NEW ZEALAND INFRASTRUCTURE COMMISSION
Te Waihanga

Sector State of Play: Energy

Discussion Document

Foreword

Our wellbeing depends on our infrastructure

Our way of life depends on infrastructure. Whether it's moving freight to keep the supermarket shelves stocked, warming our homes, driving to work or calling our friends, there are few parts of our lives that don't rely on the services provided by infrastructure.

Infrastructure decisions have intergenerational impacts, so it is essential that we take a strategic view of the planning, development and operation of infrastructure in Aotearoa. New Zealand Infrastructure Commission was formed to give infrastructure this strategic voice, and the significance of this task is reflected in our Māori name, Te Waihanga, which means *cornerstone*.

Our first task is to develop a 30-year strategy for infrastructure - this paper is a part of this work. It takes a closer look at the current state of play in New Zealand's energy sector. By understanding where we are now we can set a course for where we want to go and the steps we'll need to take to get there over the next 30 years.

New Zealand faces a range of challenges and opportunities over the next 30 years which will have significant implications for infrastructure. Our changing climate, rapidly growing cities, aging population and evolving global technologies will change what we need from infrastructure in order to maximise the wellbeing of New Zealanders. Each of us has our own experiences of infrastructure, so we look forward to receiving your feedback to ensure this State of Play report accurately reflects the current state.

Ross Copland

Chief Executive

Kupu Takamua

E whakawhirinaki ana tō tātou oranga ki tā tātou hanganga

E whakawhirinaki ana tō tātou ao ki tā tātou hanganga. He ahakoa ko te neke utanga e kī tonu ai mgā paenga hokomaha, ko te whakamahana rānei i ō tātou kāinga, ko te taraiwa rānei ki te mahi, ko te waea atu rānei ki ō tātou hoa, he iti noa ngā wāhanga o tō tātou e kore rā e whakawhirinaki ki ngā ratonga e whakaratongia ana e te hanganga.

Ka pāngia ngā uri whakaheke e ngā whakatau hanganga, nō reira, he mea whaitake kia rautaki tā tātou aro atu ki ngā mahi whakamahere, mahi whakawhanake me ngā mahi whakahaere hanganga ki Aotearoa. I whakatūria te NZIC e whai reo rautaki ai te hanganga, ā, e pūkana mai ana te hiranga o tēnei i te ingoa Māori, Te Waihanga, arā te kāmaka mō te kokonga.

Ko te whakawhanake i tētahi rautaki 30-tau mō te hanganga te tūmahi tuatahi - he wāhanga nō tēnei mahi tēnei pepa. Ka anga tēnei ki te āta titiro ki te āhua ōnāianei o te rāngai pūngao o Aotearoa. Mā te mārama ki tō tātou tūranga ōnāianei e āhei ai i a tātou ki te aro atu ki whea tātou e pīrangi ana ki te tū, me ngā hatepe e tika ana kia whāia e tae ai tātou ki reira hei roto i te 30 tau e tū ake nei.

Inā te maha o ngā taero me ngā āheinga kei mua tonu i a Aotearoa i roto i te 30 tau e tū nei. Katoa katoa e whai hīraunga whakahirahira ana. Ka panonitia ngā mea e matea ana i te hanganga e tino kino te pai ai te kounga o te oranga o ngā kirirarau o Aotearoa e te hurihanga o te āhuarangi, me te tere whanake hoki o ngā tāone nunui, me te tētere haere o tō tātou taupori kaumātua me ngā hangarau ā-ao e whanake nei, e whanake nei. Kei tēnā kei tēnā o tātou ōna ake wheako ki te hanganga, nā konā anō mātou e hiamo nei ki te whiwhi i ā koutou whakahoki kōrero e whakaū ai e tautika ana tā tēnei pūrongo State of Play whakamāori i te tūāhua ōnāianei.

Ross Copland

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1. Executive Summary

Whakarāpopototanga

The New Zealand Infrastructure Commission, Te Waihanga has been charged with developing a 30-year strategy for infrastructure. With your input, we will build our understanding of future trends and likely challenges and make recommendations on how infrastructure can support New Zealand's future wellbeing.

This chapter provides a summary of New Zealand's current energy infrastructure and collates views from numerous reports about how well the sector is placed for meeting New Zealand's longer-term opportunities and challenges.

1.1. Current energy infrastructure

Energy infrastructure refers to the assets used to extract, produce and transport gas, electricity and petroleum products to New Zealanders. It also includes the fuel stocks used to produce energy; oil, gas and coal, as well as water, steam, wind, sun and biomass for producing electricity and biomass and hydrogen for producing transport fuels and providing process heat to industry.

New Zealand has plentiful coal reserves[1] but the transition to a decarbonised economy shifts the emphasis to renewable fuel stocks that New Zealand is reasonably well-endowed with, such as wind, solar, biomass, and geothermal resources.

The current energy infrastructure largely reflects substantial cost-efficiencies arising from extracting large fuel stocks, large scale production, and then bulk transportation across the country to major load centres. Electricity transmission stretches the whole country, configured with multiple lines and as an interconnecting network of circuits to provide resilience. Similarly, gas pipelines connect load centres to supply in the Taranaki region.

However, not everything is at large scale and remotely located. In electricity, for example, there are many modest-scale generation plants located close to major load centres, and for many decades there have been smaller scale plants located around the country, connected to local distribution networks (called distributed generation). Technological advances in wind and solar generation, battery technology and electric vehicles, are shifting the sector increasingly towards distributed generation and energy storage.

The sector is predominantly characterised by large firms and mixed public-private ownership, although this is changing due to technological advances. The sector is extensively regulated due to its use of New Zealand's natural resources as well as safety impacts.

Investments are predominantly privately financed and funded by energy consumers through their purchases of delivered electricity, gas, and petroleum products. The combination of user-pays funding mechanisms and marginal cost pricing encourages infrastructure providers to invest efficiently, taking into account regulatory requirements regarding desired levels of quality and reliability of services. In addition, wholesale spot markets for both gas and electricity encourage efficient short-term utilisation

[1] "Statistics of Coal." Accessed December 2020. Ministry of Business, Innovation and Employment. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/coal-statistics/.

of infrastructure capacity and it encourages suppliers to invest in reserve generation and energy storage. For example, when a part of the transmission grid becomes ‘congested’ the spot price of electricity is generally higher in the downstream area, in contrast to transport where there is no change in price when the roads are congested (excluding the time value experienced by road users).

1.2. How is the sector performing?

It is useful to consider sector performance on three dimensions, called the energy trilemma: energy equity (prices and affordability), energy security, and environmental sustainability (see Figure 1 below).

Figure 1: New Zealand's energy trilemma

Source: World Energy Council

In 2019, the World Energy Council ranked New Zealand 10th out of 128 countries in the index. New Zealand is the only Asian-Pacific country in the top 10, with Australia placing 28th. New Zealand has been in the top 10 on the energy trilemma since 2000. Whilst there is room for improvement, New Zealand’s energy sector is globally seen to be performing well. The International Energy Agency, for example, has spoken highly of New Zealand’s electricity market and the market-driven (non-subsidised) rise in renewable generation.[2]

The World Bank notes the average retail price of electricity in New Zealand is roughly ~US$0.12 per kWh placing us 11th cheapest in the 37 members of the OECD. This compares favourably with Australia where the retail price of electricity is more volatile year-to-year and the price averages around ~US$0.20 per kWh.[3] Similarly, a recent International Energy Agency report showed New Zealand compared fairly well to other OECD countries in terms of the retail price of petroleum.[4]

Notwithstanding, there have been several Government policy initiatives in mid to late 2020 to strengthen the consumer voice in electricity regulation and reduce energy hardship, as well as initiatives to further enhance competition in the electricity and petroleum markets (following reports from the Electricity Price Review Panel on electricity and the Commerce Commission on the petroleum market).

A high degree of resilience is built into the energy sector by drawing on multiple types and locations of fuels, building multiple production units, and installing multiple transport modes and routes. There are also many regulatory systems and frameworks in place to ensure the quality of energy sector infrastructure assets, and to achieve desired levels of reliability and resilience.

The electricity sector, in particular, procures standby generation to cover the risks of the largest system asset failing (either generation or transmission), and transmission and distribution assets are

[2] “World Energy Trilemma Index.” World Energy Council, 2020. https://www.worldenergy.org/assets/downloads/World_Energy_Trilemma_Index_2020_-_REPORT.pdf
[3] “Doing Business.” The World Bank. Accessed August 2020. https://databank.worldbank.org/reports.aspx?source=3001&series=IC.ELC.PRI.KH.DB1619.
[4] “Weekly Fuel Price Monitoring.” Accessed August 2020. Ministry of Business, Innovation and Employment. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/weekly-fuel-price-monitoring/.

configured and operated to provide greater redundancy for larger demand centres. In part, this reflects the dependency of other lifeline utilities on electricity.[5]

Key areas of focus are the condition of New Zealand's gas and oil pipelines and the security of electricity supply during prolonged dry winter episodes. Pipeline problems have occurred several times over the last 10 years, driving significant regulatory effort to improve resilience. In contrast, electricity security of supply has been robust over the last decade, with concerns centred on how the sector will adjust if/when the coal-fired Huntly generation units are retired.

Overall, the energy sector is positioned well, with the main issues being equity (prices and affordability) and security, particularly in the petroleum part of the sector. The single most pressing issue is the critical reliance on Marsden Point's fuel distribution system into Auckland, as highlighted by recent failures of the Refinery to Auckland Pipeline (RAP).

1.3. Looking to the future

Looking longer term, the most significant force shaping the energy sector is climate change and New Zealand's commitment under the Paris Agreement to reduce greenhouse gas emissions by 30 percent below 2005 levels by 2030 and the Change Response (Zero Carbon) Amendment Act 2019, to be net carbon neutral by 2050.

To meet those commitments New Zealand's energy consumption is expected to place far greater reliance on electricity, which currently provides about 25% of the country's energy needs. This is expected to rise to 60% by 2050, due to mass electrification of transport and process heat for industry. This amounts to growth in electricity demand of 1.7% per year for the next 30 years, compared to 0.2% per year over the last 10 years and 1.3% per year over the last 30 years.[6,7]

Meeting this increase requires more than doubling current generation capacity by 2050, primarily from wind, solar, and geothermal, and phasing out thermal generation. Energy storage capacity is expected to increase greatly to cope with the variability of wind and solar generation.

In general, under current policy settings, regulatory and market incentives will broadly define what energy infrastructure is built, when, and where it is installed, taking into account the speed and location of population growth and industry changes. Provided appropriate carbon budgets and effective emission pricing occurs, the electricity sector is expected to increase the share of generation from renewable sources to 93-97% from current levels of 82-84% (in a normal hydrological year).[8] It is also expected to incentivise new gas-fired generation to cover capacity and dry year risks and replace old thermal generation units at Taranaki and Huntly.[9]

Longer term policy and regulatory settings will need to be congruent with the Government's climate objectives and the pace of technological change. Along those lines, the Government's goal of achieving 100% renewable electricity by 2030 needs to be considered in the context of dry year risk and pursued in a way that preserves private sector incentives to build additional hydro-firming sources of energy.

[5] Including wastewater, gas, fuel supply, and traffic management
[6] "Data tables for electricity." Ministry of Business, Innovation and Employment, table 2, row 42. Accessed December 2020, https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/.
[7] "Data tables for electricity." Ministry of Business, Innovation and Employment.
[8] "Accelerated electrification." Interim Climate Change Committee, 30 April 2019, 97. https://www.iccc.mfe.govt.nz/assets/PDF_Library/daed426432/FINAL-ICCC-Electricity-report.pdf
[9] Ibid, 38.

Decarbonisation and the impending transition are resulting in a number of macro trends. Technology and pricing improvements are expected in the next three to five years to make electrification of light and medium road vehicles cost effective.[10,11] Rapid advances in technology are improving the prospects for cost-effectively decarbonising heavy transport and process heat by 2030. Although green hydrogen has been gaining momentum in recent years, questions remain about its role in New Zealand's energy market; specifically around economic production, transport, and storage. These trends highlight the importance of timing and ensuring the transition to a lower carbon economy is balanced in regard to the energy trilemma.

Technology will also fundamentally alter what is needed from transmission and distribution infrastructure. Distributed generation (such as rooftop solar generation), combined with battery storage and effective demand-side management like smart-chargers for EVs, has the potential to reduce the need to build additional infrastructure capacity to cope with peak demand. This is a strength in relation to other infrastructure sectors where forms of congestion pricing are less or not prevalent. Adopting transmission and distribution pricing that more closely reflects marginal costs will be important for funding and incentivising efficient investment in these sources of energy and peak demand management.

Ultimately, the sector is at the precipice of a major transition. It is critically important that the settings are correct for the sector to transition in a desirable way and that the sector we are left with is well positioned to deliver future needs – an optimal balance of the trilemma.

[10] Dan Gearino. "Inside Clean Energy: How Soon Will An EV Cost the Same as a Gasoline Vehicle? Sooner Than You Think," July 30, 2020. https://insideclimatenews.org/news/30072020/inside-clean-energy-electric-vehicle-agriculture-truck-costs/.
[11] Steve Hanley. "UBS Predicts EV Price Parity In 2024," October 22, 2020. https://cleantechnica.com/2020/10/22/ubs-predicts-ev-price-parity-in-2024/.

2. Context

Horopaki

2.1. Who we are and what we do

The New Zealand Infrastructure Commission, Te Waihanga is working to improve New Zealanders' lives through better infrastructure. It aims to lift the level at which infrastructure is planned and delivered, taking a strategic approach so that we maximise the social return on our collective dollar and stand well prepared in the face of an uncertain future.

Our Māori name, Te Waihanga, means a cornerstone, or to make, create, develop, build, construct, generate. Te Waihanga therefore reflects the significance of long-term planning in shaping New Zealand's future.

A major part of this work is the development of a 30-year strategy for infrastructure. The strategy will look ahead to 2050, and consider how infrastructure might support environmental, social, cultural and economic wellbeing for all New Zealanders. This will be delivered to the government in September 2021 and will set out how we can make sure our investment in infrastructure delivers what we need, where we need it and at the right time.

2.2. About our sector State of Plays

We understand that our infrastructure works together - it is a system of systems. Our roads carry pipes and powerlines, and they connect to homes, workplaces and schools. For this reason, our strategy will focus on cross-cutting themes rather than infrastructure sectors in isolation. However, we believe that it's important we understand the infrastructure we have today, why we have what we have, and how it's already contributing to New Zealanders' wellbeing.

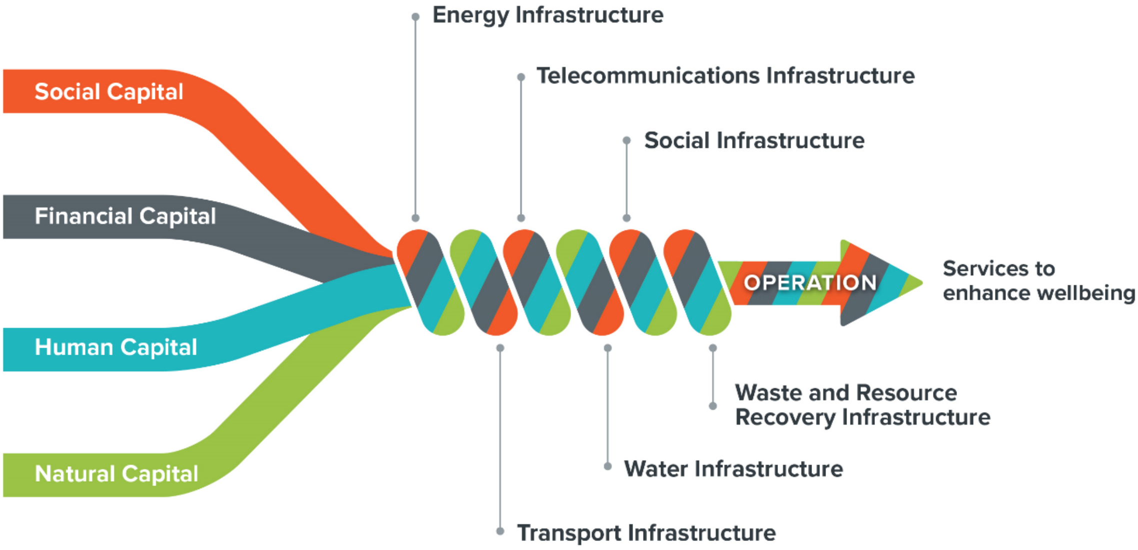
The sector State of Plays are structured around the components of Te Waihanga's working definition of infrastructure, set out in our discussion document, "Infrastructure Under One Roof".[12] Our definition places wellbeing outcomes at the core, while recognising commonalities, including the use of capital such as financial and environmental resources; the interconnectedness of physical structures; and the delivery of shared services, as well as the wellbeing benefits we get from those shared services. In short, Te Waihanga defines infrastructure as follows:

"A system of inter-connected physical structures that employ capital to provide shared services to enhance wellbeing."

Figure 2 illustrates the components of our working definition, showing how they are related to one another in delivering wellbeing services.

[12] Te Waihanga. "Infrastructure under one roof", December 2020 https://infracom.govt.nz/assets/Uploads/Te-Waihanga-Infrastructure-Under-One-Roof-2020.pdf

Figure 2: Te Waihanga's definition of infrastructure



Source: New Zealand Infrastructure Commission, Te Waihanga

By defining infrastructure in this way, we have then been able to develop a common framework to think about the integrated management of infrastructure. This considers the relationship between the enabling environment for our infrastructure, the sustainable use of the capitals employed in its development, the investment management process and the wellbeing benefits created by infrastructure services.

Our sector State of Plays are the result of desktop research, augmented by insights from our survey of infrastructure asset owners, and engagement with sector experts. These reports will be updated over time. We want to improve the picture as our understanding grows and different elements come in to focus.

2.3. Our next steps

As well as continuing to build on our picture of the State of Play, next steps include building our understanding of future trends and likely challenges, including climate change, incorporation of Mātauranga Māori, demographic change, and the role of technology. We will look at what our way of life might be 30 years from now. Based on all of this, we will begin to make recommendations as to how infrastructure might support New Zealand’s future wellbeing.

We’ll share our thinking on what will be included in the strategy, focusing on the cross-cutting themes that affect all sectors, the opportunities and challenges we can expect in the future, as well as our initial recommendations and options for consideration.

This will then be followed by a draft strategy that firms up our thinking on recommendations and provides greater detail as well as the evidence base behind them. From there, we’ll develop the document that goes to Ministers.

2.4. Have your say

We'll share our work as we go and are keen to hear what you think, starting now. Tell us what you think about our State of Play reports – have we got it right or are there issues, information or problems that we've missed?

You'll also have the opportunity to comment on the draft strategy. We'll be continually refining and assessing our work based on the feedback we get from you and others.

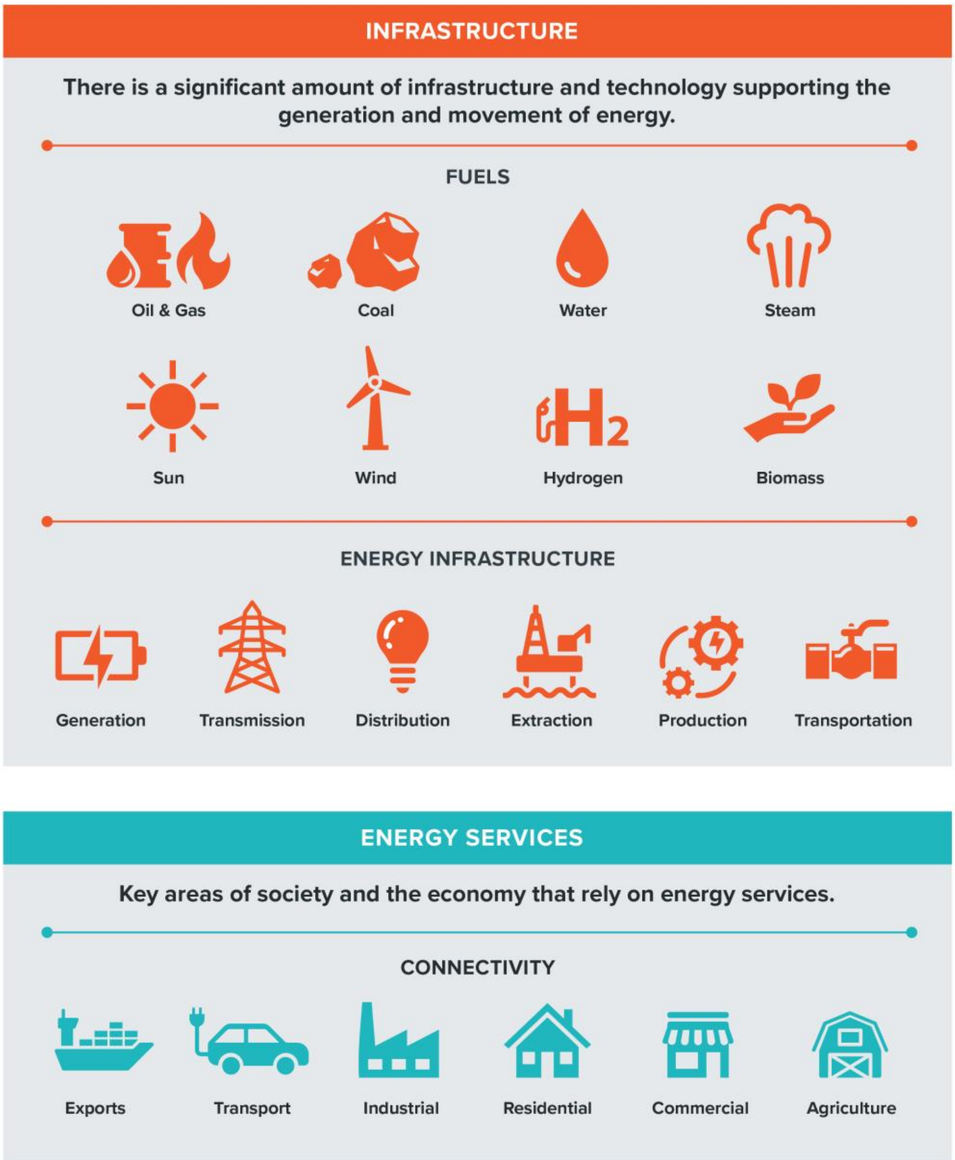
3. About the system

E pā ana ki te punaha

3.1. The services enabled by energy infrastructure

Energy infrastructure is the generation, extraction, transmission, and distribution assets for electricity as well as assets that provide or support energy flows from fuels that consume capital and through a market, provide energy to New Zealanders. The infrastructure, fuels, and corresponding services are shown in Figure 3 below.

Figure 3: Energy infrastructure and corresponding services



Source: New Zealand Infrastructure Commission, Te Waihanga

The energy that powers New Zealand is broad and multifaceted, ranging from the movement of electrons through conductive material to the combustion of hydrocarbons. Energy is not an end in itself, but rather the means for providing services and catalysing activity.[13] It is the oxygen of the economy.[14] It is essential in supporting New Zealand's export, industrial, and transport sectors.

The value of energy to society extends further than economic spheres; it is an essential enabler across almost every aspect of modern life and subsequently foundational to the wellbeing of New Zealanders. Energy consumption is a key dimension of this; whether it's keeping the lights on, powering other essential infrastructure like hospitals and schools, or keeping our homes warm through winter, energy is the foundation of a modern economy and society.

3.2. Māori and energy

Māori have fundamental interests in the energy sector due to the role of natural resources in their culture, values, and worldview (Te Ao Māori). In particular, Māori knowledge (Mātauranga Māori) is embedded in the relationship between people and natural resources, often connected with their kinship (whanaungatanga). Their intergenerational view leads naturally to a strong focus on sustainable business practices to ensure future generations enjoy the benefits of the natural resources they are using today. This is often expressed as being guardians (kaitiaki) of the land and the resources under and on it.

Māori are involved in energy production at both the resource and generation levels. They have extensive interests in land, forestry, geothermal and hydro resources. For example, in the central North Island the Tauhara North #2 Māori Trust is a joint venture partner with Mercury Energy in the Ngatamariki geothermal field; Tuaropaki Power Company owns and operates the Mokai geothermal generation plant; and Miraka Milk draws energy from the Mokai field for its dairy processing activity.

3.3. The importance of energy resilience

New Zealand's infrastructure system is largely dependent on energy infrastructure.[15] The National Lifelines Council refers to the national grid (transmission assets), distribution assets, electricity generation assets, and various elements of New Zealand's oil and gas supply chain, as 'critical infrastructure'. The Council notes that most lifeline utilities to some degree depend on electricity and although utilities typically have backup generation, a widespread outage would have broad impacts across multiple infrastructure sectors. Combined with a national dependence on fuel for backup electricity generation, and fuel for running plants and vehicles for service personnel, a major energy interruption would have widespread impacts on the economic and social fabric of New Zealand.

3.4. The physical assets

The current physical infrastructure for energy largely reflects the location of New Zealand's energy resources relative to demand centres and the economic trade-offs facing investors at the time the assets were designed and installed. Historically, substantial economies of scale (cost-efficiencies) arose

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[13] Kurt Yeager. "Energy and Economy." In *Global Energy Assessment - Toward a Sustainable Future*, edited by Nora Lustig, 416. Cambridge University Press, 2012.
[14] "Energy for Economic Growth." Geneva, Switzerland: World Economic Forum, 2. 2012. http://www3.weforum.org/docs/WEF_EN_EnergyEconomicGrowth_IndustryAgenda_2012.pdf.
[15] "New Zealand Critical Lifelines Infrastructure - National Vulnerability Assessment." New Zealand Critical Lifelines, Civil Defence 17-64, 2020. https://www.civildefence.govt.nz/assets/Uploads/lifelines/nzlc-nva-2020-full-report.pdf.

extracting from large resource fields, producing/generating at large scale, and bulk transportation/transmission of energy across the country to large load centres.[16]

However, cost efficiency is not the only factor. A high degree of resilience is built into by drawing on multiple fields, building multiple production/generation units and installing multiple transport modes and routes. In electricity, for example, large generating stations contain multiple turbines and transmission towers carry multiple cables, and notably the HVDC undersea cable across the Cook Strait is actually three separate cables.

Where it has been cost-effective, the transmission system is an interconnected network of high voltage power lines to provide different routes for power flows should one route fail. The level of redundancy built into the system is greater for larger load centres. For example, power supplies to the Auckland region are built and operated to withstand the two largest transmission assets and the largest generation unit all failing at the same time. In contrast, power supplies to medium-sized cities are built and operated to withstand only the failure of the largest transmission asset.[17]

There were severe electricity shortages in the winter of 1992, following which a Government inquiry found the underlying problem was that all major generation decisions were made by a single supplier, the Electricity Corporation of New Zealand (ECNZ). Although a fully coordinated electricity system might deliver the best cost-efficiencies, this could lead to groupthink and poor resilience.

In addition, the resilience benefits of having multiple decision-makers of key resources, such as hydro reservoirs, led to the devolution of New Zealand's electricity generation fleet in the 1990s and the formation of a wholesale electricity market in 1996.

The cost/resilience trade-off is also evident in the oil and gas sectors. New Zealand imports refined oil, which is delivered to key ports around the country, and it also imports crude oil which it refines at Marsden Point and distributes the output through three transport modes (by road tankers, coastal shipping, and by pipeline to Auckland). Resilience is arguably improved with government held (or contracted) oil reserves. However, this is not a perfect solution, as demonstrated by the recent failures in the pipeline to Auckland, where in 2017 the pipeline that brings diesel, petrol, and jet fuel from Marsden Point Oil Refinery into Auckland was ruptured, stopping transmission for 10-days.[18]

In regard to gas, commercial incentives for exploration have resulted in multiple onshore and offshore fields however gas transmission is not diversified due to all operational gas being in the Taranaki area.

Moreover, technological advances are driving disaggregation. Examples include small scale electricity generation, particularly in the form of solar rooftop units, energy storage and improved battery technology, metering and micro sensors, all combined with advances in big data and artificial intelligence to deliver individualised customer services. Although distributed generation (i.e., generation located within distribution networks) has been a significant feature in New Zealand for several decades, these technological advances are likely to continue shifting the balance towards disaggregation.

[16] Personal correspondence, Carl Hansen, Capital Strategic Advisors Limited.
[17] "New Zealand Critical Lifelines Infrastructure". New Zealand Critical Lifelines, 18.
[18] "Establishment of the Government Inquiry into the Auckland Fuel Supply Disruption." Department of Internal Affairs. Accessed December 16, 2020. https://www.dia.govt.nz/Auckland-Fuel-Line---Terms-of-Reference.

3.5. Wellbeing and capital flows

Infrastructure services are an important contributor to wellbeing. New Zealanders make heavy use of energy infrastructure every day, to participate in society and contribute to the economy. Energy infrastructure provides the fuel and electricity New Zealanders use to live their lives; enjoying the natural environment and sheltering from it, raising and educating their families, connecting with their wider family/whanau and with others socially and culturally, undertaking their jobs and communicating with their colleagues and customers.

As assessed by Te Waihanga, energy has a broadly positive impact across the 12-wellbeing domains defined in the Living Standards Framework – shown in Figure 4 below. However, inherent in the production of energy, it has the propensity to consume more natural capital than it produces. It is also important to note that these benefits are not always felt equally across New Zealand.

Figure 4: Impact of energy services on the 12-wellbeing domains

Source: New Zealand Infrastructure Commission, Te Waihanga

Fundamentally, energy infrastructure lifts the productivity with which New Zealanders undertake all of these activities, making it easier for them to improve their immediate wellbeing and provide for their future wellbeing by building their stocks of social, human, and financial/physical capital. Indeed, there is empirical research covering the United States and Europe, and more recently regarding some developing countries, that suggests the supply of energy increases productivity growth rates, not just productivity levels.[19,20,21]

Energy infrastructure also makes it easier and lower cost for New Zealanders to experience a wide range of natural environments, both here and abroad. However, far more than other forms of infrastructure, current energy production consumes a significant quantum of natural capital, particularly oil, gas, and other minerals. Longer-term, unless technological change renders the natural capital redundant, the scarcity value of the remaining natural capital increases as it is depleted. In many (but not all) cases, the growing scarcity value encourages conservation for the enjoyment of future generations.

For more information see:

[19] Dale Jorgenson. "Productivity and US Economic Growth," 1987. https://scholar.harvard.edu/jorgenson/publications/productivity-and-us-economic-growth.

[20] Luis R. Murillo-Zamorano, "The Role of Energy in Productivity Growth: A Controversial Issue?" *Energy Journal* 26, no. 2 (2005): 69–88.

[21] Barnabé Walheer. "Labour Productivity Growth and Energy in Europe: A Production-Frontier Approach." *Energy* 152 (June 2018): 129–43.

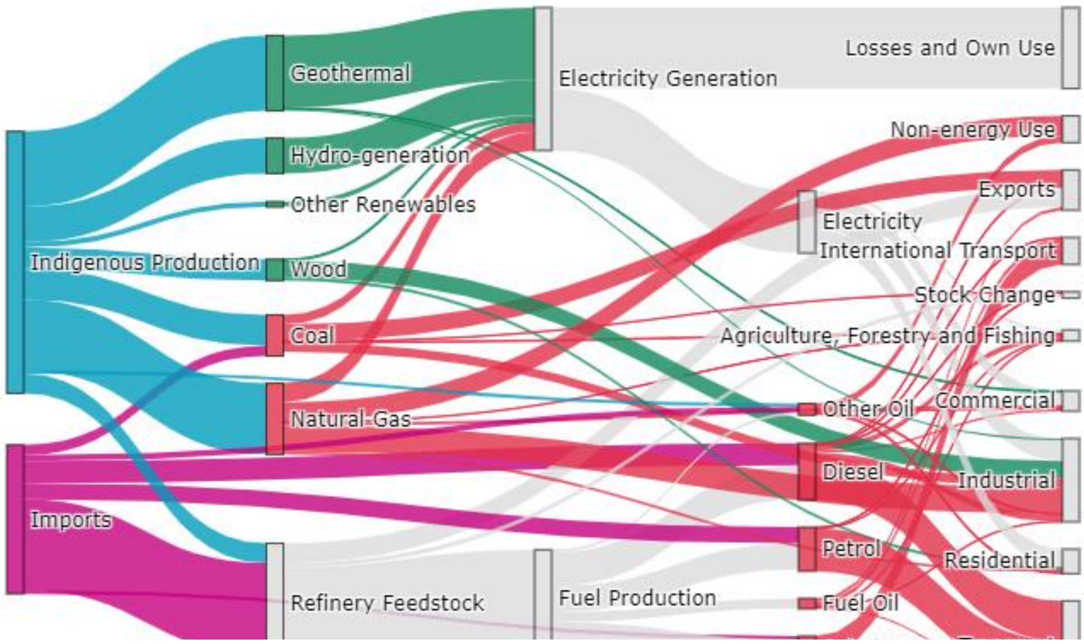
4. What shapes the sector today?

E whakaahuatia ana te rāngai e te aha?

4.1. Energy is a fundamental building block for New Zealand's economy and households

Energy is an essential ingredient for modern societies and households. Its prominence permeates almost every facet of the economy and household wellbeing.

Figure 5: Sankey diagram of New Zealand's energy flows



Source: MBIE

Figure 5 above is a Sankey diagram depicting the flow of energy in New Zealand starting from imported or domestically produced energy to end consumption. The width of the arrows is proportional to the energy flows i.e., the thicker the arrow, the greater the energy flow.

As shown, the majority of New Zealand's energy is domestically produced. Primary sources are natural gas, wood, coal, geothermal, and the gravitational potential energy of water. Minor but growing sources of electrical energy include solar, wind, and co-generation from industrial processes.

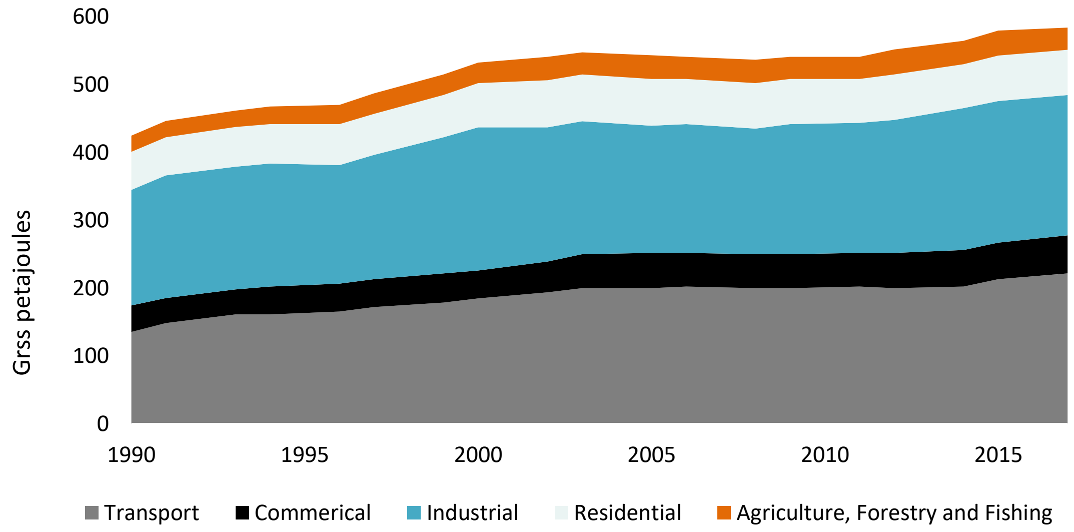
On the demand side, each year New Zealander consumes roughly 600,000 petajoules of energy.[22] This domestic production powers most industrial, commercial, residential consumption of electricity.

[22] "Energy in New Zealand 2019." Ministry of Business, Innovation and Employment, October 2019, 4. https://www.mbie.govt.nz/dmsdocument/7040-energy-in-new-zealand-2019.

Fuelling this demand, a significant amount of energy is imported predominantly in the form of oil. The majority of this is then cracked into lighter fuels at Marsden Point and used to power transport; the cars, trucks, and tractors we drive, as well as the planes that physically connect us to the world. Depending on the year coal may also be imported to supply generation units at Huntly (Huntly has three gas/coal Rankine units 250MW each, one combined-cycle 403MW unit, and one 50.8 MW open-cycle gas/diesel unit).[23,24,25,26]

The demand for energy has grown over the last several decades – shown in Figure 6 below. The main consumers of energy and significant drivers of expansion in energy demand have come from transport and industrial uses. This highlights energy's contribution in supporting New Zealand through relatively stable economic and population growth in the decade following 2010.

Figure 6: New Zealand's gross energy demand

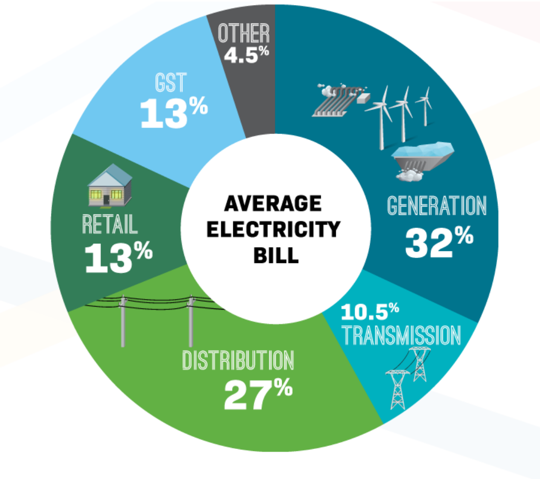


Source: MBIE

Broadly speaking, the infrastructure components combined with various taxes combine to form the cost that New Zealanders pay for energy. For electricity, this is made up of generation, transmission, and distribution, as well as retail and tax. This breakdown can be seen in Figure 7 below. For fuels, this is made up of taxes, levies, and emissions trading scheme, as well as importer margin and costs. Figure 8 shows this breakdown of price components.

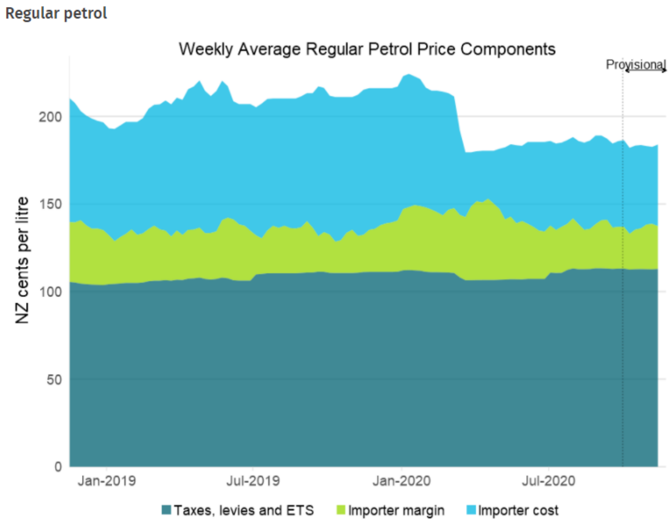
[23] "Our Generation Assets." Genesis Energy. Accessed December 17, 2020. https://www.genesisenergy.co.nz/assets.
[24] Tracey Hickman. "Managing Huntly's Coal Stockpile." Genesis Energy, November 6, 2018. https://www.genesisenergy.co.nz/about/media/news/managing-huntly%E2%80%99s-coal-stockpile.
[25] "Genesis to Recertify Huntly Unit 2 for Backup Cover." Genesis Energy. Accessed December 14, 2020. https://www.genesisenergy.co.nz/about/media/news/genesis-to-recertify-huntly-unit-2.
[26] Tracey Hickman. "Managing Huntly's Coal Stockpile."

Figure 7: Breakdown of average electricity bill



Source: MBIE

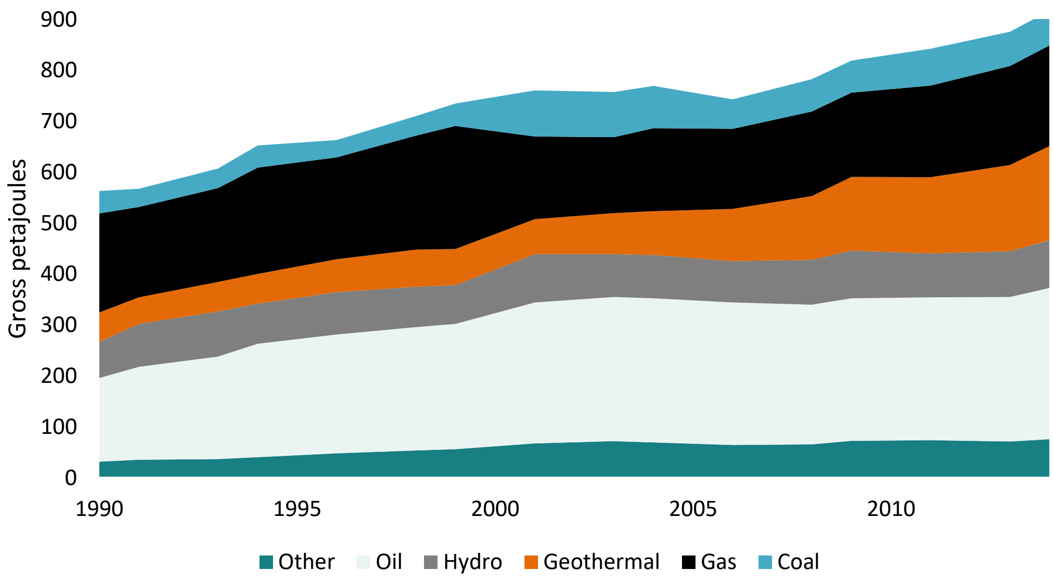
Figure 8: Breakdown of regular petrol price components



Source: Electricity Authority

There has been more volatility on the supply side, with geothermal growing significantly as a source of energy in the last two-decades. This growth is shown in Figure 9 below. Overall, about 40% of New Zealand's primary energy was supplied by renewable resources in 2019,[27] placing third highest in the OECD. Within electricity, 82% was generated from renewable sources in 2019. This trend will likely continue with initial signs pointing to a diminishing contribution of coal and oil, and a growing contribution of geothermal and other renewable generation like wind and solar.

Figure 9: New Zealand's gross energy supply



Source: MBIE

[27] "Energy in New Zealand 2020." Ministry of Business, Innovation and Employment, 2.

The demand-supply trajectories highlight the key issue the sector is facing: the transition from carbon-based fuels to non-carbon resources for energy. How each side responds to this challenge and the confluence of forces and market dynamics will be fundamental if New Zealand is to meet its carbon neutral target by 2050.

4.2. Mixed public-private ownership and regulation are important characteristics of the sector

The energy sector boasts a large number of agents with varying levels of influence and integration across the value chain.

Dating back to the 1980s, electricity generation and transmission assets were the responsibility of the Ministry of Energy.[28] As a consequence, there was significant political influence in decision making around long-term investment and energy prices, causing various issues across the sector. For example, prior to the 1980s rolling blackouts occurred from time-to-time even though generation capacity often greatly exceeded winter demand.

Similarly, in 1985 there were 61 electricity supply authorities providing distribution and retail services, a consolidation from 93 in 1945.[29] Most of the electricity supply authorities were governed directly by elected boards or local authorities and again heavily influenced by politics leading to inefficiencies. Government concerns about New Zealand's overall economic performance led to various reforms of many sectors of the economy from the mid-1980s, including the electricity sector.

The Electricity Corporation of New Zealand (**ECNZ**) was set up as a State-Owned Enterprise (**SOE**) in 1987 and operated the generation and transmission assets of the Ministry of Energy. In 1988, the transmission assets were vested to a subsidiary, Transpower, leaving ECNZ as solely a generator. In the early 1990s, many of the electricity supply authorities transitioned to ownership by local trusts or companies.[30]

ECNZ provided around 97% of New Zealand's electricity supply in 1990.[31] Despite controlling almost all generation, rolling blackouts occurred in winter 1992 due in part to poor decision-making by the single supplier ECNZ. To remove reliance on a single decision-maker for hydro generation and to introduce some competition as a means to put downward pressure on costs and prices, a wholesale electricity market (with open entry to all sources of generation connected to the national network) was established by October 1996 and some of ECNZ's South Island hydro generation plants were placed in an ECNZ subsidiary called Contact Energy. To further boost independent decision-making and competitive generation, Contact Energy was sold in 1998 and ECNZ was split into three ECNZ generation subsidiaries: Genesis, Meridian, and Mighty River Power (which changed its name to Mercury in 2016). The other three major generators were partially privatised between 2013-2014, with 51% ownership retained by the Government.[32]

Although several generators competed to supply the wholesale electricity market, the demand side remained dominated by the retail arms of the electricity supply authorities (some were trusts and companies) and a few large industrial users. To facilitate fairer access for independent retailers and to

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[28] "Chronology of New Zealand Electricity Reform." Ministry of Business, Innovation and Employment, August 2015, 1. https://www.mbie.govt.nz/assets/2ba6419674/chronology-of-nz-electricity-reform.pdf.
[29] "Chronology of New Zealand Electricity Reform." Ministry of Business, Innovation and Employment, 4.
[30] Ibid, 2.
[31] "Competition, the Internet and the Customer", Greg Sise, 28 May 2017 https://www.energylink.co.nz/news/blog/competition-internet-and-customer.
[32] Ibid, 11.

remove the ability of line businesses to use their natural monopolies, the electricity supply authorities were required in 1999 to divest either their monopoly distribution businesses or their competitive retail and generation businesses. TrustPower (which had evolved from the Tauranga Electric Power Board) decided to sell its distribution assets and retain its retail and small hydro generation assets.[33] However, virtually all others chose to sell their retail businesses to various parties, including Contact Energy and the three subsidiaries of ECNZ, leading to the formation of both the large generator-retailers (often called **gentailers**) that persist in the market today and the suppliers of electricity distribution services today (electricity distribution businesses or EDBs).

Of the major gentailers, Meridian Energy operates the two largest hydro generation stations Manapouri and Benmore, Contact owns the Clutha hydro scheme, and Genesis owns the Tongariro hydro scheme. As a result of the 2009 ministerial inquiry, Genesis acquired the Tekapo stations on the Waitaki hydro scheme from Meridian Energy.

Contact and Genesis own the major thermal generation assets, Stratford and Huntly. Genesis has announced its intention to replace baseload thermal generation with renewables and to remove the remaining coal from its back-up thermal generation under normal hydrological conditions by 2025, with an intent to remove it altogether by 2030.[34] First Gas owns a large gas storage facility in Ahuroa[35] and Genesis has a 46% ownership stake in the Kupe Gas joint venture, making it a major wholesaler of gas. Genesis and Contact are both major retailers of gas, competing with eight other gas retailers.

Currently the sector is comprised of:

- Five major vertically integrated owners of generation and retailing assets,[36] although noting that there are numerous generation businesses operating in New Zealand and more than 40 different retail electricity businesses. More information is shown in Table 1 below.

[33] "Company History - Company Development - Power Stations" Trust Power. Accessed December 18, 2020. https://www.trustpower.co.nz/getting-to-know-us/our-history.
[34] "Genesis Welcomes Government's Dry Year Risk Review, but Urges Caution on What the Best Outcome Could," Genesis Energy. July 27, 2020. https://www.genesisenergy.co.nz/about/media/news/genesis-welcomes-governments-dry-year-risk-review.
[35] Mike Watson "Gas Company Squirrels down to Expand Storage Capacity for Peak Periods." *Stuff*, October 7, 2020. https://www.stuff.co.nz/taranaki-daily-news/news/300125261/gas-company-squirrels-down-to-expand-storage-capacity-for-peak-periods.
[36] Electricity Authority - EMI. "Market Share Snapshot." Accessed August 2020. https://www.emi.ea.govt.nz/Retail/Reports/R_MSS_C

Table 1: Market share and ownership of five main gentailers

Gentailer	Percentage of total ICPs[37] (%)	Average % share of generation (2015-2020)[38,39]	Ownership
Contact Energy	19	21	Contact's ordinary shares are listed and quoted on the NZX Main Board as well as a foreign exempt listing on the ASX. Contact also has three issues of retail bonds listed and quoted on the NZX Debt Market.[40]
Genesis Energy	23	16	Mixed ownership model. The majority of the company is owned by the Government. Genesis Energy Limited is also listed on the NZX Main Board, has a foreign exempt listing on the ASX, and has bonds listed on the NZX Debt Market.[41]
Mercury NZ	16	13	Mixed ownership model. The majority of the company is owned by the Government. Mercury NZ Limited is listed on the NZX Main Board, has a foreign exempt listed status on the ASX, and has bonds listed on the NZX Debt Market.[42]
Meridian Energy	15	31	Mixed ownership model. The majority of the company is owned by the Government. Meridian Energy Limited is listed on the NZX Main Board has a foreign exempt listing on the ASX, and has bonds listed on the NZX Debt Market.[43]
TrustPower	12	8	Trustpower has just under 313 million shares on issue on the NZX. Infratil Limited holds 51% of voting shares and Tauranga Energy Consumer Trust holds 26.8% of voting shares. There are also 12,000 small parcel shareholders and 12,000 bond holders.[44]

[37] Installation Control Points.
[38] "Electricity in New Zealand." Electricity Authority, June 2018, 29. https://www.ea.govt.nz/assets/dms-assets/20/20410Electricity-in-NZ-2018.pdf.
[39] Five-year averages are reported for generation as company generation volumes move substantially due in part to weather events.
[40] "Contact Energy - Investor Reports and Presentations." Contact. Accessed December 18, 2020. https://contact.co.nz/aboutus/investor-centre/reports-and-presentations.
[41] "Genesis Energy Annual Report 2020." Genesis Energy, 2020, 44. https://gesakentico.blob.core.windows.net/sitecontent/genesis/media/new-library-(dec-2017)/about_us/investor/pdfs/fy21/genesis-energy-annual-report-2020.pdf.
[42] "Energy Freedom for a Changing World." Mercury NZ Limited, 2020, 52.
[43] "Renewing Our Future." Meridan Energy Limited, 2020, 131. https://www.meridianenergy.co.nz/assets/Investors/Reports-and-presentations/Shareholder-meetings/2020/Meridian-Energy-Integrated-Report-for-year-ended-30-June-2020-v2.pdf.
[44] "Trust Power Annual Report 2020." Trust Power, 2020, 44. https://www.annualreport.trustpower.co.nz/media/1583/trustpower-annual-report-2020_2.pdf.

- One owner of transmission assets (the national grid).
    - Transpower is a State-owned Enterprise and natural monopoly that is subject to economic regulation by the Commerce Commission and market regulation by the Electricity Authority. Transpower is also the system operator for the electricity market, which involves scheduling and dispatching electricity across the national grid in real time.

- 29 electricity distribution businesses, or EDBs.
    - The majority are publicly owned, often in the form of consumer or community trusts or local bodies. PowerCo and Wellington Electricity are owned by private infrastructure investors, and Vector has a partial NZX listing. All are subject to economic regulation by the Commerce Commission and market regulation by the Electricity Authority. Of the 29, 12 are deemed to be consumer-owned entities and are exempt from the Commerce Commission's price-quality regulation but are subject to information disclosure regulation, Figure 10 below shows these EDBs by region and type of regulation.

Figure 10: EDBs by region and type of regulation

Source: Commerce Commission

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4.3. Electricity regulation

There are two main electricity markets regulated under the Electricity Industry Participation Code 2010, administered by the Electricity Authority: a wholesale and a retail market, where generators and retailers (often the same entity) interact in providing electricity to households. The wholesale electricity market comprises the spot electricity market where electricity is bought and sold every half-hour at over 250 locations on the national grid and hedge markets where parties can buy and sell forward contracts of various types. For example, contracts can be purchased that lock-in the price a consumer pays for a specified volume of electricity. The wholesale market also includes several ancillary service markets necessary for dealing with sudden failure in large generation or transmission units.

The physical aspects of the spot electricity market are managed by Transpower in its role as system operator and the financial and pricing aspects are mostly managed by the New Zealand Exchange (NZX). The guiding principle by which the market clears is bid-based security-constrained dispatch. Security-constrained dispatch means generation resources are dispatched in a manner that preserves the security of the power system to meet electricity demand even if the largest transmission circuit (between each grid node) suddenly fails. Bid-based dispatch means generation units are dispatched in accordance with the prices bid by generators, subject to meeting the security constraints.

The North and South Island transmission systems are connected by a high voltage direct current (HVDC) cable from Benmore in South Canterbury, across the Cook Strait, to Haywards just north of Wellington City. The HVDC link is a key piece of infrastructure and has a significant impact on the market in connecting major hydro supply in the lower South Island to major demand in the North Island. The impact of the HVDC is acutely felt when it is a binding constraint on the transmission of electricity between the islands, as it can lead to large price separation between the North and South Islands. The size of the power flows from South to North are often the largest source of risk for the power system, creating a need for a sizeable amount of North Island generation to be kept in reserve mode in case of HVDC failure. Conversely, in dry years some South Island generation often needs to be kept in reserve mode to cater for HVDC failure.[45]

The retail electricity market has seen a significant influx of non-generating entrants, adding to a market historically dominated by the five gentailers. The number of retailers by parent company has increased from 10 in January 2010 to 39 today, with the vast majority of these new entrants privately owned, non-generating retailers. Their combined market share now stands at around 10%.[46] Although in aggregate the gentailers' market share across New Zealand is still vast the market structures have changed materially with competition in each submarket.[47]

4.4. New Zealand's oil and gas history

The oil and gas sector in New Zealand dates back to 1865 when an early exploration well was dug in the Taranaki.[48] With the rapid expansion of oil and gas exploration, major gas fields were discovered across the Taranaki basin. The Kapuni gas field was discovered in 1959, and Maui gas field in 1969. There was significant public and private investment in infrastructure with the Maui platform built in

[45] "HVDC Price Separation and Fast Reserves." Electricity Authority. Accessed December 16, 2020. https://www.ea.govt.nz/about-us/what-we-do/our-history/archive/about-us-archive/publications-archive/i-on-the-market/2011/4-hvdc-price-separation-and-fast-reserves/.

[46] "Market Share Snapshot." Electricity Authority - EMI. Accessed August 2020. https://www.emi.ea.govt.nz/Retail/Reports/R_MSS_C.3

[47] "2018/19 Annual Report." Electricity Authority, September 2019, 76. https://www.ea.govt.nz/assets/dms-assets/25/25790Annual-Report-2018-19.pdf.

[48] "History of Petroleum," New Zealand Petroleum and Minerals. January 19, 2017. https://www.nzpam.govt.nz/our-industry/nz-petroleum/history/.

1979 and a second, Maui B in 1993. Oil was discovered at the McKee Oil Field in 1979 which has produced roughly 48 million barrels to date. All current oil and gas production comes from the Taranaki basin, with 17 other basins in New Zealand's Exclusive Economic Zone and continental shelf mostly unexplored.

Production of oil and gas varies by year, but generally New Zealand has produced between 10 to 20 million barrels of oil per year and between 150 to 200 billion cubic feet of gas.[49] Although significant, this only equates to roughly 25% of our oil and oil derivative needs.

The Government sets a framework for private sector participation in upstream oil and gas. Generally, this means the granting of permits that allow for oil and gas exploration. If oil or gas is discovered, the extracting entity must pay royalties to ensure a fair return to the Crown for the extraction of New Zealand's resources and minerals.

Under this framework, there were several global oil and gas companies participating in New Zealand including Royal Dutch Shell, British Petroleum, and Chevron. However, the upstream industry has consolidated in recent years with Todd Energy and OMV the only major owners of production assets. Todd energy is a subsidiary of New Zealand's Todd Corporation and OMV is an Austrian multinational oil and gas company listed on the Vienna and Frankfurt stock exchanges.

4.5. Natural gas

The natural gas used by consumers in New Zealand is over 90% methane with small amounts of ethane.[50] It is often referred to as 'piped gas' or 'mains gas' and generally supplied through reticulated systems.[51]

Natural gas plays a fundamentally different role in New Zealand's energy ecosystem to other hydrocarbons. Whilst almost all of New Zealand's oil is exported the opposite is true for natural gas. Similarly, the uses of natural gas bifurcate between gas used in the generation of electricity (~20% of total production[52]) and other uses, such as industrial (two major industrial consumers are Methanex and Ballance Nutrients), process heat, and residential. As such, there is a strong relationship between natural gas and the electricity market.

As a consequence, Todd Energy is another main producer of energy and through Nova Energy is effectively a sixth major electricity gentailer with 5% market share in the retail electricity market (by ICP). Nova's electricity generation is primarily through natural gas, with some geothermal capacity.

First Gas own and operate more than 2,500km of high-pressure gas transmission. As the only provider of transmission infrastructure and hence a monopoly, they are regulated by the Commerce Commission.[53] A key piece of the network is the Maui Pipeline, New Zealand's largest high-pressure transmission line running 307km connecting the Oaonui Production Station (south of New Plymouth)

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[49] "Oil & Gas in New Zealand." PEPANZ. Accessed August 2020. https://www.pepanz.com/oil-and-gas-new-zealand/oil-and-gas-in-new-zealand/.
[50] Samuelson, Ralph. "Oil: An Introduction for New Zealanders." Ministry of Economic Development, 2008. https://www.mbie.govt.nz/assets/77e0694e33/oil-an-introduction-for-new-zealanders.pdf.
[51] "Difference Between LPG + Natural Gas," Elgas NZ. December 28, 2013. https://www.elgas.co.nz/resources/elgas-blog/151-comparison-between-lpg-natural-gas-propane-butane-methane-lng-cng-nz/.
[52] "Natural Gas." Energy Mix. Accessed November 2020. https://www.energymix.co.nz/our-resource/natural-gas/#:~:text=Today%20gas%20provides%20around%2020,for%20coal%20in%20power%20generation.
[53] "Transmission." First Gas. Accessed December 15, 2020. https://firstgas.co.nz/about-us/regulatory/transmission/.

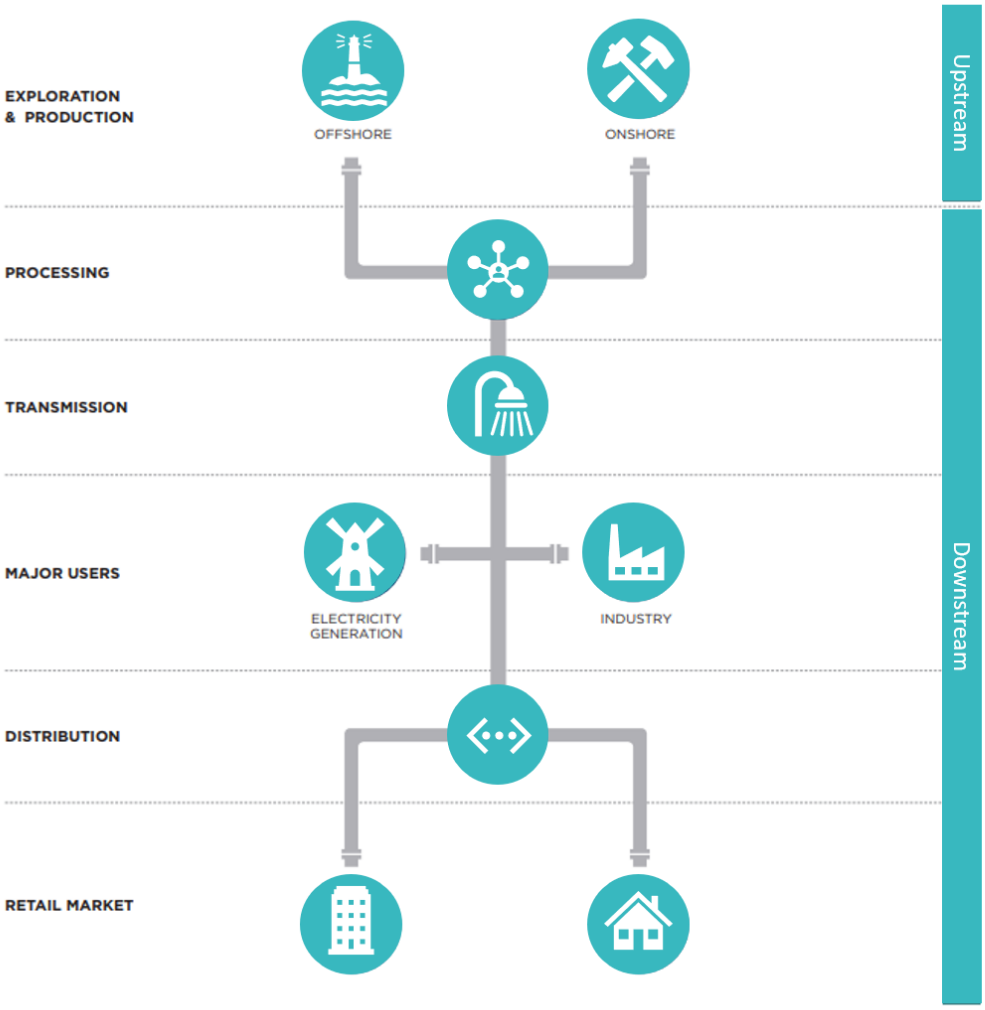
to the Huntly Power Station. First Gas is owned by First State Funds, a global diversified infrastructure fund. [54]

There are five distributors of nautral gas:

1. PowerCo – Tarankai based EDB, owned by QIC and AMP Capital;
2. Vector – Auckland EDB, consumer trust owned with NZX listed component;
3. First Gas – Gas transmission owner, owned by First State Funds;
4. Nova Energy – Todd Energy, privately owned; and
5. Gas Net – owned by Whanganui District Holdings.

The structure of the gas value chain is shown in Figure 11 below.[55]

Figure 11: Structure of gas value chain in New Zealand



Source: Gas Industry Company

[54] "Transmission." First Gas.
[55] "Structure of the Gas Industry." Gas Industry. Accessed December 15, 2020. https://www.gasindustry.co.nz/about-the-industry/gas-industry-information-portal/structure-of-the-gas-industry/.

There are several gas retailers, notably all the major electricity gentailers excluding Meridian.

Natural gas is not available in the South Island and consequently there is no major natural gas infrastructure.

4.6. LPG

Liquified Petroleum Gas (**LPG**) is typically a mixture of propane and butane. In New Zealand, LPG is generally extracted from raw natural gas but can also be produced from an oil refinery.[56]

About 1.5% of New Zealand's total energy consumption comes from LPG, the bulk of which is produced domestically. The largest users of LPG have historically been from the residential sector, however LPG consumption in the commercial sector is on an upward trend. LPG is distributed to customers either in bottles or via reticulated networks. However, the reticulated networks only make up a small fraction of the overall LPG market.[57] Hence, there is relatively little major LPG infrastructure.

4.7. Oil

Almost all of New Zealand's oil is exported.[58] This is because Marsden Point is not suited to refining New Zealand oil,[59] and the high-quality product earns a premium on international markets.[60] As a consequence, the vast amount of heavier hydrocarbons – such a petrol, diesel, and aviation fuel – are imported. Roughly 30% is imported in refined form with the remaining 70% refined in New Zealand at Marsden Point (from imported crude oil). Marsden Point is owned by Refinery NZ, which is a partnership between the three main petrol retailers Mobil, Z Energy, and BP, as well as having an NZX listed component.[61]

Once refined there are three major fuel distribution links. The Refinery to Auckland Pipeline (**RAP**) transports diesel, petrol, and jet fuel to a storage facility in Wiri. The other key links are road tankers, and coastal shipping to storage terminals across New Zealand.

The three main petrol retailers Mobil, Z Energy, and BP are both owners and customers of the refinery, selling up to 80% of fuel products nationwide.[62] BP and Mobil are both major globally listed oil and gas companies. Z Energy was formed by the divestment of Shell's New Zealand assets and subsequently listed on the NZX and ASX. In 2015 Z Energy announced that it had entered into an agreement to acquire 100% of Chevron New Zealand. The New Zealand Superannuation Fund holds approximately 10% of Z Energy Limited.[63]

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[56] Ralph Samuelson, Oil: An Introduction for New Zealanders
[57] "Retail Competition in the LPG Market." Gas Industry, September 2018. https://www.gasindustry.co.nz/publications/document/6317.
[58] See oil statistics https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics/
[59] Rebecca Stevenson. "NZ Makes Its Own Oil. So Why Are We Paralysed When a Pipeline Breaks?" The Spinoff, September 20, 2017. https://thespinoff.co.nz/business/20-09-2017/nz-makes-its-own-oil-so-why-are-we-paralysed-when-a-pipeline-breaks/./
[60] "An Introduction to New Zealand's Oil and Gas Industry." Petroleum Exploration and Production Association of New Zealand, 2016. https://www.pepanz.com/dmsdocument/16.
[61] "The Fuel Industry in New Zealand," Trading Standards. April 18, 2018. https://fuelquality.tradingstandards.govt.nz/for-consumers/the-fuel-industry-in-new-zealand/.
[62] "The Fuel Industry in New Zealand," Trading Standards. April 18, 2018. https://fuelquality.tradingstandards.govt.nz/for-consumers/the-fuel-industry-in-new-zealand/.
[63] "Infratil has agreed to sell its 20% stake in Z Energy", Infratil, 1 October 2015 https://infratil.com/for-investors/announcements/2015/infratil-has-agreed-to-sell-its-20-stake-in-z-energy/

There are a number of smaller independent retailers including Gull, Allied, and Waitomo that are privately owned.

4.8. Coal

New Zealand has rich coal reserves. These are estimated to be roughly 15 billion tonnes of which 80% is lignite or brown coal. As recently as 2015, Solid Energy (a State-Owned Enterprise) was the largest coal mining company in New Zealand. The company went into voluntary administration and was sold to various mining companies, ending major public involvement in the extraction of coal in New Zealand. Today, New Zealand has 20 producing coal mines with major fields located on the West Coast, Waikato, Canterbury, and Southland. Approximately 2.2 million tonnes of coal were extracted in 2019,[64] the vast majority of which is bituminous and sub-bituminous ranging from 60-80% carbon. Bathurst Resources are the dominant player in the New Zealand market and are ASX listed.

4.9. Wind

New Zealand also has comparatively good wind generation resources, primarily due to westerly winds known as the Roaring Forties, which blast over the South Island and the lower portion of the North Island. Current wind generation capacity is only 690 MW, supplying about 6% of New Zealand's annual electricity demand. New Zealand has commercially viable onshore wind generation resources that could provide at least 10,800 MW of generation capacity, the equivalent of 85-100% of New Zealand's current annual electricity demand. Over 70% of that capacity would be located in the North Island, where the major demand centres are also located. It is also estimated there is another 8,000 MW of commercially viable offshore wind resources, in the Auckland, Waikato and Taranaki coastal areas.[65]

To date, the majority of New Zealand's 17 wind farms have been installed and operated by Meridian Energy, Tilt Renewables (a company formed from Trustpower's wind generation assets) and NZ Wind Farms. There are four other players, including Mercury who is currently building New Zealand's largest windfarm and has a cornerstone shareholding in Tilt. The market for developing New Zealand's wind resources is competitive and is likely to become more so as New Zealand enters a substantial build phase through to 2050.

4.10. Solar

New Zealand's commercially viable solar resources are average compared to Australia (and other sunny and arid countries) and compared to New Zealand's wind resources. This is because large scale solar farming displaces other farming activities, and so its commercially viability is enhanced if it sits on poor quality grassland, of which New Zealand has relatively little. This contrasts with wind generation, where cattle farming can co-exist, and with small scale solar which is typically on the rooftops of existing buildings. Hence, large scale solar generation has not generally been commercially viable in New Zealand and is not projected to be viable until 2025-2030 (the key driver being the falling capital cost of building utility-scale solar).[66]

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[64] New Zealand Petroleum and Minerals. "Operating Coal Mine Production Figures," August 20, 2020. https://www.nzpam.govt.nz/our-industry/nz-minerals/minerals-data/coal/operating-mines/.

[65] "Wind Generation Stack Update." Ministry of Business, Innovation and Employment, June 30, 2020. https://www.mbie.govt.nz/assets/wind-generation-stack-update.pdf. and New Zealand Wind Energy Association. "New Zealand's Wind Farms." Accessed August 2020. http://www.windenergy.org.nz/wind-energy/nz-windfarms.

[66] Dr Allan Miller "Economics of Utility-Scale Solar in Aotearoa New Zealand." Ministry of Business, Innovation and Employment, May 2020, 52.

Current solar generation capacity is only 140 MW, with over 80% of it being small scale units (typically installed at homes and small businesses).[67] Solar generation currently supplies only about 0.3% of annual electricity demand.[68] Recent estimates suggest that New Zealand has commercially viable large-scale solar resources of 1,000 – 11,500 MW, with a base case estimate of 6,300 MW that could produce 24% of New Zealand's current annual demand.[69] However, the best resources are distant from New Zealand's major demand centres, being in the South Canterbury area (Mackenzie District and Waitaki Valley) due to poor grassland. Although the Tasman region is estimated to be a high yield area for large scale solar farming due to its sunshine and higher wholesale electricity prices, the higher cost of land in the Tasman area (relative to South Canterbury) counteracts those benefits. Transpower projects most of the solar expansion in New Zealand will come from residential sources, discussed below in regard to distributed energy resources.

4.11. Geothermal

Relative to other countries, New Zealand has plentiful geothermal reserves, mostly located in the Taupō and Kawerau regions but also in the Far North at Ngawha.[70] Current geothermal energy production is about 196 PJ per annum, which can be sustained over the next 30 years from existing sources. Just over 1,000 MW of electricity generation capacity comes from geothermal resources, supplying about 17% of New Zealand's annual electricity demand.[71] Recent estimates suggest only about 1,035 MW of additional geothermal capacity is available for development, although this is sensitive to assumptions about consenting and could be as low as 835 MW or as high as 1,591 MW (about half of New Zealand's high-temperature geothermal resources are currently fully or partially protected).[72] Mercury and Contact Energy are the main developers and operators of geothermal resources in New Zealand, however there are four other smaller entities operating and local iwi are co-owners of three sizeable fields.

4.12. Biomass

The potential size of commercially viable biomass energy resources (biofuel) is unclear. 93% of biofuel comes from solid matter such as wood chips, wood pellets or organic waste, providing about 9% of annual energy consumed in New Zealand.[73,74] Biofuel also takes the form of biogas (such as gas produced from waste or sewage treatment plants) and liquid biofuels (such as from tallow or used

[67] "Installed distributed generation trends." Electricity Authority, Accessed December 2020, www.emi.ea.govt.nz/r/xhp2b and www.emi.ea.govt.nz/r/vr4ke.

[68] "Data tables for electricity." Ministry of Business, Innovation and Employment, table 2, 2019 column. Accessed December 2020, https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/.

[69] Dr Allan Miller, "Economics of Utility-Scale Solar in Aotearoa New Zealand." 52.

[70] Campen, Jim Randle, Jim Lawless Bart van. "Future Geothermal Generation Stack." Ministry of Business, Innovation and Employment, March 2020, 6. https://www.mbie.govt.nz/assets/future-geothermal-generation-stack.pdf.

[71] "Geothermal Energy Generation." Ministry of Business, Innovation and Employment. Accessed December 16, 2020. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-generation-and-markets/geothermal-energy-generation/.

[72] Lawless, Jim, Jim Randle and Bart van Campen. "Future Geothermal Generation Stack." Ministry of Business, Innovation and Employment, March 2020, 42-43. https://www.mbie.govt.nz/assets/future-geothermal-generation-stack.pdf.

[73] "Data tables for renewables." Ministry of Business, Innovation and Employment, table 1, 2019 column. Accessed December 2020, https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/renewables-statistics/.

[74] "Energy balance tables." Ministry of Business, Innovation and Employment, tab Net2019, Total column. Accessed December 2020, https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-balances/.

cooking oil). With extensive forestry and cattle farming, New Zealand would appear to have substantial feedstock for some forms of biofuel, but the commercial viability of far larger scale activity is not clear.

In the Ministry for the Environment's marginal abatement cost curve analysis, biomass is highlighted as a relatively low-cost option for fuel-switching away from coal or gas for industry.[75] There are however a number of challenges outlined, primarily around the transport and existing supply capacity.

4.13. Distributed energy

Distributed energy resources (**DER**) refers to energy resources provided or managed from within electricity distribution networks rather than those provided or managed from the transmission system. For example, DER includes small scale solar generation units and batteries at consumer premises and larger scale generation and batteries connected to distribution networks. DER also includes demand response (**DR**) systems to remotely or automatically alter consumer use of grid-supplied electricity in response to the needs of the consumer and the price of grid-supplied electricity. This can come from controlling the electricity usage of fridges/freezers, hot water cylinders, space heating and cooling and/or from the charging and discharging of stationary and electric vehicle (**EV**) batteries at consumer premises. For commercial consumers, the control of pumps, fans and compressors are also sources of DR.

Other than suitable rooftops and generally sunny conditions for solar units, DER does not depend on the natural resources of an area or region, and in fact DR is perfectly ubiquitous. Up to 4,000 MW of DER capacity may be commercially viable to develop over the next 30 years.[76] This is in addition to current ripple control of hot water cylinders and the 114 MW of residential rooftop solar currently installed in New Zealand.[77] New Zealand currently has over 27,000 residential premises with rooftop solar, and over 3,000 premises with combined solar/battery units that can be remotely managed by a service provider. There are many suppliers of DER resources, particularly solar and battery units, with the most well-known ones being SolarCity and Tesla. Several of the main electricity retailers and lines companies are also competing in this market. Transpower and Contact Energy operating New Zealand's largest DR platforms.

4.14. Hydrogen

There are no existing major hydrogen infrastructure assets in New Zealand. However, recently there has been movement in the sector with government investment, through the Provincial Growth Fund, supporting the establishment of a hydrogen project in the Taranaki region.[78] The $19.9 million investment will enable two project partners Hiringa Energy and Ballance Agri-Nutrients to construct an industrial scale electrolyser, supplying renewable energy to Ballance's ammonia-urea plant in Kapuni as well as synthesising a zero-emission transport fuel. Hiringa Energy have announced the construction of a hydrogen refuelling network across the North and South Islands in partnership with Waitomo, an independent retail fuel operator. This is intended to produce green hydrogen produced through the

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[75] "Marginal Abatement Cost Curves Analysis for New Zealand." Ministry for the Environment, January 2020, 40. https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/marginal-abatement-cost-curves-analysis_0.pdf.
[76] "Distributed Energy Resources (DER) Report." Transpower. Accessed December 15, 2020. https://www.transpower.co.nz/resources/distributed-energy-resources-der-report.
[77] Ripple control refers to electrical relays that some electricity networks in New Zealand can operate to cut power to their customer's hot water cylinders. Refer to www.emi.ea.govt.nz/r/srvdy for statistics on small scale generation in New Zealand.
[78] "Hiringa & Ballance Welcome Government Support for World-First Green Energy Project." Hiringa, March 6, 2020. https://www.hiringa.co.nz/post/hiringa-ballance-welcome-government-support-for-world-first-green-energy-project.

electrolysis of water powered by renewable electricity (or steam reforming of biogas) to serve demand initially in heavy transport.

Notwithstanding the promise, challenges remain, particularly around economic feasibility. Although hydrogen production, transportation, and storage technologies are advancing rapidly, today green hydrogen production costs are challenging.[79] Similarly, depending on the use, transportation and storage remain challenging given, among other things, the efficiency of compressing a gas of very low density.[80]

4.15. A regulatory and policy environment more complex than other infrastructure sectors

Appropriately, the sector is regulated due to the extraction of natural resources owned by the Crown, the environmental and safety impacts of extracting and transporting energy, and the economic features of reticulated gas and electricity. The shared use of gas and electricity infrastructure, in particular, leads to relatively complex regulatory arrangements because the issues – such as avoiding free-rider and hold-up problems during emergencies, or apportioning the costs of the infrastructure among users – are themselves complex.

To address this, New Zealand has a Regulatory Charter setting clear expectations for what the energy regulatory system is intended to achieve. The charter also outlines key principles underlying the design of the regulatory system and describes the respective roles and functions of agencies.[81]

The Electricity Authority was established in 2010 under the Electricity Industry Act 2010 and is the market regulator of the electricity sector, particularly the competitive wholesale and retail components. The statutory objective of the Authority is to promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers.[82] In practice this results in the Authority developing, administering, and enforcing market rules (embodied in the Electricity Industry Participation Code – the 'Code') covering key aspects of the wholesale and retail electricity markets, and some aspects of transmission and distribution.

The Authority also oversees operational aspects of the wholesale and retail electricity markets and is required by the Electricity Industry Act to contract out (via competitive tender) key operational roles except for the system operator role. In regard to the latter role, the Act designates Transpower as the system operator, with the details governed by a contract between the Authority and Transpower.

Congruent with its statutory objectives, the Authority focuses on the long-term benefit of consumers. In doing so, they encourage competition for retail consumers by reducing barriers to entry for new retailers, making it easier for consumers to compare power company prices, and switch from one company to another.

Under the Commerce Act 1986,[83] the Commerce Commission has the power to regulate electricity lines and gas pipelines.[84] As a consequence, Transpower and all 29 EDBs are regulated by the

[79] "A Vision for Hydrogen in New Zealand." Ministry of Business, Innovation and Employment, September 2019, 1-89. https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper.
[80] "Hydrogen Storage Challenges", Office of Energy Efficiency and Renewable Energy, Hydrogen and fuel cell technologies office. Accessed January 2021.
https://www.energy.gov/eere/fuelcells/hydrogen-storage-challenges
[81] "Regulatory Charter: Energy Markets Regulatory System." Ministry of Business, Innovation and Employment, August 2018.
[82] Electricity Industry Act, 2010, s 15.
[83] Commerce Act 1986.
[84] "Home." Commerce Commission, November 19, 2020. https://comcom.govt.nz/.

Commerce Commission. Transpower and 17 EDBs are price-quality regulated, meaning a maximum allowable revenue is set by the Commission on the basis of the value of assets (Regulated Asset Base or **RAB**) held by the company and the weighted average cost of capital (WACC), with minimum quality standards requiring to be met. The remaining 12 EDBs are exempt from price-quality regulation on the judgement that they are consumer-owned entities (often in the form of consumer trusts). However, they are still subject to the Commission's information disclosure regulations.

Regulating natural monopolies for efficiency and the long-term benefit of consumers is complex, necessarily challenging and always evolving. For instance, a range of questions are beginning to arise as to how new technology may blur the divide between the competitive and monopoly parts of the electricity sector. An example is the participation of battery storage units in the wholesale electricity market, an issue the Electricity Authority is working on. EDBs are interested in owning and operating large- and small-scale batteries to reduce their costs of providing reliable distribution services to their customers.

These batteries may also provide value to consumers by participating in the wholesale electricity market, competing for example against other parties, including generators and retailers, who may also own and/or aggregate batteries themselves. Potentially, this competition could reduce wholesale electricity prices with flow-on effects for consumers. However, conversely, enabling EDBs to invest in batteries directly, and include them in their regulated asset bases, may crowd out investment by competing, unregulated parties.

The desired end state is one in which investors and operators of new technology such as batteries can compete on a level playing field with established technology, and new entrants to the technology markets can compete on a level playing field with established players.

4.16. Gas regulation

The Commerce Commission regulates the natural monopoly gas transmission and distribution businesses, applying price-quality regulation in a very similar manner to the EDBs, setting a maximum allowable revenue for each business depending on their asset base, an industry WACC (weighted average cost of capital), and minimum quality standards. This relates to the distribution pipelines of Vector, PowerCo, and GasNet and the transmission and distribution pipelines of First Gas.

The gas industry is also overseen by the Gas Industry Company (GIC), an industry body established under the Gas Act 1992.[85] As a co-regulatory body, their role is to advise regulation where appropriate that ensures the safe, efficient, reliable, fair, and environmentally sustainable delivery of gas.[86] The GIC's members are the major gas stakeholders however the majority of the company's board are independent.[87]

4.17. Other regulation and taxation

There have been several new taxes levied on thermal fuels in recent years. In July 2018, an Auckland regional fuel tax scheme began at a rate of 10 cents per lite on petrol and diesel, to fund local transportation infrastructure and from July 2020, a gas levy was introduced at 1.1164 cents per gigajoule of gas purchased from gas producers with the proceeds ensuring the sustainable funding of the GIC.

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[85] Gas Act 1992.
[86] "About Us." Gas Industry Company. Accessed December 16, 2020. https://www.gasindustry.co.nz/about-us/.
[87] "Board." Gas Industry Company. Accessed December 16, 2020. https://www.gasindustry.co.nz/about-us/board/./

The Commerce Commission doesn't directly regulate the oil sector as it is considered workably competitive. However, in 2018 the Government asked the Commission to undertake a study into factors affecting the competitive supply of retail petrol and diesel. The report concluded that many fuel companies had been making persistently higher profits over the past decade than would be considered normal in a workably competitive market. The core problem highlighted by the Commission is the lack of an active wholesale market given Marsden Point's dominant position providing a significant proportion of national supply.[88] The Government responded to the proposed changes in February 2020 agreeing new legislation that would include more transparent wholesale pricing and encourage competition.

The extraction of oil, gas, coal and other minerals are regulated under the Crown Minerals Act, which is administered by the Ministry of Business, Innovation, and Employment (MBIE). The Act provides for the efficient allocation rights for Crown owned minerals, to the extent that the Government grants permits for the exploration and extraction of these resources. Once extracted a royalty paid to the Government to remunerate New Zealand for the fair value of this resource.

New legislation is intended to amend the Crown Minerals Act in response to the decommissioning issues of the offshore Tui Oil Field.[89] Tamarind Taranaki, the permit operator of the field was placed into receivership in 2019 leaving the Crown as an unsecured creditor for the decommissioning cost of approximately $155m.[90] The decommissioning procurement is being managed by MBIE. Changes to legislation will reduce the risk to the taxpayer bearing the decommissioning costs of fields in the future.

There is environmental regulation surrounding oil and gas extraction in the Maritime Transport Act that governs the transfer of oil and other noxious liquids as well as plans and responses to protect marine environments from oil spills.

Looming large over the policy environment is the future direction of the price of carbon as stipulated in the emissions trading scheme (**ETS**), which is mostly administered by the Environmental Protection Authority. The ETS was created through the Climate Change Response Act passed in recognition of New Zealand's obligations under the Kyoto Protocol.[91] Loosely the ETS does this by allocating units in accordance with a national budget and allowing a market to be established in pricing the negative externality caused by the emissions. In the context of energy infrastructure, the ETS covers industrial processes (major uses of energy), fossil fuels (transport), and stationary energy (generation and heating).[92] Carbon prices are already having a material impact on the electricity market operation, electricity prices, and investment (and retirement) decision-making. The way in which the price of carbon evolves in the coming decade will have a significant impact on the energy market and transition.

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[88] "Retail Fuel Market Study Recommends Changes to Benefit Competition and Consumers," Commerce Commission, December 5, 2019. https://comcom.govt.nz/news-and-media/media-releases/2019/retail-fuel-market-study-recommends-changes-to-benefit-competition-and-consumers.
[89] "Tui Project: Decommissioning the Tui Oil Field," November 16, 2020. New Zealand Petroleum and Minerals. https://www.nzpam.govt.nz/about/tui-decommissioning/.
[90] Robin Martin. "Crown May Foot $155m Bill to Decommission Taranaki Oil Field." *RNZ*, November 27, 2019. https://www.rnz.co.nz/news/national/404275/crown-may-foot-155m-bill-to-decommission-taranaki-oil-field
[91] "About the Emissions Trading Scheme." Environmental Protection Authority. Accessed August 2020. https://www.epa.govt.nz/industry-areas/emissions-trading-scheme/about-the-nzets/.
[92] "About the New Zealand Emissions Trading Scheme," Ministry for the Environment. October 19, 2020. https://www.mfe.govt.nz/climate-change/new-zealand-emissions-trading-scheme/about-nz-ets.

4.18. Predominantly a privately financed and user-pays sector

The natural monopoly nature of some energy infrastructure leads to a market structure where the financing and funding of assets is influenced by regulation. This is especially true for investment in gas and electricity transmission and distribution assets.

For example, when seeking to invest in transmission assets, Transpower must identify transmission issues relating to future demand, new generation, or grid resilience. The Commerce Commission scrutinises and consults on, and then approves or amends, a base level of expenditure at the start of each five-year regulatory control period.

For expenditure on major grid enhancement and development projects during the regulatory control period that exceed $20m, Transpower must submit a proposal to the Commission for approval. Transpower is required to identify the options that may resolve the transmission issues and perform cost-benefit analysis to identify the option that maximises net electricity market benefit. The Commission reviews Transpower's proposal and cost-benefit analysis, consults any interested parties – typically parties paying transmission charges to Transpower – and decides whether to approve it.

Transpower can make a normal return on approved forecast costs, with rewards or penalties for under- or over-spending, incentivising prudent investment. Similar incentives for prudent investment apply to EDBs and gas pipeline businesses subject to price-quality regulation, although there are differing levels of investigation and approval depending on whether the business are subject to 'default' or 'customised' price-quality regulation.

Transpower collects revenue from its customers in accordance with a transmission pricing methodology (**TPM**) approved by the Electricity Authority. The TPM determines how Transpower apportions its revenue among its customers, which are any parties connected to the national grid (EDBs, large industrial consumers and large generators). The current methodology was approved by the Electricity Commission in 2007, before the establishment of the Authority, with adjustments made in 2017.[93]

All transmission pricing proposals since 1988 (when Transpower was established) have excited wide-ranging debate in the public sphere, partly given the quantum of dollars at stake and their regional impact. The most recent TPM guidelines from the Electricity Authority have been no exception. In June 2020, the Authority published new TPM guidelines shifting from the existing medley of partial user-pays and demand side apportionment on the basis of shares of peak demand to a more firmly beneficiary-pays approach. Under the new guidelines, beneficiaries of new grid investment (and some existing transmission assets) will be charged on a forward-looking basis. Notably, this would have seen the Tiwai Aluminium smelter realise a roughly ~$10m lower annual transmission charge.[94] The new TPM guidelines are also likely to lead to more efficient price signals for distributed energy resources (DER), to encourage consumers to take advantage of new technology where and when it is efficient to do so. The Authority expects the revised TPM to be in place by 2023.[95]

A similar approach applies to electricity distribution businesses. The Commerce Commission sets the maximum allowable revenues for five-year periods for the 17 EDBs subject to price-quality regulation. This is usually done under a default price-quality path (**DPP**) regime, which is essentially a 'one size fits all' approach. Once their revenues are set, the 17 EDBs are expected to invest to maintain the

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[93] "Transmission Pricing." Electricity Authority. Accessed August 2020. https://www.ea.govt.nz/operations/transmission/transmission-pricing.

[94] Gavin Evans. "Tiwai Point Smelter Closure Not a Risk to Transmission Pricing Benefit." *The New Zealand Herald*. June 10, 2020. https://www.nzherald.co.nz/business/tiwai-point-smelter-closure-not-a-risk-to-transmission-pricing-benefit/MOY6OPSI357AJT4TMKV2F3WS4M/.

[95] "TPM Decision and Guidelines." Electricity Authority. Accessed December 16, 2020. https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/transmission-pricing-review/development/tpm-decision-and-guidelines/.

minimum quality of service required by the Commission. The Commission monitors the revenues, quality of service, capital expenditure and asset quality of each EDB, and in serious cases seeks penalties through the High Court for EDBs that breach their quality thresholds.

A customised price-path (**CPP**) mechanism is available if an EDB needs to invest more in network assets than allowable under their DPP. The Commerce Commission reviews each application and determines whether a deviation from the DPP is acceptable for the reasons provided. There have been three CPPs adopted to date, one from Orion relating to rebuilding infrastructure from the Christchurch earthquake, one from Wellington Electricity allowing for earthquake strengthening of critical infrastructure, and one from PowerCo to perform major network upgrades to end-of-life assets and ensure safe, secure supply to growing regions such as Tauranga.[96] The Commerce Commission is currently considering a CPP application from Aurora Energy, to allow it to fund a large step up in investment to replace unsafe power poles and associated distribution assets in its Dunedin city and central Otago networks.

Whilst the remaining 12 consumer-owned EDBs are exempt from price-quality regulation, they are subject to information disclosure regulation. This requires them to provide data on pricing, future expenditure, outages and interruptions, and financial information.[97]

Just as Transpower allocates its maximum allowable revenue to its customers in accordance with its TPM, EDBs allocate their revenue requirements in accordance with their distribution pricing methodologies (DPMs). Whereas the Electricity Authority issues mandatory TPM guidelines in regard to Transpower, it issues voluntary DPM guidelines that EDBs are expected to adhere to wherever practicable and effective. Since 2016, the Authority has been encouraging EDBs to alter their DPMs to provide more efficient price signals for distributed energy resources, for the same reasons mentioned above for the TPM.[98] Similarly, EDBs have been encouraging the Minister of Energy & Resources to remove or amend Ministerial regulations they consider inhibit their ability to adopt more efficient DPMs, in particular the Electricity (Low Fixed Charge Tariff Options for Domestic Consumers) Regulations 2004.[99]

On the generation and retail ends of the electricity market, companies are operating in a competitive environment and set their prices accordingly, to provide energy to the wholesale market or competing for customers in the retail and hedge markets. Generators and retailers make investment decisions based on their judgements about expected rates of return they can earn from the market. As with businesses in other sectors of the economy, generators and retailers bear the risks of poor business decisions whereas Transpower and the EDBs face minimal revenue risk.

The underlying principle is that the users and beneficiaries of generation, transmission, and distribution infrastructure pay for the services they receive, creating a more efficient pricing signal for infrastructure users. In general, if you consume more electricity, and/or you benefit more from the infrastructure, you pay more.

Furthermore, there is a dynamic pricing aspect to deal with temporary periods of high demand, scarce generation, or limited transmission capacity. For example, when demand is high – usually a morning/evening bi-modal peak accentuated seasonally – the spot price of electricity on the wholesale market is higher. Similarly, spot prices can be high if generation capacity or fuel is particularly scarce.

96 "Electricity Lines Customized Price-Quality Path," Commerce Commission. April 3, 2018. https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-lines-price-quality-paths/electricity-lines-customised-price-quality-path.

97 "Current Information Disclosure Requirements for Electricity Distributors," Commerce Commission. April 25, 2020. https://comcom.govt.nz/regulated-industries/electricity-lines/information-disclosure-requirements-for-electricity-distributors/current-information-disclosure-requirements-for-electricity-distributors.

98 "Implications of evolving technologies for pricing of distribution services." Electricity Authority, 3 November 2015, https://www.ea.govt.nz/assets/dms-assets/20/20057Distribution-pricing-implications-evolving-technologies.pdf.

99 "Why the Low Fixed Charge is unfair for larger households." Electricity Networks Association, April 2018, https://www.ena.org.nz/dmsdocument/492

Again, this provides pricing signals that encourage more efficient short-term consumption decisions and it encourages generators to invest in reserve generation and energy storage.

All of these user-pays funding mechanisms culminate in investment signals for both public and private capital investment depending on where the investment requirement falls in the value chain. Infrastructure providers are encouraged to invest efficiently, taking into account desired levels of quality and reliability of services, and the users of infrastructure (i.e., the consumers of electricity) are encouraged to use electricity efficiently, which indirectly means they're encouraged to use infrastructure efficiently.

4.19. Congestion pricing of the electricity network

It is worth noting that, unlike the transport sector, congestion pricing is used in the electricity sector to manage use of the transport infrastructure. The spot market achieves this because when a transmission circuit is congested spot prices increase downstream of the congested circuit and fall in areas upstream of the congested circuit. In general – unless generator competition is very weak, which can occur from time to time – the spot price movements broadly reflect changes in the marginal cost of generation in the upstream and downstream areas of the grid, which represent the marginal opportunity cost of expanding the transmission grid. These spot price signals encourage generators to locate their generation plants and energy storage in areas of the country that are likely to relieve grid congestion and they encourage efficient short-term demand response in both locations. Partly as a result of this system, grid investment is more likely to occur only where and when the costs of grid expansion are expected to be lower than the marginal cost of generation and demand response.

The highly dynamic congestion pricing signals from the electricity spot market have their pros and cons. On one hand they may better reflect the rapidly changing marginal opportunity costs of transmission due to rapidly changing operating conditions affecting generators. On the other hand, participating directly in the spot market involves relatively high transaction costs (in part to manage highly uncertain prices) and so only the largest generators and largest consumers choose to do so.

The vast majority of residential and commercial consumers prefer fixed term retail prices and medium-term hedge contracts, which reflect expectations about costs over the medium-term, including expectations about future spot market prices. Most of these arrangements do not provide any congestion signals, but some do because they apply different prices at different locations along the transmission grid for different blocks of time (e.g., night vs day prices). The steadiness of these price signals reduces transaction costs for consumers, but it also reduces the correlation of prices with movements in the short-term marginal costs of supply, reducing their investment and demand-response benefits.

Without any congestion pricing, there would likely be a greater propensity for the overbuild of infrastructure. Transpower, for example, estimates that a 3% increase in peak load would bring grid investments forward by two years (an increase in investment cost of approximately 8%) and a 7% increase in peak load would bring investment forward 4-6 years, (an increase in investment cost up to 16%).[100] Ultimately, congestion pricing provides a signal for the more efficient use of infrastructure; a signal not present in several other sectors.

4.20. User-pays of other fuels

The thermal fuels sector has simpler user-pays funding arrangements due to simpler transportation characteristics – electrons are indistinguishable whereas oil, gas, coal, and biomass are discrete packets of energy with a known origin. These are essentially wholly privately functioning markets

[100] "The role of peak pricing for transmission", Transpower, 2018. https://www.transpower.co.nz/sites/default/files/plain-page/attachments/Transpower_The_Role_of_Peak_Pricing_for_Transmission_2Nov2018.pdf

operating under the constraints or forces of competition. This is the case for retail oil products and coal where the infrastructure value chain is largely unregulated, and consumers pay in accordance with their consumption decisions which flow through to funding infrastructure investments.

Gas is the exception, with price-quality regulation applying to gas transmission and distribution businesses. This is a similar method of price-quality regulation to the EDBs where the Commerce Commission sets a maximum allowable revenue under which assets are funded and financed. Similarly, the GIC regulates a gas TPM for the gas pipelines owned and operated by First Gas.

Given the nascence of hydrogen as a fuel there is no existing market under which consumers and producers interact.

5. How is the sector performing?

E pēhea ana te rāngai?

5.1. The overall state of the sector

Relative to other infrastructure sectors, price, access, and quality aspects are not as effective to assess the overall performance of the sector. Given the generally consistent quality of electricity, high-octane petroleum,[101] diesel, and hydrogen the question of quality isn't as pressing as for example, an internet connection that may vary significantly in speed and latency.

Similarly, access is a less pressing issue for energy in New Zealand given our level of development and the period over which this has occurred. The World Bank notes that 100% of New Zealanders have had access to electricity since their records began in 1990.[102] There are however some remote settlements where getting a new electricity connection is expensive as new connections are typically fully cost-recovered. This encourages consumers to choose stand-alone options where they are more cost-effective, such as for example a solar PV and battery unit combined with a diesel backup generator.

Most households in New Zealand don't have access to reticulated natural gas, however bottled LPG is available throughout most of New Zealand, including as far south as Southland and on the West Coast. Access to energy is perhaps better described in terms of affordability rather than in terms of physical connection.

Notwithstanding the access and quality aspects of energy, solely assessing the state of the energy sector on a price basis does not capture the essence of the trade-offs required in making infrastructure decisions. In response to this, leading global thinking from The World Energy Council and Oliver Wyman have defined three outcomes countries must balance, termed the energy trilemma: equity (prices and affordability), energy security, and sustainability.[103] Balancing these outcomes assists with building productivity and delivering long term wellbeing from energy.

The trilemma has gained global momentum and has culminated in an annual global index published by its creators. In 2019, New Zealand ranked 10th out of 128 countries in the index.[104] The Council notes the long-standing performance of New Zealand as the only Asian-Pacific country in the top-10 and having been there consistently since 2000, highlighting sound energy policy. These results are shown in Figure 12 below. As reference, European, especially Scandinavian countries dominate the top 10, with Australia placing 28th.

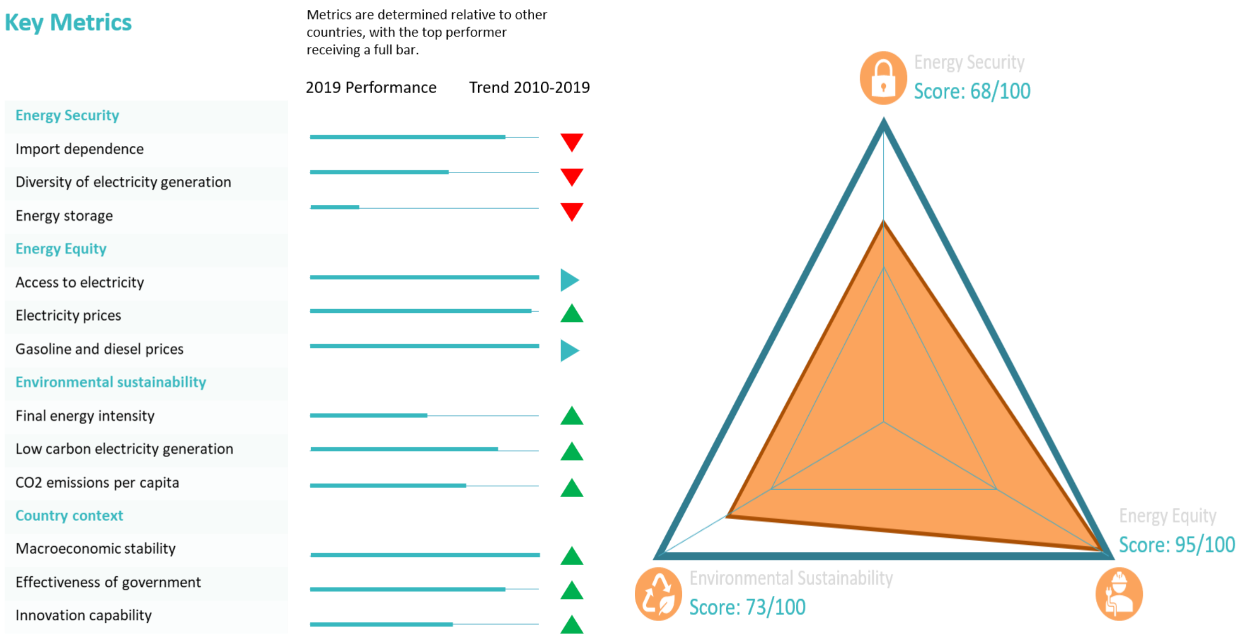
101 "Fuel Facts." AA New Zealand. Accessed December 17, 2020. https://www.aa.co.nz/membership/aa-directions/driver/fuel-facts/

102 "Access to Electricity (% of Population) - New Zealand." The World Bank. Accessed August 2020. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NZ.

103 Oliver Wyman "World Energy Trilemma." Oliver Wyman, 2015. https://www.oliverwyman.com/our-expertise/insights/2016/mar/energy-journal-vol-2/transformation/the-world-energy-trilemma.html.

104 "Energy Trilemma Index." World Energy Council. Accessed August 2020. https://trilemma.worldenergy.org/.

Figure 12: New Zealand's energy trilemma and score trends



Source: World Energy Council

New Zealand's overall ranking reflects that it is relatively well balanced across the three performance dimensions. Most other countries are far more lopsided. Hence, New Zealand is ranked 24th for equity, 18th for sustainability and 29th for security but nevertheless scores 10th overall.

Along with many other countries, New Zealand scores highly in equity. New Zealand's score reflects a reduction in the retail price of electricity and stable performance for access to electricity and price of fuels.

In regard to environmental sustainability, the World Energy Council notes the Government's commitment to net-zero emissions by 2050, the Climate Change Commission establishing provisional carbon budgets, development of a government vision for hydrogen gas and an electricity price review as positive steps towards better sustainability outcomes.[105] However, inherent in the trilemma, this may come at the cost of future energy security which the World Energy Council assessed has worsened in the last decade due to a decline in the diversity of both primary energy supply and electricity generation.

Whilst there is room for improvement, New Zealand's energy sector is globally seen to be performing well. For example, after undertaking a detailed review of New Zealand's energy market in 2016, the International Energy Agency (IEA) concluded New Zealand had a world leading example of a well-functioning electricity market, and that the non-subsidised market-driven rise in renewables was a world-class success story among IEA member countries.[106] The IEA reviewed the wider energy policy

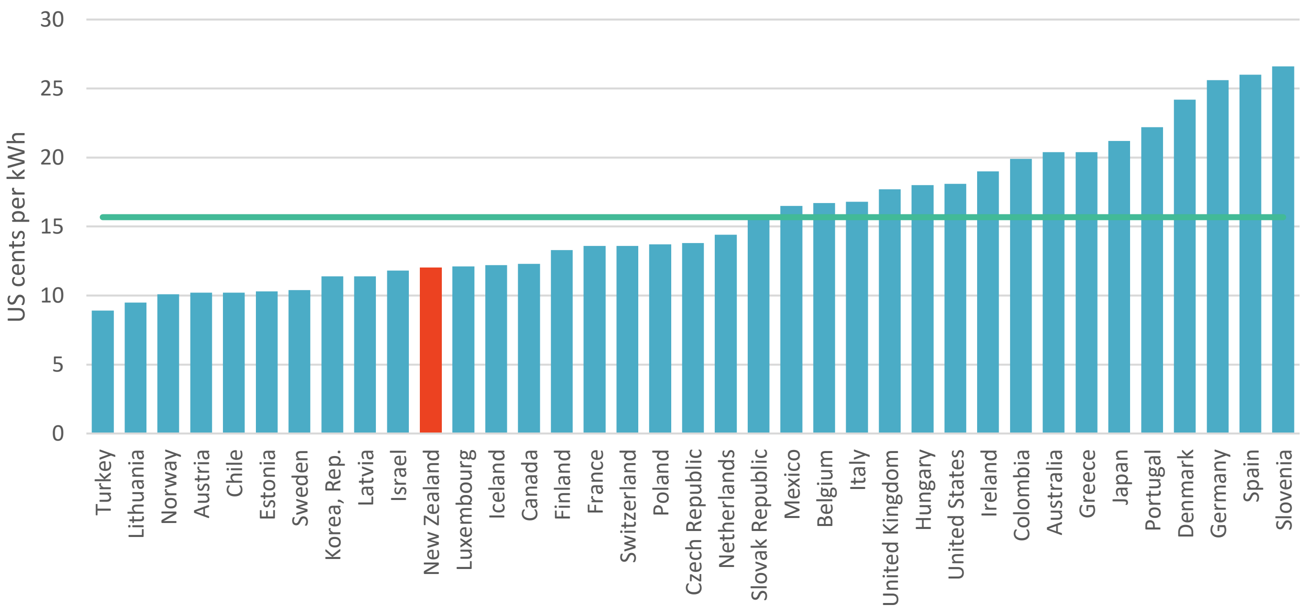
[105] "WEC Energy Trilemma Index Tool." World Energy Council. Accessed December 16, 2020. https://trilemma.worldenergy.org/#!/country-profile?country=New%20Zealand&year=2020.0
[106] "Energy Policies of IEA Countries." International Energy Agency. Ministry of Business, Innovation and Employment, 2017, 3. https://www.mbie.govt.nz/dmsdocument/181-energy-policies-iea-countries-nz-2017-review-executive-summary-pdf.

and institutional changes made since its last review in 2010, and stated all these actions contributed to a more reliable, affordable, and environmentally sustainable energy system in New Zealand.

Despite those accolades, the IEA noted that New Zealand's broader energy sector was still dependent on the use of oil, natural gas, and coal, and the country was facing a number of challenges for meeting its emission reduction commitments made under the Paris Agreement. Most of the IEA's concerns are being addressed by the Government and regulatory agencies, particularly around fuel emission standards, electrification of transport and process heat, and enhancing the electricity markets and systems to encourage and cope with greater penetration of renewable energy and distributed energy resources. Depending on these developments, the IEA suggested an additional safety-net mechanism may be warranted to further enhance electricity security of supply.

In terms of infrastructure, the IEA repeated concerns raised with it about the financial, technical, managerial and governance capability of the electricity distribution sector to respond effectively to the challenges of DER (distributed energy resources). However, it noted it had not evaluated the capacity of the distribution companies to efficiently invest in the monitoring, management, and control systems required to maintain reliability as distribution systems become more complex and subject to more dynamic real-time power flows.[107] The Electricity Authority undertook a comprehensive study of many of these matters in 2018 and did not find evidence supporting the concerns raised with the IEA.[108] The 2018-19 Electricity Price Review (**EPR**) Panel consulted on the IEA's concerns and concluded there would be value in encouraging more contracting and joint ventures between distributors but decided these matters should be acted on voluntarily by distributors as the benefits are case-specific. In part, to encourage greater collaborative activity, the EPR Panel recommended the Commerce Commission be provided with the power to compare distributors' relative performance – often called benchmarking – when setting their price-quality paths.

Figure 13: Electricity prices by OECD country



Source: World Bank

[107] "Energy Policies of IEA Countries." International Energy Agency. Ministry of Business, Innovation and Employment.
[108] "Review of Distributor's Capacity to Respond to Changing Technology." Electricity Authority, April 16, 2019, 46. https://www.ea.govt.nz/assets/dms-assets/25/25822Review-of-distributors.pdf.

5.2. Electricity prices

The World Bank notes the average retail price of electricity in New Zealand is roughly ~US$0.12 per kWh placing 11th cheapest in the 37 members of the OECD, or just in the bottom third. This ranking is shown in Figure 13 below.[109] This compares favourably with Australia where the retail price of electricity is more volatile year-to-year and the price averages around ~US$0.20 per kWh.[110]

Despite the relatively good performance based on World Bank and OECD data, the opposition parties in 2017 were concerned about whether the electricity market delivers efficient, fair and equitable prices, whether it was well-placed to adapt as technology evolves, and whether it supported a transition to a lower emissions economy. The incoming Government set up an Electricity Price Review (EPR) in November 2017 to consider these matters.

The EPR highlighted New Zealand's globally competitive position in relation to the price of energy and that the market was working well in many respects. The review recommended a range of initiatives the government could undertake to strengthen the consumer voice in electricity regulation and reduce energy hardship, and it recommended initiatives the existing regulators should undertake to further enhance competition in the retail and wholesale markets and improve transmission and distribution.[111]

Although retail electricity prices have been falling in real terms, wholesale electricity prices have increased substantially over the last two years, due in part to short-term concerns around dry North Island conditions, an unplanned outage at the Pohokura gas field, and ongoing concerns about longer-term availability of gas for gas-fired electricity generation. This was reflected in the futures market between 2018-2020 (prior to the Tiwai announcement) which can be seen in Figure 14 below.

Figure 14 shows the price of standardised electricity contracts for two maturities: short-dated contracts which mature within twelve months and long-dated contracts that mature in 1 – 4 years.[112] Prices for short-dated contracts are heavily influenced by hydro conditions and shorter-term outages, such as the Pohokura gas outage, whereas the prices for long-dated contracts are primarily driven by the longer-term outlook for the electricity supply and demand balance. The sharp reduction in the long-dated prices in mid-2020 reflects Rio Tinto's announcement in July 2020 that it intended to close its Tiwai Point aluminium smelter, which consumes around 13% of New Zealand's electricity.[113] Since then, Tiwai and Meridian (the owner of the Manapouri power station) came to an agreement to ensure the smelter won't close until 2024.[114] The prices for long-dated contracts have since bounced back.

109 "Doing Business." The World Bank. Accessed August 2020. https://databank.worldbank.org/reports.aspx?source=3001&series=IC.ELC.PRI.KH.DB1619.

110 Whilst prices are low, there can be cost discrepancies for households due to exogenous factors such as poor quality of housing stock

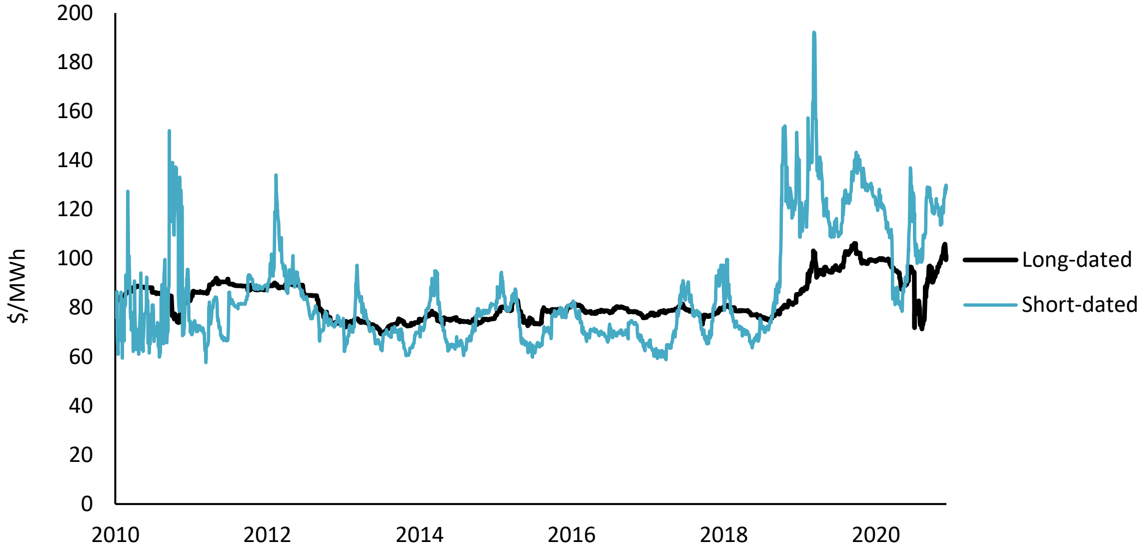
111 "Electricity Price Review." Ministry of Business, Innovation and Employment, n.d, 4. https://www.mbie.govt.nz/assets/electricity-price-review-recommendations-from-final-report.pdf.

112 "Forward price curves." Electricity Authority. Accessed August 2020. www.emi.ea.govt.nz/r/q1pdu

113 "NZAS Terminates Electricity Contract and Plans to Wind-down Operations Following Strategic Review," Rio Tinto. July 9, 2020. https://www.riotinto.com/en/news/releases/2020/NZAS-terminates-electricity-contract-and-plans-to-wind-down-operations-following-strategic-review.

114 RNZ, "Tiwai Point aluminium smelter to keep operating until end of 2024." RNZ, January 14, 2021. https://www.rnz.co.nz/news/national/434490/tiwai-point-aluminium-smelter-to-keep-operating-until-end-of-2024

Figure 14: Electricity forward price curves



Source: EMI, Electricity Authority

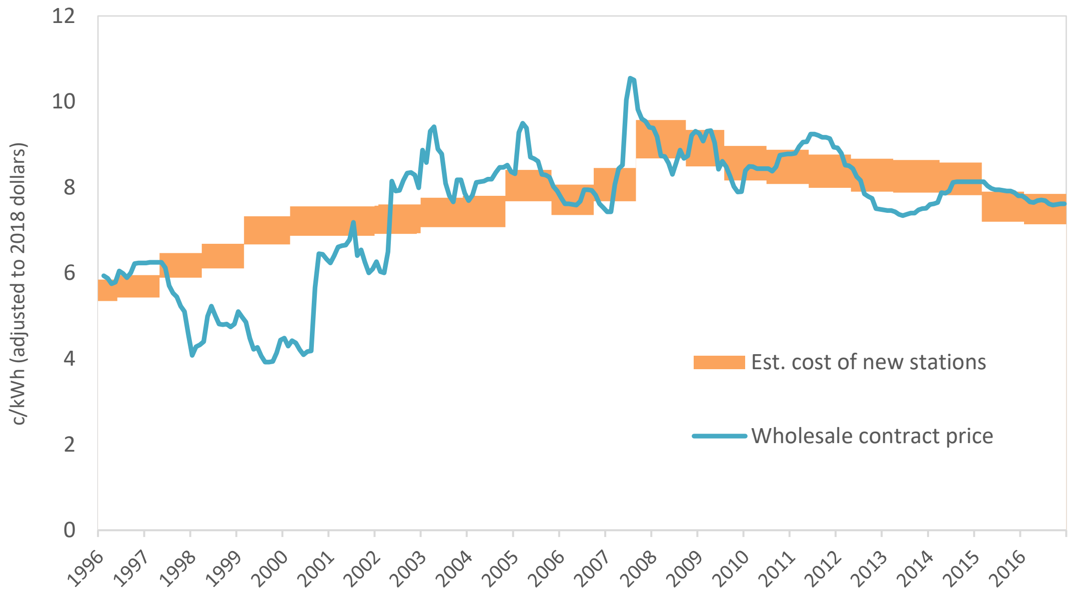
Assessing the competitiveness of investment in electricity generation infrastructure requires consideration of the retail, forwards and spot markets. The forwards market comprises financial contracts between parties that buy from the spot market, such as retailers, industrial consumers and generators. The prices for retail and forwards contracts are generally fixed well in-advance of the real-time delivery of electricity, whereas spot market prices are set shortly after real-time delivery.

Competition for retail and forward contracts is important as, in aggregate, they cover around 90% of New Zealand electricity.[115] Various reviews over the years have shown that forward prices have matched closely with independent estimates of the long run marginal cost (**LRMC**) of new generation that may enter the electricity market, suggesting the forwards market is competitive. This can be seen in Figure 15 below.[116] In part, this reflects the fact that forward sales are discretionary, whereas sales to the spot market are time critical as supply must match demand in real-time. Spot prices are highly volatile, reflecting temporary periods of tight or loose demand and supply conditions.

[115] "Vertical integration trends." Electricity Authority, Accessed December 2020, www.emi.ea.govt.nz/r/ffe52.
[116] "Electricity Price Review." Ministry of Business, Innovation and Employment, August 30, 2018, 17. https://www.mbie.govt.nz/dmsdocument/4334-electricity-price-review-first-report-technical-paper.

Driven by ongoing advances in technology, the LRMC of renewable generation (predominantly in the form of wind and solar) has declined substantially over the last decade and is expected to continue to decline over the next few years.[117] Investors have incentives to build renewable plants when their LRMC is lower than the average price those plants can be expected to earn in the electricity market (i.e., taking into account that wind and solar often operate when spot market prices are relatively low because the additional supply from those plants often makes overall supply relatively plentiful).

Figure 15: Wholesale contract prices versus cost of building new power stations



Source: MBIE, Concept Consulting Analysis. Prices and costs are adjusted for inflation and expressed in 2018 dollars.

An influx of cheap renewable generation will reduce the average price these plants can earn in the market, potentially to lower their LRMCs. Whether this reduces average prices overall depends on whether the influx alters the operating hours for backup generation. If the influx means the same backup generation is needed, but for fewer operating hours, then the backup generation will need to earn higher prices on fewer hours to remain commercially viable, in which case average prices overall may not decline much (or may stay the same or even increase, depending on the circumstances). On the other hand, if the influx of cheap renewable generation is in response to increases in electricity demand, then they don't crowd-out the operating hours of backup generation and average prices overall should decline.

The spot market, net of retail and forward sales, covers about 10% of New Zealand electricity. Standard measures of concentration in the spot market, such as the Herfindahl-Hirschman Index, have declined steadily over the last decade and are at levels widely considered to be competitive.[118] Although the five big generators account for most of the generation supplied to the spot market, there is competition at the margin to be dispatched because un-dispatched generation means forgoing spot revenue.

[117] "Levelized Cost of Energy and Levelized Cost of Storage – 2020," Lazard. October 19, 2020. https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/.

[118] "Electricity Authority Annual Report." Electricity Authority, October 6, 2020, 76. https://www.ea.govt.nz/assets/dms-assets/27/27461D.11-Electricity-Authority-Annual-Report-2019-201272638.1.pdf.

Retail and forward sales reduce any incentives generators may have to offer their generation at high prices. For example, if a generator has more forward sales than its generation, overall, it is a buyer from the spot market and so it wants low spot market prices. Over the five-year period to 2019, the five generators had the ability and incentive to unilaterally raise spot market prices for no more than 2% of trading periods.[119] For all other trading periods, spot market prices are constrained by actual and potential competitive responses by other generators, or by retail and forward sales volumes that make increasing prices unprofitable.

5.3. Power purchase agreements

Retail sales are normally for the supply of power from the electricity system generally, but they can also take the form of power purchase agreements (PPAs), which are long-term contracts for the purchase of the output of specific generation plants, typically plants installed at a customer's premises. The term of the PPA is typically linked to the life of the plant (10-25 years), and the agreement typically includes the provision of maintenance services over the life of the plant.

PPAs are more complicated and bespoke than normal retail sales contracts but they reduce long-term price uncertainty for both consumers and suppliers because the alternatives (retail and forward contracts) generally do not exceed four years. As suppliers face far lower investment risks with a PPA, they are able to offer lower prices than they could otherwise. However, one of the complications with PPAs is dealing with excess demand/supply, particularly for wind and solar generation PPAs. The issue is that the plant's output will generally not closely match the consumer's consumption profile. This leaves the consumer buying (selling) their excess demand (excess generation) from (to) their retailer or wholesale spot market or investing in a battery to manage these deviations. Often a PPA for rooftop solar will include a battery option.

Several electricity companies offer standardised PPAs for small scale generation plants, including Vector, SolarCity, Meridian Energy, KEA Energy, and Total Utilities. On behalf of several industrial consumers, the Major Electricity Users Group (MEUG) issued a tender in June 2020 for a PPA for up to 2,000 GWh of renewable generation per year (nearly 5% of total electricity demand), but at this stage details are not available on whether they have secured a supplier on acceptable terms.[120]

There are no particular barriers to consumers obtaining PPAs, except the additional costs and risks involved with bespoke arrangements. PPAs are relatively simple and standardised for small scale generation, as suppliers with a portfolio of small PPAs can cover some of the risks that they would normally leave with large PPA customers. Naturally, the negotiation costs and risks increase with the size of the generation capacity covered by a PPA.

PPAs have not been popular in New Zealand, as residential and business consumers have preferred normal retail contracts which are generally simpler as they do not have any excess demand/supply issues and it has been relatively easy to compare competing retail offers.

However, PPAs are likely to become more popular as New Zealand proceeds with electrification of transport and process heat. Business consumers will need to make significant investments to convert from oil or gas to electricity and are likely to value the greater long-term price certainty with PPAs and the lower prices will make the transition commercially viable. Also, MBIE consulted earlier this year on

[119] "Market Performance Quarterly Review Q1 2020." Electricity Authority , April 12, 2020, 8. https://www.ea.govt.nz/assets/dms-assets/26/26718Quarterly-Review-April-2020.pdf.
[120] Sophie Vorrath. "NZ Biggest Corporate PPA Seeks up to 2,000GWh a Year of New Renewables." One Step off the Grid, July 21, 2020. https://onestepoffthegrid.com.au/nz-biggest-corporate-ppa-seeks-up-to-2000gwh-a-year-of-new-renewables/.

establishing a PPA trading platform, which if implemented, could facilitate greater uptake of PPAs by reducing transaction costs.

5.4. Petroleum prices

Public concerns about regional disparities in retail petrol prices arose in early 2017 and again in 2018, leading the Government to ask the Commerce Commission to undertake a market study into the factors driving the retail price of petrol and diesel. The report concluded that many fuel companies had been making persistently higher profits over the past decade than would occur in a workably competitive market, with the core problem the lack of an active wholesale fuel market. The review led the Government to pass the Fuel Industry Act 2020, to improve the transparency of wholesale fuel prices and to provide for rules to ensure the terms and conditions of wholesale contracts are transparent and fair.[121]

Global petroleum prices are generally governed by the price of oil, which is a globally established, liquid market. There is a transportation cost getting the fuel to New Zealand, an exchange rate cost, and then a significant tax component which also flows into the retail price of fuel. A recent

Figure 16: Quarterly premium unleaded petrol prices in OECD countries, January quarter 2020

Source: International Energy Agency, Energy Prices and Taxed Q2 2020, MBIE

International Energy Agency (IEA) quarterly report showed New Zealand compared fairly well to other OECD countries in terms of the retail price with tax included – shown in Figure 16 below.[122]

Not dissimilar to petroleum, there is an established global market for coal that influences the domestic market, and in particular domestic prices. Major consumers of coal in New Zealand – including producers of electricity, cement, dairy, and pulp/paper – compete with an export market for supply.

[121] Fuel Industry Act, 2020, s 21.

[122] "Weekly Fuel Price Monitoring." Accessed August 2020. Ministry of Business, Innovation and Employment. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/weekly-fuel-price-monitoring/.

5.5. Systems and frameworks in place to ensure asset quality

There is limited publicly available information on the condition of generation assets. However, Transpower as the System Operator requires data on all assets connected to the grid and the Electricity Authority provides information on the average age of generation assets.[123] Generally, hydro generation assets are older because these assets include major civil structures that have good longevity, while newer forms of generation, including wind, are generally younger. Strong commercial incentives motivate asset management, maintenance, enhancement, and upgrading, such that generation asset quality isn't an issue in New Zealand.

The Commerce Commission tracks asset quality of both Transpower and EDBs under their regulatory framework. In the case of transmission this is published annually in Transpower's Grid Outputs Report which summarises the quality and performance of Transpower's transmission assets.[124] In the 2019 report, Transpower demonstrated positive performance of assets but missed collars on asset refurbishment and replacement. A change in strategy, asset health model improvements, and weather were cited as reasons for missing targets.[125]

Distribution asset quality is also monitored by the Commerce Commission.[126] Of the eight categories asset quality is measured across, most are judged to be of satisfactory quality. Appendix four provides more detailed information on this issue.

Issues around asset quality of EDBs were heightened following issues with Aurora Energy's infrastructure emerging in 2012 with warnings in the media by an internal whistle blower and a formal warning from the Commerce Commission. As claimed by the Commission, this underinvestment in infrastructure continued through to 2019 and resulted in an increased number of power cuts. As a consequence, Aurora faced penalties imposed by the High Court, board and management changes occurred, and a larger and faster asset upgrade programme was adopted. Aurora submitted a CPP to the Commission to provide it with the revenue it needs to pay for the additional investments. These developments highlight potential moral hazard issues for monopoly infrastructure providers, as they essentially have a captured customer base and so face far lower revenue risks from running down the condition of their assets than occurs for firms in competitive markets. Broadly, these moral hazard issues are monitored and dealt with by the Commerce Commission through prosecution.

Similar regulation is in place that encourages asset quality of gas transmission and distribution assets. The Gas Industry Company also plays a role in imposing additional safety requirements with the transport of gas. First Gas, the owner of the only major transmission lines in New Zealand, publishes their asset management plan and publicly disclose their asset quality. Most of their assets are in good condition with deficient areas known and being addressed. The Commerce Commission tracks asset quality of gas distribution assets, with the majority of these assets rated as *'green'*.

[123] Excludes decommissioned stations and stations without publicly available data on year opening.
[124] "Grid Outputs Report 2019." Transpower, 2019, 8. https://www.transpower.co.nz/sites/default/files/publications/resources/Grid%20Outputs%20Report%202019_0.pdf.
[125] "Asset Management Plan 2018." Transpower, October 2018, 35-64. https://www.transpower.co.nz/sites/default/files/publications/resources/Asset%20Management%20Plan%202018.pdf.
[126] "Performance Summaries for Electricity Distributors," Commerce Commission. January 22, 2020. https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-distributor-performance-and-data/performance-summaries-for-electricity-distributors.

The Commission recently engaged experts to assess the risk management practices applied by the gas pipeline businesses and concluded that those practices are generally in good condition.[127]

There is little publicly available information on other assets in the sector, particularly oil and gas extraction, and other fuel infrastructure. For providers competing with many other suppliers, consumer choice and competition provide strong incentives for firms to optimally trade-off the cost of maintenance versus the cost of outages. However, for large infrastructure providers it may not be feasible for consumers to switch to alternative suppliers to avoid a significant loss of service. In these cases, as occurs with large electricity generation units, it will often be necessary for a centralised party to arrange for reserves to cover for the risk of extended outages.

Fuel reliability is entirely a commercial matter, except in the case of New Zealand's treaty obligations under the International Energy Agreement. Under the IEA, New Zealand agrees to maintain stocks equivalent to 90 days of import demand net of oil exports.[128] Commercial stocks are insufficient for this purpose and the Government makes up the difference by procuring options on stock held in Europe.[129]

Generally, there are similar incentives for extractive infrastructure as there is for electricity generation. No extraction means no revenue and hence there are strong commercial incentives to optimally trade-off maintenance with the risks of breakdowns. As there are multiple types of electricity generation, gas outages are dealt with by the electricity market in the form of higher wholesale prices. Having said that, all material risks to electricity security and reliability are monitored by Transpower and industry participants, and by a Security and Reliability Council (**SRC**) which reports to the Electricity Authority.

In principle, major fuel pipeline risk is equivalent to the breakdown of the largest electricity generator or the largest electricity transmission line serving an area, and hence it is important to have alternative resourcing to deal with commensurate disruption. As there is no locational spot price for fuel, an outage of the Refinery to Auckland Pipeline (RAP), or the refinery, or a terminal could result in non-price rationing of fuel, until the outage is fixed or alternative supply routes are put in place (usually involving trucking from other terminals). This is what happened during the 9-day RAP outage in 2017.

5.6. A national infrastructure system largely dependent on energy resilience

The National Lifelines Council notes the importance of electricity from an interdependency perspective.[130] Its importance spans across fuels, telecommunications, and water infrastructure. As the providers of those services generally have insufficient battery and backup generation in major population centres the resilience of the electricity generation, transmission, and distribution system is a key focus for the Council.

There has been concern in some quarters around the resilience of the electricity system regarding dry year risk if/when the Huntly power station closes, however the SRC and industry participants monitor

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[127] "Risk Management Review - NZ Gas Pipeline Businesses." Commerce Commission, October 4, 2019, ii. https://comcom.govt.nz/__data/assets/pdf_file/0020/180461/Review-of-gas-pipeline-businesses-asset-management-plans-AECOM-report-4-October-2019.PDF.
[128] "New Zealand's Legislation on Oil Security." IEA. Accessed December 16, 2020. https://www.iea.org/articles/new-zealand-s-legislation-on-oil-security. y
[129] "New Zealand's Participation in the International Energy Programme." Ministry of Business, Innovation and Employment. Accessed December 15, 2020. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/international-engagement-on-energy/new-zealands-participation-in-the-international-energy-programme/.
[130] National Lifelines New Zealand Infrastructure Vulnerability Assessment 2020

these risks 10 years ahead, taking into account committed and likely new sources of generation, providing plenty of time to react if material problems are likely to occur.[131]

The Government's aim to achieve 100% renewable electricity by 2030 in a normal hydrological year may increase dry year risks if the additional renewable generation crowds out operating time for existing gas or coal fired hydro-firming generation or undermines the commercial viability of building additional hydro-firming sources of energy. The prospect that the Government may provide hydro-firming through a large pumped hydro storage scheme at Lake Onslow could feasibly increase dry year risks in the interim if it stalls private sector investment in other forms of hydro-firming generation.

Resilience from a transmission and distribution perspective is also clearly crucial. Both EDBs and Transpower have targets set by the Commerce Commission relating to maximum duration and frequency of outages, embedding resilience in the performance of the businesses. Security standards are published and are higher for more critical assets, such as those serving large demand centres. Interruptions occur, as the systems are not designed (and therefore customers are not paying) for absolute supply security. However, the Lifelines Council does raise concerns given the ubiquity of electricity and its uses.

5.7. Major asset risk

The HVDC link across the Cook Strait is often thought of as a single connection between the North and South islands, but in practice it comprises of three undersea cables with connection points at Benmore and Haywards, built to stringent earthquake standards. The HVDC normally provides the North Island with enough electricity to serve between 15-30% of the North Island demand. Whilst both islands have sufficient capacity to meet demand, this can sometimes be stressed during peak demand periods and extreme dry year events.

Across major industrial users, the Lifelines Council notes the Marsden Point refinery and onshore gas fields in the Taranaki are unable to operate without a grid connection potentially limiting fuel supply.[132] For households and residential consumption there are major lines that tens of thousands of customers depend on. These issues are well known and well managed by Transpower and distribution businesses, with transmission to major population centres such as Auckland comprising far greater redundancy to cope with transmission outages than smaller centres.

Significant and ongoing earthquake strengthening of key transmission assets has occurred over the years. Along with other major infrastructure, these assets were tested during the 2016 Kaikōura earthquake. Unlike the road and rail links, Transpower's assets performed well with no major damage to them and distribution restored roughly 12-hours after the earthquake following minor line damage.[133] MainPower, the local EDB had been running a significant network reinforcement program resulting in reliable performance.

Following the Christchurch earthquake, these issues are well known and monitored by Transpower and EDBs. Although there is a major risk of the potential rupture of the Alpine Fault and a major Wellington earthquake, extra resilience is being built into the Wellington network by the local distributor.

[131] "2020 Annual Assessment of Security of Supply." Security and Reliability Council, May 12, 2020. https://www.ea.govt.nz/assets/dms-assets/26/26994SRC11-SO-Annual-Assessment-of-Security-of-Supply-Appendix-Combined.pdf.
[132] "New Zealand Critical Lifelines Infrastructure - National Vulnerability Assessment." New Zealand Critical Lifelines, Civil Defence, 18.
[133] Liu *et al*. "Impact of the Kaikōura Earthquake on the Electrical Power System Infrastructure." *Bulletin of the New Zealand Society for Earthquake Engineering* 50, no. 2 (June 1, 2017): 300–305.
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New Zealand is required to maintain oil stocks of more than 90-days of net oil imports in accordance with an International Energy Treaty. The treaty was established following the oil shocks of 1974. In 2018, New Zealand's average oil stocks were 92.4 days.[134] This is a combination of physical stocks within New Zealand as well as stock tickets, essentially a contract where New Zealand pays an oil company in another country to maintain an oil stock on our behalf.

The Lifelines Council raises concern around the resilience of New Zealand's national fuel supply chain given the importance of Marsden Point and the corresponding facilities. Given that all fuel is ultimately imported, any infrastructure disruption is ultimately a distribution constraint rather than a supply shortage. If Refining NZ were to end operations, refined product imports would rise from 58% of petrol and 67% of diesel to 100% of demand. However, supply security would not necessarily be adversely affected as the refinery itself is not critical.[135]

However, the import jetty and tanks feeding the RAP and the Wiri terminal are important for supplying Auckland generally, and are critical for international travel as they are a single point of failure risk for providing jet fuel to Auckland Airport.

Another common concern is the climate related impact on hydro-storage, particularly centred around rainfall and corresponding dry year risks. However, the climate modelling results examined by the SRC led it to conclude the likelihood of dry year risk would actually decrease as a consequence of greater average rainfall in South Island hydro catchments offsetting the impact of lower average rainfall in the small North Island hydro catchments.[136] The main issue for the South Island hydro system is managing greater within-season volatility of inflows.

[134] "Energy in New Zealand 2019." Ministry of Business, Innovation and Employment.
[135] "Key Facts." Refining NZ. Accessed December 16, 2020. https://www.refiningnz.com/media/key-facts/.
[136] "New Zealand's Action on Climate Change." Ministry of the Environment , September 2016, 1. https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/nz%27s-action-climate-change.pdf.

6. How is the sector responding to what might come next?

Pēhea ai te rāngai e urupare ai ki ngā taero o anamata?

6.1. The sector is in a strong position today to deliver in the short-term

The evolution and history of retail electricity prices in New Zealand highlight a more complicated story than simply the wholesale price history. When significant investment was made in New Zealand hydrogeneration and transmission under the New Zealand Electricity Department, the cost of capital was greatly understated, effectively providing a taxpayer subsidy for electricity. Moreover, residential prices were kept artificially low because electricity supply authorities (**ESAs**), governed by elected boards or local authorities, cross-subsidised retail charges with high charges for commercial consumers, and like their generation and transmission siblings, they also greatly understated their cost of capital. The removal of all of these subsidies and cross-subsidies over a 30-year period led to a period of relatively fast growth in residential electricity prices that ceased around five years ago.[137] In the context of the OECD, this has seen our ranking move from some of the cheapest electricity in the world to now being 11th out of 37 countries, or just in the top performing third of OECD countries.

Fast-forwarding to today, the Electricity Price Review is an important and recent study of New Zealand's electricity market. The review highlighted New Zealand's globally competitive position in relation to the price of electricity and that the electricity market was working well in many respects. To this end, there are no major and obvious malfunctioning components that present as quick and easy fixes across the electricity sector.

However, concern about affordability prevails – energy is essential for all New Zealanders. Affordability in this context essentially boils down to price and poverty. The Electricity Price Review noted that those suffering energy poverty were not unique from low socio-economic groups suffering poorer health outcomes, housing poverty, and other lower-income related issues, emphasising the poverty dimension over energy prices.[138] Nevertheless, it recognised that lower prices for poorer and poorly informed consumers, and fairer use of late payment penalties, would assist with reducing energy poverty and it recommended several initiatives to address these issues. As mentioned earlier, similar concerns about the pump-price of diesel and petrol led to a Commerce Commission investigation and resulted in the Fuel Industry Act 2020, which is expected to improve competition and reduce prices paid by consumers.

These recent reviews across the sector highlight broad sensitivity to price and the subsequent social implications. External assessments against the energy trilemma, however, score New Zealand as more balanced across price, sustainability and security than most other countries.

[137] "Analysis of Historical Electricity Industry Costs." Electricity Authority, January 21, 2014, 7. https://www.ea.govt.nz/assets/dms-assets/16/16624Analysis-of-historical-electricity-industry-costs-final-published-Jan2014.pdf.

[138] "Electricity Price Review." Ministry of Business, Innovation and Employment.

Against this backdrop, was the shadow of the announced potential exit of the Tiwai Point aluminium smelter, although a deal has since been reached which will see the smelter remain open until at least 2024.[139] Movement in the forward futures market highlighted the uncertainty that had overshadowed investment decisions in the market for a number of years.[140]

Energy security remains a perpetual challenge in a changing society. The issue has several facets but broadly revolves around oil resilience and security of electricity supply. Today the most pressing issue is the critical reliance on Marsden Point's fuel distribution system into Auckland. As the Refinery to Auckland Pipeline (RAP) failure highlighted there is little redundancy in the system. If there was a significant failure, New Zealand would need to import refined fuels directly, which MBIE has advised can be sourced from numerous refineries at reasonably short notice and existing oil stocks could be drawn down in the meantime. There is similar reliance on natural gas transmission and some parts of the electricity system. Mass electrification of transport is likely to resolve this over time, however the timeframe for mass electrification will likely stretch over decades.

6.2. Looking to the future

The future needs of the sector are embodied in tomorrow's trilemma – what balance between equity (prices), sustainability, and security is right for New Zealand. The most significant force in shaping the trilemma of tomorrow is climate change and the impact this has on the sustainability dimension.

Through the Climate Change Response (Zero Carbon) Amendment Act 2019, New Zealand has set a carbon neutral target for 2050 – excluding biogenic methane. This commitment will contribute to the global effort under the Paris Agreement in limiting global average temperature increases to 1.5°C.[141]

To meet climate change commitments New Zealand's electricity demand as a percentage of total energy demand could move to an estimated 60% from 25% today.[142] Mass electrification as a driver of decarbonisation could result in an estimated 68% increase in annual electricity consumption by 2050 – shown in Figure 17 below – which amounts to a 1.73% constant average growth rate over the next 30 years. This is a considerably faster growth rate than the 1.30% constant average growth rate in electricity consumption over the last 30 years, and the 0.15% growth rate over the last 10 years.

[139] RNZ. "Tiwai Point aluminium smelter to keep operating until end of 2024." RNZ, January 14, 2021. https://www.rnz.co.nz/news/national/434490/tiwai-point-aluminium-smelter-to-keep-operating-until-end-of-2024
[140] "EMI (market Statistics and Tools)." Electricity Authority.
[141] Climate Change Response (Zero Carbon) Amendment Act, 2019, s 5w.
[142] "Whakamana I Te Mauri Hiko - Empowering Our Energy Future." Transpower, March 2020, 9. https://www.transpower.co.nz/sites/default/files/publications/resources/TP%20Whakamana%20i%20Te%20Mauri%20Hiko.pdf
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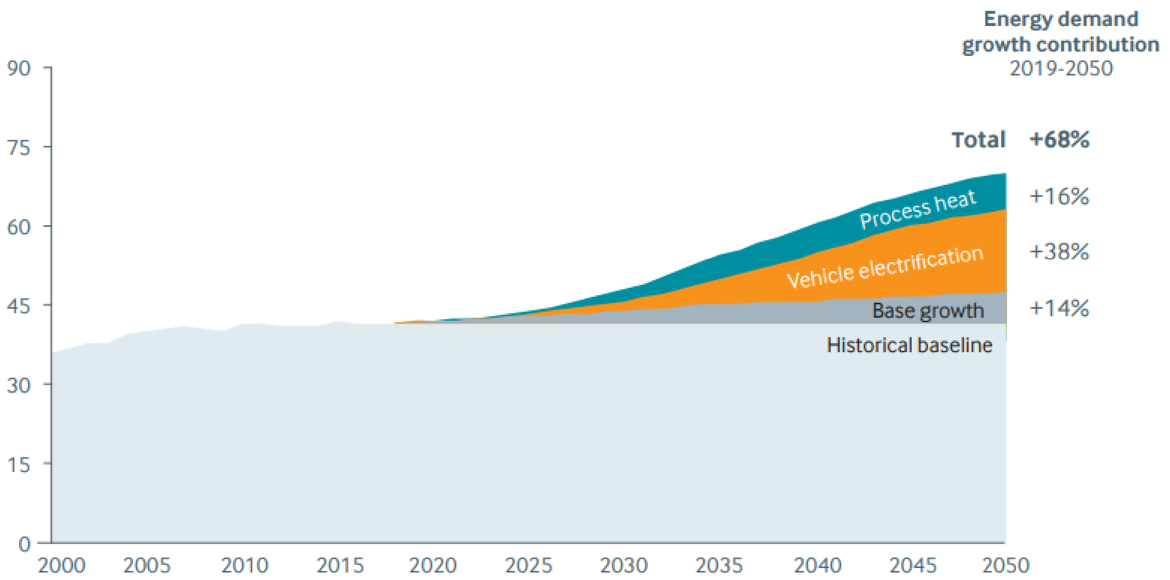
Figure 17: Projected electricity demand growth to 2050

(TWh, Accelerated Electrification)



Source: Transpower: Whakamana i Te Mauri Hiko

As wind and solar are intermittent sources of generation, generation capacity (including batteries) is estimated to need to increase by 169% over that period to supply the 68% increase in electrical energy.[143] These estimates reflect Transpower's base case, and other scenarios produce even larger increases in consumption and capacity. This will also be influenced by a growing population, partially offset by greater energy efficiency.

6.3. The future energy supply

Future mass electrification raises issues about the security of electricity supply. In many ways this is a by-product of New Zealand's topography, with New Zealand having modest-sized natural hydro reservoirs distant from large population centres. The global climate crisis has accentuated this, driving a generation mix increasingly towards renewables that do not provide firm and controllable electricity supply and so cannot be relied on to cover dry year episodes. In response the Government has approved funding to investigate possible energy storage solutions at Lake Onslow through a pumped hydro scheme or other options to ensure reliability in a 100% renewable system.[144] This was motivated in part by a report from the Interim Climate Change Committee. The report noted the difficulty in moving New Zealand from 97% renewable generation to 100% as potentially very expensive and suggests a 15% price increase for residential user and 40% for industrial users. Pumped hydro was noted as the most promising technology in bridging this final 3%,[145] but at significant cost of abatement of the equivalent of ~$250/t. [146] Pumped hydro storage at Lake Onslow could provide

[143] Ibid, 33.

[144] Ministry of Business, Innovation and Employment. "NZ Battery," Ministry of Business, Innovation and Employment. August 20, 2020. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/nz-battery/.

[145] "Independent Climate Change Committee Calls for Accelerated Electrification." Ministry for the Environment. Accessed August 2020, 3. https://www.iccc.mfe.govt.nz/assets/PDF_Library/1bdb69084c/Interim-Climate-Change-Commitee-Accelerated-electrification-MEDIA-STATEMENT.pdf.

[146] Caruso *et al.* "Modelling Climate Change Impacts on Hydropower Lake Inflows and Braided Rivers in a Mountain Basin." *Hydrological Sciences Journal* 62, no. 6 (April 26, 2017): 19.

5,000-12,000GWh, largely solving the dry year issue that would be created if the electricity sector became 100% renewable.

6.4. Demand response and distributed energy resources

In addition to the focus on having adequate energy supply for dry winters, mass electrification leads to higher daily peak demand which requires additional transmission and distribution capacity, costing about $1.5 billion per GW, and additional peaking generation. [147] However, Transpower's March 2020 analysis of mass electrification has peak demand increasing by 3.6 GW or 40% by 2050 in their base case scenario despite annual electricity consumption increasing by 68% over that period.[148] The weaker rise in peak demand reflects their analysis that distributed energy resources (**DER**) will be far cheaper and more prevalent by 2035, allowing substantial demand response (**DR**) through 2.1 million smart appliances and 1.4 million smart charging EVs.[149] Large scale batteries also contribute. By 2050, Transpower's base case has total battery capacity reaching 3,200 MW (from 100 MW currently).[150] Whether DER and DR will flourish to this extent depends in part on whether the Onslow scheme is expected to be built and how it is expected to be used to smooth daily peaks and troughs in spot market prices.

As indicated above, the benefits of DER come from multiple sources (reducing transmission, distribution and generation costs). This raises issues about whether investment and funding of DER will be adequate to meet future challenges. A key requirement is to have cost-reflective pricing occur in all parts of the electricity supply chain, so that the full benefits of DER flow through to the DER provider. This has been a key focus of the Electricity Authority over the last five years as cost-reflective pricing is essential for investors to make efficient investment decisions, by appropriately trading off the cost of DER with the cost savings they can deliver to the supply chain. Easy connection to distribution networks, and a level playing field for providing network support services to distributors, will also facilitate efficient investment in DER. Further changes in retail and wholesale market rules may also be needed to reduce barriers to aggregators of DR services.

6.5. Getting the policy settings right

Achieving the additional generation can be done in several different ways with varying levels of intervention. It is important in finding a balance in getting the trajectory correct: leveraging renewable resources should reduce energy cost if done efficiently, the use of new technologies should help in optimising how we use infrastructure, and policy can fill gaps where the market may not demonstrate desirable behaviour; for example, in assisting an electrification of process heat and transport. The process by which this is done will fundamentally change New Zealand's energy landscape.

There are several factors likely to weigh heavily on supply-side decision makers. Firstly, market incentives will broadly define what infrastructure is built, when and where. Population growth, likely felt more heavily in the Upper North Island, will put upward pressure on wholesale prices in the region, providing investment signals for new generation as close as economic to the load centres. To adapt to a changing climate, effective pricing of emissions through the Emissions Trading Scheme will be essential to drive new generation in renewable forms, likely in geothermal, wind, and solar in

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[147] "Our Strategy." Transpower. Accessed August 2020. https://www.transpower.co.nz/about-us/transmission-tomorrow.
[148] "Our Strategy." Transpower.
[149] Ibid.
[150] "Whakamana I Te Mauri Hiko - Empowering Our Energy Future." Transpower, March 2020, 33, Figure 10. https://www.transpower.co.nz/sites/default/files/publications/resources/TP%20Whakamana%20i%20Te%20Mauri%20Hiko.pdf
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combination with large- and small-scale battery storage. This has implications for dry year risk, with the Lake Onslow pumped hydro scheme touted as one possible solution.

Secondly, serious consideration will need to be given to securing the skilled labour force needed to deliver the investments mentioned above. According to Transpower, the sector is struggling to recruit the highly-skilled workers needed for current levels of investments and this problem is likely to worsen over time due to a bulge in retirement over the next 15 years as the electricity industry workforce ages, as well as further growth in investment. Transpower has identified several other factors inhibiting labour supply to the industry, including the decline of vocational training, the weakness of the electricity industry's employment brand relative to other industries, stricter immigration laws and growing international competition for New Zealand-trained workers. On top of this, New Zealand government spending on other infrastructure investment is likely to increase domestic competition for skilled workers.

Thirdly, policy and regulatory settings will have to be congruent with the shifting landscape. This will be challenging given the quantum of technological change and the already complex regulatory settings. Moreover, providing certainty for the exit of industries like oil will be important in defining their roles in the transition. Getting this right is essential in ensuring our energy infrastructure delivers what New Zealand needs in the future.

In many ways this highlights an opportunity in the ETS. Long-term uncertainty around the price of carbon could distort future investment decisions. If there was a transparent method by which carbon was allocated and this was then crystallised into a liquid and tradable market where carbon futures would provide implied price transparency, one could expect better decision making around generation investment, as well as consumption in areas like transport.

Ultimately, the sector is at the precipice of a major transition. It is critically important that the settings are correct for the sector to transition in a desirable way and that the sector we are left with is well positioned to deliver future needs – an optimal balance of the trilemma.

6.6. Major opportunities for decarbonisation

Transport is at the nexus of the sustainability dimension of New Zealand's trilemma. Transport emissions accounted for 19% of total emissions, with road transportation roughly two-thirds of this.[151] The issue centres around the timing of the transition. The Ministry for the Environment (MfE), through analysis of marginal abatement costs estimates that electrification of light and medium road vehicles would deliver material emission savings, but that heavy transport (road, marine, and aviation) will result in material cost if they were electrified today.[152] Moving to 2030, it is likely that even heavy trucks will be cost-effective to be electrified, but long-haul aviation and shipping may require other low carbon solutions. This highlights the importance of timing and ensuring the transition is optimised under consideration for the trilemma. The confluence of transport and energy is inevitable and will be a defining characteristic of success going forward. The challenge is optimising the transition when factoring in forces like technology and climate change.

Process heat is another key opportunity for decarbonisation. The Ministry of Business Innovation and Employment (MBIE) is working with the Energy Efficiency and Conservation Authority (EECA) to improve process heat efficiency and explore opportunities to reduce its ~11% contribution to New

[151] "Marginal Abatement Cost Curves Analysis for New Zealand." Ministry for the Environment, January 2020, 40. https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/marginal-abatement-cost-curves-analysis_0.pdf.
[152] Modelling done over a 10-year period

Zealand's gross greenhouse gas emissions.[153] The technical report presents several opportunities for reducing the emissions of process heat by improving energy efficiency, electrification, and the use of woody biomass.[154] This will ask different questions of energy infrastructure and it will have to respond in enabling the renewable shift.

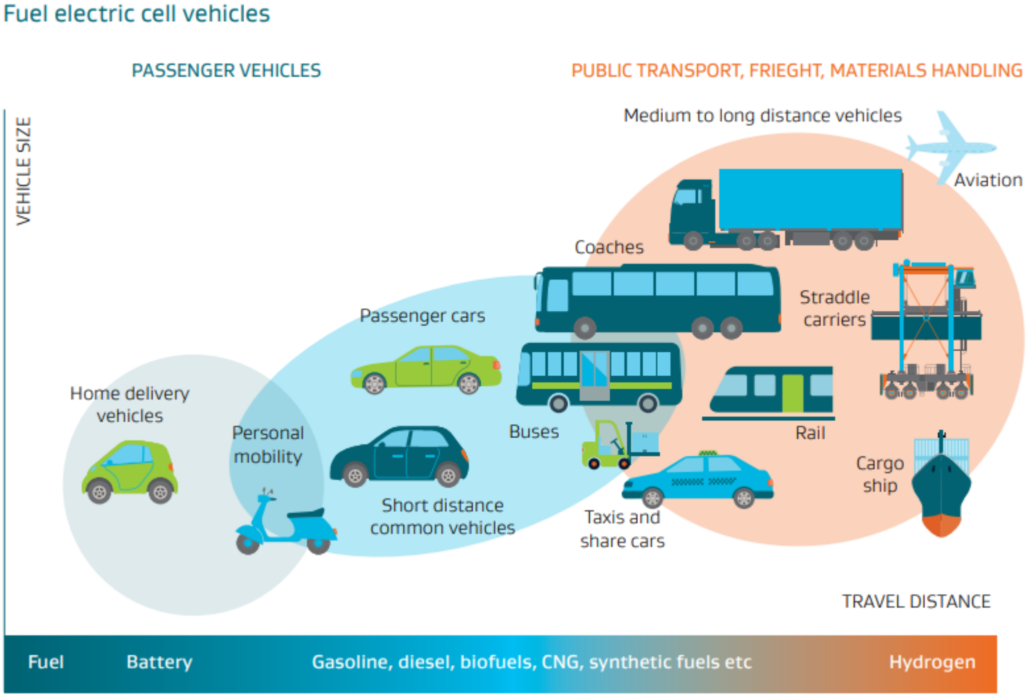
Mass electrification and its impact on the trilemma extends further than transport and process heat. Hedonic pricing elements of the future trilemma are likely to be crucial in defining a desirable energy future – to what extent are the users of infrastructure prepared to pay for sustainability and resilience. Again, the pathway is important. Sudden mass electrification will likely result in a sub-optimal trade-off in comparison to timely electrification. Technology is inevitably a major force in the hedonic model. An example of this is Swanson's Law, an observation that the price of photovoltaic cells (solar panels) drops roughly 75% each decade,[155] not dissimilar to Moore's Law. Again, the timing of electrification is an important factor, as Swanson's Law predicts, whilst making investment in solar is becoming increasingly economic, there is a counterbalancing incentive to wait for the technology to improve and cost to decrease. This can be observed broadly across the sector with improving technologies in battery storage and electric vehicles other clear examples. There may be a role for policy to accelerate a desired transition that might otherwise take longer due to these considerations.

The ubiquity of technology's influence on the sector extends to fuels. Momentum for the use of hydrogen as a fuel has increased in recent years. In 2019, MBIE released a green paper "A vision for hydrogen" in New Zealand, providing a broad vision scoping the potential of hydrogen as a cog in the energy sector – with various uses shown in Figure 18 below.[156] The report notes the potential applications of hydrogen as a fuel are vast, including seasonal electricity storage, decentralised generation, process heat, and transport. Furthermore, the report identified green hydrogen, hydrogen generated by the electrolysis of water using 100% renewable energy, as the greatest opportunity for domestic use and potential export. Combining this with the Ministry for the Environment's work on marginal cost abatement, the analysis noted a potential role for hydrogen in the economy. However,

[153] "Process Heat – Overview." Ministry of Business, Innovation and Employment. August 2020, 2. https://www.mbie.govt.nz/assets/8c89799b73/process-heat-current-state-fact-sheet.pdf.
[154] "Process Heat in New Zealand: Opportunities and Barriers to Lowering Emissions." Ministry of Business, Innovation and Employment, January 2019. https://www.mbie.govt.nz/dmsdocument/4292-process-heat-in-new-zealand-opportunities-and-barriers-to-lowering-emissions.
[155] Richard Swanson "A Vision for Crystalline Silicon Photovoltaics." *Progress in Photovoltaics: Research and Applications* 14, no. 5 (August 2006): 443–53.
[156] "A Vision for Hydrogen in New Zealand." Ministry of Business, Innovation and Employment, September 2019, 1-89. https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper.

electricity and biofuels were more appealing as 'green' alternatives from an abatement perspective across a number of transport modes.

Figure 18: Potential fuel by use type



Source: MBIE

Technology will also fundamentally alter what is needed from transmission infrastructure. Distributed generation (generally photovoltaics) combined with battery storage has the potential to reduce the importance of a grid built for peak demand. Combined with more effective demand-side management like smart-chargers and battery storage enabling load-shifting and peak-shaving, the maximum demand for which the grid is built for can be managed more efficiently. This results in a long-term investment signal cautioning against overbuilding in the long-term, to avoid stranded asset risk.

Whilst the impacts of climate change are most acutely mitigation based (i.e., the role of the energy sector in reducing emissions), adaptation will also be an issue. The rise of sea level and extreme weather will impact infrastructure. It is essential that New Zealand's future energy infrastructure is able to withstand the growing demands placed on it by a changing climate.

7. Appendix one: Process, assumptions and limitations

Āpitihanga Tuatahi: Te tukanga, ngā whakapae, me ngā herenga

7.1. Our process

This State of Play was developed between July and December 2020 drawing on publicly available information. Key data sources include:

- MBIE: Energy in New Zealand 2020, Energy in New Zealand 2019;
- MBIE: Electricity Price Review;
- Transpower: Whakamana i Te Mauri Hiko;
- Electricity Authority: EMI (market statistics and tools);
- New Zealand Critical Lifelines Infrastructure National Vulnerability Assessment;
- World Energy Council: Energy Trilemma Index;

A full list of all literature cited can be found in the reference list (Appendix three).

Findings were cross-checked against the results of a survey of infrastructure asset owners, carried out by Mobius Research and Strategy Limited on behalf of Te Waihanga between September and October 2020, which asked about the issues, risks, and opportunities as perceived by asset owners across the sector.

On completion of the initial draft, we also met with individuals from a range of organisations across the sector to get their views on a high-level summary of our findings, and to understand their thoughts on current challenges. A draft of the complete report was peer reviewed by Te Waihanga's Board and by a sector expert.

7.2. Limitations

While every effort is made to ensure the accuracy of the information contained herein, Te Waihanga, its officers, employees and agents accept no liability for any errors or omissions or any opinion expressed, and no responsibility is accepted with respect to the standing of any firms, companies or individuals mentioned. Te Waihanga reserves the right to reuse any general market information contained in its reports.

8. Conclusion

Whakatepenga

Ultimately, the essence of New Zealand's energy future and the infrastructure we build or choose not to build is captured in the trilemma of tomorrow. These trade-offs were captured in the Business Energy Council's 2050 Energy Scenarios.[157] Two future scenarios were modelled, one representing a market driven sector where businesses and consumers make decisions based on their own interest and a government led sector where, due to heightened environmental awareness decisions are made for the collective greater good. In the first scenario, the result is energy equity prioritisation over security and the environment. In the second, sustainability is prioritised over security and equity. Although these are presented as two simplified outcomes of a possible energy future, they highlight the importance of the trilemma of tomorrow. The desired end state is an optimised balance across the trilemma. However, most important is the pathway to this desired state – the more efficiently New Zealand can do this, the more benefit realised by all.

[157] "New Zealand Energy Scenarios." Business Energy Council. Accessed August 2020. https://www.bec.org.nz/our-work/scenarios/bec2050/new-zealand-energy-scenarios.

9. Appendix two: Glossary

Āpitihanga Tuarua: Kuputaka

OECD: Organisation for Economic Co-operation and Development

ECNZ: Electricity Corporation of New Zealand

SOE: State-Owned Enterprise

EDB: Electricity Distribution Business

DPP: Dynamic Price Path

CPP: Customised Price Path

IEA: International Energy Agency

MW: Megawatts

MWh: Megawatt-hour

GW: Gigawatts

GWh: Gigawatt-hour

KW: Kilowatt

KWh: Kilowatt-hour

ICP: Installation Control Point

EPR: Electricity Price Review

LRMC: Long-Run Marginal Cost

NZX: New Zealand Exchange

ASX: Australian Stock Exchange

HHI: Herfindahl-Hirschman Index

PPA: Power Purchase Agreement

HVDC: High Voltage Direct Current

RAP: Refinery Auckland Pipeline

MBIE: Ministry of Business Innovation and Employment

MoT: Ministry of Transport

MfE: Ministry for the Environment

NZTA: New Zealand Transport Agency

NCG: Natural Gas Corporation

BP: British Petroleum

NCCRA: National Climate Change Risk Assessment

EA: Electricity Authority

ESA: Electricity Supply Authority

RAB: Regulated Asset Base

WACC: Weighted Average Cost of Capital

GIC: Gas Industry Company

ETS: Emissions Trading Scheme

TPM: Transmission Pricing Methodology

GHG: Greenhouse Gas

EECA: Energy Efficiency and Conservation Authority

DER: Distributed Energy Resource

DR: Demand Response

RCPD: Regional Coincident Peak Demand charge

EV: Electric Vehicle

10. Appendix three: References

Āpitihanga Tuatoru: Ngā tohutoro

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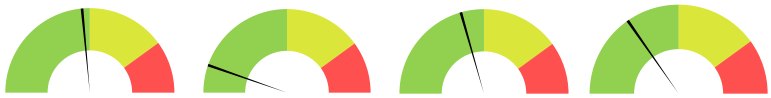
11. Appendix four: Quality of Electricity Distribution Assets

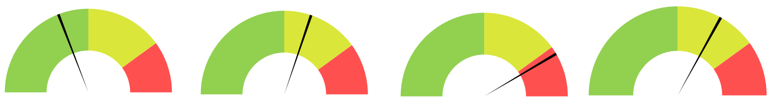
Āpitihanga Tuawhā: Te kounga o ngā Rawa Whakarato Hiko



Estimated state of the assets

	Distribution & LV O/H lines	Distribution & LV U/G cables	Subtransmission lines and cables	Poles
Quantity	98,549km	44,096km	11,640km	1,360,973
RAB Value	$2,446.2m	$2,781.1m	$1,318.7m	*
Average grade (H1-H5)	3.73	4.28	3.87	4.14
Grade 1 / 2	3.8% / 7.7%	0.2% / 3.5%	2.7% / 6.2%	1.4% / 3.1%
Unknown grade	2.9%	1.9%	2.4%	1.6%
Average age	38 years	26 years	36 years	33 years
Over generic age	8,931km (9.1%)	555km (1.3%)	1,294 km (11.1%)	166,176 (12.2%)
Unknown age	0.9%	0.9%	1.6%	2.7%
5yr replacement req (est)	7.7%	2.0%	5.8%	3.0%
5yr planned replacement	4.8%	1.3%	4.9%	5.3%
Forecast repex (ave)	$175.0m +3%	$53.5m +69%	$36.3m +32%	*
Repex series				*

Switchgear and transformers



Estimated state of the assets

	Distribution transformers	Distribution switchgear	Zone-substation transformers	Zone-substation switchgear
Quantity	189,189	216,786	1,280	12,202
RAB Value	$1,518.2m	$893.0m		<----- $1,446

				.7m --- -->	
Average grade (H1-H5)	4.06	3.96	3.87		3.83
Grade 1 / 2	1.6% / 3.8%	2.9% / 4.3%	2.8% / 7.4%		3.7% / 5.2%
Unknown grade	1.8%	3.6%	0.0%		0.1%
Average age	24 years	22 years	31 years		23 years
Over generic age	30,620 (16.2%)	55,048 (25.4%)	554 (43.3 %)		3,538 (29.0%)
Unknown age	0.4%	3.3%	0.2%		1.0%
5yr replacement req (est)	3.5%	5.1%	6.5%		6.3%
5yr planned replacement	4.6%	7.6%	6.5%		11.7%
Forecast repex (ave)	$36.7m -18%	$54.9m +34%		$72.6 m +35%	
Repex series