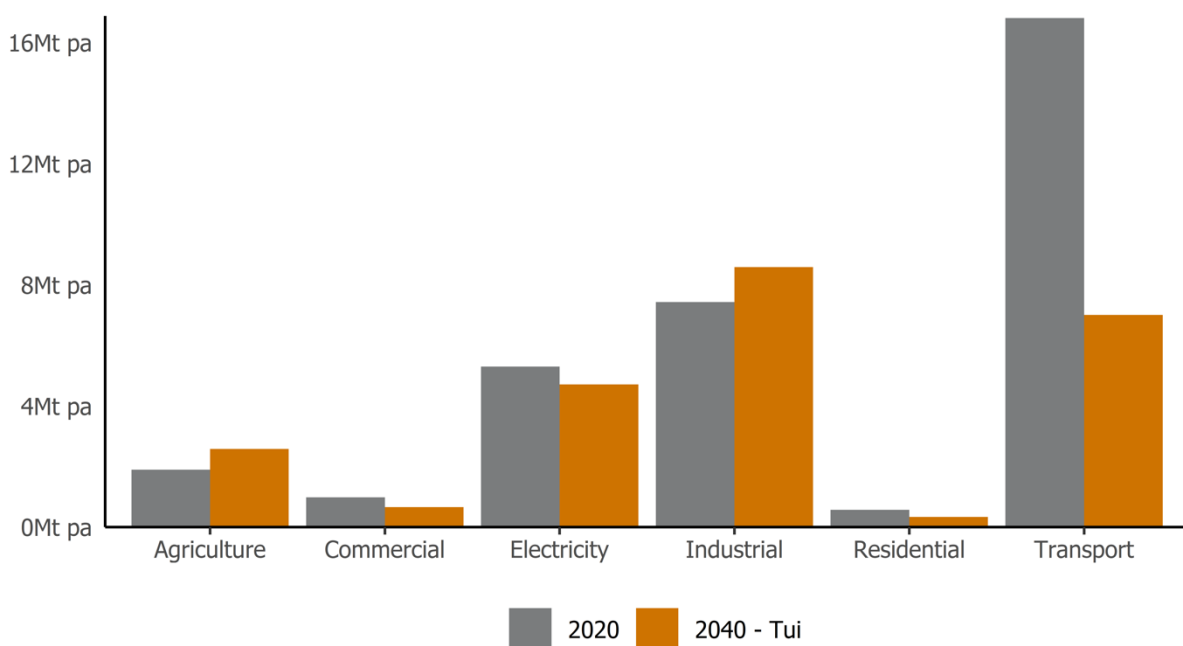
**Figure 36 - Natural Gas Prices – Tūi**



## Emissions

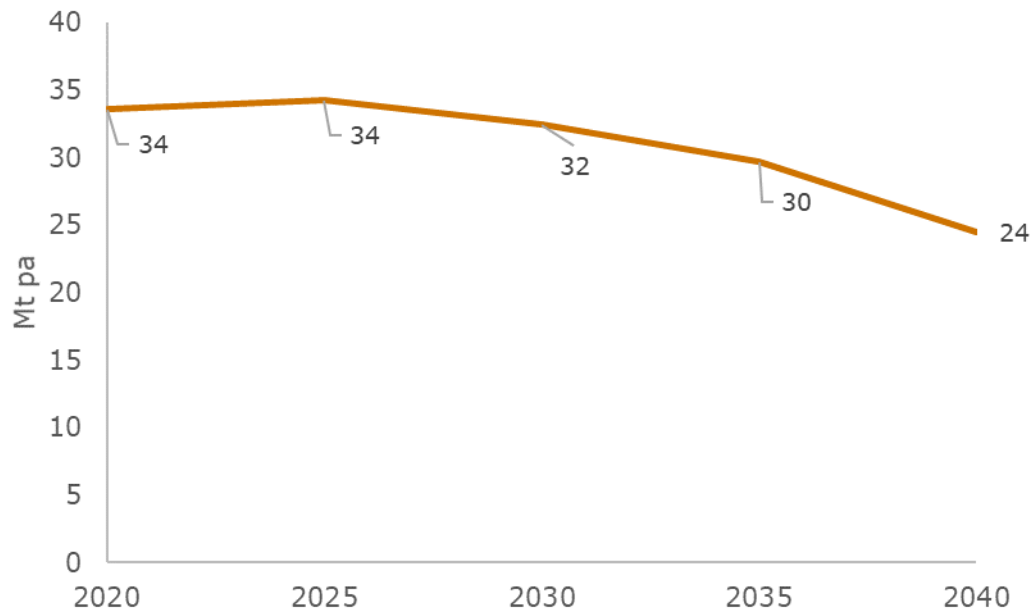
The critical outcomes for the energy sector include cost to consumers and carbon emissions. We are well aware that our economic path will be heavily influenced by the stance we take with respect to our emissions profile. Figure 37 breaks down the reduction in emissions that follows the energy profile set out above. The rise to 75% renewable energy in the economy translates into emissions reductions of 11.9 mt p.a. in the transport sector and 2.0 p.a. for industrial processing. Emissions from electricity generation rise slightly in 2040 compared with the present day due to the rapid expansion of geothermal generation.

**Figure 37 - Emissions Reductions by Sector – Tūi**



Emissions in Tūi have fallen from ~34mt p.a. in 2020 to ~24 mt p.a. The remaining emissions come from aviation (domestic and international), rail, shipping, and diesel in agriculture, industrial sectors and fossil fuel powered generation providing security of supply. Gas is the main contributor until other technology, such as coal with CCS, becomes more competitive on cost.

**Figure 38 - Energy Sector CO<sub>2</sub> Emissions – Tūi**



## BEC2060 NARRATIVES: KEA

### Economic Transformation

*New Zealand adopts the position that the economy cannot remain internationally competitive with a relatively high emissions economy and New Zealand plays a leadership role in lowering emissions, choosing to undergo an aggressive economic transformation.*

In this scenario, society has a strong sense of a shared goal and common purpose thereby underpinning the transformation that occurs and the rationale for it. Individuals act increasingly for the common good on environmental issues, change behaviours to reduce emissions, and accept other environmental solutions such as moving towards a circular economy<sup>15</sup> and the reduction of wasteful disposable activities and products.

The New Zealand economy has made an aggressive transition away from a goods-producing economy towards an economy dominated by low energy demand and/or emission intensity production (the 'lower-weight' economy). In agriculture, plant-based protein production has become mainstream on land suited for cropping although on the remainder of pastoral land animal-based protein production continues. By implication, food processing has declined to the extent food processing and transport costs for animal-based protein replace the equivalent costs for animal-based protein.

This scenario is not risk free. Transforming the economy away from a goods producing economy to one driven more by high-value/value-added products and high-end services is a challenge for New Zealand. While there is a strong global commitment to decarbonisation, some countries are less committed than others, including some of our trade competitors. New markets have been sourced for our new product mix. Some countries have also attracted energy intensive businesses displacing them from New Zealand's high carbon-priced economy and policy position (of full carbon exposure) on what are currently known as the EITE industries. New Zealand is ahead of these countries in terms of emissions reductions, but the possible cost is that trade is harmed and there is carbon leakage in the near term.

This transformation has taken time and has been costly for many communities and businesses, especially lower socio-economic groups. Some marginal industries have shut down, increasing unemployment and limiting output and thus national GDP growth. Further, the increased carbon price and associated policies have driven up the price of many commodities and services, which, combined with higher unemployment, has a consumption/affordability effect.

In recognition of the nature and scale of the transition, governments have set out the principles they are following to make the transition and engage with affected stakeholders to help them better navigate it. Governments have been empowered to allocate significant capital and operating budgets so as to lay down the infrastructure for an energy and climate transformation.

GDP won't be relied on as the only measure of economic well-being. The success of this scenario will be seen in terms of natural capital, social capital and productivity along with GDP. Thus, even in this case where GDP is sluggish in the early part of the scenario, other measures will remain strong.

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<sup>15</sup> A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.

## The Kea World in 2040

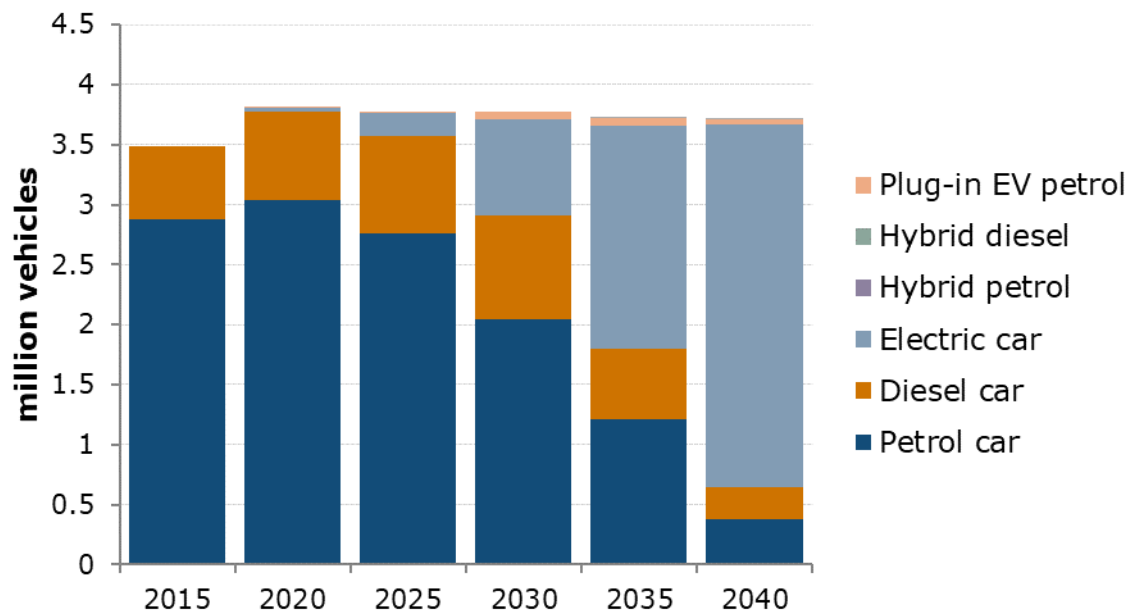
The consensus to drive down emissions reaches nearly every corner of society. Technology change/reduction in cost, combined with a high cost of carbon flowing through to consumers, drives some significant decisions.

- implied carbon prices have reached \$140/t, among the highest in the world;
- the economy has emerged from the difficult period of structural change, having grown 50% (a little over 2% per annum) over the 20-year period. However, this growth has been driven primarily by the commercial/services sector; industry and agriculture have been hit hard and are only now getting to their feet;
- population has grown a little over 10% through selective immigration, reaching 5.6m. Most of this growth has been in the major cities, fuelled by the prospect of service sector and technology jobs. Rural areas have suffered, some declining into non-existence; and
- technological change has seen the cost of electric vehicles, wind and solar drop significantly

Where possible, energy use in the economy has been electrified or non-fossil fuels adopted. At the beginning of the period transport was the biggest emitter and through to 2040 gets the most focus by governments and individuals in this scenario. By 2040 almost all the cars and trucks we drive are different, predominantly electric but with 1PJ biodiesel (10% blend). The government's aspiration of 100% renewable light fleet has almost been realised, save for ~600,000 (out of a fleet of nearly 4 million) older hybrid vehicles remaining on the road from earlier years.

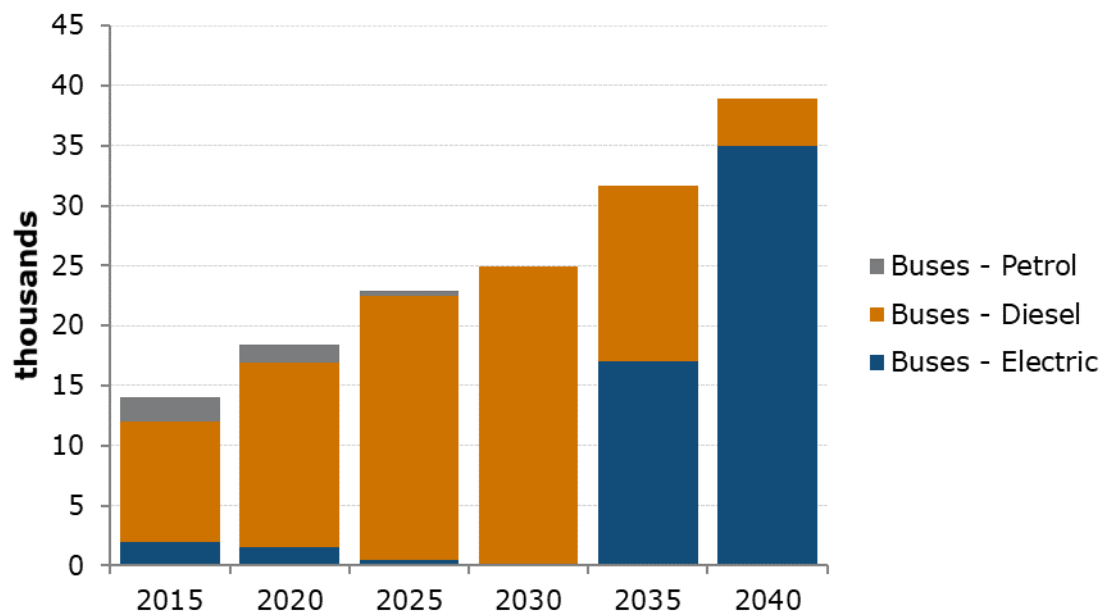
Figure 39 shows the replacement of the car fleet from predominantly petrol currently to predominantly electric with no solely petrol vehicles at all. In 2040 efficient diesel cars are still in use. The size of the car fleet remains static despite the population growth over the period.

**Figure 39 - Car Fleet – Kea**



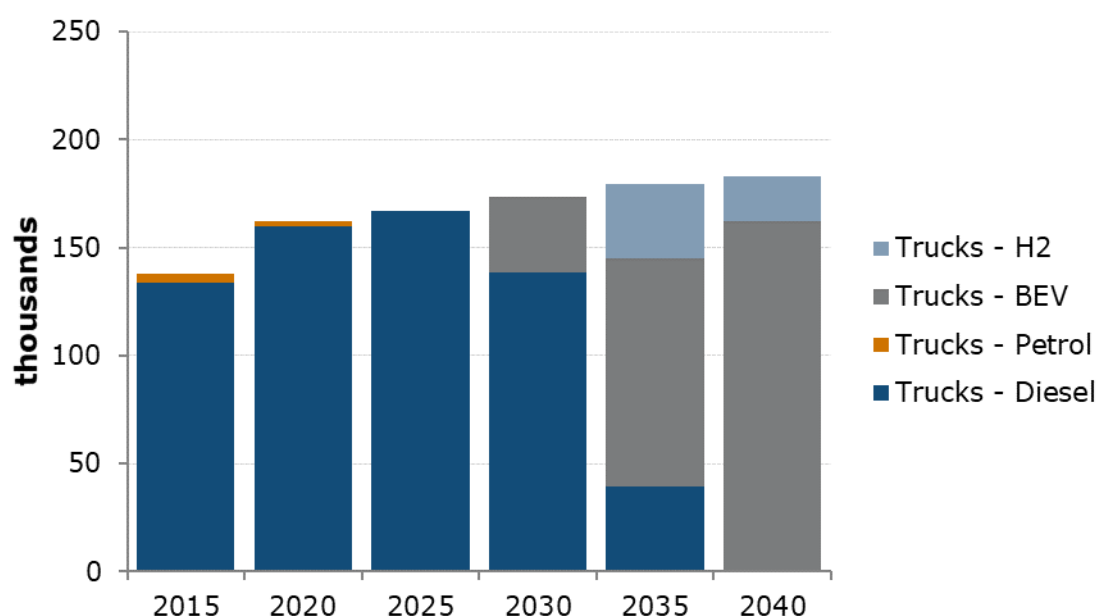
The use of public transport has grown such that the heavy bus fleet has more than doubled in size over the last 20 years. While diesel remained the dominant fuel for some time, the switch to electric buses began in 2035, and is almost complete in 2040, with around 5,000 diesel buses (roughly 1 in 7 buses) left on the road.

**Figure 40 - Heavy Bus Fleet – Kea**



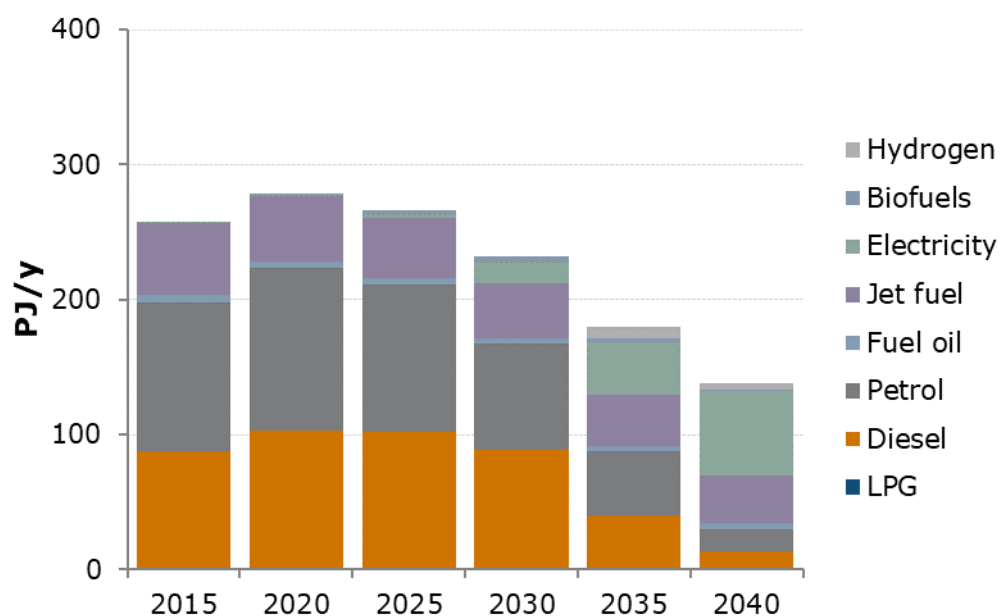
A similar transition has occurred for trucks; diesel trucks are almost phased out. However, since 2035 hydrogen trucks – at the heavy end of the spectrum – have entered the fleet, illustrating a slight superiority to electric trucks due to the payload implication of batteries. It is a close race between electric and hydrogen, and with 8-year life cycles for trucks combined with an established hydrogen and electricity distribution network, the future is uncertain.

**Figure 41 - Truck Fleet – Kea**



In Figure 42 we see the net effect on transport fuels – electricity has largely displaced petrol (in the light fleet) and is reducing diesel consumption through the electrification of heavier vehicles. Hydrogen is now playing a role in heavy trucking. Jet fuel consumption has decreased, with 3% efficiency gains being partly offset by a modestly increasing demand for air travel.

**Figure 42 - Fuels in Transport – Kea<sup>16</sup>**



<sup>16</sup> The BEC2060 modelling was baselined on 2015 data, and growth rates applied thereafter. In most cases, this has provided plausible estimates for 2020. However, in the case of jetfuel, demand increased significantly immediately after 2015, due to a range of drivers (the cost of jetfuel, tourist numbers, and increasing international competition for NZ-bound flights, for example); noting that this steep increase has abated more recently. We will re-baseline jetfuel demand in 2020.

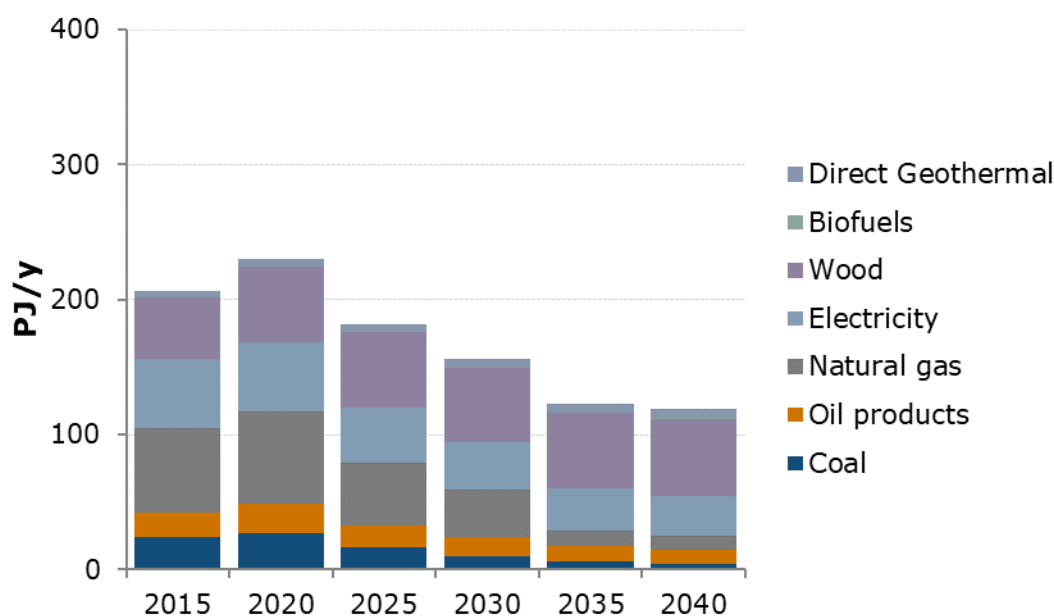


Industrial process heat has switched away from a dependence on fossil fuels to a high use of (low emissions) electricity.

Industry has been hardest hit by the structural change away from emissions-heavy energy consumption. While the exit of methanol production in 2035 had a sharp and immediate impact on gas consumption, food manufacturing (especially dairy), basic metals and other manufacturing sectors have all contracted in size over the last 20 years. Only the wood, pulp and paper sector managed to come through the economic transformation relatively unscathed, as timber (and associated products) became an important domestic and global commodity over the period, and the timber processing sector was able to increasingly rely on woody biomass to substitute for natural gas and coal consumption. The wood sector has emerged as the dominant part of the industrial energy landscape.

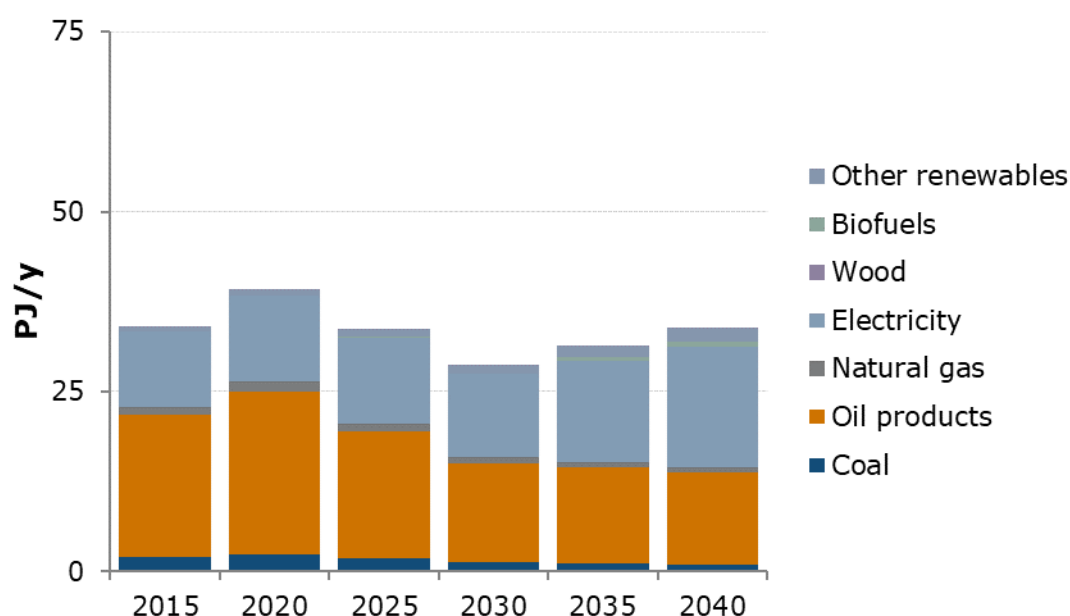
Coal has all but been eliminated from the industry sector, with a very small number of manufacturing and dairy processing plants retaining coal boilers for heat applications (Figure 43 -, below). Woody biomass has gone from around 25% of industrial energy consumption to nearly 60% of the sector, providing nearly 60PJ per annum of industrial heat. Hence biomass supply chains are strategically important to a number of industrial firms, primarily concentrated in the wood sector.

**Figure 43 - Fuels in Industry – Kea**



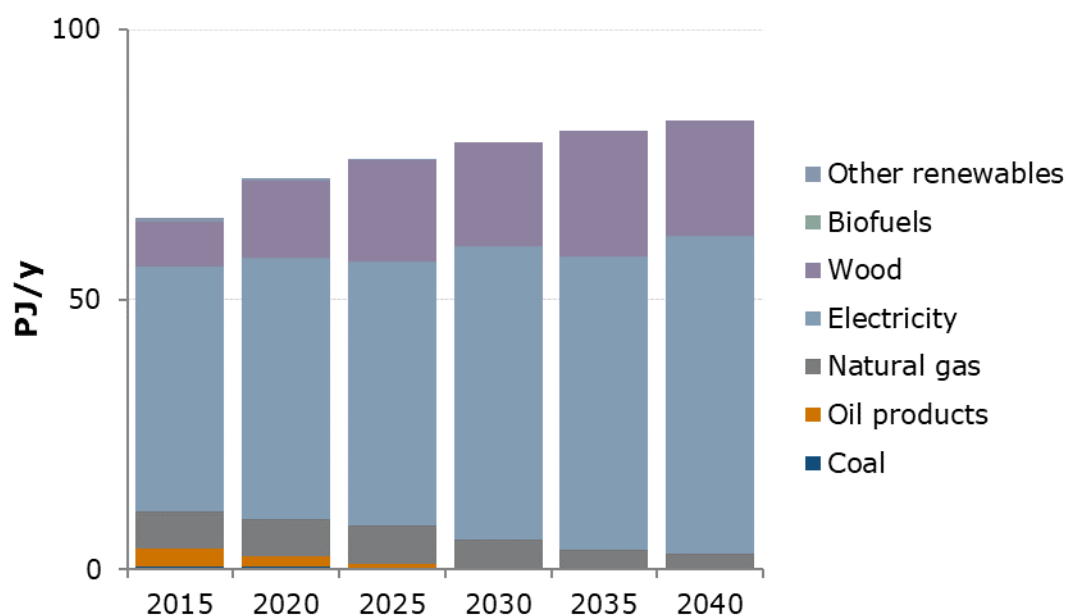
The agriculture sector struggled through the first 20 years of the period and transitioned to some usage of oil products (primarily diesel) to electricity. In 2040, electricity is over half the energy supply of this sector, and biodiesel and biogas are emerging as genuine alternatives.

**Figure 44 - Fuels in Agriculture – Kea**



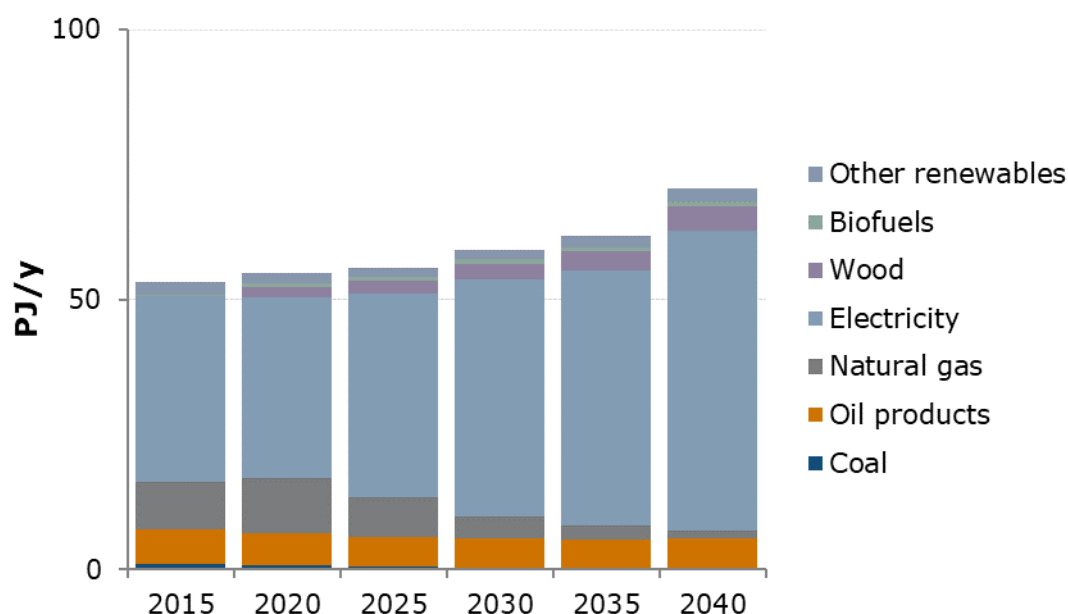
While, in 2040, electricity has a much larger role in transport, it has also become the fuel of choice in the residential and commercial sectors; consumers and businesses have largely dispensed with coal and natural gas as a form of heating homes and businesses. Our homes have almost become 100% renewable, with gas only remaining as a fuel for cooking for consumers that prefer it.

**Figure 45 - Fuels in Residential – Kea**



The commercial sector has enjoyed modest growth through the structural change period, emerging in 2040 also with a highly electrified energy supply, eliminating natural gas for cooking and water/space heating. Some oil products remain, primarily for motors.

**Figure 46 - Fuels in Commercial – Kea**



### Overall: The Energy System is Taking a Different Shape

The combined effect of structural change (including Methanex's departure in 2035), the carbon price, and the increased desire to adopt new technologies that reduce emissions and increase energy efficiency, have a dramatic effect on energy demand, as the economy struggles under the adjustment to low emissions.

Total energy demand has declined over 200PJ (30%), as a result of the combined effects of structural change and more carbon and efficient use of energy (most dramatically driven by the replacement of internal combustion engines with electric motors in the transport sector).

**Figure 47 - Total Fuel Consumption by Fuel Type – Kea**

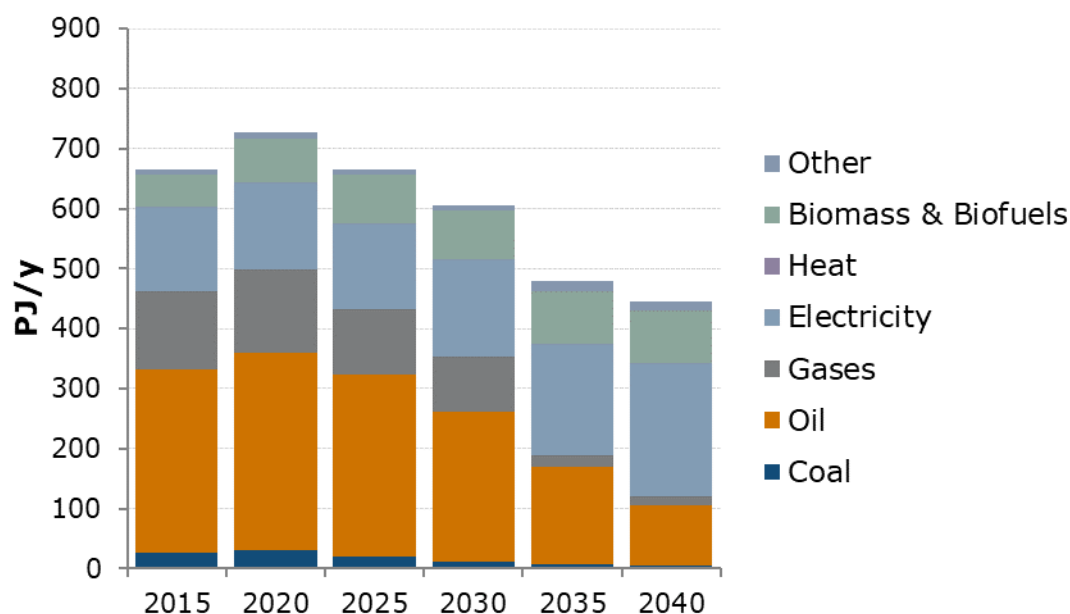
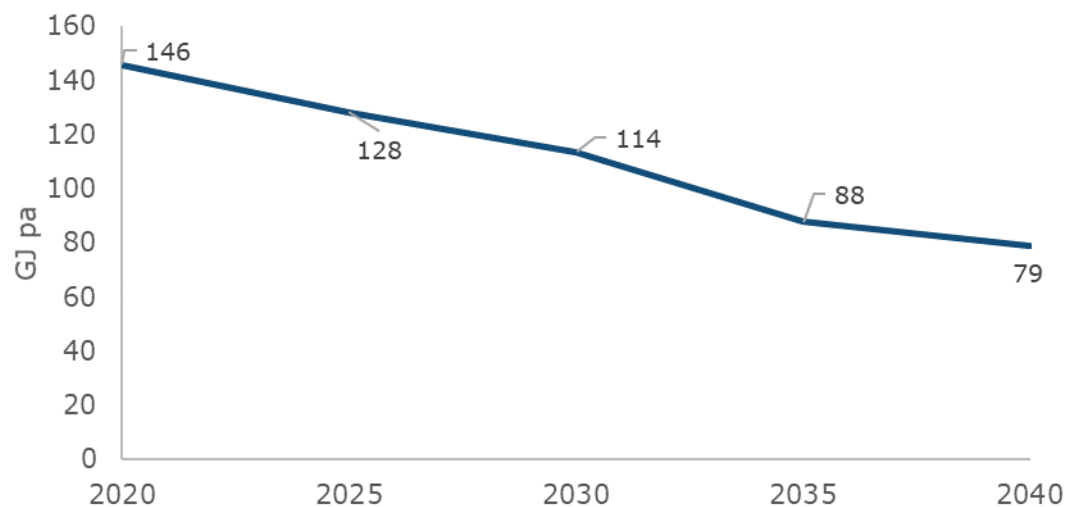


Figure 48 shows that energy consumption per capita has declined by 54% in 2040 from the present.

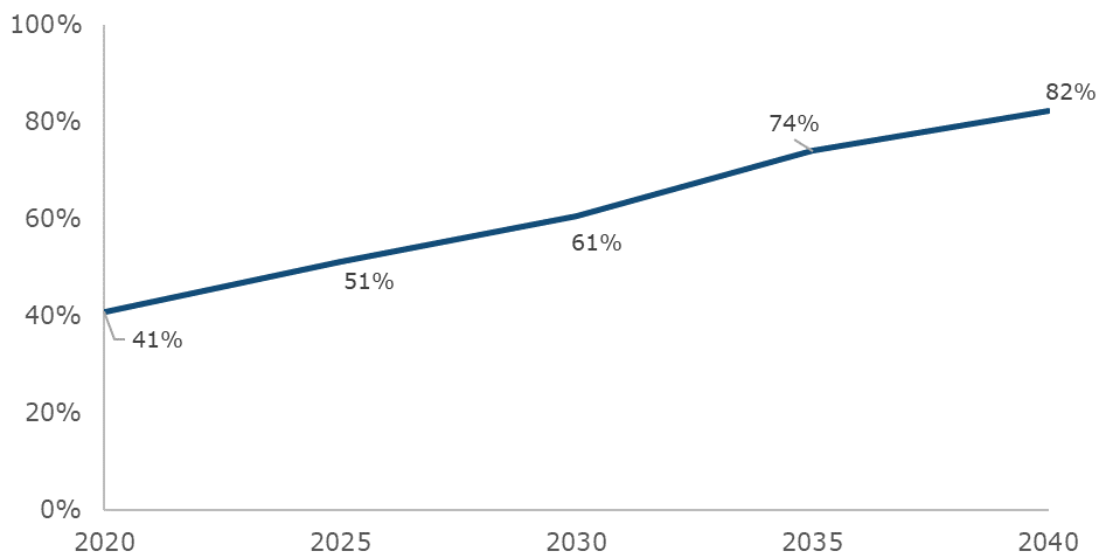
**Figure 48 - Final Energy Consumption Per Capita – Kea**



Understandably, the very high carbon prices and other policy options employed by government have resulted in the contraction of fossil fuels, and the expansion of renewable electricity (and, to a lesser extent, bioenergy). This dramatic transformation is supported by a societal response to the climate change challenge, supporting governments to take action and then allowing the carbon price to flow through the economy.

The result of the transformation period of 2020-2040 is shown in Figure 49 below. New Zealand has reached 82% renewable energy in the economy by 2040 – double the proportion in 2020.

**Figure 49 - Renewables Proportion in Energy – Kea**

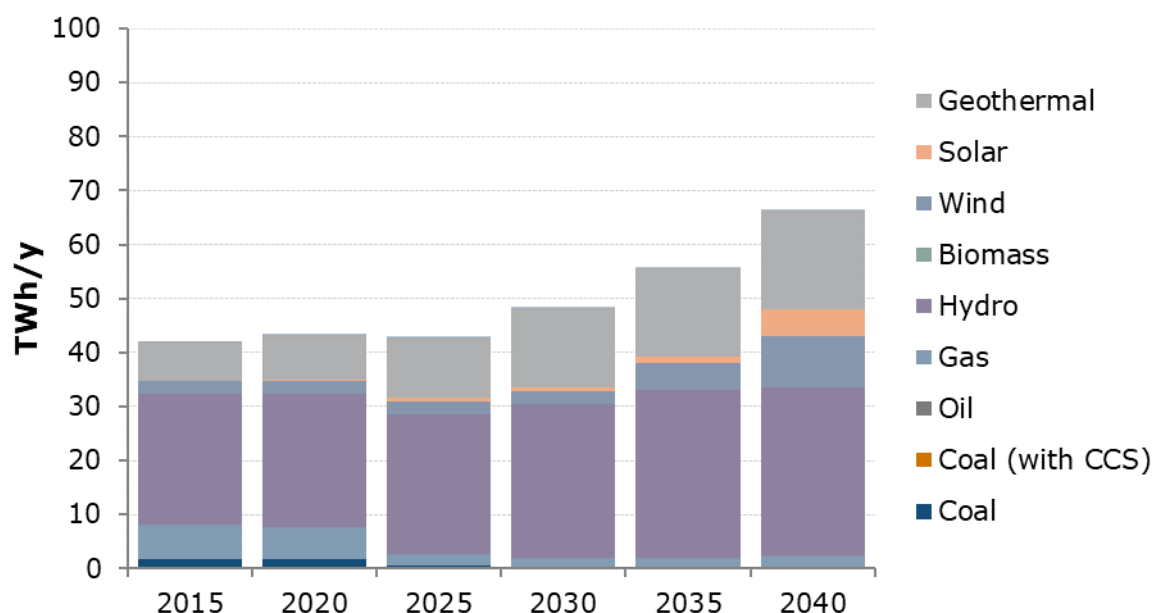


## The Role of Electricity

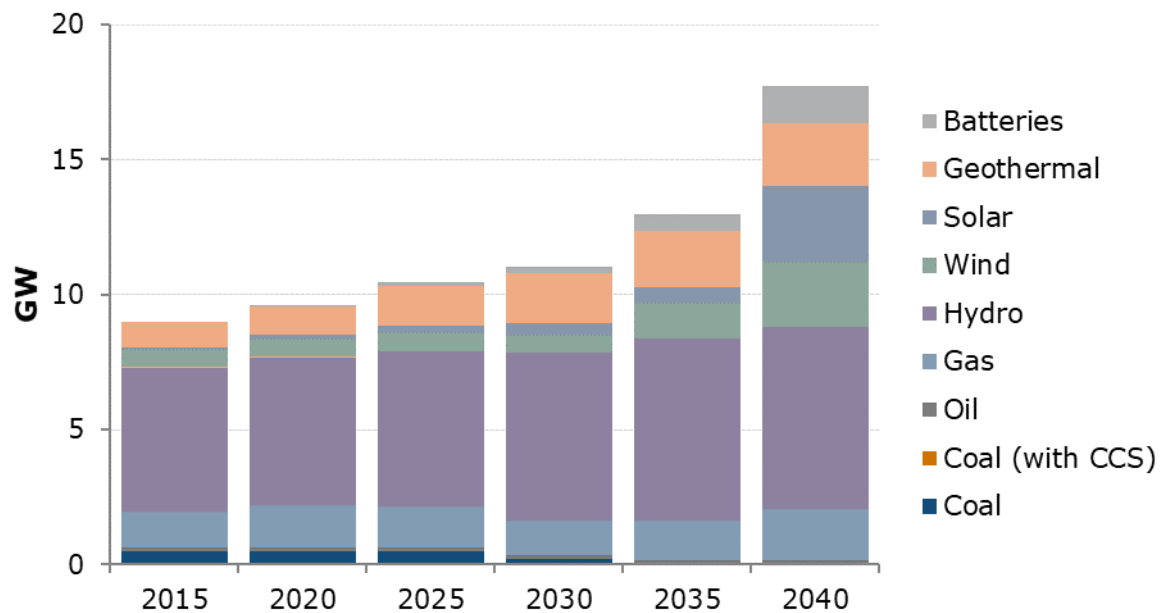
The importance of electricity to the transformation cannot be understated. Figure 50 illustrates how total electricity demand increases to cater for the electrification of the transport fleet and heat in the residential, commercial and agriculture sectors. The commercial imperative of the carbon price means this electrification is driven by a sector's ability to not only maintain but increase its renewable component. The amount of fossil fuel powered generation declines significantly by 2025 as thermal units withdraw from the market i.e. the average proportion of renewable electricity generation goes up and the demand growth is picked up substantially by renewable energy.

However, in order to maintain a secure supply, we see three effects. Firstly, we see a degree of overbuilding of renewable capacity, principally in geothermal. Secondly, over 1.5GW of batteries – local and grid scale – have been assisting in the management of peak demand, usurping the historical role of gas peakers. And thirdly, even with the overbuild of renewables and batteries, the model projects that a limited amount of thermal generation is required to ensure that the reformed supply profile is able to provide security of supply, especially as solar begins to emerge in 2040 as a material component of the electricity system. Its generation profile – low in winter, and high in summer – compounds New Zealand's existing difficulties with hydro inflows. Flexible thermal generation is required to meet demand at all times during the year.

**Figure 50 - Electricity Generation – Kea**



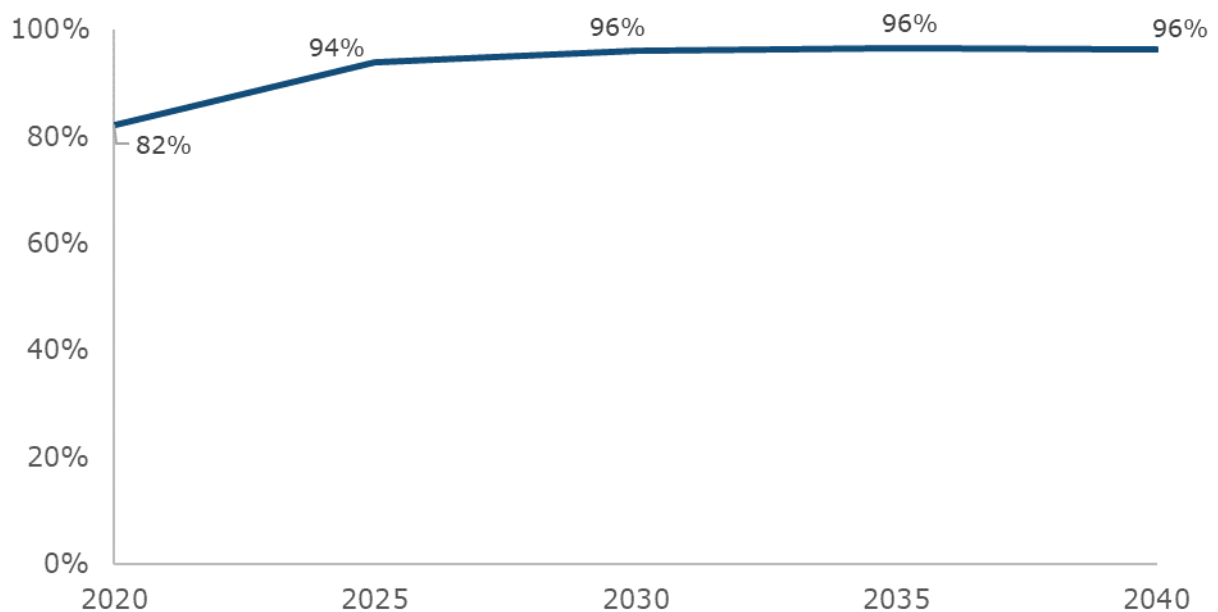
**Figure 51 - Electricity Capacity – Kea**



Figures 50 and 51 tell the story about how consumed electricity is powered and how provision is made to provide for a secure grid regardless of the conditions that emerge over time. As a result of higher demand from electrification and less fossil fuel powered generation available to provide resource adequacy, there is a degree of overbuild of renewables, primarily geothermal, which is used in a summer vs winter capacity-shifting mode. These renewables, in turn, are highly variable (wind, hydro, solar), and, while installed capacity grows, their utilisation is lower than 50%. This necessitates the expansion of new firm capacity technologies (batteries).

In terms of renewable electricity production, Figure 52 shows that the electricity system has both kept pace with rising demand from new uses, and increased average renewable generation to 96%.

**Figure 52 - Renewables Proportion in Electricity – Kea**

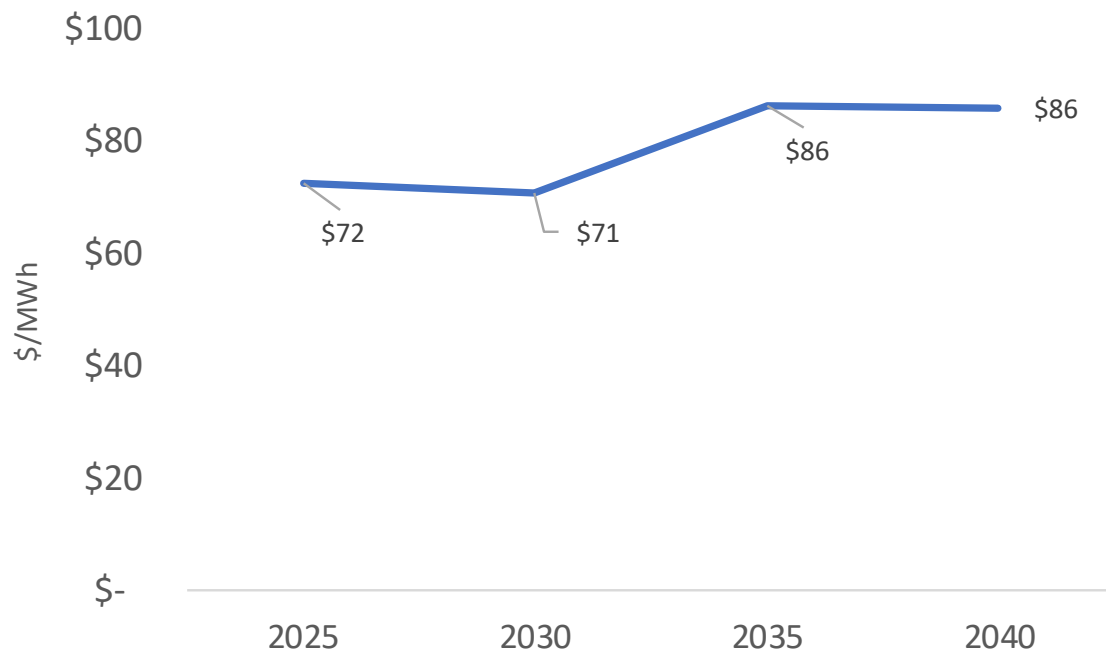


The plateau in the renewable proportion of electricity supply from 2030 reflects the fact that investors can no longer see the expansion of renewable electricity as the way to meet rapidly growing demand. The construction of a gas and coal/CCS plant in 2040 reflects growing pressure on security of supply, and that thermal plant is the most economic option to fill this need even in a world where reductions of carbon emissions is of the highest priority.

Figure 53 shows that, despite the declining cost of some renewables (for example, wind and solar), the need to invest in low-utilisation geothermal, as well as some thermal capacity for security of supply, has kept some modest upward pressure on wholesale prices over the last 20 years.



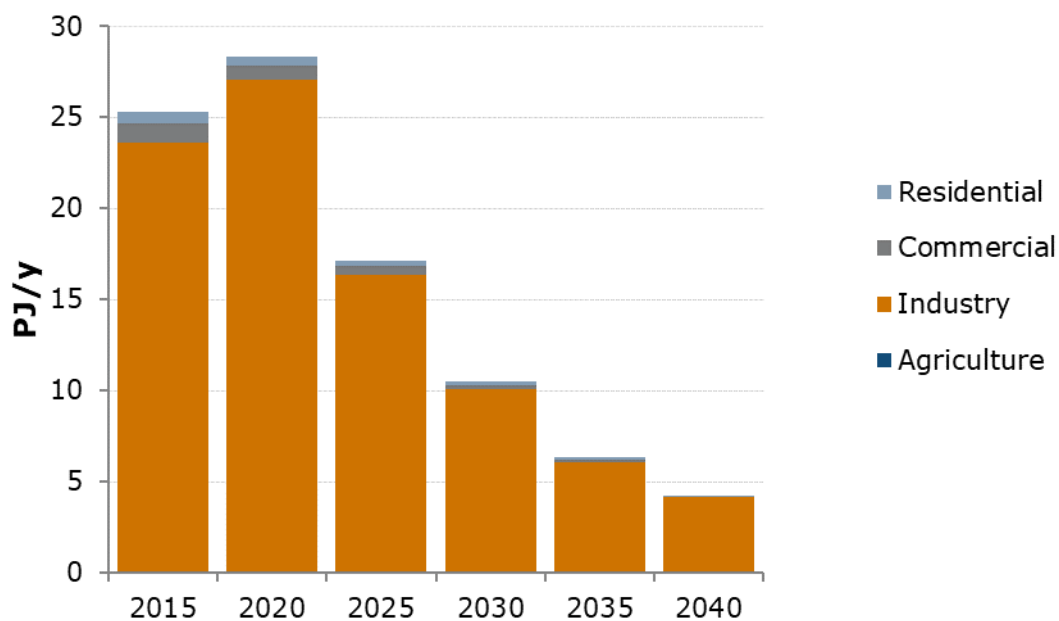
**Figure 53 - Electricity Prices – Kea**



## Resources Sector

In response to explicit government initiatives coal's use as an industrial fuel peaks in 2020 at 28 PJ/Y declining to 4 PJ/y in 2030

**Figure 54 - Coal Consumption by Sector – Kea**

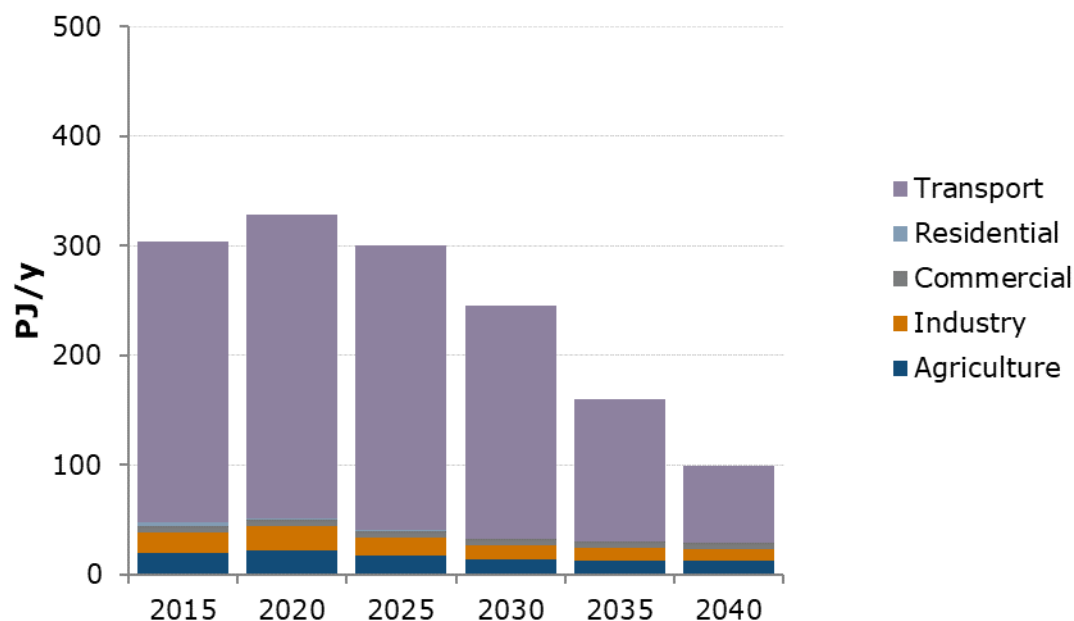


## Oil

Principally as a result of the increased adoption of electric vehicles that accelerated in earnest after 2025, New Zealand's consumption of petrol has reduced to the point that it is

almost eliminated from the energy system. However, as discussed above diesel remains the fuel of choice in the heavy vehicle fleet, and jet fuel in aviation. Overall, imports of oil and oil products have reduced around 20% by 2040. Diesel's role in agriculture and other manufacturing also remains moderately strong.

**Figure 55 - Oil Consumption by Sector – Kea**

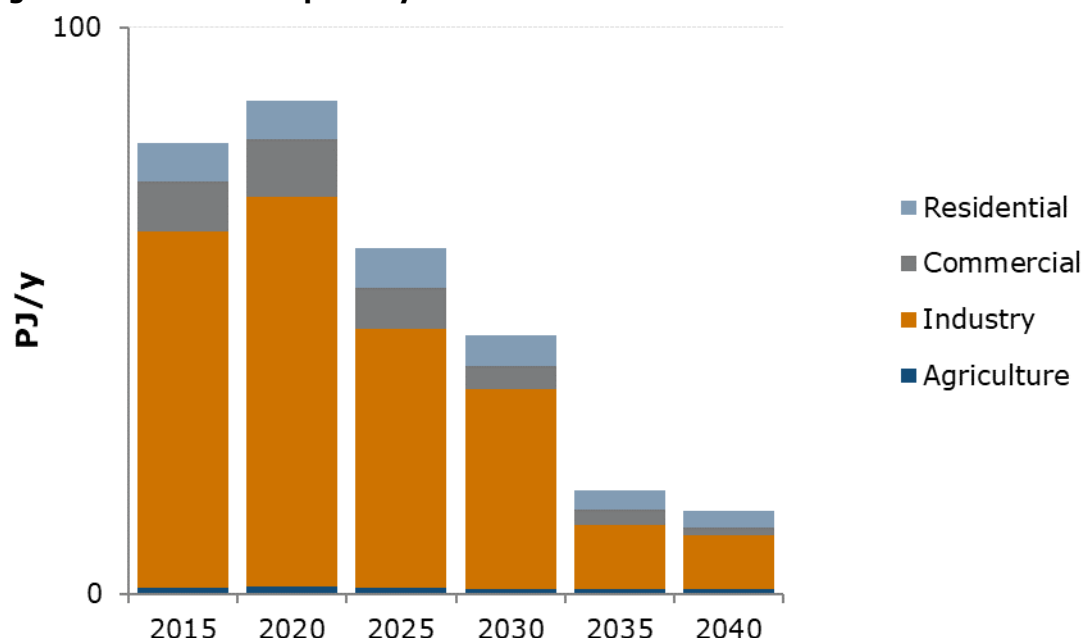


The country's reliance on imported oil has decreased from 25% of primary energy in 2020, to 20% in 2040.

### Gas

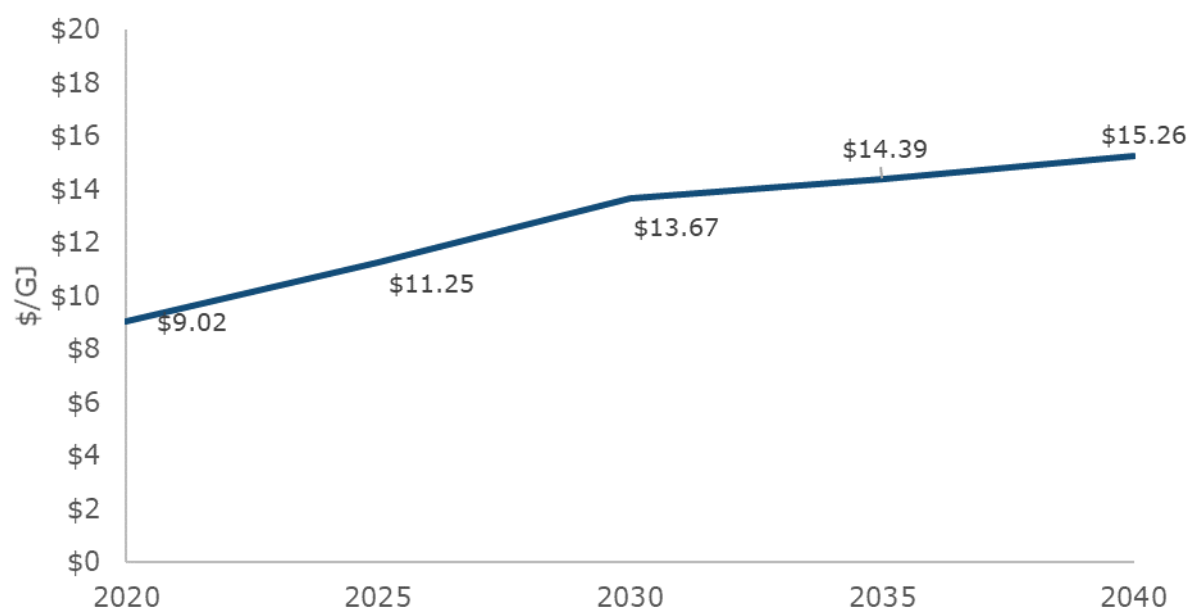
Gas consumption reduces significantly in this scenario, to a little over 30PJ by 2040. The impact of the Methanex departure, shortly after 2030, on energy and non-energy gas consumption is dramatic, slowing the rate of extraction from domestic reservoirs. The majority of the gas consumption in 2040 is in the electricity industry, principally for flexible inter-seasonal hydro firming, and also to support the seasonal patterns of solar, which is beginning to make its presence felt in the electricity industry, as discussed above. Any gas energy requirements for dry year support are not included in these figures.

**Figure 56 - Gas Consumption by Sector – Kea**



Biogas (methane) has recently emerged as an economic source of gas for the agricultural sector and some industrial heat applications. Together with the departure of Methanex early in the period, current 2P and 2C reservoirs are more than sufficient to meet the country's needs for the foreseeable future. Despite rising gas prices, the low prospect of increased demand and governments' reluctance to support rising gas use has dampened any driver for explorers to embark on extraction from as-yet undiscovered fields.

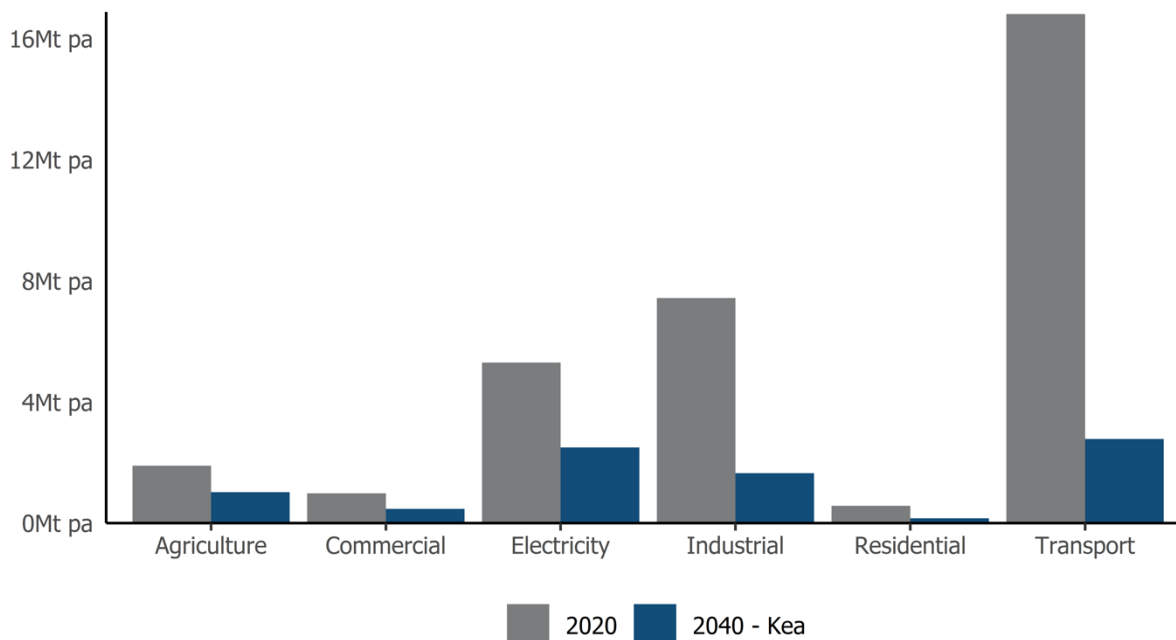
**Figure 57 - Natural Gas Prices – Kea**



## Emissions

The critical outcomes for the energy sector include cost to consumers and carbon emissions. We are well aware that our economic path will be heavily influenced by the stance we take with respect to our emissions profile. Figure 58 breaks down the reductions in emissions that follow the energy profile set out above. The rise to 82% renewable energy in the economy translates into emissions reductions of 15 mt p.a. in the transport sector and 6 mt p.a. for industrial processing. Emissions from electricity generation also fall by 3 mt p.a. in 2040 compared with the present day.

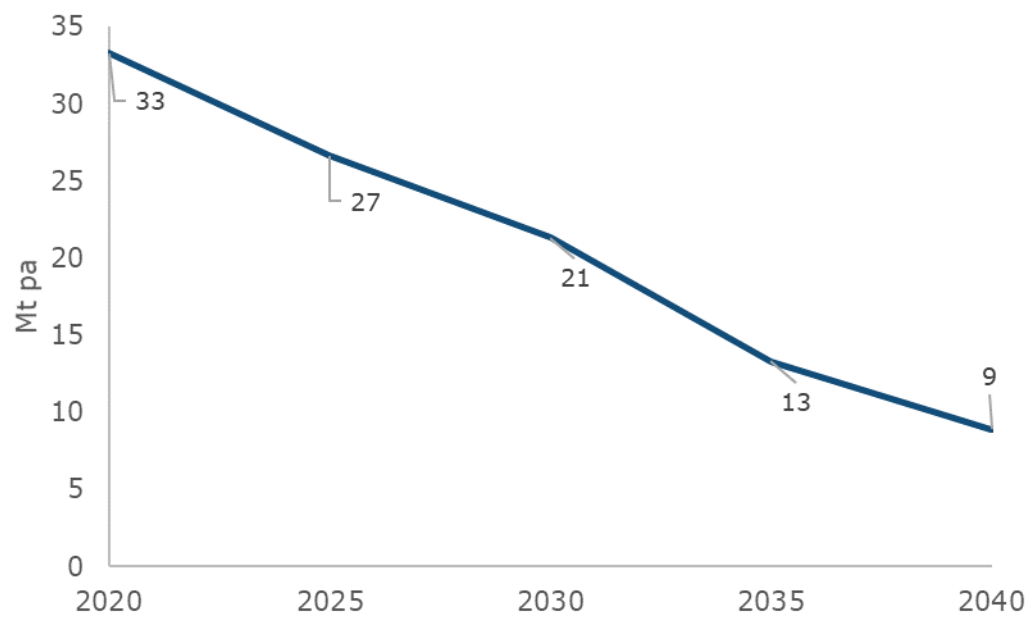
**Figure 58 - Emissions Reductions by Sector – Kea**



The net effect of these changes on energy sector emissions is significant, but by no means complete. By 2040 energy emissions have declined 55% from ~34mt p.a. to ~12 mt p.a. The remaining emissions come from aviation (domestic and international), rail, shipping, and diesel in agriculture and industrial sectors, hence the decarbonisation job is not yet complete.

Emissions in Kea have fallen 80% from ~33mt p.a. in 2020 to ~9 mt p.a. The remaining emissions come from aviation (domestic and international), rail, shipping, and diesel in agriculture, industrial sectors and fossil fuel powered generation providing security of supply. Gas is the main contributor until other technology, such as coal with CCS becomes more competitive on cost.

**Figure 59 - Energy Sector CO<sub>2</sub> Emissions – Kea**



## TŪI AND KEA: 2040 – 2060

Modelling the scenario narratives from 2040 – 2060 is even more challenging than modelling to 2040 with more assumptions and more uncertainty. Uncertainty is, in many ways, one of the reasons for developing these scenarios and taking an explorative approach. The inertia in long-lived energy supply assets, consumer preferences and the wider economy lead us to take a more contemplative risk-based approach to the second half of the scenario period.

At some point, though, we lose confidence that any individual narrative is staking out a *bound* on the future. For these narratives we have located that point at around 2040. Most importantly, though, the period beyond 2040 is where, in our narratives, the consequences of the decisions made by New Zealand society in the early part of the period (2020-2030) come to light. In reality, these consequences will be the result of an inestimable number of individual decisions passing through the filter of societal, technological, political and economic systems for more than two decades. But our methodology requires the two storylines – Kea and Tūi – to extend as two single threads beyond 2040 and we have modelled the two scenarios out to 2060. The narrative authors, and the modelling, had to articulate what these consequences are.

The combination of acute uncertainty, and the need to judge the long-term consequences of actions today, leads us to weigh the prospects of success with the risks of our wildly different scenarios. We said at the outset that neither is risk free.

In Kea, the narrative is that climate change action is the priority that eclipses other priorities society may have. In this scenario, society pursues economic transformation that delivers an aggressive decarbonisation; one that pursues a global leadership role. The transition is costly in terms of GDP growth and by 2040 New Zealand will begin to know whether the transformation has lifted the economy to a different level and found trade partners supportive of the stance New Zealand has taken (which has been to go ahead of the world's decarbonisation efforts). The risk is that the cost of this transition, and/or the constraints of our traditional economic powerhouse of producing animal-based protein and tourism, hinder our ability to transform ourselves into a truly green economy which is globally attractive.

In Tūi, the narrative is that climate change action is one of a number of priorities society wishes to pursue. In this narrative, the need for energy security and the cost of decarbonisation weigh against aggressive climate change action. Society stays with a preference for getting value from our traditional comparative advantages and leaves decarbonisation to market forces. This path may have sustained GDP growth through to 2040 but by then, despite New Zealand taking a 'wait and see' approach on decarbonisation compared with the rest of the world, demand for our agriculture is maintained and we still have a range of options for international trade. The risk is that our trading partners have been able to find superior alternatives to the produce we export, and, in this case, we would face a potentially more painful transition to a green economy.

It is important to recognise that the risk and reward in both scenarios is intimately linked to the rest of the world. We argued in Kea that the world would be decarbonising aggressively and that New Zealand would attempt to lead. We argued in Tūi that the world's decarbonisation efforts would be more muted, but that New Zealand would be even more careful, comfortable with falling behind. The uncertainty in 2040 is not just how successful New Zealand has been at pursuing its strategy domestically, but also how global forces have arranged the world of international trade (including tourism).

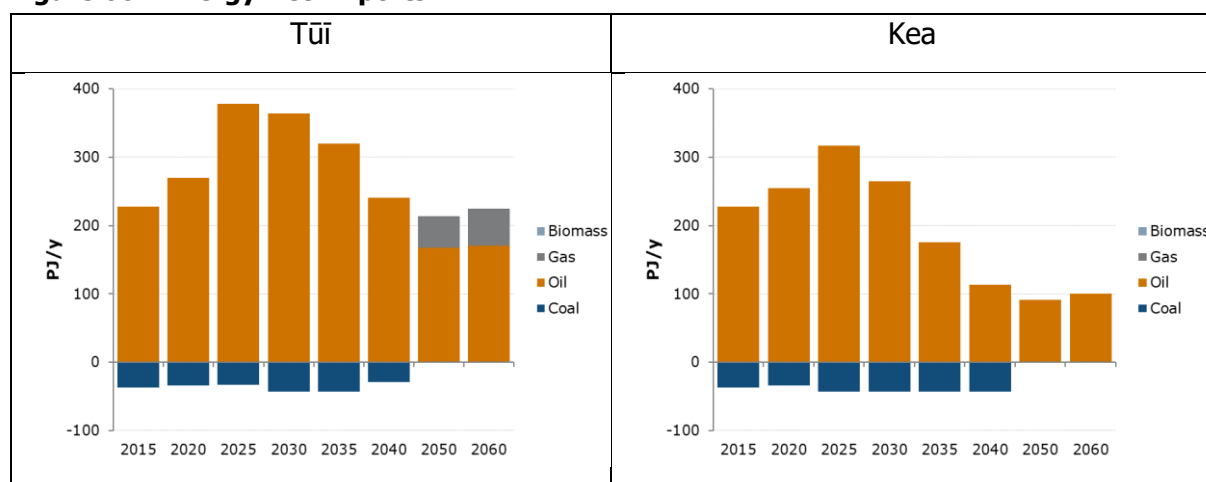
The modelling outputs for the last part of the scenario period tell the story that the combined effect of electrifying the economy and increasing the levels of renewable

electricity supply (at the rate of change of either Kea or Tūi) creates significant security of supply issues.

In both cases electrification has been supported by expansion of geothermal, solar and wind capability. There is no expansion of hydro so resource adequacy – the ability to store energy and shift it through time – is more challenging than in the early part of the period. In both scenarios gas is still part of the mix, but further gas development in Tūi is hampered by the fact that domestic gas resources have been exhausted and we are reliant on imported LNG (whereas gas demand in Kea has been more moderate). The next cheapest option to satisfy security of supply, based on technology costs we can foresee today, is coal fired generation with CCS. CCS is not a proven technology yet so it may be the answer, or some other technology may emerge by the later years.

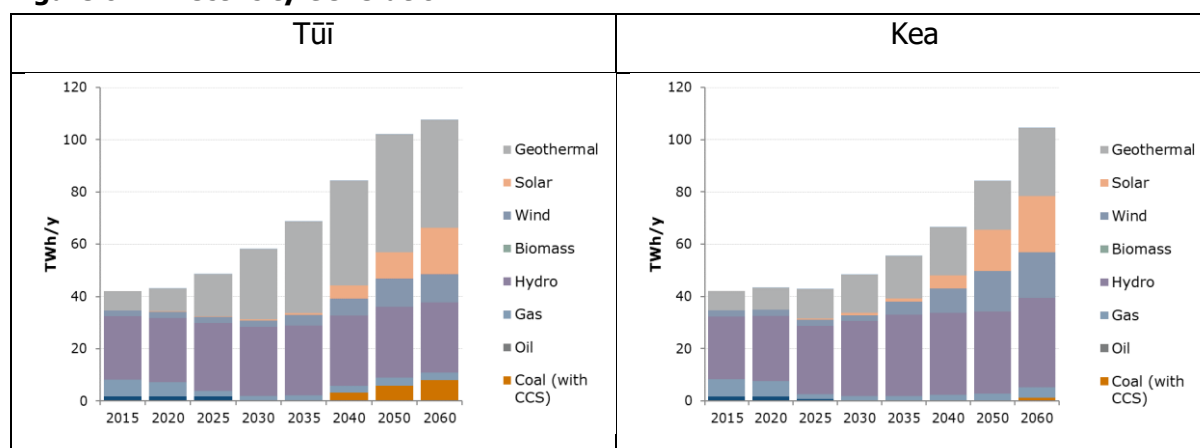
The way the two scenarios differ most markedly is in the way gas is supplied. In Kea, the natural gas supplies are eked out and are still supporting the electricity sector in 2060. This is aided by the departure of Methanex earlier rather than later in the period. In Tūi, Methanex stays later through the scenario period and natural gas supplies are run down. LNG imports are required to support industry and security of supply in electricity. This is illustrated in Figure 60. Oil is imported at much lower levels than the present day between 2040 and 2060 but LNG is not required (as long as natural gas is still available and coal with CCS or something else is viable by then.) In Tūi, LNG is imported from 2040.

**Figure 60 - Energy Net Imports**



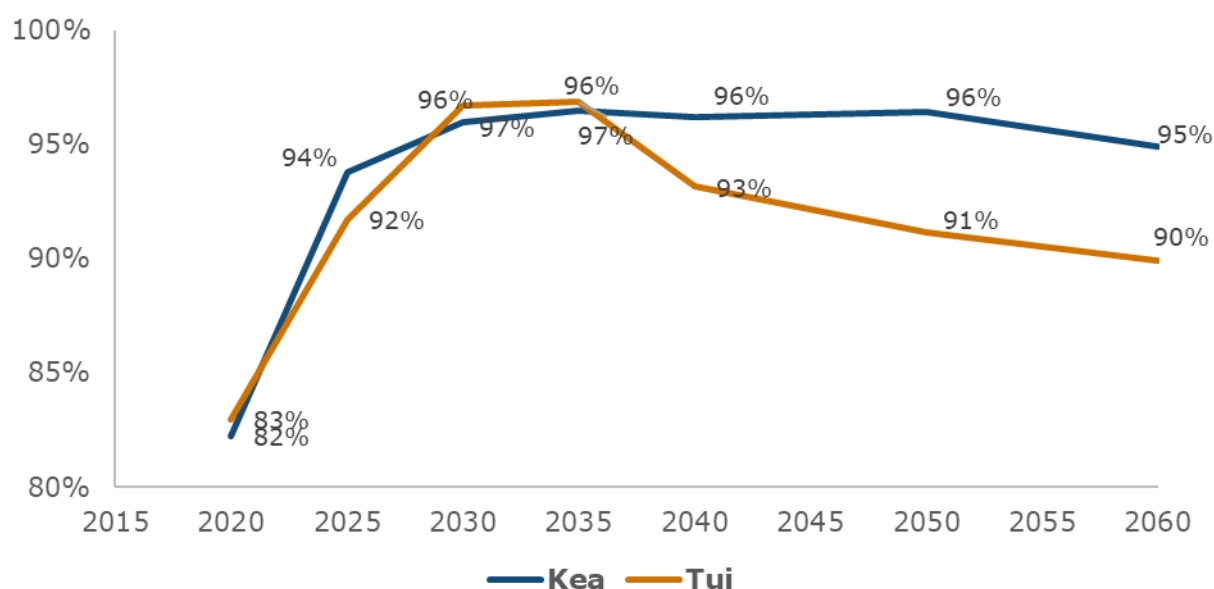
The issue of precisely which fuel and technology provides security is not the major point though, the issue is that we will need much more storable energy capability than we currently have. Figure 61 shows the level demand reaches following electrification, the contribution from geothermal, wind and solar and the re-emergence of fossil fuels to assist with the resource adequacy problem.

**Figure 61 - Electricity Generation**



One implication of the resource adequacy challenge is that the level of renewable electricity generation in both scenarios will have peaked by 2035. In the case of Tūi, it could fall back as low as 90% by 2060 but that depends on how the security of supply problem is addressed by then.

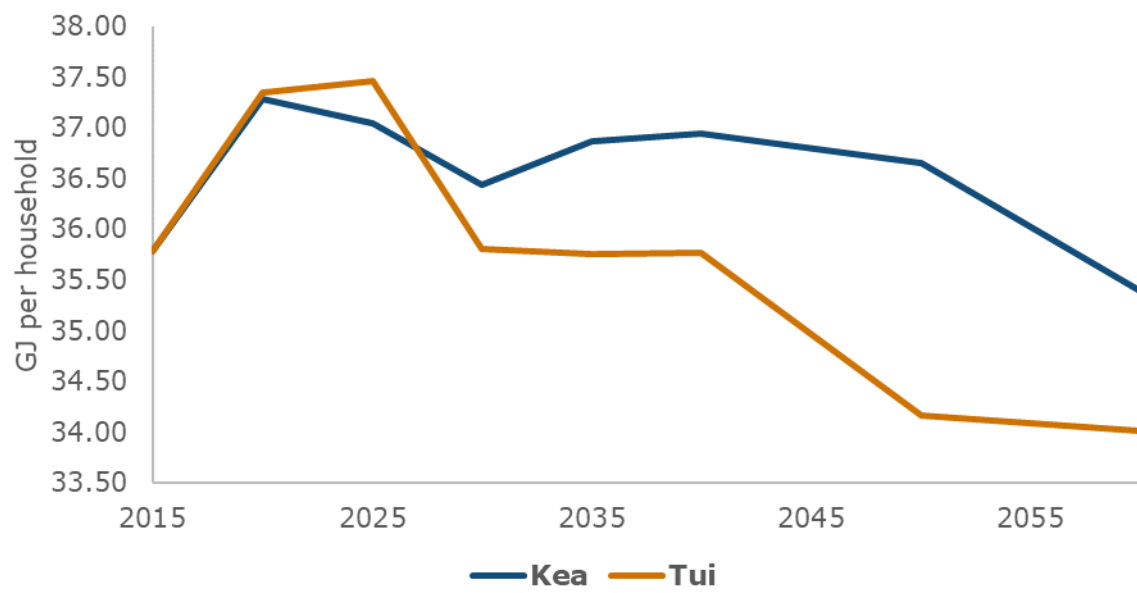
**Figure 62 - Renewables Proportion in Electricity**



The outcome for the energy sector is summarised in Figure 63. The energy per household consumed doesn't vary much, it declines in both scenarios. Notably, non-transport energy consumption ends up lower in Tūi than in Kea by ~1.5GJ per annum from 2040 to 2060. That is a response to the cost of energy. In Kea, the market doesn't have to resort to imports so the combined cost of energy supplied and associated carbon doesn't send as sharp a signal or elicit the same response as in Tūi.



**Figure 63 - Energy Consumption Per Household (non-transport)**



## Appendix 1: Useful Information

This appendix provides general information on units and conversion 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 <sub>2</sub>	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
IEA	International Energy Agency
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
MBIE	Ministry of Business, Innovation and Employment
MFE	Ministry for the Environment
NGOs	non-governmental organisations
NZD	New Zealand Dollar
OECD	Organisation for Economic Co-operation and Development
PHEVs	plug-in-hybrid electric vehicles

PV	photovoltaic
TPES	total primary energy supply
USD	United States Dollar
WTO	World Trade Organisation

## UNITS

<b>Coal</b>	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
<b>Emissions</b>	ppm	parts per million (by volume)
	CO <sub>2</sub> -e	carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
<b>Energy</b>	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	Gcal	gigacalorie (1 calorie x 10 <sup>9</sup> )
	TJ	terajoule (1 joule x 10 <sup>12</sup> )
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
<b>Gas</b>	bcm	billion cubic metres
<b>Mass</b>	kg	kilogramme (1 000 kg = 1 tonne)
	Kt	kilotonnes (1 tonne x 10 <sup>3</sup> )
	Mt	million tonnes (1 tonne x 10 <sup>6</sup> )
	Gt	gigatonnes (1 tonne x 10 <sup>9</sup> )
<b>Monetary</b>	\$ million	1 NZ dollar x 10 <sup>6</sup>
	\$ billion	1 NZ dollar x 10 <sup>9</sup>
<b>Oil</b>	b/d	barrel per day
	mb/d	million barrels per day
<b>Power</b>	kW	kilowatt (1 watt x 10 <sup>3</sup> )
	MW	megawatt (1 watt x 10 <sup>6</sup> )
	GW	gigawatt (1 watt x 10 <sup>9</sup> )
	TW	terawatt (1 watt x 10 <sup>12</sup> )

## General Conversion Factors for Energy

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
<i>From:</i>	multiply by:				
<b>TJ</b>	1	238.8	$2.388 \times 10^{-5}$	947.8	0.2778
<b>Gcal</b>	$4.1868 \times 10^{-3}$	1	$10^{-7}$	3.968	$1.163 \times 10^{-3}$
<b>Mtoe</b>	$4.1868 \times 10^4$	$10^7$	1	$3.968 \times 10^7$	11 630
<b>MBtu</b>	$1.0551 \times 10^{-3}$	0.252	$2.52 \times 10^{-8}$	1	$2.931 \times 10^{-4}$
<b>GWh</b>	3.6	860	$8.6 \times 10^{-8}$	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.

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