BEFORE THE HEARING COMMISSIONERS APPOINTED BY OTAGO REGIONAL COUNCIL

Under	the Resource Management Act 1991
In the matter	of the proposed Otago Regional Policy Statement 2021 (excluding provisions renotified as part of a freshwater planning instrument)

STATEMENT OF EVIDENCE OF DAVID THOMAS HUNT (ECONOMICS) ON BEHALF OF CONTACT ENERGY LIMITED

23 November 2022

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1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is **David Thomas Hunt**.

1.2 I am a Director of Concept Consulting Group Ltd (**Concept**) which is a specialist energy and economics consultancy providing services to clients in New Zealand, Australia and the wider Asia Pacific region. I have been a Director of Concept since joining the firm in 2006.

1.3 In my role, I undertake a range of consulting assignments for government agencies and companies in the energy and utilities sectors with a strong emphasis on economic analysis.

1.4 For the last 25 years, my career has been energy focussed. By way of an overview:

(a) Between 1986 and 1996, I held a number of government roles including Manager, Energy Policy at the Treasury and Economic Advisor to the Minister of Finance. I provided advice on a wide range of energy policy issues including market design, competition issues, and structural reform.

(b) Between 1996 and 2005 I held various roles at Contact Energy Limited (**Contact**) in the finance, business development and strategy areas.

(c) In 2005, I was appointed Executive General Manager of Corporate Development at Origin Energy based in Sydney. At that time, Origin was a large producer of oil, gas and LPG, had a sizeable electricity generation portfolio, and was a retailer of gas, LPG and power. During my time at Origin, I oversaw a number of strategic initiatives, including analysis regarding potential expansion of Origin's LPG retail business.

(d) Between 2005 and 2006, I was Chief Executive at Contact. That was the last management role I held before joining Concept.

(e) At a governance level, I have served as a Director of Synergy, the largest electricity generator and retailer in Western Australia, and I am currently a board member of the Accident Compensation Corporation.

1.5 I have a BA Hons (First Class) in economics and a BA in statistics.

2. CODE OF CONDUCT

2.1 I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in my brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

3. SCOPE OF EVIDENCE

3.1 In preparing my evidence I have reviewed at a high level the relevant provisions of:

(a) the proposed Otago Regional Policy Statement (**proposed RPS**);

(b) Contact's submissions and further submissions; and

(c) the Otago Regional Council's (**Regional Council**'s) section 42A report, including the version showing recommendations from the Regional Council's supplementary evidence and additional supplementary evidence (**section 42A report (October version)**); and

(d) the other statements of evidence prepared on behalf of Contact (including both corporate and expert evidence).

3.2 The purpose of my evidence is to provide an overview of the following matters:

(a) the New Zealand electricity system;

(b) the future of the electricity system and the role that renewable electricity will play;

(c) the benefit of existing and new renewable electricity schemes, including for decarbonisation;

(d) the Clutha Hydro Scheme's contribution to the New Zealand electricity system; and

(e) the economic and decarbonisation benefit of the Clutha Hydro Scheme.

4. EXECUTIVE SUMMARY

Electricity sector overview

4.1 Over half (57%) of New Zealand's electricity demand is currently met by hydro generation. The remaining demand is met by a mixture of thermal and other forms of renewable generation. The electricity system must always be kept in tight balance at all locations on the electricity grid. As demand and intermittent generation (such as wind and solar) constantly fluctuate, flexible generation such as hydro or thermal is important to maintain this balance.

4.2 The electricity industry is entering a period of massive change. Electricity is already important in our daily lives, but it is expected to become even more vital due to New Zealand's decarbonisation goals. Achieving these goals will require electrification of many parts of the economy currently dependent on fossil fuels (such as the use of light vehicles) and a phase down of much or all fossil-fuelled thermal generation. To meet demand growth and phase down fossil-fuelled thermal generation, new renewable generation sources will need to be developed at an unprecedented rate. Much of this new renewable generation will be intermittent generation, with the proportion of intermittent generation expected to increase from around 6% of total electricity supply at present to about 50% in 2050. As a result, the importance of flexible hydro generation (including from the Clutha Hydro Scheme) will grow in the future.

The benefit of existing and new renewable electricity schemes

4.3 There is both economic and decarbonisation benefit from allowing existing renewable generation to continue to operate to its full capability and allowing new renewable generation to be built. The economic and decarbonisation benefit can be considered by looking at the costs (including the emissions impact) that would incur if existing renewable power stations were not allowed to continue operating to their (current) full capacity, or if some otherwise attractive new renewable generation resources were not allowed to be developed.

4.4 I consider that these costs can be grouped into three parts:

(a) Higher electricity-sector costs due to more expensive renewable generation resources needing to be developed. The increase in costs would be particularly large if existing renewable generation needed to be replaced. This is because it is much less costly to run existing plant than build new generation. Restricting the development of otherwise attractive new generation will also raise electricity sector costs. This is because the cost of electricity from different new generation projects varies, and the cheapest generation resources are generally developed first. If these cheaper generation resources can't be developed this will require more expensive renewable generation resources to be developed.

(b) Carbon emissions and electricity costs could increase due to an increased need for fossil-fuelled thermal generation. If the generation capacity of existing renewable generation was reduced with minimal warning or the development of new renewable generation resource was hindered, then more fossil-fuelled thermal generation would likely be required to 'fill the gap' until alternative new renewable generation could be developed. In most cases, fossil-fuelled generation is both more expensive to operate and has higher carbon emissions than renewable electricity resources.

(c) An increase in electricity prices, due to environmental restrictions on renewable generation, is also likely to result in increased 'indirect' emissions for the rest of the economy. This is because electrification has been identified as one of the key means of decarbonising significant parts of our economy and higher electricity prices will tend to discourage energy consumers from moving away from fossil fuels to electricity.

4.5 In the body of my evidence, I set out broad estimates for some of the potential costs described above.

The economic and decarbonisation benefit of the Clutha Hydro Scheme

4.6 The Clutha Hydro Scheme is made up of two power stations on the Clutha River that generate approximately 3,900 GWh of electricity each year. For a sense of scale, this is roughly the same as the total consumption of all South Island residential electricity consumers.[1]

[1] According to Electricity Authority data, total energy consumption for South Island residential consumers was 3,832 GWh in 2021. This excludes transmission and distribution losses conveying the power to customers' homes.

4.7 If the generation from Clutha Hydro Scheme needed to be replaced at short notice, the only viable alternative would be increased thermal generation. I estimate it would cost between $326 million and $625 million per year in the short run to replace Clutha Hydro Scheme using existing thermal generation capacity. This would also increase New Zealand's emissions by between approximately 1.5 million and 3.6 million tonnes of carbon dioxide equivalent per year.

4.8 In the longer run, if the Clutha Hydro Scheme were unavailable, its output could be replaced with new renewable generation. The most likely alternatives are geothermal, solar, or wind generation, or some mix of these. On a dollar per unit of energy basis, they would have lower economic costs than thermal generation, but they would all involve upfront capital expenditure and take some time to build.[2] I estimate this would cost between $3.3 billion and $4.3 billion (in present value terms).

4.9 The Clutha Hydro Scheme also provides some short-term flexibility (intraday and within a week). This means that in the short term it can generate more when electricity is valued more (eg when demand is high in the morning and evening peaks) and less when electricity valued less (eg overnight). I expect the electricity system benefits provided by this short-term flexibility to increase in the future as the proportion of intermittent generation on the system increases substantially.

5. ELECTRICITY SYSTEM OVERVIEW

Summary – electricity system overview

5.1 Regulation of the electricity generation sector is designed to encourage competition. At its centre there is a regulated auction-based spot market in which generators make supply offers every 30 minutes. The generators with the lowest offer prices are selected to satisfy demand in each half hour.

5.2 Spot prices vary depending on the relative balance of electricity supply and demand at different times of the day and year. Prices also vary by location on the national grid (**grid**), reflecting the local supply/demand balance and the extent of network constraints and power losses which occur when electricity is transported on the grid.

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[2] This investment in new generation would also be in addition to the substantial investment in renewable generation required to help New Zealand meet its decarbonisation goals.

5.3 The spot prices generated in the electricity market provide important information about the value of different types of generation, such as whether it has controllable output or not, and where it is located on the grid.

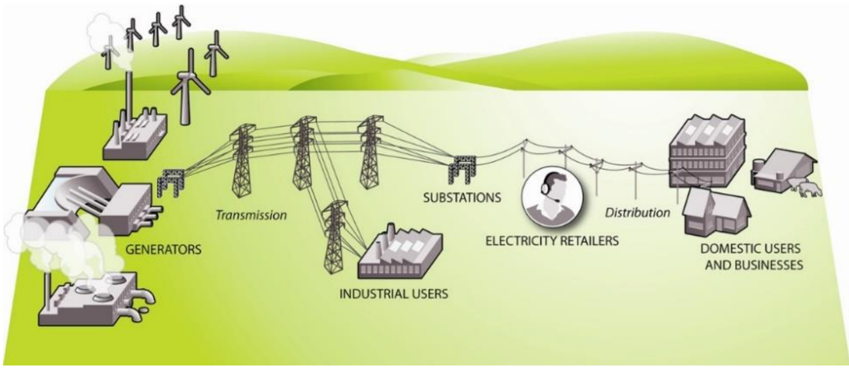
Electricity industry structure

5.4 The electricity supply chain can be divided into four main segments: generation, transmission, distribution, and retail sales. This is shown diagrammatically in Figure 1 below.

5.5 Competition is possible in the generation and retailing segments and regulation of these sectors has been focussed on facilitating competition.

5.6 The transmission and distribution segments are not subject to competition because it is generally uneconomic to replicate electricity networks. These businesses are regulated under Part 4 of the Commerce Act 1986. This provides for price control of their services, except where there is strong alignment of supplier and consumer interest via community ownership of a network.

Figure 1: Overview of electricity industry structure



Source: Ministry of Business, Innovation and Employment

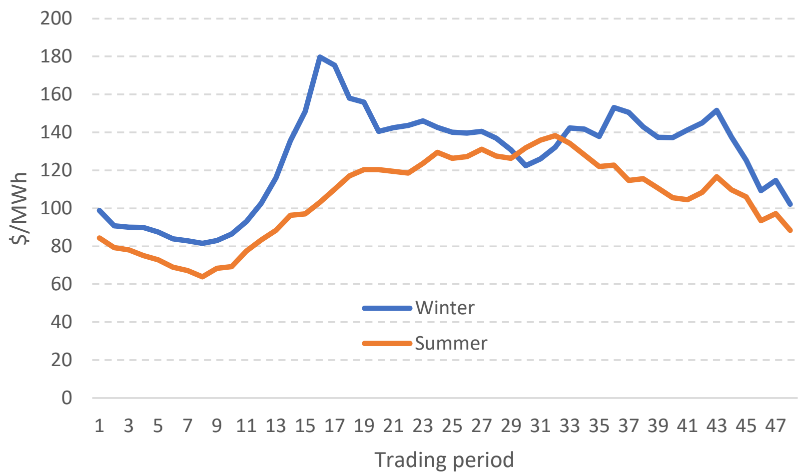
Wholesale electricity market

5.7 The platform that underpins generation sector competition is the wholesale electricity spot market. All generators connected to the grid are required to participate in this market where their electricity is sold in a half-hourly auction process. The cheapest combination of generation offers that will securely meet demand is used to determine which generation will be selected to run in each half hour.

5.8 Supply and demand conditions can vary substantially within a day and across the year. The cost of generating power in peak demand periods is typically much higher than other periods. This leads to relatively predictable variations in spot prices across the year, as shown in Figure 2 below.

5.9 Spot prices will also fluctuate due to unexpected events, such as the early arrival of a cold front which lifts power demand for electric heating, or tighter supply, such as a prolonged calm weather period which reduces wind generation.

Figure 2: Spot prices – illustrative winter day versus summer day



Source: Electricity Authority data

5.10 Because spot prices are higher when the supply/demand balance is tight and vice versa, generators[3] that can control and shift their output are able to earn a premium over those that operate at a constant rate or cannot control their output. The presence of this premium is important to maintain reliable supply because it encourages generators to be available when there is the greatest need for additional supply. I discuss the need for flexible supply in more detail from paragraph 5.14.

Supply and demand must be balanced at all times

5.11 Electricity is unusual because supply and demand must always be kept in a tight balance at all locations on the grid. If this is not achieved, it can lead to widespread blackouts. In particular, if insufficient electricity is supplied to meet demand, the electrical frequency will begin to drop below the normal level of 50 Hertz (and vice versa). Power plants are designed to operate within a fairly narrow frequency range and if the grid frequency moves

[3] Or other types of resources that can improve the supply/demand balance, such as batteries or electricity consumers who can reduce their usage – known as demand response providers. While battery consumers and demand response providers have not provided much flexibility in the New Zealand electricity system to date, it is widely considered that they will provide much more flexibility in the future.

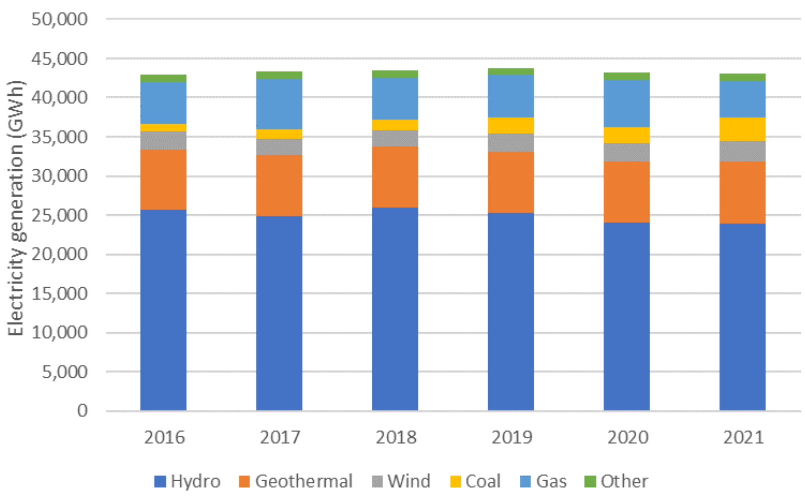
outside this range for too long, the power plant will automatically disconnect from the grid (called a 'trip') to protect itself from damage.

5.12 Ultimately, if too many power plants disconnect due to a frequency disturbance there will be 'sympathetic tripping' by other plant and cascade failure. This can lead to widespread blackouts affecting many customers. For example, over 850,000 customers lost power in Australia in 2016 due to an event of this type. Restoring power after such events can take some time as supply and demand need to be brought back in a way that maintains balance throughout the system.[4] In the Australian event power was restored to some customers within a few hours while for others it took several days.

Current make-up of supply

5.13 Electricity is supplied by a range of generation types as shown in Figure 3 below. During the last five years hydro was responsible for around 57% of electricity generation in New Zealand. The other significant generation types were geothermal (18%), gas (13%), and wind and coal (both 5%).

Figure 3: Historical electricity generation



Source: Energy in New Zealand 2021, MBIE.

Need for flexible supply

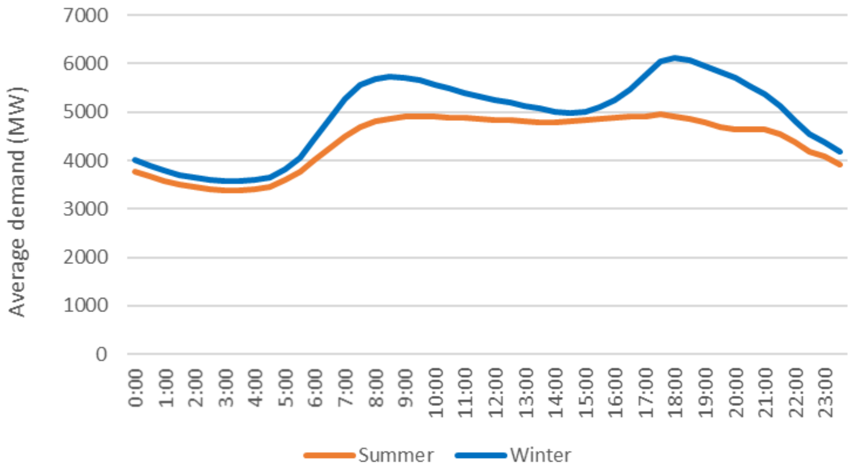
Varying power demand creates a need for flexible supply

5.14 Demand for electricity is not constant through the day or across seasons. Figure 4 below shows grid power demand for a typical summer and winter

[4] See https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

day. The chart shows how demand varies between a minimum level of around 3,400 MW and a peak of 6,100 MW – a variation of over 80% between trough and peak. Another point to note is the steep increase in demand on winter mornings, with a rise of around 50% between 5am and 9am.

Figure 4: Average electricity demand for summer and winter days in 2020



Source: Electricity Authority data.

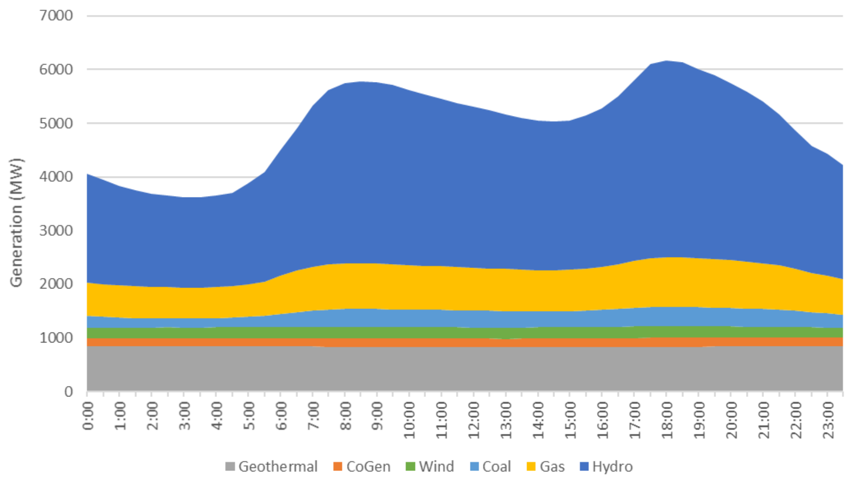
5.15 These sorts of changes in demand mean that the electricity system needs flexible supply sources that can be ramped up or down quickly to ensure that the grid remains balanced.

Uncontrollable generation increases need for other flexible supply

5.16 Some forms of generation cannot be readily controlled – often being referred to as 'intermittent generation' or 'variable renewable generation'. Examples are wind and solar generation, whose power output will vary with prevailing weather and solar conditions. Another intermittent source is 'run-of-river' hydro generation. These are hydro power stations that have little or no access to storage lakes, and hence generate according to natural flows in the river.

5.17 By contrast, hydro stations with sizeable storage reservoirs are an important source of flexible supply. These stations provide much of the short-term flexibility needed to counteract hourly, daily, and seasonal variations in demand and intermittent supply. This is illustrated by Figure 5 below which shows the variation in hydro generation at the national level across a typical winter day, and how this is a major source of flexibility to meet varying levels of demand.

Figure 5: Average generation by generation type for winter 2020



Source: Electricity Authority data.

5.18 However, even hydro stations with storage are exposed to supply fluctuations. This is because they are dependent on rainfall and/or snow melt to fill their storage lakes. Accordingly, after prolonged dry periods storage lakes will be lower, limiting the amount of power that the associated hydro stations can generate.

5.19 Thermal stations (running on diesel, gas and coal) also provide flexibility in the New Zealand electricity system, including during prolonged dry periods. However, as I discuss later, fossil-fuelled thermal generation will have a lesser role in the New Zealand electricity system in the future due to New Zealand's decarbonisation goals.

6. FUTURE OF THE ELECTRICITY SYSTEM

The electricity industry is entering a period of massive change

6.1 Electricity is important in our daily lives. Many of the social and economic benefits we enjoy stem directly from technologies relying on electricity. Looking ahead, electricity is expected to become even more vital as New Zealand moves to decarbonise the economy using renewable generation sources.

6.2 To meet its decarbonisation objectives, New Zealand needs to develop new generation sources at an unprecedented rate (as discussed below). Much of that generation will be from wind and solar power. Although these are very cost competitive, their output is subject to fluctuations due to weather and other factors.

6.3 While batteries are expected to help in smoothing out much of the very short-term fluctuation in supply from these sources, they are not suitable for addressing variations which occur from week to week or longer. Other sources of flexibility will be needed. One of the most important sources is expected to be hydro generation that has access to stored water. This type of generation has the twin benefits of being renewable and controllable – both of which will be increasingly important as New Zealand decarbonises its economy.

New Zealand's decarbonisation goals

New Zealand law requires net zero emissions by 2050

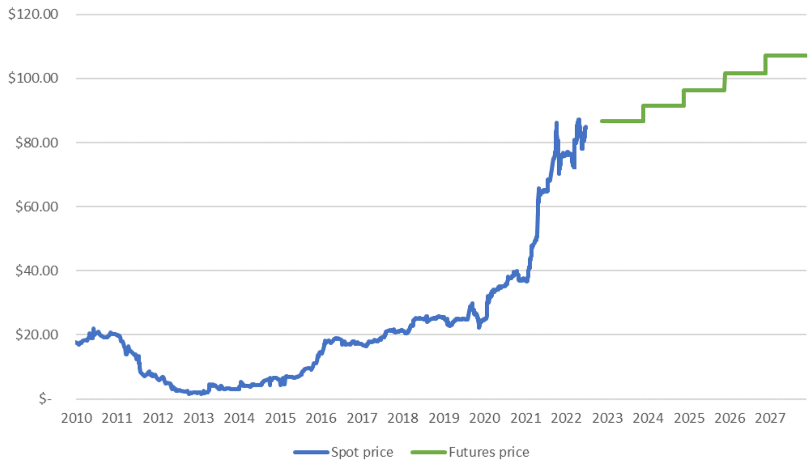
6.4 New Zealand law sets a target for the country to reduce net emissions of greenhouse gases (except biogenic methane) to zero by 2050.[5] The Climate Change Commission was established in 2019[6], which has the role of providing independent expert advice and monitoring to help keep successive governments on track to meet the legislated long-term goals.[7]

6.5 A key instrument for achieving the net emission target is the Emissions Trading Scheme. In essence, this scheme requires greenhouse gas emitters to purchase emission units issued by the New Zealand government to offset their domestic greenhouse gas emissions.[8]

6.6 The market clearing price for emission units in New Zealand is discovered by trading among parties, such as those who need to buy units to acquit their emission liabilities and/or those who generate units. The price of an emission unit has increased substantially in recent years (as shown in Figure 6 below). It is expected to rise even further, as shown by prices of NZU futures for coming years (in green in Figure 6).

[5] Climate Change Response Act 2002, section 5Q.
[6] Climate Change Response Act 2002, section 5A (inserted, on 14 November 2019, by section 8 of the Climate Change Response (Zero Carbon) Amendment Act 2019 (2019 No 61).
[7] Climate Change Commission, 2021 Draft Advice for Consultation, 31 January 2021, p11.
[8] Strictly speaking, the obligation to purchase and surrender units may fall on a party other than the final emitter (eg gas producers rather than consumers). Nonetheless, in such cases, final emitters are likely to bear the cost of acquiring the emission units when they purchase gas from producers.

Figure 6: New Zealand carbon price ($NZ/tonne carbon equivalent)



Source: CommTrade and Carbon News (downloaded 7 November 2022).

100% renewable electricity supply target

6.7 The Government announced an aspirational target to achieve 100% renewable electricity supply by 2030.[9] While not enshrined in legislation, this aspirational target is reflected in various policy documents issued by the Government (including the Emissions Reduction Plan released in May 2022).[10] The target is expected to be reviewed at the 2025 emissions budget.

Decarbonisation is expected to substantially lift electricity demand

6.8 Electricity demand is expected to grow substantially as New Zealand uses more electricity to decarbonise the economy. For example, electricity is expected to largely displace petrol and diesel as an increasing number of electric vehicles take to the country's roads. Likewise, electricity is expected to replace coal and gas for industrial process heat in many applications, and for domestic heating.

6.9 Figure 7 below shows a projection of future electricity demand published in early 2022 by the Market Development Advisory Group (MDAG), a cross-industry body appointed to provide advice to the electricity regulator.[11]

6.10 Clearly, the very long horizon of the projection (to 2050) means that there is some inherent uncertainty. Having said that, projections from other sources such as Transpower and the Climate Change Commission show a broadly

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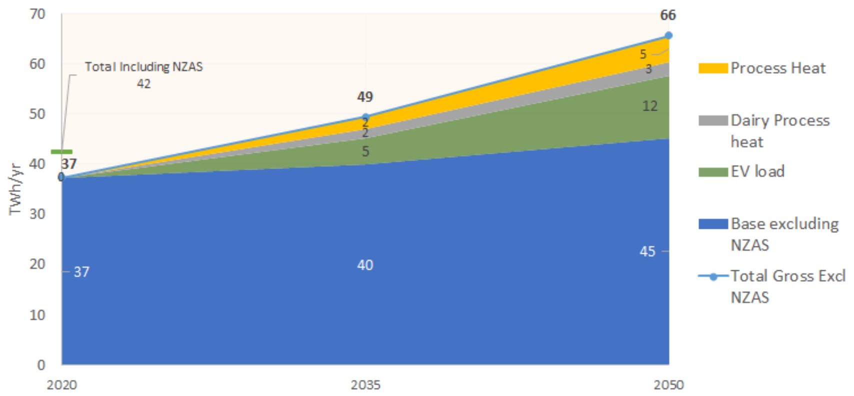
[9] Speech from the throne | Beehive.govt.nz and New Zealand Labour Party Policy, September 2020.
[10] *Aotearoa New Zealand's first emissions reduction plan*, page 220.
[11] The projection was published in an issues paper which can be found at Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz.

similar picture.[12] In particular, while there are some differences in pace and scale of electrification, they all predict significant increases in demand over time as major sectors switch from fossil fuels to electricity.

Figure 7: Projected future electricity demand projection



Source: Market Development Advisory Group (Figure 2, [Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz])

6.11 Key points to note from the projection are:

(a) Demand (excluding for the Tiwai aluminium smelter (discussed further below)) is expected to grow by around 32% by 2035, and a further 35% by 2050. This projection assumed the Tiwai smelter would close after 2024. If the smelter remains in operation (see later discussion from paragraph 6.32), this would lift the 'starting point' level of demand, but is not expected to affect the growth trajectory associated with decarbonisation.

(b) Most of the increase is expected to come from electric vehicles and the increasing use of electricity for process heat in industry, especially food processing.

(c) Base demand is projected to be relatively stable – this is because population and economic growth are expected to be largely offset by rising efficiency of energy use (for example through greater insulation of homes).

Substantial growth in renewable electricity supply will be required

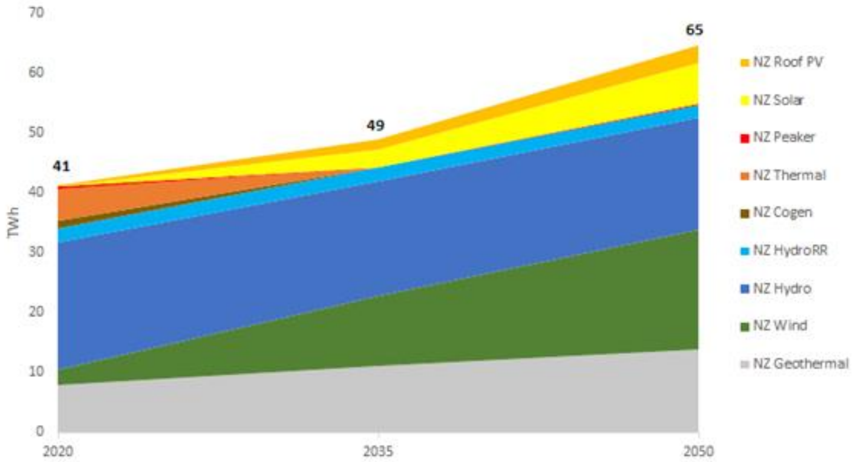
6.12 Very large increases in renewable generation will be required to provide the electricity to meet New Zealand's decarbonisation goals. Some of the new generation will be needed to displace existing thermal generation and

[12] See Whakamana i te Mauri Hiko data report figures | Transpower.co.nz and Electricity market modelling datasets 2021 final advice | Climatecommission.govt.nz.

directly reduce electricity sector emissions, but ultimately an even greater volume will be needed for electric vehicles and electricity for process heat to decarbonise other parts of the economy.

6.13 Figure 8 below shows a recent projection of the potential sources of future supply generation. As with projected demand, given the long horizon there is some inherent uncertainty about the precise mix of sources. Nonetheless, the projection is mainstream and other sources paint a similar picture for new supply.

Figure 8: Projected future electricity supply



Source: Market Development Advisory Group (Figure 3, Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz)

6.14 Key points to note from the projection are:

(a) Geothermal power is expected to grow over time – reflecting its position as a proven technology with competitive costs. However, its growth is limited by the availability of sites with access to the underlying energy source.

(b) A much larger contribution to new supply is expected to come from wind and solar generation. These have become much more competitive over time with improving technology, and further gains are expected.

(c) In aggregate, the proportion of electricity generated from intermittent sources (solar and wind) is expected to increase from 6% in 2020 to around 50% by 2050. As discussed below from paragraph 6.18, this change has significant implications for the role of flexible hydro generation.

6.15 Achieving New Zealand's decarbonisation goals will require the development of generation at a pace that is unprecedented. We estimate that it will require the development of around 1,100 GWh of new renewable generation capability on average every year until 2050.[13] This pace of development is more than three times the rate achieved in the 30 years up to 2020.

6.16 To provide a sense of scale, it is roughly equivalent to adding a new set of Clyde and Roxburgh hydro stations to the electricity system every 3.5 years until 2050.

6.17 These projections assume that all existing renewable stations will retain their current generation capabilities after their current resource consents expire. However, if the operating capabilities of existing renewable stations are reduced during future reconsenting processes, the required future scale-up in renewable development would be even greater than this. The required generation projections are also dependent on demand growth assumptions. If demand is higher than anticipated (eg if a hydrogen or other so-called 'power-to-X' economy evolves) then additional generation will be required.

Increased need for flexible supply

6.18 As I noted in paragraphs 5.14 - 5.19, the electricity system needs flexible electricity supply that can be ramped up or down quickly to ensure the grid remains balanced at every instant in time. This need for flexible supply will increase in the future due to a substantial increase in the proportion (from 6% in 2020 to approximately 50% in 2050) of electricity generated by wind and solar, which can only generate when the wind blows or the sun shines, respectively.

6.19 To date, fossil-fuelled thermal stations have provided some of this flexibility, but operation of these stations will need to be phased down to meet New Zealand's decarbonisation goals.

6.20 In short there will be a rising overall need for flexibility at the same time that some existing sources of flexibility are being withdrawn.

[13] This assumes an increase in demand of around 29,000 GWh/yr between 2020 and 2050 (consistent with the growth shown in Figure 7 but assuming the Tiwai smelter remains in operation plus a modest new build allowance to replace/repower some existing renewable sources as they reach the end of their lives. For example the Wairakei geothermal station is due to retire before 2031. Likewise the Tararua wind farms are likely to be progressively replaced.

6.21 To fill this gap new sources of flexibility will be required. A range of possible solutions are being explored, including storage options such as batteries or pumped storage hydro, bio-fuelled plant and increased use of flexible demand response (electricity consumers who can reduce their usage at times).

6.22 It is too early to know which of the new flexibility options will be developed in New Zealand given their technical and cost uncertainties. However, it is clear that maintaining access to flexible hydro generation will have substantial electricity system benefits for New Zealand. This is because:

(a) there are significant costs associated with developing any new flexibility source – unlike the hydro generation system which has relatively low costs to maintain (because the build costs have already been incurred);

(b) the hydro generation system produces energy which is relatively flexible. By contrast, some of the flexibility options are storage devices, and therefore need an energy source to operate; and

(c) as discussed in paragraphs 5.17 to 5.18, hydro generation is currently a major source of flexibility for the electricity system. Any reduction in flexibility from this source would increase the need to develop other sources of flexibility and result in additional costs for New Zealand.

Diversity of generation sources will be important

6.23 The expected increase in the proportion of electricity generated by intermittent generation will also increase the need for diversity of generation sources. Relying heavily on one type of intermittent generation, particularly if it is located largely in the same region, will lead to there being a high correlation between when these power stations can generate and when they cannot (for example, if a large proportion of New Zealand's generation capacity was from wind farms located in the same region, it is likely that these wind farms would all stop generating (due to low wind) at the same time). This would likely result in there being excess generation in some periods and shortages of generation in other periods.

6.24 A diversity of generation types (eg wind, solar, hydro, and geothermal) and location reduces the risk of both supply shortages and excess generation occurring. It will also be important for there to be non-intermittent generation supply that can provide “baseload” (constant generation over time) and flexibility (as discussed in paragraphs 6.18 and 6.19 above).

Uncertainties to take into account

6.25 When making predictions about the future it is important to consider any factors which could significantly affect the outlook. In this subsection I briefly discuss the key areas of uncertainty and their implications for the electricity system outlook.

100% renewables policy

6.26 As noted in paragraph 6.7 the Government has announced an aspirational target to achieve 100% renewable electricity supply by 2030. This target is subject to change, with the potential for either the target date or the target itself to change.

6.27 A change in renewables target would change the rate of generation investment needed to replace thermal generation. However, even if the target is softened (by extending the target date and/or reducing the target itself), I still expect investment in renewable generation to be required at an unprecedented rate.

6.28 The key reason for this view is that the target of net zero carbon by 2050 is enshrined in statute. Achieving that target will require decarbonisation of the transport and industrial process heat sectors, shifting from fossil fuels to renewable electricity and other zero carbon energy sources. That in turn will not be possible without major expansion of renewable generation.

Rate of demand growth due to electrification

6.29 The rate of electricity demand growth due to electrification will be affected by a range of uncertainties, such as the extent and uptake of electric vehicle rebates, battery technology improvements, and wider government policy. If the rate of electrification is slower than projected, that would reduce the required rate of renewable development, and vice versa.

6.30 However, there is growing international and domestic concern about climate change. Therefore, I expect that renewable growth projections presented in Figure 8 are more likely to be understated than overstated.

6.31 More generally, the Russian invasion of the Ukraine and other rising international tensions have lifted fossil-fuel prices. If this pressure is sustained, it is likely to accelerate the shift to renewable electricity as an energy source.

Tiwai smelter

6.32 There is uncertainty around whether the Tiwai Point aluminium smelter will continue to operate long term and, if not, when it will cease operation. The smelter's electricity purchase contract with Meridian is currently due to expire at the end of 2024. Therefore, it is possible that the smelter could exit at the end of 2024. Were this to be the case, approximately 5TWh of annual electricity demand would be lost. However, New Zealand Aluminium Smelters, the owner of the smelter, confirmed in July 2022 that it had started exploring options for electricity supply beyond 2024.

6.33 Figure 7 presents a projection of electricity demand excluding the Tiwai Point aluminium smelter out to 2050 and indicates that demand will grow by 78% between 2020 and 2050. However, even if the smelter were to exit, electricity demand is projected to grow by 57% over the same period.

6.34 This would reduce the projected new renewable generation requirement by 2050 from around 33 TWh to 28 TWh.[14] This would still require investment in renewable generation at an unprecedented rate.

7. THE BENEFIT OF EXISTING AND NEW RENEWABLE ELECTRICITY SCHEMES

Summary – the benefit of existing and new renewable electricity schemes

7.1 In this section I discuss the benefit of allowing existing renewable generation to continue to operate at its full capability and allowing new renewable generation to be built.

7.2 I consider the benefit of renewable electricity resources in general terms in this section. Later in my evidence (in section 9) I discuss in more detail the benefit of the existing Clutha Hydro Scheme.

7.3 The economic and decarbonisation benefit of existing and new renewable generation can be considered by looking at the costs (including the emissions impact) that would be incurred if existing renewable power stations were not allowed to continue operating to their (current) full

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[14] Based on reference case projection in MDAG's issues paper. Details of the projection can be found here: https://www.ea.govt.nz/assets/dms-assets/29/06-100-Renewable-Electricity-Supply_-Simulation-Assumptions-and-Results-Concept-Consulting-and-John-Culy1341585-v2.1.pdf.

capacity or if some new renewable generation resources were not allowed to be developed.

7.4 I consider the costs incurred in three parts:

(a) increased electricity costs due to more expensive renewable generation resources needing to be developed;

(b) increased carbon emissions and electricity costs due to increased fossil-fuelled thermal generation; and

(c) increased carbon emissions due to electrification becoming more expensive.

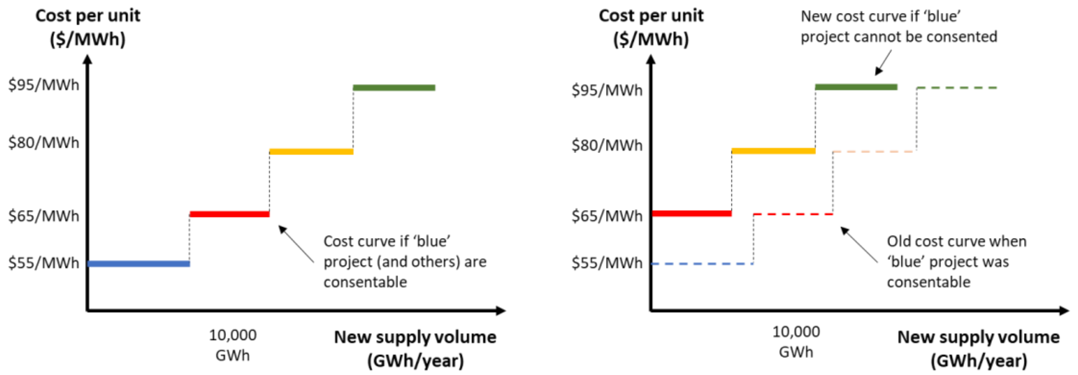
7.5 In the remainder of this section I discuss each of these costs in more detail.

Increased electricity costs if more expensive renewable generation resources need to be developed

7.6 To assess the effect of greater environmental restrictions on existing and new renewable generation on electricity costs, it is useful to apply a simplified model of New Zealand's electricity development choices.

7.7 Each prospective new project has a cost level and annual generation output. Ranking the projects from the lowest cost to the most expensive and graphing cost/volume data will produce a cost stack in the form shown on the left-hand portion of Figure 9.

Figure 9: Illustrative cost stack



Source: Illustrative data

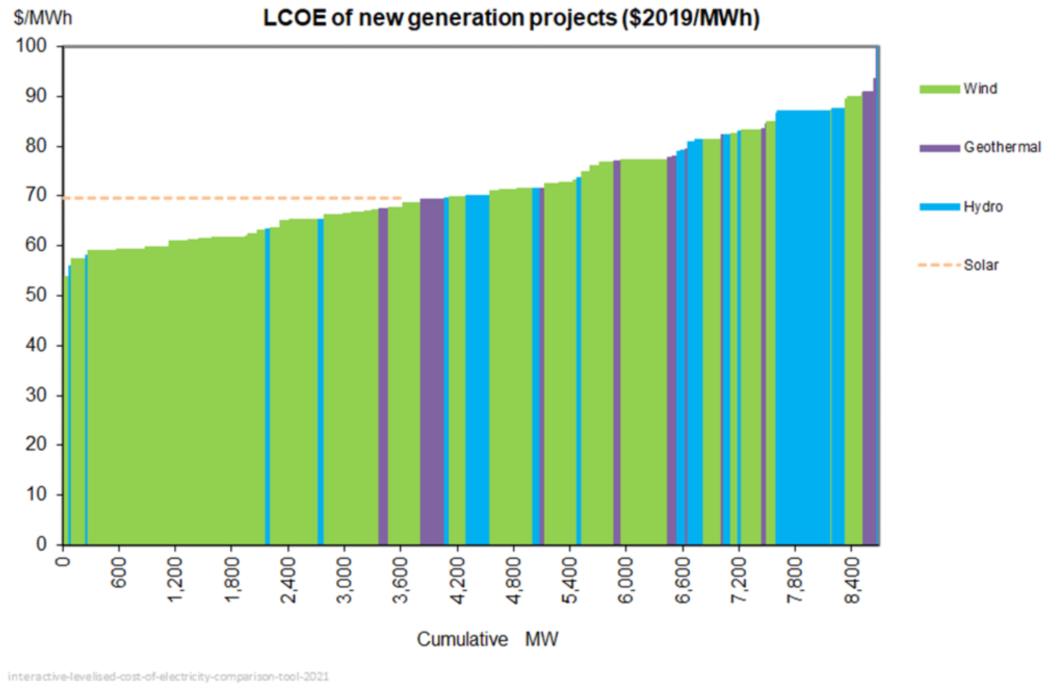
7.8 In this illustrative example, there is a tranche of relatively cheap power available from the blue project ($55/MWh), with progressively more expensive power available from the red, yellow, and green projects. If an additional (say) 10,000 GWh/year of supply was needed by 2030, this could be met from development of the blue and red projects with costs of $55/MWh and $65/MWh respectively.

7.9 Now I consider the effect on electricity costs if it was made impossible for some projects to be developed due to environmental restrictions. This is illustrated on the right-hand side of Figure 9. In this example, the blue project is removed but other project costs and volumes are unchanged. Removing this blue project results in a new cost stack. To satisfy the need for an additional 10,000 GWh of supply, the red and yellow projects are needed, with costs of $65/MWh and $80/MWh respectively. Thus, in this example, costs have increased because the relatively more expensive yellow project ($80/MWh) has needed to be developed to replace the loss of the cheaper blue project ($55/MWh) which is no longer able to be developed.

7.10 A similar effect will occur if environmental restrictions mean that existing renewable generation resources are not able to continue to generate at their existing levels. The reduction in generation capacity of the existing resource will require additional investment in new renewable generation resources in addition to the investment already required to meet increased electricity demand and to replace fossil-fuelled thermal generation (as discussed above from paragraph 6.12). This additional investment will move us further along the cost stack, thereby increasing costs.

7.11 The Ministry of Business, Innovation and Employment (**MBIE**) publishes generation cost stack estimates from time to time. Figure 10 shows the information available in April 2022 (noting the estimates were likely finalised in 2020/2021). I note that the projects are at varying stages of maturity in terms of site selection, resource consents, transmission connection capacity etc. Some projects are shovel ready, whereas others require significant preparatory work before they could be developed.

Figure 10: MBIE estimated cost stack for new renewable generation (2021)[15]



Source: Ministry of Business, Innovation and Employment

7.12 MBIE states that the data shown are "illustrative only".[16] While this health warning should be borne in mind, I consider that the stack nonetheless provides a reasonable guide to the expected costs of potential future generation projects. This is based on a comparison and analysis of the data with other (less comprehensive) public sources. Further, while other sources may have individual projects at higher or lower costs, they all present a picture with an upward sloping cost curve. I also note that despite the caveat above, MBIE itself uses generation stack information in its energy and climate modelling.

7.13 MBIE's stack does not include individual solar farm projects due to limitations in information. In practice I expect solar projects will make up a significant proportion of new generation build over the next 20-30 years. Having said that, solar projects can be expected to vary in their costs to reflect differences in solar levels, infrastructure requirements, etc for each development. Put another way, had individual solar projects been included in MBIE's cost stack, I expect the same overall picture would remain – with

[15] Source: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/interactive-levelised-cost-of-electricity-comparison-tool/ downloaded 4 April 2022. A different version of the chart appears on the MBIE website. This version has been extracted from MBIE's spreadsheet and shows a fuller range on the x-axis and only renewable generation sources.
[16] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/interactive-levelised-cost-of-electricity-comparison-tool/ downloaded 12 October 2022.

an upward sloping stack reflecting projects with differing costs, albeit with a less steep gradient.

7.14 On the other hand, MBIE's stack includes some projects which may never be built. In some cases this is because consented projects may no longer represent the most efficient new investment, as they may not be consented for the optimal location or latest technology, so may be put on hold, possibly indefinitely, even in the existing consenting environment. The Castle Hill wind farm, for example, is consented for 860MW of wind generation, but has not been constructed despite the consent requiring construction to begin by 2023. If the consented projects that are unlikely to proceed for location, technology or similar reasons are removed from the cost stack, the gradient becomes steeper.

7.15 In summary, the MBIE cost stack represents one snapshot of possible developments based on information available in 2020/2021. The picture will continue to evolve, but the crucial point is that I expect the cost of electricity from different projects will vary, and this leads to an upward sloping cost stack.

Increased electricity costs and carbon emissions if fossil-fuelled thermal generation needs to generate for longer

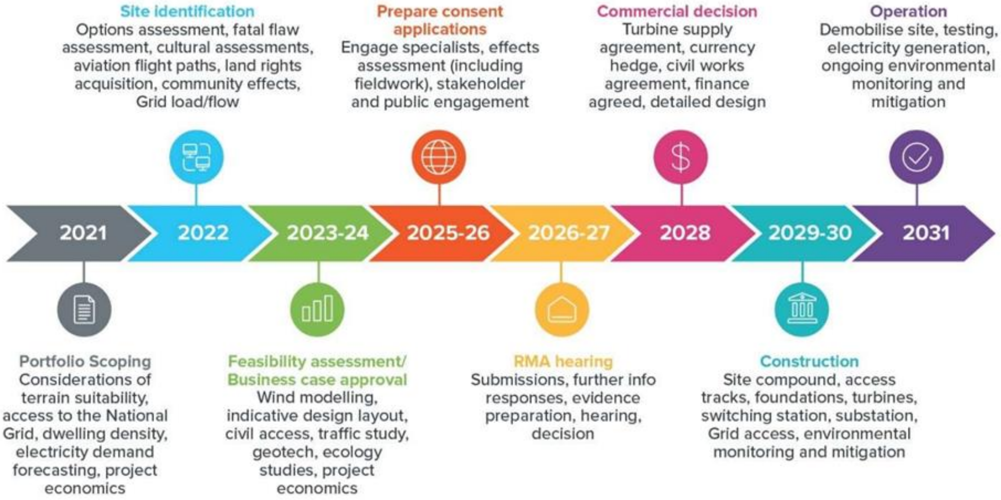
7.16 If the generation capability of existing renewable generation was reduced with minimal warning (eg due to issues with reconsenting) a deficit would likely emerge between the actual level of renewable generation and the level needed to achieve decarbonisation goals. To avoid power cuts, the generation deficit would need to be filled by additional fossil-fuelled thermal generation.[17] The deficit could last for some years as it would take time for additional renewable generation developments to be ready to operate. Furthermore, during the catch-up period there would be a need to develop renewable projects at an even faster rate than projected in section 6 in order to clear the backlog.

7.17 A similar effect is likely if environmental restrictions mean that the current pipeline of potential new renewable generation resources was disrupted. As shown in Figure 11 potential developments typically move through a series of stages over some years. If new restrictions were to disrupt the

[17] However, the extent to which this is possible depends on how much renewable generation capacity is cut. As I note below in paragraphs 9.10 - 9.11 (in relation to the Clutha Hydro Scheme) if capacity is cut considerably there may not be enough thermal generation to replace the lost capacity.

pipeline, it could take some time for pipeline to fill up with sufficient alternative renewable generation projects .

Figure 11: Development timeframe for a windfarm under Resource Management Act



Source: Te Waihanga – Infrastructure Commission[18]

7.18 In most cases, fossil-fuelled generation is both more expensive to operate (due to high fuel and carbon costs) and has higher carbon emissions than renewable electricity resources. Therefore, if higher environmental restrictions on existing and new renewable electricity resources increase the use of fossil-fuelled thermal generation this will likely increase electricity costs and carbon emissions.

Increased carbon emissions if electrification becomes more expensive

7.19 In addition to the direct emissions impact from higher levels of fossil generation (as I discussed in paragraphs 7.16 - 7.18), an increase in electricity prices, due to greater environmental restrictions on renewable generation, is also likely to result in increased 'indirect' emissions for the rest of the economy. This is because electrification has been identified as one of the key means of decarbonising significant parts of our economy, particularly transport, space and water heating, and industrial process heat.[19] An increase in electricity prices will discourage energy consumers from moving away from fossil fuels to electricity.

[18] See www.tewaihanga.govt.nz/assets/Uploads/Te-Waihanga-Natural-and-Built-Environments-Bill-submission-to-Environment-Select-Committee.pdf, downloaded 4 April 2022.
[19] For example, see https://ccc-production-media.s3.ap-southeast-2.amazonaws.com/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa.pdf, paragraph 55.

8. CLUTHA HYDRO SCHEME PROVIDES RENEWABLE AND FLEXIBLE ENERGY SUPPLY

The Clutha Hydro Scheme's contribution to the electricity system

8.1 The Clutha Hydro Scheme contributes to the electricity system in two key ways:

(a) it provides a significant proportion of New Zealand's renewable electricity supply to help power homes and businesses across New Zealand; and

(b) it is a source of controllable energy (particularly in the short term), which helps in balancing the overall electricity system.

8.2 I discuss each of these contributions in more detail in the remainder of this section.

The Clutha Hydro Scheme provides renewable energy

8.3 The Clutha Hydro Scheme is made up of two power stations on the Clutha River – one at Clyde and one at Roxburgh. Together these two power stations have a nameplate capacity of 752 MW. Since 2000, the Clutha Hydro Scheme has produced about 3,700 GWh of electricity each year on average.[20] However, in the past four years (2018-2021) generation has increased to just over 3,900 GWh of electricity per year. Most years, the Clutha Hydro Scheme generates about 12% of New Zealand's renewable generation and about 10% of New Zealand's gross electricity demand.

8.4 For a sense of scale, this is roughly the same as the annual electricity consumption of the South Island's nearly 500,000 residential electricity consumers.[21]

Clutha Hydro Scheme provides some storage capacity

8.5 The level of generation from the Clutha Hydro Scheme can be controlled (ie raised or lowered (within limits)) to reflect the needs of the electricity system. While the Clutha Hydro Scheme is largely run of river, it does have some flexibility in the headponds behind the Clyde and Roxburgh dams. This allows some short-term flexing of output (eg across a day).

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[20] The average between 2000 and 2021 was 3,718 GWh per annum.

[21] According to Electricity Authority data, total energy consumption for South Island residential consumers was 3,832 GWh in 2021. This excludes transmission and distribution losses conveying the power to customers' homes.

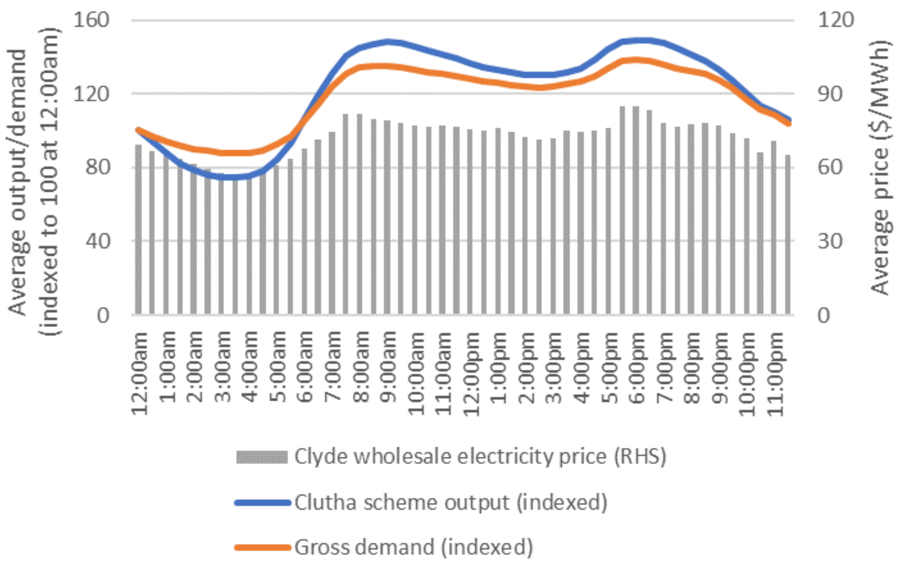
8.6 In addition, the scheme has some seasonal flexibility due to Lake Hāwea's storage capacity of 291.75 GWh.

8.7 While Lake Hāwea's active storage capacity is substantially smaller than some other hydro lakes it is still very useful. For example, it is approximately half the storage of Lake Taupo (587.24 GWh). Lake Hāwea makes up 8% of New Zealand's hydro generation storage.

The Clutha Hydro Scheme provides intraday flexibility

8.8 Clutha Hydro Scheme's intraday flexibility is apparent when comparing the Clutha Hydro Scheme's average output to the average level of electricity demand for the entire country by time of day since 2000. This is shown in Figure 12 below.

Figure 12: Clutha Hydro Scheme – average output by time of day (indexed)



Source: Concept analysis of Electricity Authority data for 2000-2021

8.9 Figure 12 shows how national demand (the orange line) dips in the early hours of the morning, before rising steeply from around 6am as New Zealanders get ready to go to work or school, etc. Demand dips slightly around midday before rising again to the evening peak. These peaks in demand coincide with higher wholesale electricity prices at Clyde (the grey bars).[22] This is because when electricity demand is greater the value of electricity is higher (if supply conditions are unchanged) and vice versa.

[22] The Clyde wholesale price is the time-weighted average price (TWAP) for each trading period in the day. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.

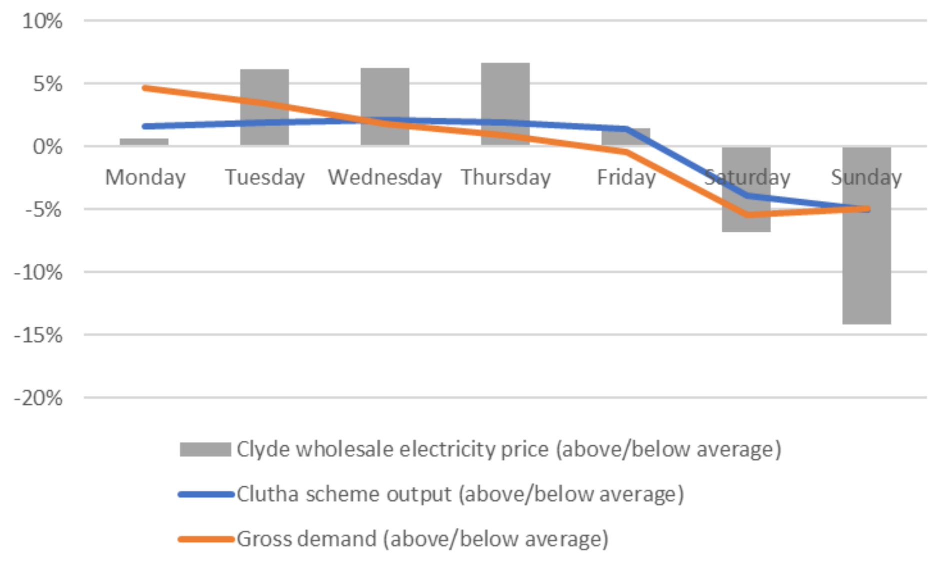
8.10 The average output of the Clutha Hydro Scheme (the blue line) follows the same broad pattern, but with more pronounced peaks and troughs. This illustrates that the Clutha Hydro Scheme varies its output throughout the day to contribute higher supply when the system values it more (ie when national demand is higher each day) and vice versa.

The Clutha Hydro Scheme also provides some within week flexibility

8.11 The Clutha Hydro Scheme also provides some within week flexibility. Over the 22 years from 2000 to 2021, the Clutha Hydro Scheme's output was 6% lower on Saturdays and Sundays than on weekdays (on average). This lower output on Saturdays and Sundays is likely a response to lower electricity demand in the weekend, leading to lower wholesale electricity prices.

8.12 Figure 13 below illustrates how the Clutha Hydro Scheme's output, system demand, and the wholesale price at the Clyde node vary by the day of the week. The blue line shows that on Monday through to Friday, the Clutha Hydro Scheme's output is greater than its average output, while on Saturday and Sunday it is lower. This follows the pattern of gross electricity demand, although Clutha Hydro Scheme's output does not vary by as much as gross demand throughout the week. The greater electricity demand on weekdays relative to weekends is reflected in the wholesale price at the Clyde node – prices on Saturdays and Sundays are significantly lower than prices on weekdays at the Clyde node (as shown by the grey bars).

Figure 13: Clutha Hydro Scheme – output relative to average by day of the week



Source: Concept analysis of Electricity Authority data for 2000-2021[23]

8.13 Being able to vary the Clutha Hydro Scheme's output (to a limited extent) throughout the week is also very important for the electricity system. It means that it has some ability to react to within week changes in the value of electricity, including changes driven by both demand and supply (eg changes in output of intermittent generation (wind and solar) or unplanned generation outages). As I noted in paragraphs 6.18 - 6.19, this will become even more important as the proportion of electricity generated by intermittent supply increases.

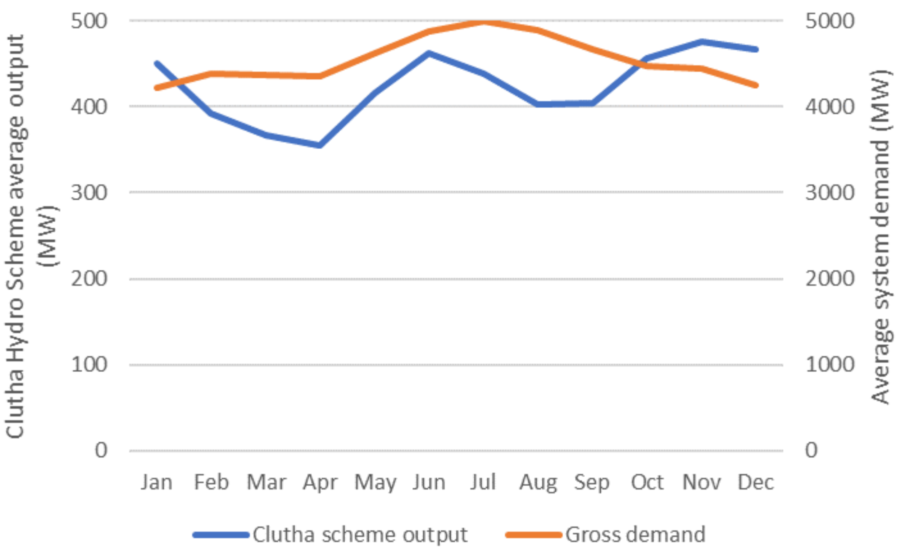
The Clutha Hydro Scheme has a modest ability to alter its output across the year

8.14 The Clutha Hydro Scheme has limited flexibility to alter its level of generation across the year. This is because the storage capacity at Lake Hāwea is modest relative to the annual hydro inflows to the whole scheme.

8.15 This is illustrated by Figure 14 which shows the average monthly generation of the Clutha Hydro Scheme and system demand. While national demand peaks in mid-winter (July), the Clutha Hydro Scheme's output peaks in November-December, with a second (slightly lower) peak in June. While the Clutha Hydro Scheme has (on average) lifted its output temporarily in the lead-in to winter it is not able (in an average year) to sustain that higher output over the remainder of the winter months.

[23] The Clyde wholesale price is the time-weighted average price (TWAP) for each day of the week. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.

Figure 14: Clutha Hydro Scheme – average output by time of year



Source: Concept analysis of Electricity Authority data for 2000-2021[24]

The combined effect of Clutha Hydro Scheme's flexibility over different time dimensions

8.16 Figure 12, Figure 13, and Figure 14 illustrate that the Clutha Hydro Scheme is able to provide short-term flexibility (intraday and within a week), but less able to provide flexibility over the course of a year.

8.17 A statistic which summarises the combined effect of multiple flexibility dimensions is the so-called 'capture rate'. This is defined as the average spot price earned by a specific generator divided by the average price received by a notional generator that has constant output every hour.[25] This constant output generator can be thought of as providing 'vanilla' or 'baseload' electricity into the system.

8.18 Generators that achieve a capture rate above 100% are (on average) providing supply when it is more beneficial to the system. The premium above 100% indicates their output is more valuable than the standard vanilla product.

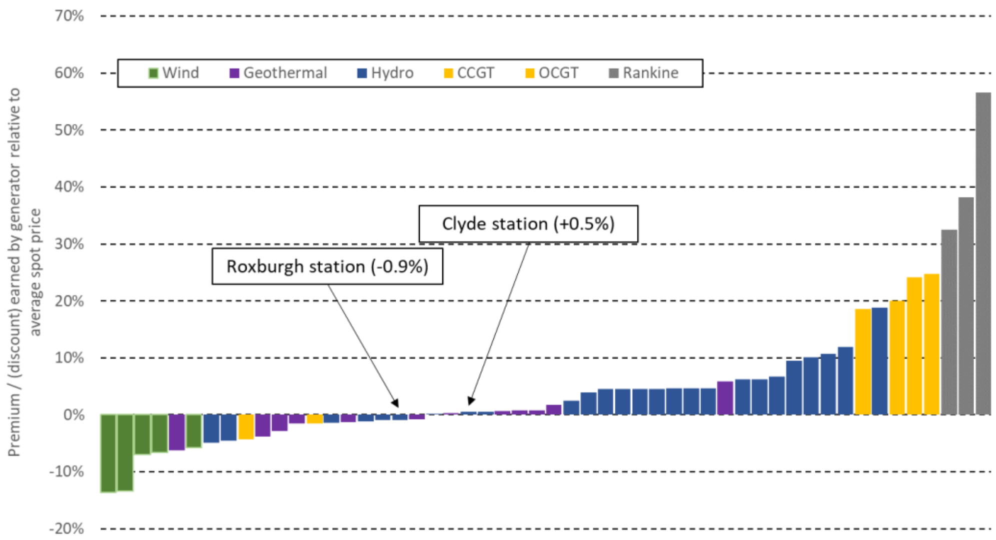
8.19 In contrast, generators with a capture rate below 100% are (on average) contributing supply at times when it has lower benefits to the system – and

[24] The Clyde wholesale price is the time-weighted average price (TWAP) for each day of the week. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.
[25] The capture rate is also known as the GWAP/TWAP ratio where GWAP is the generation weighted average price and TWAP is the time weighted average price.

are therefore net contributors to the need for flexibility.[26] Put another way, their output is less valuable that the standard vanilla product.

8.20 Figure 15 below shows the capture rates for all major power stations in New Zealand since 2015, with the rates expressed as a premium or discount to 100% (ie the rate applicable for the 'vanilla' generator).[27]

Figure 15: Indicative flexibility premium/(discount) earned in spot market



Source: Concept analysis of Electricity Authority data

8.21 Key observations from the chart are that since 2015:

(a) the Clyde hydro station earned a small premium to the vanilla energy value – indicating that it was a net contributor to system flexibility;

(b) the Roxburgh hydro station earned a small discount to the vanilla energy value – indicating that it was a small net user of system flexibility;

(c) many stations earned a greater premium than the Clyde and Roxburgh hydro stations, with the highest premia for the combined cycle gas turbine, and open cycle gas turbine, and Rankine units.[28] However, all of these generation types currently operate on fossil-fuels, and fossil-fuel use is likely to phase down as the electricity sector decarbonises; and

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[26] Investment in such generators may still be economically attractive, provided their costs are low enough to offset the reduced system benefits they provide.

[27] Rates are shown based on data for the 2015 year. Rates for individual stations vary from year to year in absolute terms, but the relativities between stations are fairly stable over time.

[28] Combined cycle gas turbines (CCGT) and open cycle gas turbines (OCGT) run on gas or diesel, and Rankine units operate on gas or coal.

(d) some stations (for example wind generators and run-of-river hydro) received a substantial discount to the vanilla price. This indicates the stations were net users of system flexibility due to their intermittent output.

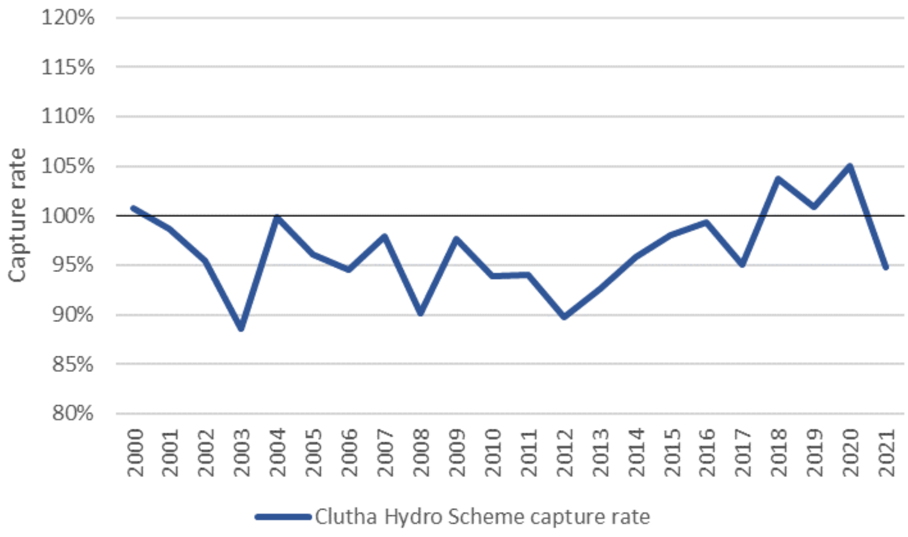
8.22 Looking more closely at the capture rates for the Clutha Hydro Scheme, Figure 16 below shows the annual capture rate for the Clutha Hydro Scheme over the past 22 years. It shows that Clutha Hydro Scheme's capture rate:

(a) has been less than 100% in most years;

(b) can change significantly from year to year; and

(c) has increased (on average) over the last decade.

Figure 16: Clutha Hydro Scheme capture rate over time



8.23 I consider that the Clutha Hydro Scheme's capture rate is less than 100% in most years because the Scheme's ability to respond to changes in demand and supply in the short-term (intraday and within week) are outweighed by its limited ability to 'save' generation for the times of the year (autumn and winter) when wholesale electricity prices are higher. However, I consider that the Clutha Hydro Scheme's capture rate is likely to increase in the future, which I discuss in paragraph 9.17 below.

Conclusion on the contribution of the Clutha Hydro Scheme to the electricity system

8.24 The Clutha Hydro Scheme plays an important role in meeting New Zealand's electricity demand. The Scheme generates about 12% of New Zealand's renewable electricity generation, roughly equivalent to the consumption of the South Island's nearly 500,000 residential electricity consumers. It also has some flexibility to respond to intraday and longer changes in electricity demand and supply due to Lake Hāwea's storage capacity. The Clutha Hydro Scheme's flexibility is expected to become even more important as the proportion of electricity generated by intermittent supply (wind and solar) increases.

9. THE ECONOMIC AND DECARBONISATON BENEFIT OF THE CLUTHA HYDRO SCHEME

9.1 The national economic and decarbonisation benefit of the Clutha Hydro Scheme's energy supply can be estimated by considering the costs (including the emissions impact) that would be incurred if the Scheme were not available to operate. The greater those costs, the greater the benefits from continued operation of the Scheme and vice versa.

9.2 Before discussing the estimates themselves, it is important to emphasise that I have compiled estimates of economic effects, that is, the economic impacts on New Zealand society as a whole. The commercial effects for the owner of the Clutha Hydro Scheme will differ from the wider economic effects for a range of reasons. It is also important to recognise that the estimates only incorporate electricity-related effects.

9.3 Returning to the estimation of the cost if the Clutha Hydro Scheme were not available to operate, it is useful to consider two timeframes: the short-term (when alternative energy resources already in existence must provide the substitute energy); and the longer-term (when permanent substitutes could be in place, noting it generally takes years to construct new power stations).

9.4 In this section I consider the:

(a) short-term cost impact if supply from the Clutha Hydro Scheme were not available;

(b) longer-term cost impact if supply from the Clutha Hydro Scheme were not available; and

(c) additional cost impact of losing the Clutha Hydro Scheme's controllable energy (ie its flexibility).[29]

Short-term cost impact if supply from Clutha Hydro Scheme not available

9.5 The electricity system normally has some unutilised plant that can operate at relatively short notice to provide so-called reserve. This reserve is largely comprised of capacity at fossil-fuelled thermal power stations. However, this type of plant has high operating costs (one of the reasons it is seldom used) and significant carbon emissions so is therefore not suitable as an ongoing substitute.

9.6 If the Clutha Hydro Scheme were not available, the most likely initial effect would be the increased operation of thermal power stations, running on gas or coal.

9.7 Table 1 sets out estimates of the costs of obtaining power from these types of generation units. The underlying fuel cost estimates are based on the historical longer-term average prices for gas and coal (prices are currently much higher) and forward projections for New Zealand carbon prices.[30]

Table 1: Initial annual costs to substitute for Clutha Hydro Scheme supply

	Gas-fired substitute	Coal-fired substitute
Cost to replace lost energy ($m/year)	$ 326	$ 625
Increase in emissions (tCO2e/year)	1,450,135	3,606,747
Emissions equivalent (number of cars)	782,615	1,946,505

Clutha hydro scheme analysis.xlsx

9.8 As shown in Table 1, it would be very costly to replace energy from the Clutha Hydro Scheme with electricity generated from thermal power stations. Even the cheapest option (gas-fired) would incur a cost of over $326m per year. Using coal-fired generation instead would almost double the cost.

9.9 It is important to note that the estimates in Table 1 assume that sufficient spare thermal plant is available to fully substitute for the Clutha Hydro

[29] The estimates of the short-term and longer-term cost impacts noted in paragraphs 9.4(a) and 9.4(b) do not make any allowance for the value of the flexibility that the Clutha Hydro Scheme provides.
[30] If current fuel costs were used, the cost estimates in Table 1 would be much higher. See https://www.commtrade.co.nz/ for the information on projected carbon prices.

Scheme. That assumption is optimistic given the large volume of energy that would be lost if the Clutha Hydro Scheme could not operate.

9.10 A more likely outcome is that thermal generation would be a partial substitute, and power rationing would be required in some periods (eg cold winter evenings) due to insufficient spare thermal capacity. In that case, the costs would be even higher than those shown in Table 1.

9.11 Table 1 also shows the expected emissions impact of replacing the renewable energy from the Clutha Hydro Scheme with output from thermal power stations. If gas-fired units were used as the source (a best case for fossil-fuelled thermal energy), emissions would rise by over 1.4 million tonnes of carbon dioxide equivalent per year. If coal-fired units were used as the source, there would be an increase of almost 3.6 million tonnes per year. To put these figures into perspective, that would be roughly equivalent to the emissions from nearly 800,000 or two million petrol light passenger vehicles respectively on the roads.[31]

Longer-term cost impact if supply from Clutha Hydro Scheme not available

9.12 If supply from the Clutha Hydro Scheme were not available on an ongoing basis, new generation sources would need to be developed as a replacement. The most likely alternatives are geothermal, solar, or wind generation, or some mix of these. On a dollar per unit of energy basis, they would have lower economic costs than the thermal plant options discussed above. However, they would all involve significant upfront capital expenditure and take some time to build. This investment in new generation sources would also be in addition to the substantial growth in renewable generation required to provide the electricity to meet New Zealand's decarbonisation goals (as discussed from paragraph 6.12 above).

9.13 Table 2 below shows my estimates of the ongoing costs to produce substitute energy if the Clutha Hydro Scheme was not available. The estimates incorporate the additional expenditure that would be required on alternative new power stations, less an allowance for avoided expenditure on the Clutha Hydro Scheme assets.[32]

[31] These estimates are based on the average emission/km travelled of new vehicles, and assuming they each travel 10,500 km per year (the New Zealand average for 2020).
[32] This allowance roughly reflects the average reported capital expenditure for another hydro scheme that is thought to have broadly similar costs.

Table 2: Ongoing costs to substitute for Clutha Hydro Scheme supply

	Lower est.	Higher est.
Annual cost ($m/year)	$204	$260
Total over 35 years ($m)	$3,348	$4,261

Clutha hydro scheme analysis.xlsx

Source: Concept estimates. Present values have been calculated using 5% discount rate (pre-tax real) as recommended by NZ Treasury for calculating economic costs and benefits of energy projects).

9.14 Given the uncertainties in some variables, I have calculated lower and higher cost estimates for obtaining substitute energy. The overall cost impacts range from $204 to $260 million per year. These estimates are lower than the costs associated with replacing Clutha Hydro Scheme output with thermal generation but are still very substantial in annual terms.

9.15 They are even more significant when viewed over the likely lifetime of substitute energy sources such as solar or wind farms. In present value terms, the costs would be approximately $3.3 to $4.3 billion.

The cost impact if controllable energy from Clutha Hydro Scheme was not available

9.16 The cost estimates for substitute energy I have discussed so far assume that the Clutha Hydro Scheme produces vanilla or baseload energy. As noted in paragraph 7.1 the Clutha Hydro Scheme does provide short-term (intraday and within a week) flexibility.

9.17 My assessment above of the Clutha Hydro Scheme's capture rates (in paragraphs 8.16-8.23) indicates that the economic benefit of the Scheme's flexibility in the short-term has (to date) been outweighed by the cost of the Scheme's lack of flexibility over the longer-term. However, I expect that in the future the economic benefit of the Clutha Hydro Scheme's short-term flexibility will increase and that its capture rate will correspondingly increase. This is because, as noted above in paragraph 6.14(c), the proportion of intermittent generation (wind and solar) on the system is expected to increase substantially in the future (from around 6% of total supply now to about 50% in 2050). These intermittent forms of generation require flexible energy sources to firm up their output, particularly over short periods (eg within a month).

9.18 For this reason, the economic cost estimates to replace the energy from the Clutha Hydro Scheme in paragraph 9.15 are likely to be conservative (ie low).

David Thomas Hunt

23 November 2022