SWITCHED ON!

Achieving a green, affordable and reliable energy future

Matt Burgess

THE NEW ZEALAND INITIATIVE

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About the New Zealand Initiative

New Zealand Initiative is an independent public policy think tank supported by chief executives of major New Zealand businesses, including energy companies. We believe in evidence-based policy and are committed to developing policies that work for all New Zealanders.

Our mission is to help build a better, stronger New Zealand. We are taking the initiative to promote a prosperous, free and fair society with a competitive, open and dynamic economy. We are developing and contributing bold ideas that will have a profound, positive and long-term impact.

Disclosure

The author has invested in a small holding of New Zealand Units through the NZX-listed Carbon Fund.

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Executive Summary

New Zealand's electricity system works. Electricity here is reliable and more affordable than in most other OECD countries. But what sets New Zealand apart is that 83% of its electricity is produced from renewable sources, mainly hydro, geothermal and wind, the third-highest share of renewables in the OECD. Just 3% of our electricity comes from emissions-intensive coal. Over the next 20 years, renewables will increase their share to between 90% and 97%. Renewables work in New Zealand.

Electricity's impressive record in New Zealand has largely been achieved without subsidies or direction from policymakers. Despite remaining in majority public ownership, businesses and regulators in the electricity sector operate independently of elected governments. For 30 years, government's relationship with electricity has been mostly conducted through overarching environmental and competition legislation, rather than ministerial direction.

Until now, that is. The 2017 Labour-Green coalition agreement has set a target: By 2035, 100% of New Zealand's electricity will be generated from renewable energy, excluding dry years. It is an expensive policy. By one estimate, it could add more than $800 million to the annual cost of electricity. More importantly, it is a needlessly expensive way to reduce carbon dioxide emissions: the cost of more than $1,000 per tonne is 40 times the current price of emissions units on New Zealand's Emissions Trading Scheme (ETS). Worse, the 100% renewables policy could actually raise emissions if the higher cost of electricity delays the anticipated transition of transport and industry off fossil fuels on to electricity.

The first 95% of the government's renewables target is expected to happen without any help from policy – renewables make sense in New Zealand with its vast natural resources. But there is no feasible combination of hydro, wind, solar or geothermal that can supply the last 5%. When policy forces electricity demand to be met using the wrong technologies, the main way to correct for the technology mismatch is by overbuilding. Alternatives such as demand response and battery storage have potential but look expensive.

Other countries have aggressively supported renewables to pursue their emissions targets. Unlike New Zealand, the electricity sectors in Australia, Germany and the UK operate more or less under the direct control of elected governments. These governments have directed investments worth hundreds of billions of dollars into solar and wind generation. The result? Substantial increases in the cost of electricity in those countries for only limited cuts in emissions.

This does not reflect any problem with renewable technologies. The problem is policies that force renewables into roles within electricity systems for which they are a poor fit. It is one thing to build renewable generation, but quite another for that generation to find a productive home within an electricity system where it is actually used. It is no coincidence that affordable, clean electricity has emerged in one of the few countries, perhaps the only country in the OECD, where investment in electricity generation is determined not by policy and subsidies but by competition between technologies on a level playing field beyond the reach of politics. If electricity is to be affordable and clean, technologies must each find their own level within an electricity system.

The government does not need to be in the business of picking winners to reduce emissions. Policies like 100% renewables choose one part of one sector for emissions reduction without weighing the alternatives across the rest of the economy – an impossible task for policymakers when those alternatives can cost millions. The problem is not that the government picked the wrong winner with its 100% renewables policy, but that it tried picking any winner at all.

The government can reliably reduce emissions at less cost by pricing carbon. The decentralised nature of emissions gives price the advantage over policy as a mechanism for reducing emissions. New Zealand prices carbon through the ETS, established in 2008. The government recently said it sees the ETS as its "main tool" for achieving its emissions targets and is taking steps to tighten it up.

It is right to do so. Research suggests a huge performance gap between government policy and carbon pricing as mechanisms. Results vary widely, but on the whole governments spend $5 to avoid emissions costs of $1. In a properly calibrated ETS, emitters spend up to $1 to avoid emissions costs of $1. Together, these suggest an order of magnitude gap in the performance of an ETS and government policy on the basis of cost per tonne abated.

New Zealand's ETS has not been effective to date, but this reflects a watering down rather than any inherent problem with the mechanism. A stronger ETS will increase investment in renewables as well as in R&D, but getting there will require dealing with difficult problems, including leakage and whether and how to include agriculture. These problems are worth solving because the prize is huge: the ability to achieve any emissions target at a fraction of the cost of the policy alternative.

Policy's goal, apart from building an effective ETS, should be to maximise the emissions scheme's share of abatement efforts. But politics puts limits on how much can be done with an ETS.

Political support for the ETS can be lifted by a commitment to revenue neutrality in the scheme, that is, a commitment to use the revenues from the sale of emissions rights to lower taxes elsewhere. This will prevent carbon pricing from being seen as a 'tax grab', while carrying the potential, by no means guaranteed, of a 'double dividend': benefits first from pricing the carbon externality, and second from lowering other distortionary taxes. Other ways to lift political support for an ETS include independent evaluations of all emissions policies on a cost per tonne basis, and a commitment to reallocate funds from less- to more-effective policies based on the evaluation findings.

The government is right to seek cross-party policy consensus on climate policy. A policy's credibility matters when the goal is to move incentives that affect long-term investment.

This consensus should be extended to rule out direct policy interventions in the electricity system. Investment decisions over large and expensive generation facilities are highly sensitive to the potential for further intervention. Even limited government interventions in electricity markets tend to cascade, as seen here in New Zealand in the 1970s and currently abroad. The importance of policy credibility strongly favours consistent, institutionalised solutions like the ETS over *ad hoc* approaches such as the 100% renewables policy. Like governments, policies come and go, but institutions are permanent.

Distributional effects of carbon pricing should be resolved using the welfare system, not by watering down environmental policies. It is not clear in any case that policy as a mechanism is less regressive than a carbon price on average. A sound general policy principle is to protect households and individuals via incomes, not prices.

The next 20 years will likely see growth in electricity and waves of new technologies. New Zealand's current electricity model

– independence from political influence, prices on electricity and carbon that reflect costs, competition between generation, storage and other technologies on a level and credible playing field – puts us in an ideal position to extend our lead over most other countries for affordable, green electricity. In emissions as for electricity, the government's role is a choice between deciding the answer, or providing the level playing field that enables its discovery. In both cases, the government's opportunity to add value is to support discovery.

CHAPTER 1
Introduction

1.1 How not to do a renewables policy

One can only hope no country will ever spend as much money to do as little for the environment than Germany with its renewable energy policy.

Germany introduced its Energiewende policy, meaning 'energy turnaround', in 2010 and sharply accelerated it the day after the Fukushima earthquake in March 2011. The policy is a commitment to phase out nuclear power in Germany by the early 2020s and replace it with wind turbines and solar panels. Its scale is extraordinary: 20 years, €550 billion, about €25,000 for every household. That's three times the cost of the entire US Apollo programme in today's money.

The Economist reported on the progress of Energiewende in 2013, three years after the policy's launch.[1] The policy had succeeded in lifting the share of solar and wind generation and reducing that of nuclear. But emissions from Germany's electricity sector had increased, not fallen.[2] Germany was burning more brown coal than at any time since shortly after the fall of communism in 1990. Germany's households were now paying some of the highest electricity prices in the world. Worse, Germany was looking at spending *€1 trillion* more on transmission to transport the renewable energy generated in the northern states to the population and industrial centres in the south.[3] Today, Germany's total emissions are almost unchanged from 2010.

How did this come about?

In Germany, electricity investment is decided politically. State and federal governments, not generating companies, determine how many solar panels and wind turbines are to be built in Bavaria, Bremen and Berlin in a year. A complex system of subsidies involving thousands of different prices, all politically determined, channels investment in solar and wind.

Such complexity inevitably leads to absurdities. In 2011 and 2012, it cost around three times more to generate 1kW of power from a solar panel than from a wind turbine. Subsidies for solar were set at a level sufficient to offset this cost gap, making solar competitive. The world price for solar panels was falling rapidly, much faster than for wind turbines, but political pressure in Germany prevented downwards adjustments to solar subsidies to compensate. Solar subsidies became overly generous. High-cost solar suddenly became far more profitable than lower-cost wind.[4]

Solar investment boomed to such an extent that by 2013, Germany, one of the least sunny countries on earth (even Antarctica receives more annual sunshine hours),[5] held nearly 50% of the world's installed solar capacity. The same number of solar panels located in Spain would have produced 2.5 times more energy than in Germany.[6] Only since 2013 have subsidies in Germany been adjusted in favour of wind, leading to a boom in wind energy generation.[7]

Investment subsidies had several adverse consequences. The flood of renewable energy into the market crashed wholesale electricity prices, cut the credit ratings of Germany's largest energy utilities, and compromised the financial viability of competing, unsubsidised coal and gas generators. But without any way to store large quantities of energy, Germany needed its coal and gas generators to keep the lights on, ready to step in whenever output from solar and wind dropped. So in 2016, Germany introduced legislation to prevent closing coal and gas plants, and introduced subsidies to keep their financial heads above water.[8]

By 2016, Germany's households and businesses had paid renewables companies €176 billion for electricity worth €5 billion.[9] Even so, an early exit from Energiewende is impossible. Livelihoods now depend on the generous subsidies continuing. Political movements in Germany's regions, and a powerful solar lobby, have emerged to block attempts at reform.

Energiewende's defenders note the valuable learning and technology the policy has generated, while the German public continue to support renewable generation.[10] Notwithstanding, Energiewende is a policy disaster with far-reaching lessons for the New Zealand government as it considers various options for achieving its emissions targets.

1.2 Electricity in New Zealand

Electricity in New Zealand interestingly had started with renewable energy.[11] The first plant was most likely a hydroelectric plant built in 1885 in Bullendale, Otago, to power a mine stamp, a machine used for crushing rock and coal. In 1888, Reefton became the first town in the Southern Hemisphere to distribute hydroelectricity using permanent lines from a station on the nearby Inangahua River.

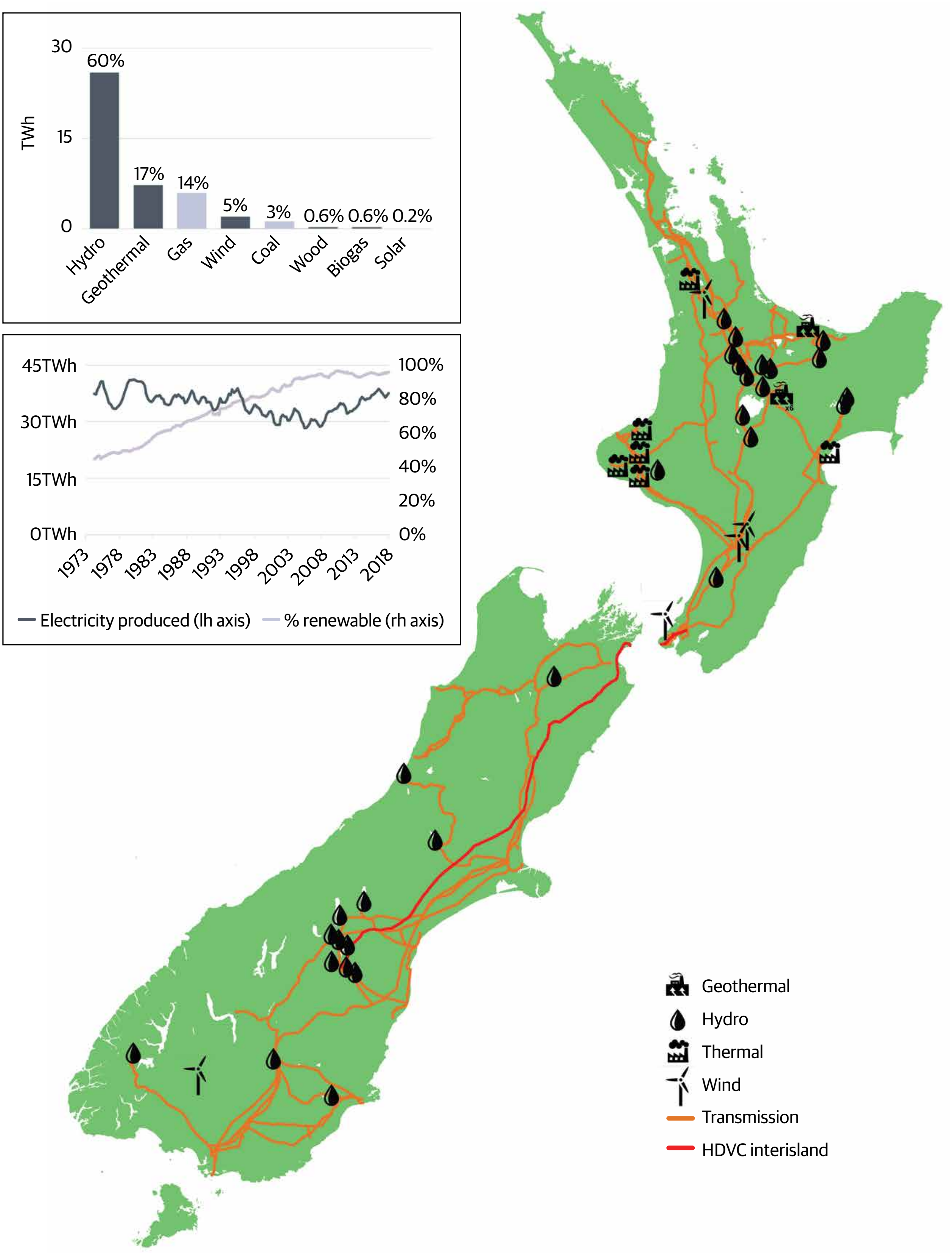
The nation's first large-scale station, a 10MW hydrogenerator, was built on the Waikato River near Cambridge in 1913. This station was later submerged in 1947 by the construction of the larger Karapiro station and its reservoir, Lake Karapiro. New Zealand's first geothermal generator, a 161MW station north of Lake Taupo, as well as the first large-scale coal generator, the 210MW Meremere station in Waikato, both arrived in 1958. Natural gas was discovered in Taranaki in 1959, leading to the first large-scale gas-fired station in New Plymouth in 1974. Biomass and modern wind generators first appeared in New Zealand in the early 1990s.

Through the early 20th century to the mid-1980s, electricity was entirely publicly owned and under the direct control of elected governments. Beginning in 1903, legislation reserved all hydrogeneration to the Crown. By the 1970s, Ministers were using their control of the electricity sector to pursue various political objectives such as employment generation – goals unconnected to supplying electricity at least cost. Consumers were paying prices far below cost. High-cost projects were selected over cheaper alternatives. Projects frequently ran late and over budget. Marsden B, a major power station, was built at a cost of nearly $1 billion in today's dollars but never used. In early 1984, Treasury estimated the economic costs of this mismanagement of the electricity sector at $3 billion in 1983 dollars, an astronomical sum at a time when national income totalled $35 billion.[12,13]

The reforms that followed put operational decisions out of the reach of politics, and gradually adjusted prices to reflect costs. Decision-making shifted from a government department, an entity that ministers are legally entitled to direct, to a new kind of entity, the state-owned enterprise which ministers had only limited powers to direct. Managers of SOEs have a statutory obligation to operate on a commercial basis. Electricity sector regulators, who were to emerge later, would eventually operate at arm's length from the government under a consumer welfare objective. Households faced higher electricity prices over time as subsidies were unwound.

The majority of the reforms took place between 1986 and 1996, reorganising the sector largely into

Figure 1: Electricity sources in New Zealand



Source: Transpower, "Maps and GIS data," Website, https://www.transpower.co.nz/keeping-you-connected/maps-and-gis-data-0.

the form we see today. Control of generation and transmission was initially shifted to the state-owned Electricity Corporation of New Zealand, which would later be split into Transpower, to run the national grid, and four of the five major generating companies operating today. Lines companies mostly remained in local public ownership. Regulation brought discipline to the natural monopolies of lines and transmission. Generators and retailers competed for their business.

The first major test of the reforms came in the winter of 1992 when exceptionally low lake inflows and unusually cold weather combined to produce a major energy shortage. For the first time, it was industry – not government – that took the initiative to coordinate the industry response, with support from the government. Blackouts, New Zealand's time-honoured response to shortages, were avoided and have not been seen since, at least as the result of low lakes in dry years. The reformed system had survived its first major test, driving the final nail in the coffin of central control of the New Zealand electricity system.

The reforms were substantially completed with the launch of the wholesale electricity market in October 1996. After this date, major changes have included the introduction of private participation in 1999 with the sale of Contact Energy, and a shift from self-regulation to full regulation from about 2000. The sector remains in majority public ownership.

Today, 69 generators operated by 12 companies supply electricity to a national grid with 12,000 kilometres of lines running the length of the country. Five generators – Meridian, Contact, Mercury, Genesis and Trustpower – generate around 94% of electricity. Twenty-seven local lines companies take electricity from the national grid and distribute it to 2.1 million households and businesses. Each week, the average residential consumer uses 134 kilowatt-hours and pays $38 for electricity, about 27 cents per kilowatt-hour.

The wholesale market was launched in 1996. By 2008, demand for electricity had increased by 20%. Since then, demand has been flat and per capita consumption has fallen, mirroring trends in other OECD countries. Growth in demand for electricity is widely expected to resume in New Zealand with the anticipated electrification of transport and industrial processes in the coming decades.

Generation in New Zealand is completely unsubsidised, including renewables. Until the 100% renewables policy was introduced in 2017 by the Labour-led coalition (see section 1.3), the government has had virtually no direct say in the mix of generation since 1988. The government's influence is exercised indirectly through overarching energy, competition and environmental legislation that is mostly technology-neutral. Electricity is a part of the Emissions Trading Scheme (ETS), meaning generators face the cost of their emissions. Anybody, including homeowners, can invest in generating capacity and sell their electricity to buyers via the wholesale spot market or using long-term contracts. With carbon priced, and without direct intervention by the government, competition between generators and between generating technologies occurs on a level playing field. Generating technologies find their own level within the system by competing on their merits. This hands-off approach by government in New Zealand may be unique among OECD member countries.

The results are impressive:

- Around 83% of New Zealand's electricity is generated from renewables, far higher than almost all other OECD countries[14]
- Consumers pay the 12th lowest electricity prices among 33 OECD countries (Figure 2), industry the 7th lowest[15]
- Electricity sector emissions as a share of New Zealand's total emissions are low by international standards[16]

- One-fifth of all households and businesses change their electricity retailer each year,[17] the highest annual switching rate in the world, and[18]
- Security of supply is comparable to that in other developed countries.[19]

Renewables are generally expected to exceed a 90% share of generation in the next decade, and may reach 95% share by 2035 without any intervention by the government. Renewables clearly work in New Zealand.

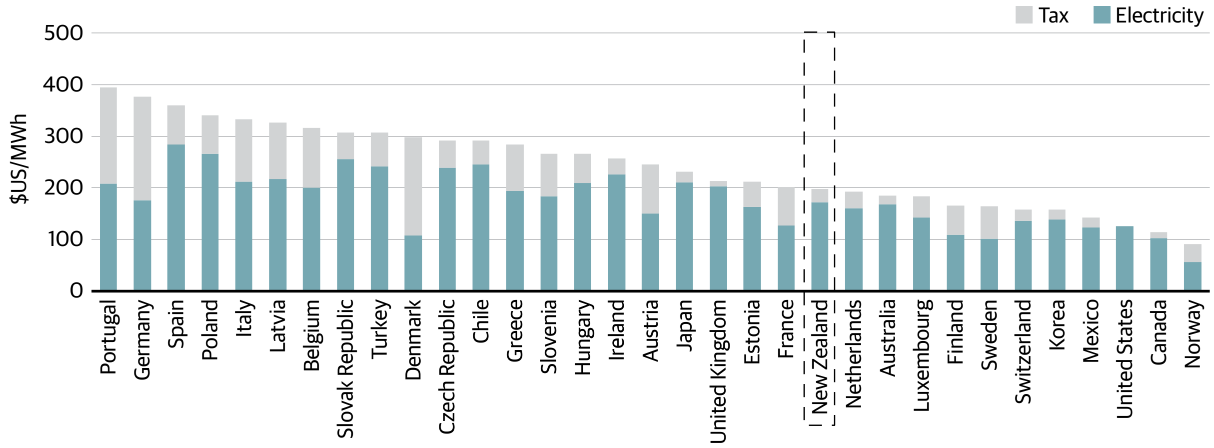
1.3 The 100% renewable generation policy

In October 2017, the Labour-led coalition government announced a policy to achieve 100% renewable generation[20] "in a normal hydrological year" by 2035, the latest in a number of renewables policies for New Zealand since 1993.[21] An Interim Climate Change Committee, announced in April 2018, is preparing advice for a permanent Climate Change Commission, which is expected to be established in late 2019.[22] The interim committee is tasked with, among other things, advising on the delivery of the 100% renewables policy. The advice is expected in April.

The policy's "hydrological year" exemption is significant. About 60% of New Zealand's electricity is produced by hydroelectric generation. But inflows fluctuate, falling by as much as 20% below long-term averages in a year.[23] The exemption leaves room for thermal generation – coal, gas and diesel – to continue to provide cover for energy shortfalls in dry years. But in normal hydrological years, the policy amounts to a ban on the use of thermal generation.[24]

The 100% renewables policy is in fact about that last 5% from a 95% share to 100%. For this small fraction of the demand for electricity, there is no feasible combination of hydro, solar, wind and geothermal generation that can meet demand at anything like a competitive cost. To understand what makes renewables so costly for the last 5%, and why policies like 100% renewables threaten an electricity system that is working so well, we must first understand how electricity systems work.

Figure 2: Residential electricity prices in OECD countries



Source: Miriam R. Dean, et al. "Electricity Price Review Hikohiko Te Uira, First report for discussion" (Wellington: New Zealand Government, 2018), Figure 9, 23.

CHAPTER 2

Economics of electricity and renewables

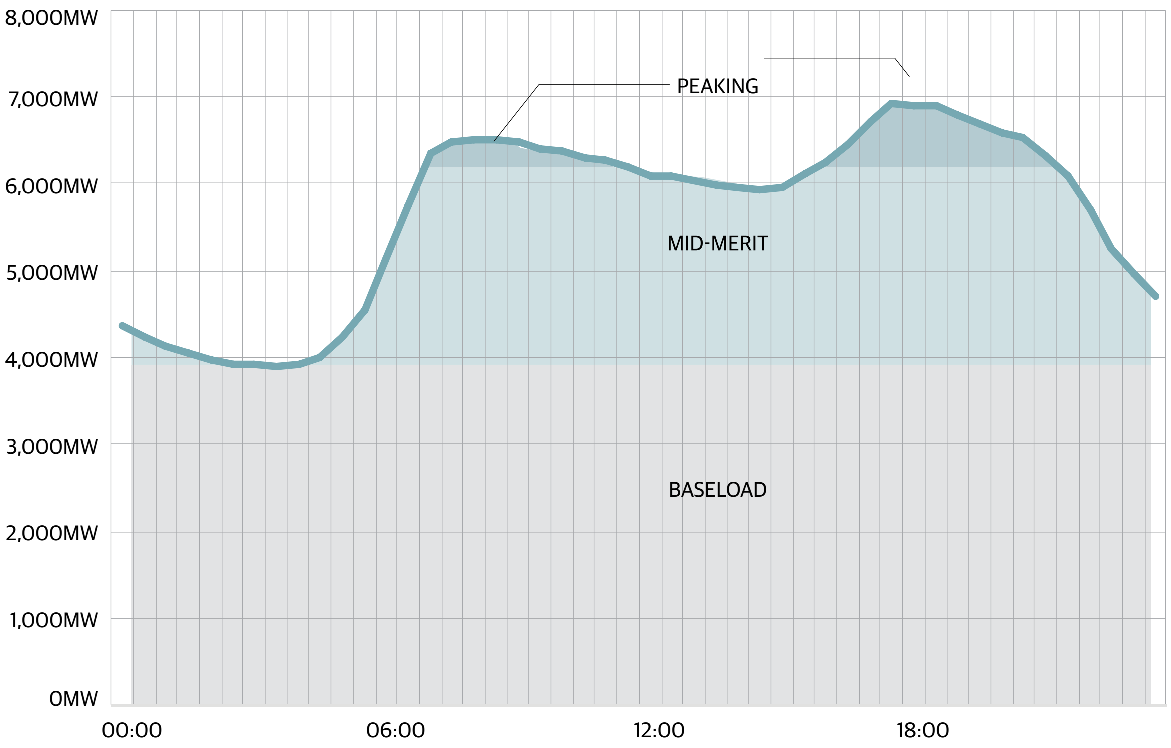
Whenever you switch on a light or a television, you add somewhere between 7 and 140 watts to the national demand for electricity.[25] At that same moment, the energy you consume must be generated somewhere in the country.

If the demand for electricity were constant every day, electricity supply might be relatively simple. A matter of building just enough generation to meet demand, plus some in reserve to deal with outages, transmission losses, and variations in output from generators. But the demand for electricity is peaky.

While electricity production over the year averages about 5,000MW, demand can vary by as much as 60% of this average within a day (Figure 3) and by as much as 80% of this average over the year (Figure 4).

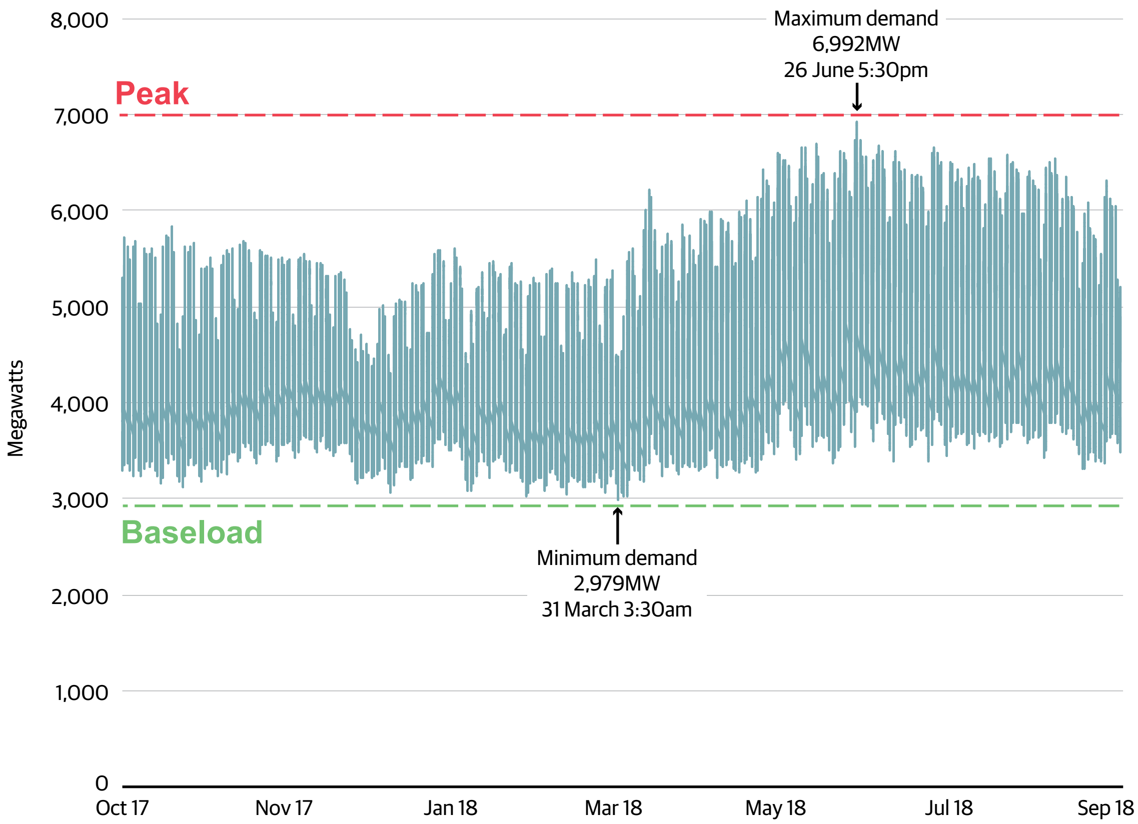
The peaks and troughs of electricity demand help determine the design of the system. Peak demand determines the smallest total generating capacity a system needs. Minimum demand defines *baseload*, the smallest amount of generating capacity that will be needed at every moment in a year.[26]

Figure 3: New Zealand electricity demand (26 June 2018)



Source: Electricity Authority, "Generation output by plant," Website, https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD.

Figure 4: Demand for electricity (1 October 2017 to 30 September 2018)



Source: Electricity Authority, "Generation output by plant," Website, https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD.

Electricity systems minimise overall costs by building generators that specialise in meeting either baseload or peaks:

- Baseload generators are designed to run for high proportions of every year, churning out gigawatt-hours of electricity at a constant, optimised rate. Baseload generators use economies of scale to squeeze as much electricity out of every tonne of fuel as possible. Coal, geothermal, combined cycle gas turbines hydro, and (overseas) nuclear are baseload specialists.
- Peaking generators, or 'peakers', specialise in meeting infrequent peaks in electricity demand. Peakers may run for only a few hours in a year. The Whirinaki diesel plant in Hawke's Bay, for example, ran for just 97 hours in the year to October 2018.[27] Peakers can also be pressed into action as cover for disruptions elsewhere in the system, albeit at a high cost. Technologies specialising in peaking include open cycle gas turbines and diesel generators.[28]

In between peak and baseload generators sit 'mid-merit' generators capable of fulfilling both roles. In New Zealand, hydro provides mid-merit capacity.

2.1 Capital costs matter

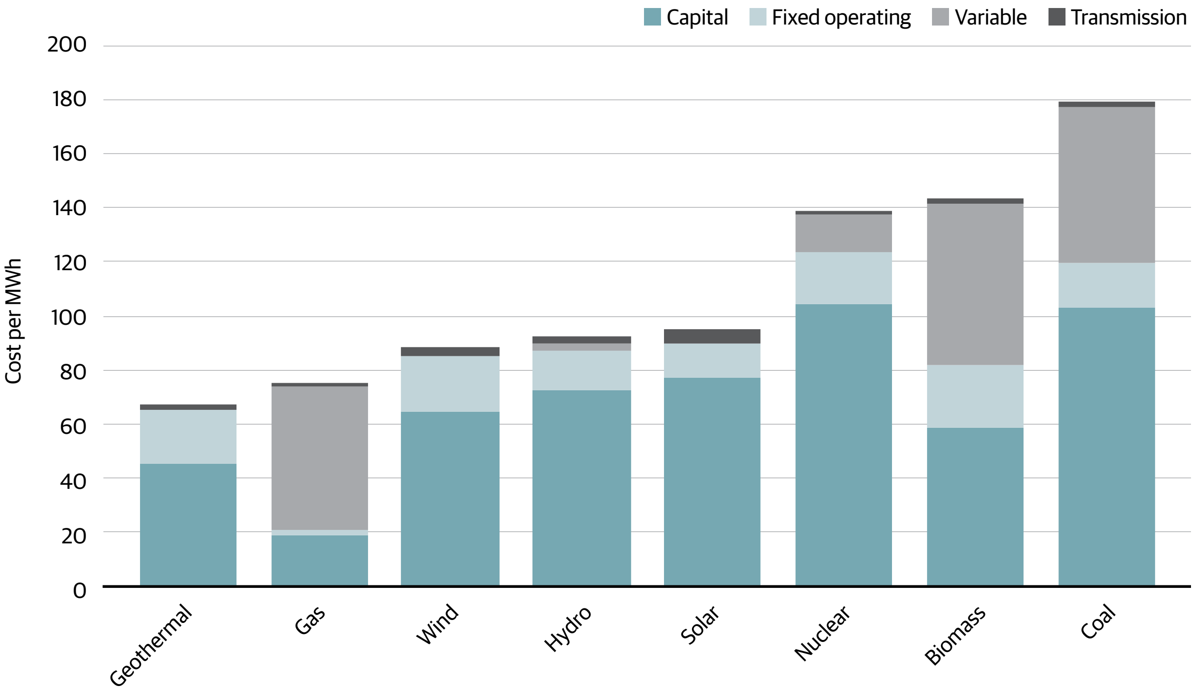
Specialisation by generators emerges from a fundamental trade-off between operating and capital costs. Peakers are usually smaller than baseload generators, using less concrete, steel and other equipment per megawatt, forgoing economies of scale. As a result, peakers burn more fuel and produce more emissions per megawatt than baseload generators. But for a plant that runs for only a few hours each year, it is worth making this trade-off of higher operating costs for the use of less capital. It is expensive letting capital collect dust.

Generators specialise depending on their cost characteristics. Consider geothermal, an excellent technology for baseload but quite unsuited for peaking. Geothermal stations have relatively high construction costs per megawatt, but once built geothermal energy arrives at little additional cost.[29] In economics jargon, its costs are fixed. If a geothermal station runs at near 100% capacity throughout its life, its lifetime cost of energy – lifetime costs of construction, maintenance and operations divided by the energy it produces – may be $70/MWh. But geothermal's low cost of energy once built cuts both ways – a geothermal station sitting idle is almost as costly as one that is producing electricity. Fixed costs make geothermal an expensive peaker. If electricity from a geothermal station costs $70/MWh at 100% capacity, it will cost about $700/MWh running at 10% capacity as a peaker. By comparison, a gas peaker running at 10% capacity might cost $250/MWh – higher than baseload ($70/MWh) but far less than the cost of pressing a baseload generator into action as a peaker ($700/MWh).

Electricity systems minimise costs by taking advantage of the cost and output characteristics of different generation types (Figure 5). If technologies are forced into roles they are not suited for, the overall cost of electricity can dramatically increase.

Capital costs matter, and ignoring them has consequences. New Zealand's energy policy in the 1970s, a time when electricity investment was politically determined, operated under the misguided view that "the use of self-replenishing

Figure 5: Levelised cost of electricity by generation type[30]



Source: US Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018," *Independent Statistics and Analysis* (2018), 6.

hydro resources is preferable to the use of consumable thermal resources, on the grounds that lower operating costs are in some way preferable to lower capital costs incurred at the time of construction…"[31] A modern wind turbine can consume 185 tonnes of concrete and 44 tonnes of steel to build.[32] These materials embed costs and environmental effects the same way as fossil fuels, albeit in different proportions. Governments and government policies can be curiously reluctant to recognise costs and environmental consequences. The financial and environmental disaster in New Zealand that was Think Big embedded an implicit view that capital comes free.[33] Financial and environmental outcomes are likely to improve only when decision-making takes all costs into account: fuel, operations, emissions and capital. It is not as if renewable energy requires capital costs be ignored to look affordable – renewable energy *is* affordable when all costs are considered.

2.2 How supply meets demand in a wholesale electricity market

> *A price is a signal wrapped up in an incentive.*
> —Alex Tabarrok, George Mason University

Electricity systems divide neatly into four parts: generation, transmission, distribution (local lines) and retail. The 100% renewables policy is mainly concerned with generation. To understand how the policy could play out, we must first consider how generators are built.

In New Zealand, generation works on a competitive model. Anybody can build a generator[34] and sell electricity. Owners of generation trade their energy with buyers on the electricity wholesale market in a process managed by Transpower, the System Operator, as well as the owner of the national grid.[35] Wholesale market buyers are mainly large businesses or electricity retailers contracting for energy on behalf of their customers.

The cost of building and operating generating assets is entirely funded by the sale of electricity from those assets.[36] Investors build at their own cost, and in competition with other generating companies and other generating and storage technologies. There are no generation subsidies. The wholesale market is technology-neutral, and competition between generators and generation technologies occurs on a level playing field.[37] Standards strictly regulate the electricity supplied to the national grid, but not the technology used to generate it. Electricity's participation in the ETS means generators bear the costs of their emissions, including from geothermal energy.

Trade between buyers and sellers of electricity produces a *wholesale price* for electricity. The wholesale price reflects the intersection of the nationwide demand and supply of electricity, uninterrupted by subsidies or any special treatment for favoured technologies. As such, it approximates a real-time measure of the social value of electricity – a useful property for a price that serves as the organising principle for investment and operations across the system. The wholesale price:

- **measures scarcity:** when supply falls or demand spikes, the wholesale price reacts immediately. For example, when a faulty valve on an offshore platform was discovered in the Pohokura natural gas field in September 2018, gas generators lost access. At the same time, lakes were well below average for that time of the year, and the world price for methanol was high, increasing the competition for limited gas supplies. Electricity was suddenly scarce, a fact reflected in the wholesale price (Figure 6). Coal and gas generators use the wholesale price as an advance warning to increase their stockpiles of fuel ahead of dry winters.
- **represents the price paid to generators** subject to contracting arrangements (discussed below). For buyers, the

wholesale price is a cost comprising about one-third of their electricity bill.

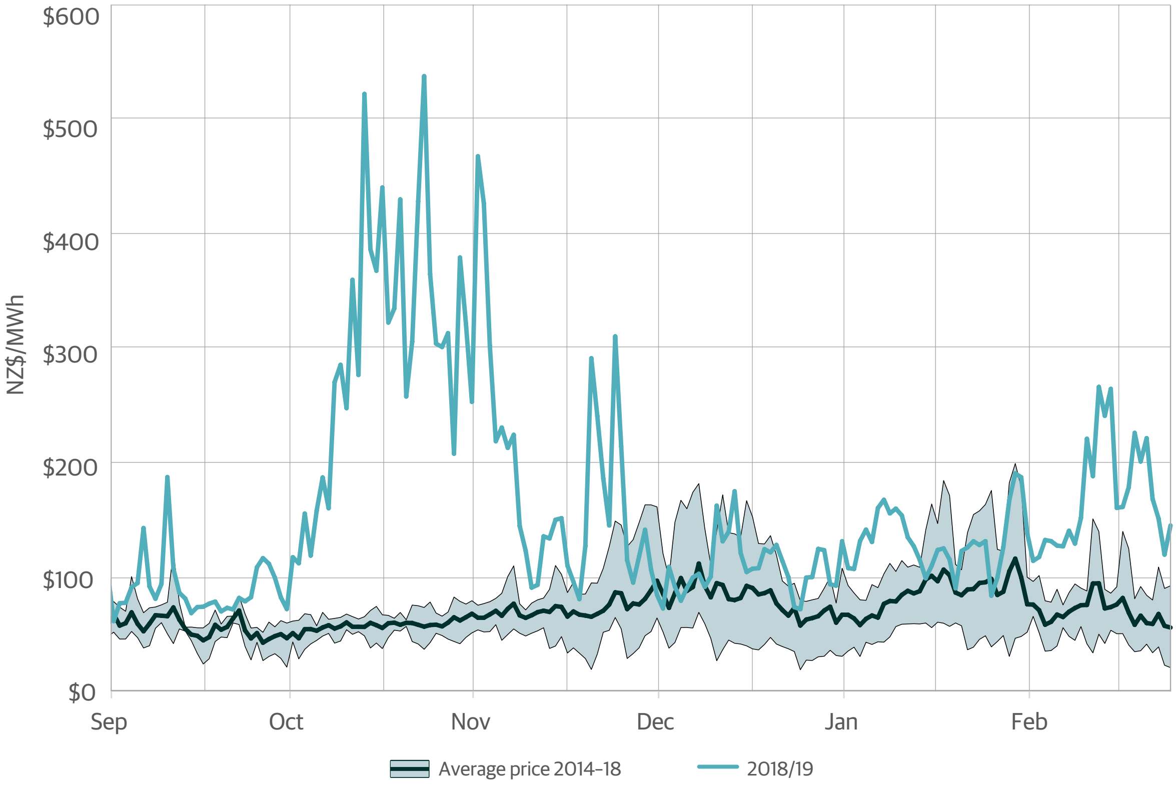
- **signals demand for new investment** in generation capacity.
- **encourages energy conservation** when electricity is scarce.

Around 85% of transactions on the wholesale market occur via hedges, or long-term contracts. Hedges are important for at least two reasons. First, they shield households and businesses from the short-run movements in the wholesale price, giving certainty. Second, owners of generating assets use hedges to share revenue risk with other parties. For example, the owner of a generating asset used only infrequently, such as a peaker that sits idle for weeks at a time, can use a hedge to smooth revenue.[38]

When is society's interest served by investing in new generation? The answer is straightforward in principle: when the value of electricity produced by a generating asset justifies the cost of resources sunk in its construction and operation. In practice, generating companies build their investments on paper long before they first break ground. Companies build investment pipelines, planning new assets, arranging funding, and obtaining resource consent for their construction. This gives companies the right to build new capacity at any time within the window of the resource consent.[39] A company must then decide when to trigger construction of the asset. Investment will generally commence when the company wishes to expand, and the hedge price for electricity from other generators is higher than the cost of building a new generating asset.

Thus the quality of investment directly depends on a wholesale price (reflected in the hedge price) that conveys information about the value society places on electricity. When the wholesale price reflects the social value of electricity, investors' private interest in a return from their next

Figure 6: New Zealand daily wholesale electricity prices 2014–2019



Source: Electricity Authority, "Wholesale energy prices," Website, https://www.emi.ea.govt.nz/Wholesale/Reports/.

investment in generation coincides with society's interest in the sinking of further resources into the production of electricity. This is the power of good pricing.

Because assets are funded from the sale of electricity they generate, assets must be *used* once they are built otherwise investors lose their shirts. This is an important filter on investment – one that can be lost when governments intervene.

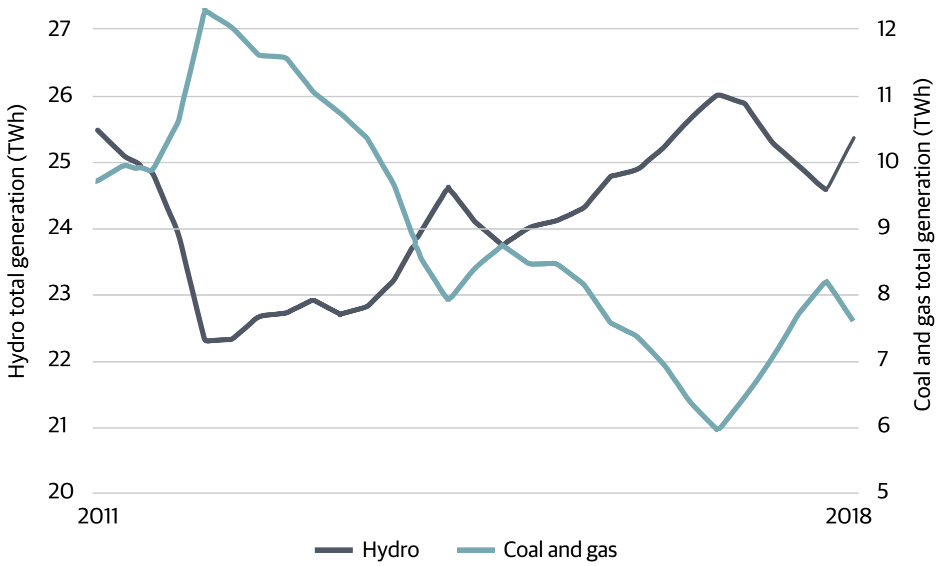
2.3 Generators cooperate when they compete

The previous section alluded to just how complicated the investment decision is. A generating asset could last 50 years. During that time there will be any number of shocks to demand, supply, innovations and government policy, all of which must be considered by investors who want a return and buyers looking at entering into a long-term contract. No less complicated are decisions about how generating assets are used and the intricate coordination between generators and between different technologies. These dynamics emerge from the jostle of competition as generators seek the highest possible price for their energy, and as they respond to disruptions, innovation and constantly changing conditions. Understanding some of this interplay is necessary to understand the challenge policymakers take on when they intervene.

Hydrogeneration is by far the most important source of electricity in New Zealand with a 60% share of production. Hydro fulfils several roles that vary with the rise and fall of lakes. When lakes are full, hydro provides baseload and a high proportion of 'mid-merit' demand each day (see Figure 3). In dry years, however, hydro tends to step back from baseload and concentrates more on peaking capacity, where electricity's value is highest. Gas and coal generation fill the energy shortfall in dry years (Figure 7).[40]

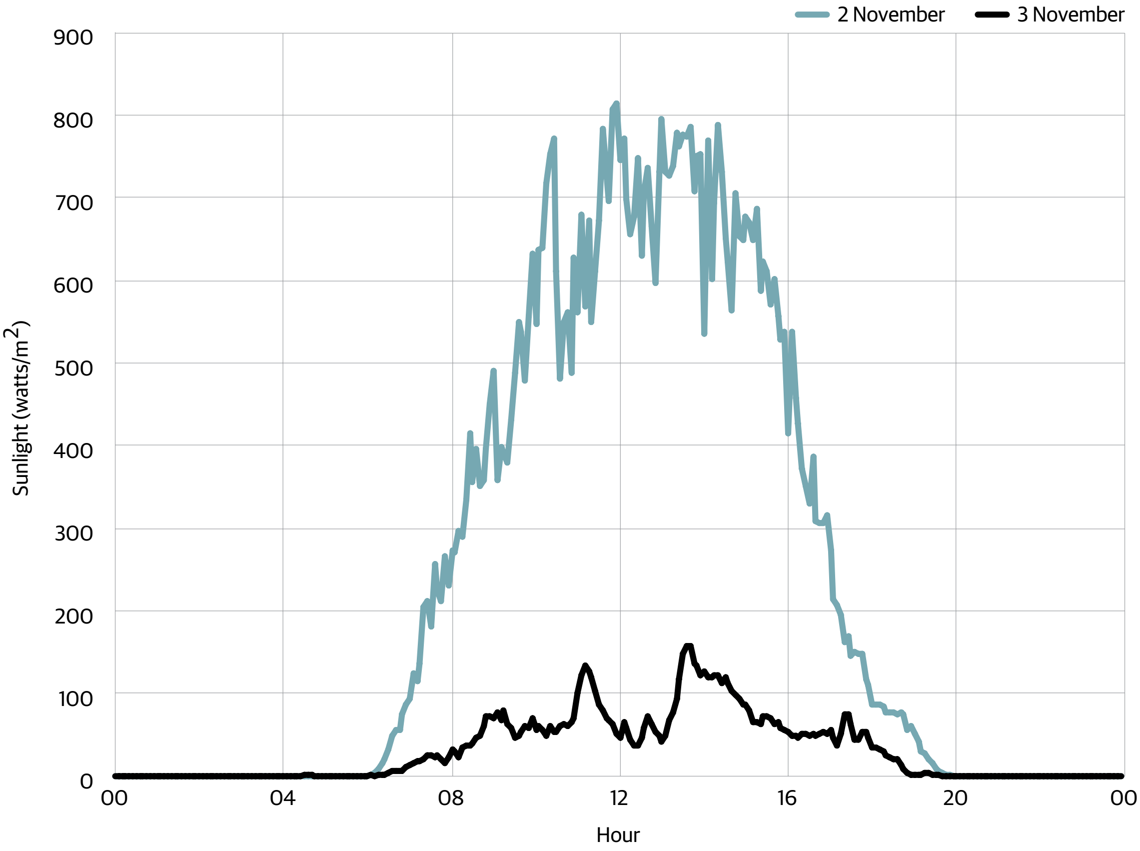
When lake levels are low, hydrogenerators have to decide when to use their limited reserves of water. Generators want the highest price for their energy (the wholesale price is as important to operational decisions as it is to investment); when lakes are low, water used for generation today may be water that cannot be used next week.

Figure 7: Coal and gas backs hydro in dry years



Source: Ministry of Business, Innovation and Employment (MBIE), "Electricity statistics – Data tables for electricity," Website, https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/.

Figure 8: Available sun energy in Wellington on 2 November vs 3 November 2018



Source: Weather Underground, data from 12 stations in Wellington suburbs.

Each generator must work out the minimum wholesale price it would take to generate today rather than wait, called a 'shadow price'. The higher the shadow price, the more inclined a generator is to wait. When to use water, and when to wait, is one example of the many complicated and subtle problems generators must constantly solve.

2.4 Intermittency

We close this chapter by introducing the concept of intermittency. Energy from solar and wind is intermittent. Their output depends on the local weather (Figure 8 shows solar is strongly affected by cloud) and the height of the sun above the horizon.[41] In contrast, energy from geothermal, hydro (mostly), coal, gas, oil and nuclear is *dispatchable* – or available on call.[42]

Earlier in this chapter, we discussed how cost differences between generation types lead to specialisation in supplying either baseload or peaks. Intermittency is another factor that affects specialisation, relevant to understanding what roles solar and wind can productively fulfil in an electricity system. Intermittency can be thought of as a cost, in the sense that part of the problem of meeting the demand for electricity is having generation available at the moment it is needed.

Box 1: The UK electricity system

The UK has made renewables commitments that will cost £100 billion over 20 years. Estimates suggest electricity prices are 20% higher due to renewables policies. And despite the global financial crisis rendering flat the demand for electricity, the UK has seen capacity margins fall to "dangerously low" levels, threatening security of supply.[43] No blackouts have yet occurred, though.

Support for renewable generation in the UK works through a combination of carbon pricing and top-down policy interventions, of which there are dozens. Interventions include subsidies through the Renewables Obligation (2002) and the Small-Scale Feed-In Tariff (2010), and an assortment of policies: the EU Third Energy Package (2011), carbon price floor (2013), interconnection policy (2013), Contracts for Difference (2014), capacity market auctions (2014), and emissions performance standards (2015).

An official review of the UK energy market in 2017 was scathing.[44] The sheer number of overlapping interventions makes it impossible to understand the effects of policies. Complexity has led to ever more complexity. A lobbying industry has emerged to press the government and regulators for ever more support. Every major energy company and every major energy-consuming company has its own regulatory team.

Perhaps the most striking aspect of electricity in the UK is the 'quasi re-nationalisation' of investment decisions that occurred in just seven years, between 2010 and 2017. The introduction of government-backed capacity contracts in 2013 means the government is responsible for determining the quantity of generation investment. And in a pattern repeated in Germany, Australia and New Zealand under Think Big, the UK government is using its increasing control to invest in the most expensive technologies first, and then exploring even more expensive options.

Consumer electricity price rises have led to demands for ever more intervention. In September 2018, UK regulator Ofgem announced electricity price caps to "save consumers £1 billion," roughly equal to the combined profits of the major energy companies in 2017. All this in an electricity system that already has capacity pressures.

The 2017 review concluded that far more decarbonisation could have been achieved more quickly at much less cost with less intervention and a more uniform price on carbon.

As economist Paul Joskow put it:

> Wholesale electricity prices reach extremely high levels for a relatively small number of hours each year and generating units that are not able to supply electricity… at those times are (or should be) at an economic disadvantage.[45]

Intermittency's cost strongly depends on circumstances. When timing matters, as it does when supplying peaks in electricity demand, then intermittency is a major problem. System Operators will take and use electricity from solar and wind to help meet peaks when it is available. But to keep the lights on reliably, the System Operator will not generally count on solar and wind availability at the moment of a peak and will make sure there is sufficient dispatchable generation in reserve ready to step in should solar or wind output drop.[46]

But there are other parts of electricity supply that are less time sensitive. Here intermittency's costs are low. Intermittency's costs are also reduced by access to energy storage, which raises intermittent energy's value by making it dispatchable. As Chapter 3 shows, intermittency has proved to be an Achilles' heel for renewables policies overseas. But it need not be that way. Understanding intermittency – when it is a serious problem and when it is not – is central to making renewables work.

CHAPTER 3

Why renewables policies fail

> *Government has got into the business of "picking winners". Unfortunately, losers are good at picking governments… The scale of the multiple interventions in the electricity market is now so great that few if any could even list them all, and their interactions are poorly understood. Complexity is itself a major cause of rising costs, and tinkering with policies and regulations is unlikely to reduce costs. Indeed, each successive intervention layers on new costs and unintended consequences. It should be a central aim of government to radically simplify the interventions, and to get government back out of many of its current detailed roles.*
> —Dieter Helm (2017)[47]

Overseas, renewables policies generally achieve four things: raise the share of renewable generation, increase the cost of electricity, reduce the security of supply, and hardly reduce emissions. In practice, policies pushing investment in solar and wind have struggled to fit the square peg of intermittency into the round hole of reliable and affordable electricity.

Three principles help explain why government support for renewable energy has so frequently failed to deliver for the environment:

Iron law #1: The lights must always stay on.

Iron law #2: Electricity must be generated in the moment it is consumed.[48]

Iron law #3: Renewables reduce emissions only by displacing other generation.

These principles are labelled 'iron' in this report because they are strict constraints on renewables policies.

The first law is the most important. In practice, no government will allow a coal or gas plant to close if that would jeopardise security of supply, and no government will hesitate to reinstate coal or gas generation to secure supply. Governments confronted with choosing between energy security and emissions targets will not hesitate.

The second iron law says at every moment of every day, available generating capacity must at least equal electricity demand. Given the lights must stay on, this sets an absolute minimum for the amount of dispatchable generation that must be available. Every megawatt of demand must be backed by an equal amount of dispatchable capacity.[49] No amount of investment in intermittent capacity can reduce this minimum requirement for dispatchable capacity – see the first iron law.

The third iron law says investment in clean generation benefits the environment only to the extent that it reduces the use of coal, gas and diesel. This is the key idea of *displacement*, a concept with profound consequences for how a renewables policy is implemented – and the central idea of this chapter. As we saw in Chapter 2, not all generation is equal. At a minimum, displacement can only occur when the lights stay on. So what are the circumstances in which investments in intermittent generation will actually lead to the exit of dispatchable thermal generation? The environmental benefit of renewable energy depends on the answer to this question.

3.1 When intermittent generation works best

Efficient electricity systems solve the problem of meeting the demand for electricity at least cost. This means building just enough generation and storage capacity to keep the lights on reliably, and protecting affordability by building no more.[50]

As a result, electricity systems operate close to one of two fundamental constraints. Most countries operate close to the 'capacity constraint'. At peaks in demand, these countries have just enough generating capacity to burn fuel, and convert wind, solar and water energy, at a high-enough rate to keep up with demand.

New Zealand operates close to a different constraint. We have more than enough generating capacity to meet peaks. Our constraint is total energy, known as a 'firming constraint'. In our hydro-dominated system, dry years can take out more than 3 terawatt-hours of energy from the system, about 7% of all electricity produced in a year. This risks running out of energy. If capacity-rich New Zealand is a V8 Holden that runs low on petrol every few years, everyone else is a Vespa with a full tank.

It turns out New Zealand's firming constraint is wind's opportunity. Although energy from intermittent wind cannot be counted upon at any given moment – making it unsuitable for time-sensitive problems like reliably meeting peaks in electricity demand – over time wind produces predictable quantities of energy that makes it useful in a system that from time to time runs low on energy. Here is how it works.

Wind energy is sent to the national grid whenever it is available. Hydro is used to back wind, stepping in to fill the gap whenever wind energy falls. Together, wind and hydro produce a smooth combined output of electricity. But more importantly, wind's partnership with hydro keeps lake levels higher. Higher lake levels reduce emissions because coal and gas back hydro (Figure 7). In effect, wind has displaced coal and gas generation with hydro as the middleman.

Hydro is an especially good fit for the role of backing intermittent generators: hydro is (mostly) dispatchable; it can operate at below 100% capacity without losing much efficiency, unlike other generation types; and hydro also has a high 'ramping rate' – it can reach 100% capacity from a standing start in just 6 seconds, making for a timely entrance when energy from solar or wind falls.[51]

Hydro has one other characteristic that makes it a good fit for backing intermittent generation: large-scale energy storage. New Zealand's lakes are effectively huge batteries, holding a combined total of up to 3,350GWh energy.[52] Storage reduces the cost of intermittency, or equivalently increases the (gross) value of electricity from intermittent generators, by allowing energy from solar or wind to be available when needed, rather than whenever the sun shines or the wind blows.[53]

3.2 Displacement breaks renewables policies

Notice how in the wind-hydro partnership described in the previous section, wind's emissions benefits are not automatic – those benefits occur mainly because in New Zealand coal and gas step in for hydro in dry years. Winds emissions benefits might largely disappear if hydro were backed by another technology. Renewable generation can only help the environment if it reduces the use of thermal generation, and there are many circumstances in which investment renewables leaves the need for thermal generation unchanged.

I prefer using the term *displacement pathway* as shorthand to describe the sequence of steps by which generation of one sort leads to the reduced use of another. The previous section discussed a two-step displacement pathway operating in New Zealand: hydro backs wind, and coal and gas back hydro. Gas can also directly back wind without hydro in the middle, which is the case in parts of Australia.

But displacement pathways do not always exist, and even where they exist they can be broken. In every electricity system there is a point at which intermittent generation will cease to displace other generation. Before that limit is reached, each unit of solar or wind will displace fewer and fewer units of other generation. If renewables investment continues beyond the point it ceases to displace other generation, the additional solar panels and wind turbines will provide no further benefits, only costs. These limits exist because different generating technologies are not perfect substitutes for one another.

Consider some of the ways the wind-hydro-coal/gas pathway discussed above can break down:

- when capacity rather than firming is the constraint – capacity is time sensitive, making intermittent generation an expensive solution
- further investment in wind could lead to any or all of the following constraints becoming binding:[54]
    - lakes reach full capacity more often, during which times wind does not add to the total energy in the system
    - hydro runs out of generating capacity sufficient to back wind
    - use of hydro assets falls to the point hydro's economics suffer
    - transmission capacity sets an upper limit on how much wind can be backed by hydro.

There might be a dozen other ways the wind-hydro partnership could break down. All of this makes electricity a tough space for policymaking. To make things even more complicated for policymakers, the precise point at which constraints becomes binding and renewables cease to have much or any effect shifts with the seasons, changes in demand, or the arrival of new technologies; when renewables already produce a high proportion of electricity, renewables policies risk displacing other renewables, rather than thermal generation; and it may only be years later that it becomes clear a renewables policy ceased to deliver any environmental benefits.

With so many unseen constraints and without short-term feedback, policymakers take on an impossible task when they decide to use policy to direct investment in electricity systems. Policies fail when they push investment far beyond the point at which displacement ceased. If policies push investment hard enough and far enough, countries end up building and maintaining two electricity systems. This is why renewables policies overseas have done so much to increase the cost of electricity but so little to reduce emissions.

Renewables policies can also compromise security of supply. At high market shares, swings in output from intermittent solar and wind become large enough to stress the transmission grid, raising maintenance costs, and spending on upgrades. In addition, investment in load balancing – additional generation needed to step in at short notice to fill drops in solar and wind output – becomes necessary. Together, these are called 'integration costs', and at high market shares for solar or wind these costs can be significant. A 2013 study of the electricity system in Germany found that at 25% and 40% market share, solar and wind respectively would impose integration costs large enough to nearly double the cost of energy from solar and wind.[55]

Another risk to energy security is the potential compromising of the ability of System Operators to manage the frequency of alternating current in transmission lines. Nearly all countries have adopted a frequency standard of either 50 Hertz or

60 Hertz (New Zealand uses 50 Hertz). Frequency is a function of the balance of energy added to the grid by generators against the energy used up by consumers. When a generating plant trips offline, for example, the grid frequency would fall because electricity demand exceeds supply. Frequency keeping would require energy be added to the grid, or demand be reduced, to restore the balance between supply and demand.

System Operators use a range of technologies and procedures to regulate grid frequency. One strategy for managing grid frequency is to use generators that produce electricity at a frequency precisely aligned with the grid – a property called 'synchronous'. Thermal generators generally have this property but other generating technologies – including solar and wind (in most cases) – do not. So this frequency control strategy depends on synchronous generation holding a high-enough share of overall generation at all times to give System Operators sufficient control.[56]

All this may sound rather abstract, but there were real consequences on 28 September 2016 when a momentary loss of frequency control led to a state-wide blackout in South Australia (see Box 2).

3.3 It's the policy, not renewables

Nothing in this chapter should be read as criticism of renewable energy. Every generating technology has pros and cons. The problem is not with renewables but with policies that drive investment towards technologies past the point at which those technologies add value, or into roles within a system they are not suited for. In an efficient electricity system, and indeed in efficient emissions reduction, technologies must be allowed to find their own level.

One of the goals of this chapter is to illustrate what a difficult place electricity is for policymaking. Policy is the bull to electricity's china shop. There are almost unlimited ways an intervention from the top into an electricity system can bump into unseen financial or security of supply constraints, breaking the policy or the system, or both.

The problem is not that the bull turned left at aisle two when it should have turned right. The problem is the china shop has a bull in it. This report is critical of neither renewables generation nor the government's 100% renewables policy. It is critical of attempts by governments to direct investment when policy is inherently unfit for that purpose given the nature of the emissions problem. Policy has a crucial role in reducing emissions, but in a different capacity.

3.4 Explaining Germany

> *It is hard to think of a messier and more wasteful way of shifting from fossil and nuclear fuel to renewable energy than the one Germany has blundered into.*
> —The Economist (2012)[57]

Based on the lessons learned from the previous two chapters, we are now in a position to understand the policy disaster unfolding in Germany.

Germany's generous solar and wind subsidies have almost certainly led to investment in solar and wind generation continuing far past the point at which the displacement of other generation ceased.

Germany has only limited access to storage capacity, and without it the energy from solar and wind has lower value. A higher proportion of energy from solar and wind is produced when it is least needed, and there is no guarantee the energy will be available during peaks when it is needed most. To keep the lights on, most of Germany's coal and gas generators have had to remain in service. Solar and wind has not

Box 2: South Australia blacks out

In September 2016, tornadoes in South Australia simultaneously cut two remote transmission lines 170 kilometres apart. The disruption was relatively minor. However, in the space of about 2 minutes it cut off South Australia from the national grid, and almost immediately after caused a state-wide blackout lasting nearly 3 hours. This was the "first ever reported blackout incident due to high renewable penetration".[58]

The affected lines produced a sequence of voltage dips that led to nine wind farms – at a total 456MW capacity generating more than half of South Australia's wind energy – tripping offline as automated self-protection. The lost capacity immediately triggered the import of electricity from neighbouring Victoria through an interconnection cable called Heywood. The energy transmitted exceeded the capacity of the interconnector, and 0.7 seconds after losing the wind farms the Heywood interconnector also failed. This left South Australia isolated from the national grid and without access to enough generating capacity to meet demand. With demand far exceeding supply, grid frequency began to fall rapidly.

Even in this situation, the SA network was expected to survive. To bring demand back in line with the reduced supply, load shedding – the automated disconnection of large electricity users – immediately commenced.

It did not work. Grid frequency was falling faster than load could be shed. When the grid frequency reached a critical 47Hz threshold, more generation automatically tripped offline, worsening the undersupply. Outages cascaded. At 4:18pm, 2 minutes after the loss of a few remote transmission lines, the entire state blacked out.

The first customers had power restored nearly 3 hours later. By midnight, between 80% and 90% of customers were online. In all, 1.7 million people were affected. Estimated losses totalled AU$367 million.

In its review, the Australian Energy Market Operator (AEMO) noted how rapidly South Australia's network frequency fell after losing the Heywood interconnector, a rate too quick for load shedding to work. This rapid fall in the grid's frequency was the result of low 'system inertia'.

South Australia's System Operator at that time relied on synchronous coal generation for frequency control. Wind generation in the state was asynchronous. At the moment Heywood failed and isolated South Australia from the national grid, coal was generating just 18% of the state's electricity – a share too small to slow the fall in grid frequency by enough to allow load shedding to catch up. Heywood had failed several times previously without causing blackouts. What made this event different was the exceptionally low synchronous reserve generation.

South Australia's investment in wind had successfully displaced some coal generation, but it had also inadvertently destabilised the electricity system by removing too much of the type of generation needed to regulate grid frequency.

After the blackout, Tesla installed a large battery to provide frequency control, and the SA government proposed more regulation and generation subsidies. South Australia later introduced a regulated "fair market default price" for electricity, and underwrote private investment in new generation, including coal and gas, to guarantee supply.

The Minister responsible said the energy market was already so distorted that further heavy-handed measures were required.

In November 2018, the AEMO announced South Australia and Victoria were at a high risk of blackouts in the coming summer.[59]

displaced coal and gas, and to a considerable degree, Germany has built and now maintains two electricity systems.

Coal continues to dominate electricity production, with a 40% share, and Germany has had to back intermittent energy from solar in wind with its coal generators. Coal is an especially poor fit for this role. Germany's coal generators are designed for baseload, running continuously at an optimal rate to produce electricity as efficiently as possible. Coal plants suffer large operating efficiency losses at below 100% capacity, as well as significant wear and tear from ramping production up and down.

Worse, Germany's coal plants have long ramping times – too long to go from a cold start up to production to be able to back solar or wind in a timely way. To keep the lights on, *Germany has been forced to keep many of its coal plants hot and spinning even when solar and wind are producing electricity.*

The financial viability of coal and gas generation has been damaged not only by the collapse in wholesale prices brought about by solar and wind subsidies, but also by a collapse in utilisation, the proportion of a plant's available capacity that is actually used. These huge capital-intensive baseload generators designed to operate for long durations of the year have been pressed into a role akin to that of peakers, and at an enormous cost.

Germany's connection with the wider European electricity system has helped paper over Energiewende's excesses. Germany ships excess energy to other countries and offsets energy shortages through imports, a luxury New Zealand does not have. Germany's energy security depends on surrounding countries not following its lead. Without the ability to store energy, it is not clear how Germany's huge investment in solar and wind will make its recently announced exit from coal over the next two decades any easier.

Perhaps the greatest irony is that even if Energiewende reduces emissions from Germany's electricity sector, Europe's emissions will not fall by a single gram. Europe's emissions are capped by the number of emissions certificates issued under the European ETS. To the extent Energiewende succeeds, it will simply free up emissions certificates, leading to equal and offsetting increases in emissions elsewhere in Europe.[60] This effect of emissions trading on other policies is looked at in Chapter 6.

CHAPTER 4

Cost of New Zealand's 100% renewables policy

As energy policies go, the government's 100% renewables policy is not bad, at least when compared with some of the excesses of renewables policies overseas. The policy effectively bans the use of thermal generation in normal hydrological years, but it sensibly exempts dry years and imposes no conditions on the mix of renewables. Nevertheless, it is a top-down policy imposed on a complex system that becomes expensive as the share of renewable generation approaches 100%. The policy also has the potential to increase emissions. This chapter looks at why costs are expected to turn vertical. Chapter 5 shows how the government can achieve its emissions goals without resorting to *ad hoc*, high cost interventions in the electricity sector or anywhere else.

4.1 The outlook

Since its announcement in 2017, the 100% renewables policy has been the subject of considerable quantitative work on how the policy could play out. Something like a consensus seems to have emerged from this work about the outlook for New Zealand to 2050.

Growth in the demand for electricity is widely anticipated to resume after an unprecedented decade without growth, a product of the global financial crisis and improvements in energy efficiency also seen in other countries. Growth will be driven by the anticipated electrification of industry, with electricity replacing coal and gas for heating, electrification of transport, and population growth.[61] Estimates of annual electricity demand in New Zealand in 2050 lie in the range of 55TW/h to 90TW/h, up from the 43TW/h currently produced each year.[62] Electricity demand in winter peak is expected to become more pronounced relative to summer. However, electricity demand within winter days is expected to become smoother as the share of demand from less-peaky industry and transport increases relative to more-peaky commercial and residential demand.[63]

Renewables are widely expected to increase their share of generation over the next 20 years without any policy intervention, continuing a trend since 2006 when renewables generated 63% of electricity (83% today).[64] Expectations vary, but by 2035 renewables are likely to generate 90–97% of New Zealand's electricity,[65] with geothermal and wind expected to lead the increase.

There is less agreement about how much solar generation is in New Zealand's future.[66] Solar's value depends in part on access to energy storage, so the differences in outlook may reflect differences in views on future costs of storage or electric vehicle (EV) uptake. Additional hydro is expected but not by a lot, reflecting geographic constraints and anticipated local opposition to any major new projects.

4.2 Costs estimate

Renewables generation succeeds in New Zealand in part because of favourable local conditions. However, for a small share of the demand for electricity, about 5%, renewables are expensive. Transpower explains the problem in research published in 2018.[67] Output from wind, hydro and solar all dip in winter at about the same time as demand for electricity reaches its winter peak (Figure 9). This coincidence of supply falling as demand peaks penalises solar, hydro and wind generation relative to thermal and geothermal technologies that are not affected by the weather.[68]

Transpower's modelling, based on a scenario in which thermal generation has fully exited by 2040, suggests the penalty is significant:[69]

> New Zealand's exposure to supply shortages in winter and/or a dry year is expected to grow from 4 TWh today, which is covered by 7 TWh of current thermal generation capacity, to 9 TWh by 2030 and 12 TWh by 2050. The winter supply gap is largely driven by expected growth of intermittent supply, especially solar… New Zealand's exposure to winter supply shortages, in a normal year from our base case generation mix, is estimated to grow as solar generation grows to over 20 per cent of New Zealand's generation capacity by 2050. Exposure also increases as thermal peakers are progressively retired. Thermal peakers are the current means for securing reliable and controllable winter supply.

The question then is to identify a least-cost way to replace thermal generation in a 100% renewable system. Transpower lists various alternatives:[70]

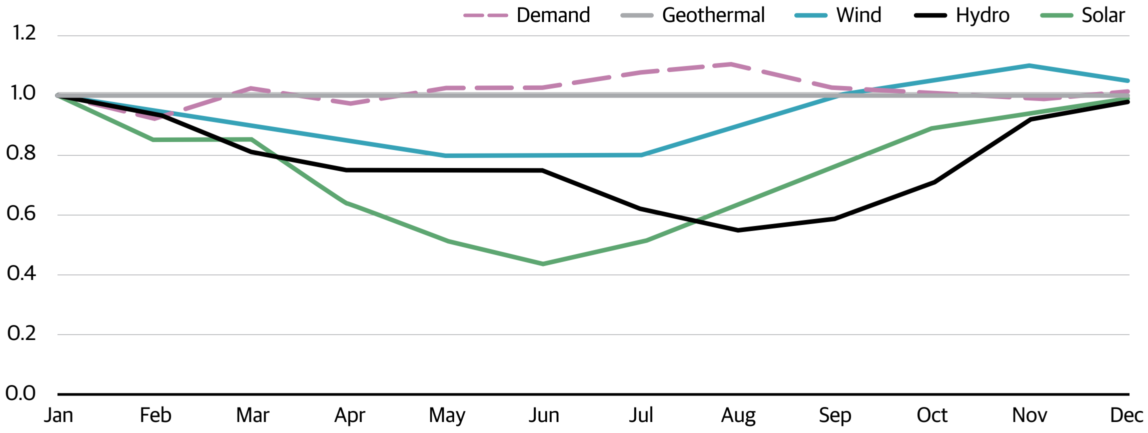
Generation over-build: Build additional renewables generation sufficient enough to overcome the lower available energy from renewables in winter. The cost of this approach substantially reduces generation capacity factors (i.e. utilisation), leaving a large quantity of capital sitting idle for months or years at a time.[71]

Batteries: Likely to become cost-competitive as peakers, but for the foreseeable future batteries are out of the question for large-scale storage capable of shifting energy collected in summer to winter. The costs are prohibitive for large-scale energy storage.[72]

Biofuels: Existing thermal power stations can be converted to burn timber, a biofuel. However, the energy density of biofuels requires large-scale land use changes that make overall emissions benefits of biofuels ambiguous, and expensive per tonne.[73]

Hydrogen storage: Hydrogen storage using ammonia as a chemical transport uses existing infrastructure for fertiliser production, but its

Figure 9: Renewable generation output vs demand in New Zealand



Source: Transpower, "Te Mauri Hiko" (Wellington: 2018), 29.

feasibility is yet to be demonstrated.[74] Round-trip efficiency for storage using hydrogen-ammonia is currently 30–40%.[75]

International connection: Build an undersea cable to Australia via Tasmania.[76]

Additional hydrogeneration: Potential geographic areas are available (Transpower points to a basin in the South Island) but constrained by planning and likely local opposition.

Geothermal as firming capacity: Extremely costly given geothermal's high fixed costs per kilowatt of capacity (section 2.1); it would mean a large amount of capital sits idle between dry years.

Other possibilities: The 'bionic leaf' and energy storage using compressed air.

Transpower concludes: "… none appears definitely feasible and economically attractive."[77]

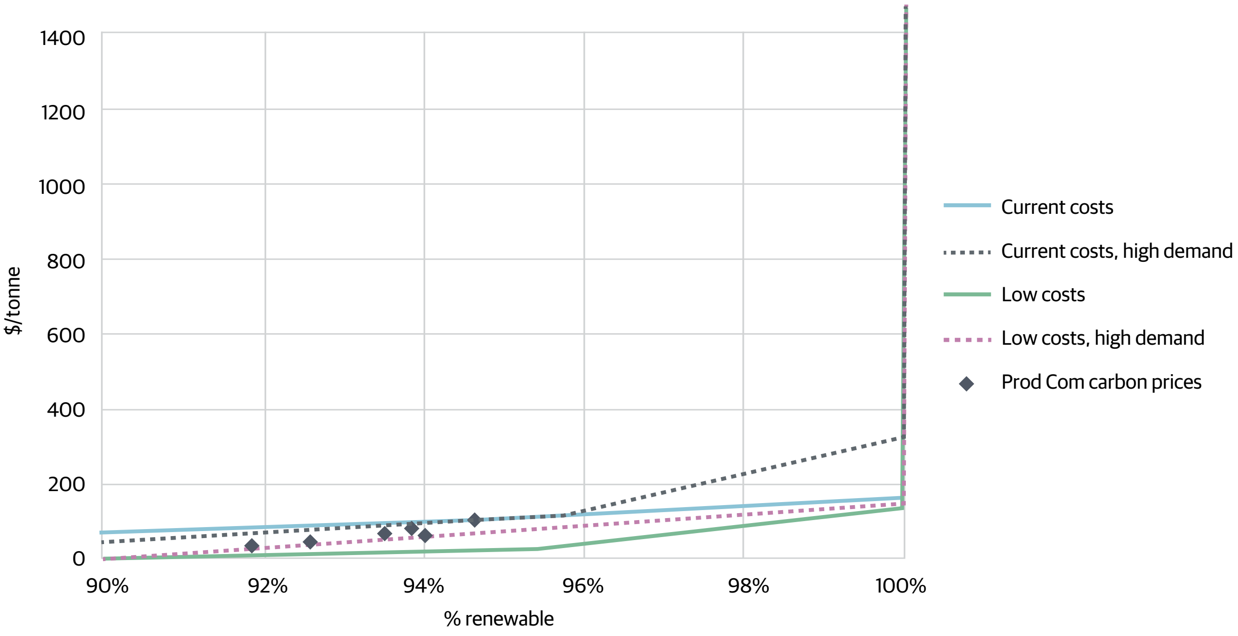
Electricity gentailer: Contact has calculated an expected cost of the 100% renewables policy. Contact estimates that 100% renewables generation with an allowance for dry year reserve thermal generation at Huntly could add $500 million to the cost of electricity each year and reduce carbon emissions at a cost of around $200/tonne. 100% renewables, without any dry year reserve thermal generation, could add more than $800 million to the cost of electricity each year and reduce emissions at a cost of more than $1,000/tonne (Figure 10), more than 40 times the current price of carbon on the New Zealand ETS.[78] The 100% renewables policy also has potential consequences for security of supply.[79]

4.3 Picking winners is expensive and unnecessary

The 100% renewables policy is an example of a government policy that picks winners from the top down. Despite its dry year exemption and neutrality among renewables technologies, both having a significant effect in reducing costs, the policy will nevertheless take carbon out of the atmosphere at a far higher cost per tonne than alternatives.

The high cost of the 100% renewables policy is common to many, though not all, top-down

Figure 10: Estimated 2035 carbon abatement curve



Source: Contact Energy, "Thermal Transition – The trade-offs faced as we decarbonise NZ's electricity system in the 2020's and beyond" (2018), Figure 29, 42.

emissions reduction policies. The nature of emissions makes life especially difficult for policymakers. Emissions occur in many places in an economy, with each source having its own abatement cost that depends on the value of the activity and the relative cost of non-emitting alternatives to that activity. For most of these sources, the first tonne of emissions is cheaper to cut than the last. And to make matters considerably more complicated, abatement costs vary not only by source but by each person. It might be far more difficult for a solo parent to catch the bus to work one day a week than for a single person to catch the bus four days a week rather than three. It might be far easier for 10 businesses to shift production times by an hour than for one business to reorganise a production line to achieve the same reduction in emissions. These costs may be obvious to the individuals affected, but they are almost entirely invisible to policymakers as they design their interventions.

Without access to this information, policy operates at a disadvantage large enough that it can be measured. A recent paper in the *Journal of Economic Perspectives* reviewed 50 studies of interventions aimed at reducing emissions.[80] The interventions were evaluated on the basis of cost per tonne abated, and the results compared to an Obama-era EPA[81] estimate of the social

Table 1: Cost of abatement by policy (US$)

Policy	Estimate ($2017/ton CO_2e)
Behavioral Energy Efficiency	-190
Corn Starch Ethanol (U.S.)	-18 to +310
Renewable Portfolio Standards	0-190
Reforestation	1-10
Wind Energy Subsidies	2-260
Clean Power Plan	11
Gasoline Tax	18-47
Methane Flaring Regulation	20
Reducing Federal Coal Leasing	33-68
CAFE Standards	48-310
Agricultural Emissions Policies	50-65
National Clean Energy Standard	51-110
Soil Management	57
Livestock Management Policies	71
Concentrating Solar Power Expansion (China & India)	100
Renewable Fuel Subsidies	100
Low Carbon Fuel Standard	100-2900
Solar PV Subsidies	140-2100
Biodiesel	150-250
Energy Efficiency Programs (China)	250-300
Cash for Clunkers	270-420
Weatherization Assistance Program	350
Dedicated Battery Electric Vehicle Subsidy	350-640

Notes: Rounded to two significant digits. The authors have converted all estimates to 2017 dollars for comparability. See Appendix Table A-1 for sources and methods. CO_2e denotes conversion of tons of non-CO_2 greenhouse gases to their CO_2-equivalent based on their global warming potential.

Source: Kenneth Gillingham and James Stock, "The Cost of Reducing Greenhouse Gas Emissions," *Journal of Economic Perspectives* 32:4 (2018), 53–72.

cost of carbon of US$46/tonne. The findings are presented in Table 1. Further estimates of the abatement costs of other top-down programmes are in Appendix 1.

A striking aspect of Table 1 is the wide variation in costs, suggesting high-cost interventions are being selected by governments over lower-cost alternatives. The wide variation and absence of weighting among different programmes make an overall estimate of interventions difficult. However, the available information suggests top-down interventions may exceed the social cost of carbon by a factor of 5.[82] In other words, government policies may be spending $5 on average to avoid emissions costing $1.

Two other factors plague the effectiveness of government interventions around the world aimed at reducing emissions. First, governments do not have a track record of abandoning emissions policies that turn out to be ineffective. If anything, political incentives seem to reward governments that double down on bad emissions policies. Second, when governments take on the job of deciding where and how the burden of abatement will fall within an economy, industry and special interest groups – lobbyists – inevitably arise to advise governments on where next to introduce or expand subsidies or write new rules. Lobbying is a deadweight loss. It thrives when governments give themselves wide discretion in a complex area involving big dollars. In this game, governments' best move is not to play.

4.4 The danger of capacity contracts

The 100% renewables policy has the potential to affect the security of electricity supply. A potential solution to any concerns about security of supply is to use government-backed capacity contracts. Capacity contracts are the purchase of the availability of generating capacity, separate and additional to the purchase of electricity generated by those assets. In New Zealand, generating assets are currently funded from the sale of generated electricity. Hedge contracts between wholesale market participants essentially operate as capacity contracts in some cases.

Regardless of whether or how the 100% renewables policy poses a security of supply risk, officials and ministers should be fully aware of the potential consequences of introducing government-backed capacity contracts. Their introduction – or even the likelihood of their introduction – is likely to shift most or all investment decisions on generating capacity away from the electricity sector to officials and ministers. If the shift occurs it will likely be immediate. This is precisely what government-backed capacity contracts achieved in the UK when they were introduced in 2014:[83]

> **At a stroke**, the market was transformed from one in which private companies made decentralised decisions about how much generation to invest in… to a centralised central buyer system, in which… all new investment is in practice determined by government-backed contracts. [emphasis added]

Decision-making shifts because the introduction of capacity contracts, or a credible promise to introduce them, will cause investors to hold off on investment until they can obtain a capacity contract. Holders of capacity contracts receive additional payments on top of revenues from the sale of electricity, and can potentially offload some financial risk to the government. Equally, investors will be reluctant to compete against other generators holding those contracts without holding a contract of their own.

Even if security of supply were a serious concern, the government should be aware of this important likely by-product of introducing capacity contracts and consider alternatives.[84]

CHAPTER 5

A better way to reduce emissions

> *Economics contains one fundamental inconvenient truth about climate change: For any policy to be effective in slowing global warming, it must raise the market price of carbon… the only way to have major and durable effects on such a large sector for millions of firms and billions of people and trillions of dollars of expenditure is to raise the price of carbon emissions*
> —William Nordhaus, Nobel laureate in Economics (2018)[85]

> *The carbon price has proved particularly effective in reducing emissions and delivering value for money. The majority of the estimated £39 billion that households spent on decarbonisation policies between 2010 and 2017 was targeted at the electricity sector. The single biggest contributor to emission reductions was the carbon price, accounting for around half of the reductions. We estimate that the net cost to consumers of the carbon price was around £27 for each tonne of carbon dioxide emissions it saved. Other policies were significantly more expensive.*
> —UK regulator Office of Gas and Electricity Markets (Ofgem) (2018)[86]

How can emissions be reduced at least cost? Economics offers a crisp answer: price carbon.[87] Specifically, a price equal to the damages of emitting an additional tonne of carbon. Prices are better suited to solving decentralised problems like emissions than top-down policies like 100% renewables. Whether carbon is priced via an ETS or a carbon tax is far less important than whether the government selects carbon-pricing over winner-picking as its emissions reduction strategy.[88]

5.1 Emissions trading

An ETS, also known as cap-and-trade, requires emitters to surrender government-issued emissions units for each tonne of greenhouse gases they emit.[89] The theory is straightforward. Emissions units trade for a price that reflects the supply and demand of emissions rights. The price paid for emissions rights is passed down the supply chain, raising the relative cost of emissions-intensive goods and services, encouraging substitution to lower-carbon alternatives.[90] If the quantity of emissions units is capped, and the cap is enforced, the government can control overall emissions by the number of units it chooses to issue.

In practice, things are less tidy. New Zealand established its ETS in 2008, taking retrospective effect on 1 January of that year. The electricity sector entered the scheme in 2010. Today, the ETS covers nearly half of emissions – from fossil fuels and industrial processes to waste[91] – but agriculture, the other half of emissions, remains outside the scheme. Emissions units are capped at $25/tonne, the government giving effect to the cap by issuing unlimited emissions units at that price. This leaves the quantity of emissions units uncapped. The government recently announced it will introduce auctioning of units from a fixed reserve that eventually replace the price cap.[92]

An ETS (or its price-based counterpart, the carbon tax) solves the problem of finding emissions reductions at least cost wherever the solution lies in the economy (or the parts of the economy covered by the ETS). When carbon is priced, emitters who can reduce emissions for a cost that is less than the carbon price will do so. Where abatement costs more than the carbon price, the lower-cost option is to pay the price and allow emissions to continue. In this way, a price on carbon discovers the least cost ways to reduce emissions. Using a carbon price, information about the cost of emissions known to individuals and businesses but largely unavailable to policymakers can be brought to bear on the problem of lowering a country's emissions. The effectiveness of the system depends on one price for carbon:[93]

> Since the emission of a ton of greenhouse gases causes the same environmental damage, wherever, whenever and however it is emitted, a single global price for CO_2 should guide public and private agents in their investment, production and consumption decisions. This encourages polluters to take all available steps to reduce emissions which cost less than that price, guaranteeing that we get the "best bang for the buck", namely the highest environmental benefit for our collective sacrifices.

Under an ETS-led approach, policymakers are responsible for building and maintaining a credible scheme for allocating, trading and surrendering emissions units, and for determining the future quantities of emissions units that will be issued over time.[94] A carbon price that aligns private and social interests leaves policymakers with nothing more to do, at least with respect to emissions. The carbon externality that policy was tasked with solving is solved. (Distributional issues are discussed below.)

Society's interest in achieving any commitment to emissions reduction at least cost is served by investment in renewable generation up to the point that renewables cease to be the lowest-cost source of emissions reduction in the economy. For policymakers, working out the location of that critical point is an extremely difficult problem. In contrast, a carbon price can discover this critical point for investment without difficulty, as illustrated in the following scenario.

5.2 A hypothetical

Let us imagine the quantity of emissions units in the ETS is capped, and the cap is enforced. Emissions units trade for $75/tonne. At this carbon price, renewables generate 95% of electricity and thermal generators 5%.[95] These shares reflect the high cost of replacing the last few units of thermal generation with renewable generation (see Chapter 4). How did the ETS discover the 'right' amount of thermal generation to retain?

Consider this discovery process from the perspective of a coal generator that is part of the 5% thermal generation. Like all generators, the coal plant earns revenue from the sale of electricity on the wholesale market. Every year, the coal station's manager must purchase and then surrender emissions units equal to the number of tonnes emitted by the plant – a substantial cost when units are trading for $75/tonne.

Over the years, as the carbon price gradually increased to its current level, other coal and gas plants found they could not keep up with their low-carbon competitors. One by one, thermal stations exited. However, the manager of one of the last remaining thermal generators has been able to find buyers willing to pay a good price for the firming and peaking capacity her generators can offer in dry years. For those buyers, alternative sources of dry year capacity (as well as large-scale storage and demand response technologies) are even more expensive. Buyers were willing to write long-term contracts to purchase energy at a price high enough to cover the coal plant's costs, including buying emissions units. Managers in the other remaining gas and coal plants went through similar processes with their buyers.

This is how an ETS, or a carbon tax, solves the problem of how much thermal generation to retain. The solution is emerges from aggregating the preferences of buyers, and of the end consumers they represent. Thermal generation is retained only to the extent that for buyers all the alternatives are worse.

There are three points to take from this hypothetical. First, complex trade-offs between generation types and emissions sources were made without any input from policymakers. The job for policymakers was to determine the quantity of emissions units and provide a binding, credible ETS as a level playing field enabling discovery.[96] After that, it was up to the market players to work through the trade-offs. Building a binding, credible ETS is not a trivial problem for policymakers, to be sure, but it is solvable and a problem where governments hold a comparative advantage.

Second, retaining coal generation *did not raise New Zealand's emissions at all.* Remember, the quantity of emissions units is capped in this hypothetical. The manager purchases emissions units from a finite pool by outcompeting other bidders. Emissions from this manager's coal plant are necessarily offset by lower emissions (or greater carbon capture) elsewhere in the economy.[97] The fact that coal outbids its competitors for emissions units reveals that it is those other sources, not coal, that have lower costs of abatement. That information is generally not available to policymakers intervening from the top down, nor anybody else: it is revealed by competition for limited emissions rights under cap-and-trade.[98]

Third, pricing the externality unlocks effortless scalability. A price on carbon means abatement occurs automatically in normal market transactions. Market players simply respond to the prices confronting them – just as we all do every day. That is what it means to internalise the externality. The manager's job in this scenario was simply to calculate her maximum willingness to pay to avoid the cost of abatement. The point at which her buyers become unwilling to pay enough to cover the costs, including the cost of emissions, is the signal that her business is now a least-cost source of emissions reduction, and should exit. As the quote from William Nordhaus at the start of this chapter suggests, it is the alignment of private and social interests that provides the scalability necessary to deal with the emissions problem.

The purpose of offering this scenario is not to suggest it will be easy to develop a binding ETS. It is to point out the enormous prize of successfully putting a price on carbon.

5.3 Managing distributional issues

Carbon pricing has an effect on the distribution of income, an important responsibility of the government. Distributional issues are sometimes used to justify *ad hoc* policies circumventing the ETS. It is not possible, it is argued, to reach our emissions targets using carbon pricing alone because of the need to protect vulnerable people and households.

All policies affect distribution. It is neither necessary or desirable for the distributional issues created by environmental policies to be resolved by those same policies. It might in some sense seem only fair that the policy that causes a problem also solves it. However, giving any policy two objectives all but guarantees neither will be delivered.

The alternative is to resolve distributional issues created by environmental policies such as a price on carbon through the welfare system, which specialises in re-distribution and which can look across the effects and interactions of all policies. Allowing policies to specialise in one objective carries the enormous advantages of greater transparency, simplicity and effectiveness – both for the environment and for fairness.[99]

To illustrate, consider the following example. Joe drives from his home in Papakura to a work site in Tamaki every day. The introduction of a carbon price will reduce Joe's weekly disposable income by $30. The government, concerned about the effects of the carbon price on people like Joe, can respond in one of two ways. The government could exempt Joe from the carbon price, say by extending the community services entitlement. This would give Joe access to a petrol price that excludes the carbon tax, leaving Joe no worse off than before.

Alternatively, the government could decide not to exempt Joe from the carbon tax and instead compensate Joe through his income, for example, by increasing the Working for Families entitlement. This too would leave Joe no worse off if he continues driving to work. But this second approach preserves Joe's incentive to reduce his carbon footprint, which he could do by using public transport more. If his circumstances allow, and if he chooses, Joe can *raise* his income by reducing his carbon footprint – exactly what the policy intends.

Policymakers are right to be concerned about distribution but are responding the wrong way. Distribution does not justify resorting to mostly ineffective ad hoc policies, nor does it require carve-outs that water down environmental policies. It is not even clear ad hoc policies deliver preferred distributional consequences on average, or that governments measure enough to know the difference.[100] The better approach is to resolve distributional issues through incomes using the welfare system. Use incomes, not prices or policy carve-outs, to protect households.

5.4 Is an ETS actually effective?

Carbon pricing is all well and good in theory – but is it effective? To date, New Zealand's ETS has not been effective. Other than for some small evidence of the effects of the ETS in the forestry sector, the scheme has not had any clear ramifications on domestic mitigation efforts.[101] This lack of a response is hardly surprising. New Zealand's ETS has been watered down by cheap international units and a 2-for-1 policy. And the ETS operates without a cap on the quantity of emissions units. The issue, so far, has been the implementation, not the theory.

Evidence from overseas strongly suggests carbon prices and pollution taxes more generally do work. This evidence, largely drawn from the most recent assessment report of the Intergovernmental Panel on Climate Change (IPCC), is listed with references in Appendix 2. The IPCC concluded:

> Of course, many factors may be at play, and these differences cannot be attributed solely to differences in taxation. **Overall, the evidence does suggest that carbon taxes, as part of an environmental tax reform, lead to abatement of GHG emissions**, generate revenue for the government, and allow reductions in income tax threatening employment. Theory strongly suggests that if a tax is implemented then it would also be cost effective, but it is for natural reasons hard to demonstrate this empirically at the macro level. [emphasis added]

CHAPTER 6

What's the strategy? The futility of emissions policies under an ETS

> *[I]f a cap-and-trade system has a sufficiently stringent cap then other policies such as renewable subsidies have no further impact on total greenhouse emissions.*
> —Intergovernmental Panel on Climate Change (IPCC), AR5[102]

> *Carbon emissions associated with electricity generation are captured within the EU Emissions Trading Scheme and capped. Therefore any changes in consumption should not affect emissions or the UK's legally binding energy targets.*
> —UK energy regulator Ofgem explains why its proposal to introduce consumer electricity price caps will not increase overall emissions[103]

> *… it should be noted that the Renewable Energy Sources Act and the Combined Heat and Power Act are essentially not suitable instruments for achieving their ambitious goals [to reduce carbon emissions]… they are redundant against the background of European emissions trading.*
> —Germany's Monopolies Commission on why targeted interventions under an ETS will not reduce overall emissions[104]

> *With the beginning of a functioning market for CO_2 emission licences in Europe… [the Renewable Energy Sources Act] serves to subsidise CO_2 emissions in Europe outside the German power plant sector… [The Act's] overall effect on the reduction of CO_2 emissions will be zero… It will then become an ecologically useless but economically expensive instrument and should consequently be abolished.*
> —Academic Advisory Council to the German Federal Economics Ministry[105]

> *Because CO_2 emissions in the EU are capped by the EU ETS, the EU's policy to increase its use of renewable energy can have no effect on those emissions.*
> —Richard Schmalensee, MIT[106]

The government is on the right track with many of its responses to climate change. A consultation document on the ETS, released in August 2018, declared the ETS as "New Zealand's main tool for reducing emissions".[107] Ministers James Shaw and Shane Jones also referred to the ETS as the "main tool" in a press release accompanying the consultation document's release. At the end of 2018, the government announced its intention to tighten the cap on the quantity emissions units in the ETS.[108] It is also clear ministers and officials understand the need for policy credibility on matters affecting long-term investment.

Given New Zealand's international commitments to emissions reduction, this report endorses the primacy granted by the government to the ETS over other *ad hoc*, top-down measures. On the evidence presented earlier in this report, top-down interventions offer only a small fraction of the environmental benefits per dollar compared with a binding ETS.

Despite its support for the ETS, the government has announced a stream of top-down initiatives, including a green investment fund,[109] a ban on oil and gas exploration,[110] electric vehicle subsidies,[111] as well as the 100% renewables policy.

Significantly, these interventions mostly target parts of the economy already covered by the

ETS. At the point the ETS caps the quantity of emissions units at a level that is binding, top-down interventions in parts of the economy covered by the ETS *will cease to have any effect on emissions.* That is because overall emissions will be determined only by the quantity of emissions units issued. Interventions that leave the quantity of emissions units unchanged cannot reduce overall emissions.

To see why, consider the following example. Imagine the government sells 10 emissions units every year. Each unit entitles its bearer to emit 1 tonne of carbon dioxide. Each year, the electricity sector produces 1 tonne of emissions. Accordingly, it buys and surrenders 1 emissions unit per year. The remaining nine units are purchased across the rest of the economy. Annual economy-wide emissions total 10 tonnes.

Now imagine the government introduces a 100% renewables policy with a goal to reduce emissions. The policy is a great success, and electricity sector emissions fall to zero.[112] But the 100% renewables policy has made absolutely no difference to emissions across the whole economy. Despite the fall in electricity's emissions, annual emissions remain exactly 10 tonnes. Why?

Because the government is still issuing 10 emissions units each year. The emissions units previously purchased and surrendered by the electricity sector each year have been freed up for purchase and surrender somewhere else in the economy. The renewables policy actually *lowers* the price of carbon because there are now fewer buyers for the same number of emissions units (this is why in the quote at the start of this chapter, the Advisory Council to the German Federal Economics Ministry complains that the result of Germany's renewables policy amounts to a pollution subsidy for the result of Europe).

In this example, the only effect of the 100% renewables policy is to raise the cost of emissions reduction by forcing abatement to occur in certain parts of the economy. Electricity's willingness in this example to buy an emissions unit rather than reduce emissions, before the introduction of the policy, reveals it is a relatively high-cost source of abatement. Without the policy, the same abatement would have occurred elsewhere in the economy at a lower cost.

Of course, the government could cut the number of emissions units from 10 to nine after successfully reducing the electricity sector's emissions. But the government could just have reduced the emissions units by one without the renewables policy. Either way, the only effect of the policy is to force emissions reductions to occur through high cost channels for no environmental benefit.

6.1 Political tolerance for the ETS

What about politics? Ministers and officials have argued that while using the ETS to reduce emissions at least cost is desirable, politics prevents carbon prices from rising high enough to achieve the necessary cuts in emissions. This, it is argued, is why *ad hoc* measures are necessary. Conventional wisdom has low expectations for the public's tolerance for an ETS.

This report stands firmly against this conventional wisdom for two reasons. First, the performance gap between carbon pricing and government winner-picking appears to be huge, a gap that should make any government reluctant to circumvent abatement using carbon prices if it is serious about reducing emissions. If the public finds an ETS intolerable, it can hardly follow that alternative channels which reduce emissions at perhaps 10 times the cost per tonne are the better bet.[113] Even if the ETS cannot get us all the way, the performance advantage of the ETS implies higher environmental returns to investing in raising political support for the ETS, and do more through that channel, rather than resorting to ineffective *ad hoc* policies. Every effort should be made to maximise the share of abatement activity through the ETS.

Second, declarations of political infeasibility are being made in advance of any serious attempt to discover what is actually possible with an ETS. Political feasibility is not something governments must take as given. It is a function of policy quality. Voters' objections to carbon pricing probably depend at least as much on certainty, sufficient warning, policy credibility, access to compensation, and fairness as they do on the price level. High carbon prices are sometimes presented as if they are in tension with certainty, fair warning, compensation and fairness. They are, in fact, complementary.

There are instances of strong acceptance of high prices on pollution:

- Sweden has levied a carbon tax of 1,100 krona (US$165) per tonne since 1991, with exceptions for industry,[114]
- New Zealand's ETS prices, affecting much of the New Zealand economy, have increased substantially between 2013 and 2018 following delinking from international markets and phasing out of the 2-for-1 rule, without any significant public reaction,
- Britain's carbon price floor, announced in 2011 and which took effect in 2013, applies to the electricity sector and is set at £18 per tonne, which until recently was well above the price of emissions units on Europe's ETS,[115] and
- New Zealand's existing tax and ETS levies on petrol amount to NZ$331 per tonne of carbon.[116]

Of course, there are also instances of public rejection of carbon pricing, most recently the *gilets jaunes* protests in Paris. But it seems likely policy quality is at least as important as emissions pricing per se.

Many options for improving the political feasibility of a binding ETS remain untried. On top of the list is a commitment to revenue neutrality, an idea strangely missing from the New Zealand debate.[117] Revenue neutrality is a commitment to use the revenues raised through the ETS or a carbon tax to reduce taxes elsewhere.[118] There is nothing about the carbon externality that demands an overall increase in the size of government. The carbon externality is internalised by a carbon price that reflects its social cost, not by how the revenue raised by a carbon tax is spent.[119]

There is some precedent for using *quid pro quo* to quell political opposition. Fuel excise increases were intensely political until the 2000s, when the government introduced the hypothecation of petrol taxes. Hypothecation – a commitment to use revenue raised from petrol excise to build and maintain roads – subdued much of the opposition with the credible promise of benefits for motorists. More recently, the 2010 tax switch, which paired a GST increase with an offsetting reduction in income taxes, was received with only muted opposition. Revenue neutrality has been used in other countries to increase political acceptability of pollution taxes.[120]

There are other ways to increase support for carbon pricing through an ETS: evaluating all existing and new top-down emissions reduction initiatives on a cost-per-tonne basis; committing to reallocate funding from less- to more-effective programmes; evaluating behavioural changes caused by the ETS emissions reductions in households and firms to reveal effects that might otherwise go unnoticed; committing to an ETS price floor; and seeking bi-partisan support for an accelerated tightening of the ETS. The government has also indicated it may consider re-introducing recognition of selected international units,[121] potentially a source of significant cost savings.[122] Other things being equal, a lower cost of abatement will translate to greater support.

CHAPTER 7

Recommendations

Regulation, deregulation, competition, and various combinations of them are not good or bad in the abstract as some ideologues would have us believe. They are merely different ways of organizing economic activity to achieve certain ends. They are all imperfect. Whether we should regulate or not, how we should regulate, and what mixture of competition and regulation will be most effective in promoting consumer welfare depend on the specific characteristics of individual products and markets. To make the right choice requires that we carefully balance the advantages and disadvantages of different institutional arrangements in light of the characteristics of the products and firms to which these institutions will apply.
—Alfred Kahn, *The Economics of Regulation*[123]

Tempting though it is to many observers to predict how this transformation is going to take place, and profitable to many lobbyists to persuade government that their specific technologies and projects are the right answers, the design of energy policy and the interventions to achieve the objectives should be driven by the uncertainty about the detailed shape of the decarbonisation path. In order to achieve the prize, it is important not to try to pick winners, and to focus on the framework within which the private sector brings new ideas, new technologies and new products to the end-user. Avoiding detailed intervention is a key to keeping down the cost of energy.
—Dieter Helm (2017)[124]

7.1 Findings

The New Zealand electricity system is performing well. It delivers electricity that is relatively affordable and secure, and far more clean than in almost all other OECD countries. There is no problem that justifies re-politicising the electricity system.

As a source of emissions reduction, the 100% renewables policy is far more expensive than alternatives.

Introducing a capacity contracts mechanism risks an immediate shift of investment decisions from the electricity sector to government, as has occurred in the UK.

The decentralised nature of emissions, lobbying and political incentives to double down on bad policy all make top-down policy a poor strategy for emissions reduction. Governments around the world are using policy to direct investment worth billions to avoid emissions costs worth millions. Carbon pricing reliably reduces emissions at a measurably and substantially lower cost.

New Zealand's ETS should continue to be tightened and its scope gradually expanded. All abatement should occur through the ETS, or as much as possible, given its likely performance advantage.

Political constraints on using the ETS in New Zealand do not justify using vastly inferior *ad hoc* measures. Political feasibility is substantially a matter of policy design.

7.2 General policy principles

Aim to reduce emissions at least cost. Other things being equal, more can be done for the environment within political and fiscal constraints, and New Zealand is more likely to meet its international obligations and at a lower cost per tonne.

Price carbon to reduce emissions at least cost and make polluters pay. Least-cost abatement depends on one price for carbon.

Tax the pollution, do not subsidise non-polluting alternatives. Environmental benefits of green subsidies depend on the displacement of polluting technologies. Unintended consequences are all but certain when technologies are not close substitutes.

Cost of command is increasing in specificity. A policy that specifically promotes solar in Northland, for example, is more expensive than a policy that promotes renewables.

Protect individuals and households through income, not price. The organising principle of electricity generation in New Zealand is the transmission of information through prices. Both emissions reduction and affordable electricity can be best achieved by **sending the right signals to players. Let environmental policy focus on the environment and use the welfare system to manage important distributional issues.**

All decision-making arrangements are imperfect. Choosing between decentralised decision-making, command or a mix of both depends on the expected performance of each arrangement under the circumstances. **Market failure is the wrong test for direct intervention by government.**

In electricity, intervention begets intervention.

7.3 Implementing the 100% renewables policy and wider emissions reductions

Above all, **preserve the political independence of the electricity system**. Capacity contracts risk upending the electricity system.

Consider the 100% renewables policy in the wider context of carbon abatement opportunities elsewhere. But do not pick different winners. Just price carbon.

Electricity is an input into all other parts of the economy. Unintended consequences are certain, most clearly in the potential to delay the electrification of transport and industry. All top-down measures in pursuit of emissions reduction are vulnerable to counterproductive outcomes like this.

Build policy credibility. Investment in long-lived assets depends on an expectation that the policy on which an investment depends will remain in place and is predictable. In particular, investment in building a credible commitment to the ETS, and a credible commitment to retain the political independence of the electricity system in New Zealand. These commitments are mutually reinforcing.

Commit to the independent evaluation of all emissions policies on a cost per tonne basis, and publish the results. Improve incentives for good environmental outcomes by committing to reallocating funding from less- to more-effective interventions. Commission and publish regular reports on abatement efforts attributable to cap-and-trade, which might otherwise be invisible due to the decentralised nature of ETS-induced cuts in emissions.

If direct intervention is absolutely necessary… Pick winners in the least-specific terms, pre-commit to no further interventions, include offramps and sunset clauses in any policy, maximise transparency by ring-fencing funding for the intervention, if possible avoid directly intervening in investment decisions, and commit to the independent measurement and reporting of the results on the basis of cost per tonne abated.

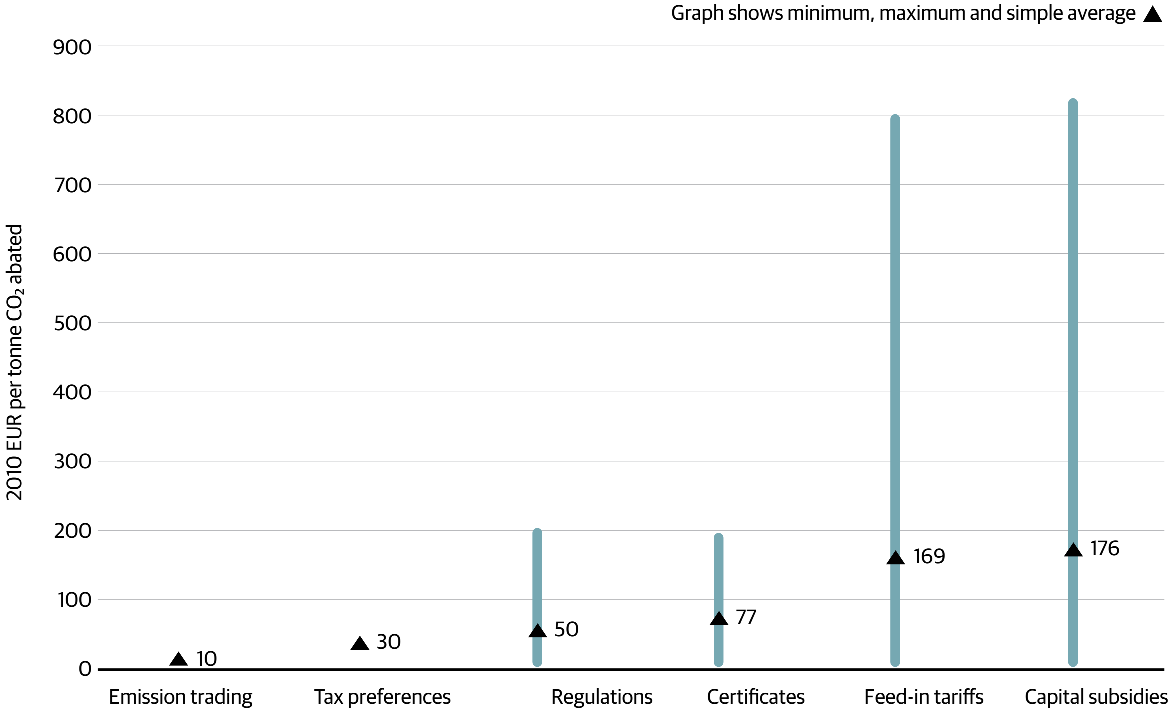
APPENDIX 1

How cost effective are top-down programmes on emissions reduction?

Assessments of emissions reduction programmes on a cost per tonne basis include:

- Offshore wind in New England costs US$300/tonne carbon avoided.[125]
- The OECD estimates that an implicit carbon price of biofuel subsidies in the road transportation sector can be as large as €1,000/tonne.[126]
- UK regulator Ofgem reported large-scale renewables cost of £101/tonne, small-scale renewables cost of £315/tonne, and a renewable heat incentive cost of £142/tonne.[127]
- Renewable energy tax credits will cost America US$250/tonne of reduced carbon dioxide between 2012 and 2035.[128]
- US biofuels tax credits cost $2,300/tonne to *increase* carbon dioxide emissions. It is estimated that removing the tax credits would reduce overall emissions by 4.8 million tonnes.[129]
- An energy efficiency programme in Michigan spends more than US$200/tonne to reduce carbon dioxide and achieve a social rate of return of -7.8% – and negative private returns, including among low-income households.[130]
- The OECD estimates that renewables subsidies are around 17 times more costly per tonne relative to emissions trading, and capital subsidies and fuel mandates in the transport sector cost around eight times more per tonne than taxes (Figures 11 and 12).

Figure 11: Estimated effective carbon prices in the electricity sector



Source: OECD, "Climate and Carbon: Aligning Prices and Policies," OECD Environment Policy Paper No. 1 (2013), Figure 5, 31.

Research on electric vehicle (EV) subsidies include:

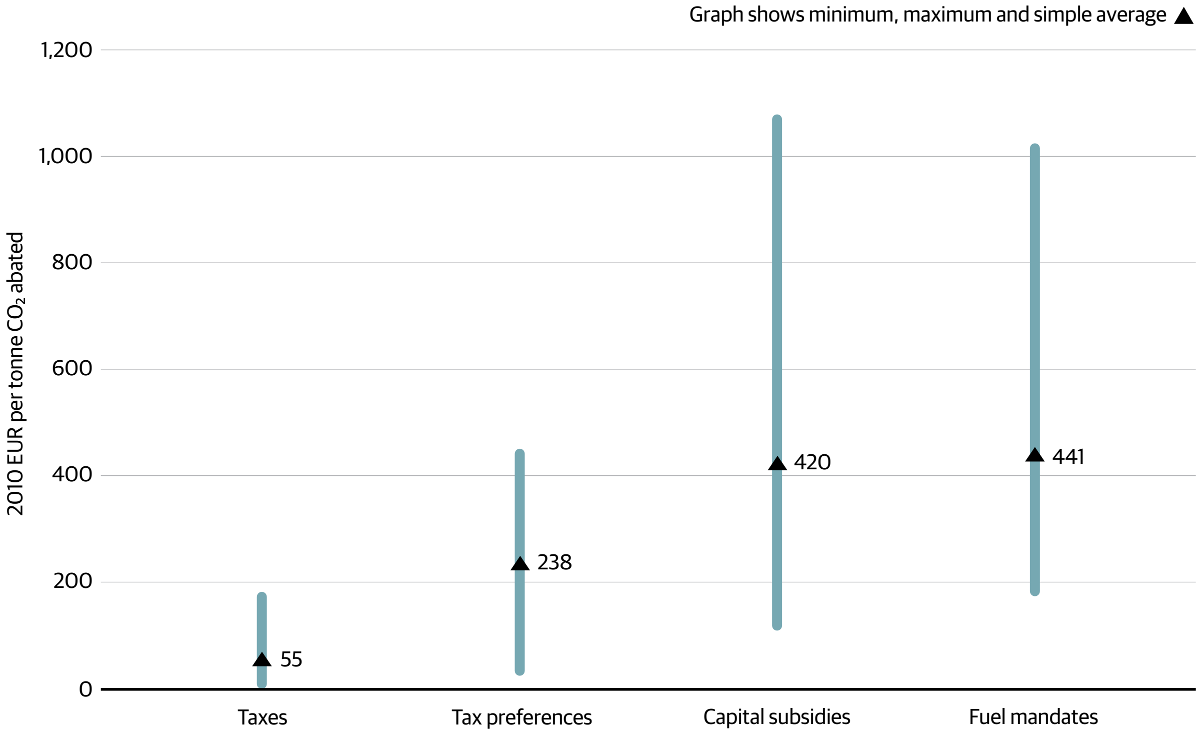
- Norway, a world leader in EV uptake, spends US$6,000/tonne of carbon avoided through EV subsidies.[131]
- Quebec pays CA$1,560/tonne avoided using EV subsidies.[132]
- California's EV subsidies reduce emissions at US$2,785/tonne avoided.[133]
- North Dakota pays US$4,964/tonne to *raise* emissions via its EV subsidies.[134]

It is perhaps instructive to see some of the specific reasons EV subsidies can fail to translate to reduced emissions using Norway as an example. This may also help illustrate the complexity that top-down emissions reduction strategies must deal with:[135]

- Conventional vehicles in Norway travel an average of 12,600 kilometres each year. EVs travel just 5,700 kilometres.
- 85% of households in Norway that own an EV own two or more cars.
- Only 15% of EV owners use their EV for all their daily trips. Most households use their EV as an additional vehicle.
- Manufacturing a fully electric vehicle produces 13.7 tonnes of emissions, including 5.2 tonnes for the battery alone, compared with 6.5 tonnes for a conventional vehicle.[136]
- An EV's range is nearly halved when temperatures reach -25°C.
- Where electricity is produced by coal, an EV's carbon dioxide footprint can be as large as that of an SUV.[137]

There is reason to think New Zealand's EV programme is likely to perform better than the quoted examples from the US and Norway: New Zealand's electricity is clean (like Norway, unlike parts of the US), New Zealand's temperatures are EV-friendly, and New Zealand starts from a low base. Unfortunately, it is not clear how the effectiveness of the New Zealand EV programme, on the basis of cost per tonne abated, will be assessed.

Figure 12: Estimated effective carbon prices in the transport sector



Source: OECD, "Climate and Carbon: Aligning Prices and Policies," OECD Environment Policy Paper No. 1 (2013), Figure 6, 32.

APPENDIX 2

Overseas evidence for the effectiveness of carbon and pollution taxes

Overseas research suggests carbon prices, when binding and credible, reduce emissions and lead to other responses. For example:

- The UK's 2013 introduction of a carbon price floor at £18 dramatically reduced the use of coal for electricity generation from 30% to less than 10% of the UK energy mix, a significant reduction in UK's GHG emissions.[138]
- The European Union's ETS led to an increase in climate technology-related patents for member countries.[139]

In its most recently assessment report, the Intergovernmental Panel on Climate Change (IPCC) surveyed the evidence for the effectiveness of carbon and pollution pricing:[140]

- Rising energy prices increased the rate of patenting with respect to alternative energy sources and energy efficiency, with more than half the effect coming within five years of energy price changes.
- Rising energy prices increased the energy efficiency of the menu of household appliances available for purchase in the United States.
- The Norwegian carbon tax appears to have triggered technology innovation in the form of carbon dioxide storage in the Sleipner gas field.
- Fuel taxes moved auto industry innovation towards more efficient technologies.[141]
- After the 1990 Clean Air Act amendments in the US implemented a tradable permit programme for sulphur dioxide, the rate of patenting on techniques for sulphur removal increased. Both capital and operating expenditures for scrubbers were reduced.[142]
- A survey of research on the effects of tradable permit systems on technology innovation and diffusion cited in the IPCC report concluded: "The general result is that tradable permit programs have improved the pollution control technology compared to the previous regulation used."[143]
- The very high fee on nitrogen oxide in Sweden has led to a rapid process of both innovation and technology diffusion for abatement technologies.[144]
- From 1990 to 2007, the carbon dioxide-equivalent emissions in Sweden were reduced by 9% while the country experienced an economic growth of 51%. In Sweden, with the highest carbon tax in the world (albeit with exemptions for some industrial sectors), there was a very strong decoupling of carbon emissions and growth with reductions in carbon intensity of GDP of 40%.
- Per capita emissions in Denmark were reduced by 15% from 1990 to 2005; the experience in Scandinavia, the UK and the Netherlands was similar.

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1. The Economist, "How to lose half a trillion euros: Europe's electricity providers face an existential threat" (15 October 2013).
2. Nikolai Ziegler, et al. "Compendium for a Sensible Energy Policy," Vernunftkraft (Germany: 2018), 20.
3. The Economist, "How to lose half a trillion euros," op. cit.
4. Hubertus Bardt, E-mail (8 November 2018).
5. World Meteorological Organization (WMO), "Sunshine," Website, http://data.un.org/Data.aspx?q=Sunshine+&d=CLINO&f=ElementCode%3a15. WMO data shows mean annual sunshine from the two Antarctic stations in its records as 1,644 hours per year. The mean annual sunshine from the 19 stations in Germany is 1,631 hours. Germany ranks 113th out of the 126 countries and territories in WMO's data set.
6. Justus Haucap, "Tales from Absurdistan," Speech to The New Zealand Initiative (Wellington: 13 February 2013).
7. Energy Charts, "Annual increase and decrease of net installed electricity generation capacity in Germany," Website.
8. The Strommarktgesetz (electricity market bill) contains regulations regarding market exit. According to this law, power plants should stay in a security reserve for four years in order to be used in extreme situations of electricity scarcity. There are some lignite power plants within that reserve and they will be shut down afterwards. Hubertus Bardt, E-mail (8 November 2018).
9. Nikolai Ziegler, et al. "Compendium for a Sensible Energy Policy," op. cit. 20.
10. Hubertus Bardt, E-mail (1 November 2018).
11. The Energy Efficiency and Conservation Authority defines renewable energy as "from sources that are naturally replenished in a relatively short timeframe". Renewable generation generally includes hydro, solar, on- and offshore wind, biomass, geothermal and marine (waves and tides) technologies. See Energy Efficiency and Conservation Authority (EECA), "Renewable energy resources," Website.
12. Treasury, "Review of Electricity Planning and Electricity Generation Costs," Report to the Minister of Finance (Wellington: New Zealand Government, 1984), https://www.dropbox.com/s/rn9ny1blkpdad92/McLachlan_Treasury_Mar_1984.pdf.
13. Statistics New Zealand, "Gross domestic product," Website.
14. Ministry of Business, Innovation and Employment (MBIE), "Electricity statistics – Data tables for electricity," Website.
15. Miriam R. Dean, et al. "Electricity Price Review Hikohiko Te Uira, First report for discussion" (Wellington: New Zealand Government, 2018), 23–24. If electricity does not feel especially cheap in New Zealand, despite a relatively low cost per unit for electricity, perhaps it is because households in New Zealand consume more electricity each year than households in other countries. In 2014, households here consumed 7,368kWh, which is more than in Australia (6,839kWh), the United Kingdom (3,941kWh), and Germany (3,079kWh), but less than in the United States (12,305kWh) or Canada (11,135kWh). World Energy Council, "Energy efficiency indicators: Average electricity consumption per electrified household," Website, https://wec-indicators.enerdata.net/household-electricity-use.html.
16. Productivity Commission, "Low Emissions Economy: Final Report" (Wellington: New Zealand Government, 2018).
17. Miriam R. Dean, et al. "Electricity Price Review Hikohiko Te Uira, First report for discussion," op. cit.
18. Australian Competition and Consumer Commission (ACCC), "Restoring Electricity Affordability and Australia's Competitive Advantage: Retail Electricity Pricing Inquiry—Final Report" (Canberra: Government of Australia, 2018), 298.
19. In its Doing Business survey of countries, the World Bank ranks New Zealand approximately mid-table across 212 countries and territories for electricity reliability. World Bank, "Doing business," Website, http://www.doingbusiness.org/en/data.
20. Renewable energy refers to sources of energy that are naturally replenished in a relatively short time frame. Energy Efficiency and Conservation Authority (EECA), "Renewable energy resources," op. cit. Renewable generation usually refers to biomass, hydropower, geothermal, wind, solar and marine using waves or tides. Biomass includes wood and wood waste, collected rubbish, landfill gas and biogas, ethanol and biodiesel. See Energy Information Administration, "Renewable energy explained," Website.
21. The government's Renewable Energy Policy Statement in 1993 aimed to "facilitate the development of cost-effective renewable energy". Productivity Commission, "Low Emissions Economy: Final Report," op. cit. 97.
22. New Zealand Government, "Interim Climate Change Committee announced," Press release (17 April 2018).
23. In 2011–12, hydro inflows were about 18% below average.
24. Put another way, it allows thermal capacity to exceed thermal generation in producing a virtually zero thermal-generation market.
25. 1 watt equals 1 joule of energy per second. A 1kW electric heater consumes 1,000 joules of energy per second. If the same heater ran for 1 hour, it will consume 1 kilowatt-hour of energy, or 3.6 million joules. A watt measures a flow of energy (joules/second), whereas a kilowatt-hour measures a stock of energy (joules). In the year to June 2018, New Zealand had consumed a net total of 42,963 GW-hours of electricity. Dividing this by the number of hours in a year (365 x 24 = 8,760 hours), the average rate of energy consumed over the year is 4,903MW.
26. This story is presented as taking the demand for electricity as given. In fact, demand depends on the cost of generation and transmission, the extent to which customers are confronted with the difference in costs between peak and off-peak, and so on. Demand is endogenous, in other words.
27. See Electricity Authority, "Wholesale datasets," Website.
28. Depending on the value of their fuel, discussed later in the report.
29. Geothermal has ongoing costs for operations and maintenance, but a significant proportion of these costs are necessary whatever the plant's output.

30. Based on data from US Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018," *Independent Statistics and Analysis* (2018). Source figures are in US dollars, converted to New Zealand dollars at an exchange rate of 0.6658. Natural gas based on Conventional CC; wind based on onshore wind costs; solar based on "Solar PV"; coal based on "Coal with 0.9 CCS". Levelised cost of electricity (LCOE) has a major drawback in not recognising the costs of intermittency, a cost that for solar and wind generation can be as large as the cost of generation itself. Intermittency and its consequences are discussed later this in chapter.
31. Treasury, "Review of Electricity Planning and Electricity Generation Costs," op. cit. 11.
32. Based on the Vestas V47 660kW wind turbine, installed at New Zealand's largest wind farm (New Zealand Wind Energy Association, "Tararua Wind Farm," Website). Vestas V47 materials specifications are from Younes Noorollahi, Saeid Mohammadzadeh Bina and Kiana Rahmani, "Life Cycle Energy and Greenhouse Gas Emission Assessment of a Wind Turbine Installed in Northeast of Iran," *International Journal of Energy Policy and Management* 3:1 (2018), 8–15.
33. In 2009, Michael Cullen reportedly called the Clyde Dam "the single most monstrous environmental sin over the last 30 years". Reported in Sapere, *Electricity Sector Review 2018* (Wellington: 2018), 45.
34. Or battery.
35. Transpower is the System Operator.
36. In other countries, generation assets are part-funded by capacity contracts. These are payments for making generating capacity available. The purchase of electricity generated from those assets is paid for separately. In New Zealand, compensation for both capacity and electricity generated is via a single payment.
37. Competition is regulated by the Electricity Authority.
38. In this example, the hedge is effectively a capacity contract. A capacity contract purchases access to generating capacity. Where capacity contracts are used, a separate contract generally covers the purchase of electricity from the generating asset.
39. The Electricity Authority publishes a pipeline of consented new generation. Electricity Authority, "Proposed generation plant," Website.
40. The 100% renewables policy applies only in "normal hydrological years". This dry year exclusion allows for thermal (coal and gas) generation to cover the shortfall in energy when lakes run low. Hydro generation can fall by as much as 3,200GW/h below long-term averages in any year, which occurred in 1992. Gas generation has emissions of 455kg/MWh, coal 630kg/MWh, according to Ministry of Business, Innovation and Employment (MBIE), "New Zealand Energy Sector Greenhouse Gas Emissions" (Wellington: New Zealand Government, 2015), 9. Using these ratios, the emissions associated with coal and gas generation necessary to replace 3,200GW/h of lost hydro energy (assuming 90%/10% split between natural gas and coal, consistent with experience) is 1,512 tonnes of carbon dioxide. At a carbon price of $25, this is worth $37,800. Between 1990 and 2018, hydro energy shortages averaged 167GW/h per year (above-average hydro years were treated as average). Meeting this hydro shortfall with gas and coal at the above ratios produces average annual emissions of 78.9 tonnes worth $1,973 per year. The policy's dry year exclusion is sound: $1,973 per annum over 25 years (a common estimate for the economic life of a wind turbine) would amount to just 0.7% of the installed cost of a single commercial-scale wind turbine.
41. Every technology has pros and cons, including solar. This report does not argue for or against any particular technology. Instead, this report argues for technologies to be allowed to find their own level within the electricity system according to their merits, including environmental effects.
42. Hydro is sometimes considered intermittent because availability is affected by variation in lake inflows. A related concept is *dispatch predictable.* Geothermal, which produces 17% of New Zealand's electricity, is noteworthy as a major source of renewable energy that is independent of the weather.
43. Dieter Helm, "UK Cost of Energy Review," Report to Office of Gas and Electricity Markets (2017), xii.
44. Ibid.
45. Paul Joskow, "Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies," Discussion draft (2011), 3.
46. Another aspect of generation is ramping rate, the time for a generator to go from a standing start to full output. To back solar and wind, a generator must not only be dispatchable, but also ideally have a high ramping rate that allows rapid replacement of unanticipated fluctuations in energy from solar or wind. Ramping is discussed later in the report.
47. Dieter Helm, "UK Cost of Energy Review," op. cit.
48. Or released from battery storage. At current prices, batteries fulfill mainly technical roles in electricity networks such as frequency control. They are not economic as large-scale stores of electricity, for now.
49. Or consumers who are willing to reduce demand, or battery storage.
50. Other things being equal. The point holds when electricity demand is increasing over time.
51. Gas generation shares these characteristics, though it is less efficient than hydro when generating at less than 100% capacity, and has longer ramping times (10–20 minutes). Generation technologies with longer ramping rates are unsuited to backing intermittent generation.
52. See Electricity Authority, "Historical hydro risk curves," Website. To put this amount of energy storage in context, at a world price for Li-ion batteries of US$158/kWh a battery with 3,350GW/h capacity would cost US$529 billion to build, about 2.7 times New Zealand's GDP. Batteries have many potential roles in electricity systems and elsewhere, but even with falling costs it is hard to imagine large-scale battery storage ever being feasible.
53. The net change in the value would deduct the cost of storage. Demand response can also reduce intermittency's costs by improving alignment of electricity supply and demand from the demand side.
54. The term "binding" refers to a constraint that is tight enough to force a change in behaviour. For example, if annual emissions in an economy total 40 million tonnes, an emissions cap set at 60 million tonnes is not binding but an emissions cap set at 35 million tonnes is binding.
55. Falko Ueckerdt, Lion Hirth, Gunnar Luderer and Ottmar Edenhofer, "System LCOE: What Are the Costs of Variable Renewables?" *Energy* 63 (2013), 61–75.
56. Other ways to manage frequency include using batteries, and the use of synthetic inertia technology. System Operators generally procure frequency keeping, along with other ancillary services, including instantaneous reserves and black start.
57. The Economist, "Energiewende" (28 July 2012).
58. Ruifen Yan, et al. "The Anatomy of the 2016 South Australia Blackout: A Catastrophic Event in a High Renewable Network," *IEEE Transactions on Power Systems* 33:5 (2018), 5374–5388.

59. Stephanie Dalzell, "There'll be blackouts this summer if nothing is done, AEMO report warns," ABC News (16 November 2018) and Australian Energy Market Operator (AEMO), "Summer 2018–19 Readiness Plan" (2018), 4.
60. Discussed in Chapter 6. It might be argued Europe's ETS cap could be lowered by an amount equal to Energiewende's contribution to reduced emissions. But the cap could have been lowered by the same amount without Energiewende. Abatement would then be determined by market discovery at a lower cost per tonne. Each tonne of carbon taken out of the atmosphere by Energiewende is expected to cost hundreds of euro (Hubertus Brandt, Personal interview, 24 October 2018), many times the current and foreseeable price of carbon. Whether the ETS cap is lowered or not, Energiewende's contribution is to increase the cost of abatement for no environmental benefit.
61. Transpower, "Te Mauri Hiko" (Wellington: 2018), 20. Transpower expects EVs to achieve 40% share by 2030 and 85% share by 2050. Transpower anticipates transport will demand 19TW/h of electricity by 2050, nearly half of the total electricity demand in 2018 (43TW/h).
62. TW/h is terawatt-hour, equal to 1,000 gigawatt-hours (GW/h), or 1 million kilowatt-hours (kW/h).
63. Transpower, "Te Mauri Hiko," op. cit. 22.
64. The increase was primarily led by investment in geothermal and wind. Between 2006 and 2018, geothermal energy increased 2.4 times and wind generation increased 3.3 times. Thermal's share of generation, measured as a five-year average to look through dry years, fell from 31% to 18%. This change in the generation mix occurred without any direct support for renewable energy. Ministry of Business, Innovation and Employment (MBIE), "Data tables for electricity," Website.
65. Based on published forecasts by government agencies, industry and academics.
66. Solar currently produces just 0.2% of New Zealand's electricity. Ministry of Business, Innovation and Employment (MBIE), "Data tables for electricity," op. cit.
67. Transpower, "Te Mauri Hiko," op. cit.
68. The penalty is the additional cost of building capacity necessary to overcome the coincidence of lower output per unit of capacity occurring at about the time demand peaks. Other things being equal, a positive correlation between demand and output, so that the peak in demand coincided with the peak in available output would mean demand can be met with fewer units of capacity.
69. Ibid. 54.
70. Ibid. 31–33. This list adds commentary and references that was not part of the discussion in the cited Transpower paper.
71. Idle capital is also a cost with thermal generation. However, renewables tend to leave relatively more capital sitting idle per kilowatt of generation (discussed in Chapter 2), and as noted here the profile of renewable output widens the dry year energy gap.
72. Batteries are extremely expensive as a source of long-term energy storage. At a world price of US$231 per kW/h for lithium-ion batteries (Statist, "Lithium-ion battery pack costs worldwide between 2010 and 2019 (in U.S. dollars per kilowatt hour)," Website), and assuming a 10-year economic life of batteries and a NZ:US exchange rate of 0.67, the cost of building a battery with storage equal to the 3,900GW/h energy capacity in New Zealand's lakes (Electricity Authority, "Inflows boost hydro storage," Website) is around NZ$135 billion, about 46% of GDP. Battery costs have fallen at around 17% per year since 2010.
73. See Intergovernmental Panel on Climate Change (IPCC), "AR5 Climate Change 2014: Mitigation of Climate Change," Working Group III Contribution to the Fifth Assessment Report (Cambridge University Press, 2014), section 8.33; Brian C. Murray, Maureen L. Cropper, Francisco C. de la Chesnaye and John M. Reilly, "How Effective Are US Renewable Energy Subsidies in Cutting Greenhouse Gases?" *American Economic Review* 104:5 (2014), 569–574, 573; Jean Tirole, "Carbon Pricing for a Climate Coalition" (2016), 3.
74. Susan Kraemer, "Missing link for solar hydrogen is... ammonia?" PHYS (9 January 2018). The article suggests renewables-based hydrogen production is competitive where renewable energy costs US$30/MWh or less.
75. Energy Storage Association, "Hydrogen Energy Storage," Website.
76. HVDC cables lose around 3% energy per 1,000 kilometers. Feasibility studies of an undersea cable between Iceland and the UK, about half the distance between Fiordland and Tasmania, are being undertaken. In 2014, The Economist reported the 1,000-kilometre cable would cost £4 billion (The Economist, "Power under the sea" (20 January 2014)).
77. Transpower, "Te Mauri Hiko," op. cit. 54. It must be emphasised that none of this presents a problem for the 100% renewables policy *per se*. All policy has costs. The question in this case is whether the energy gap can be closed using alternatives to thermal generation at a cost that is low enough to make 100% renewables a cost-effective way to reducing emissions.
78. Contact Energy, "Thermal Transition – the trade-offs faced as we decarbonise NZ's electricity system in the 2020's and beyond" (October 2018). The research by Contact uses scenario analyses based on current technology and current technology costs. Additional system costs are derived from the requirement to significantly overbuild intermittent renewable power stations and associated infrastructure to reliably replace dispatchable thermal energy. Contact's analysis shows 90–95% renewable electricity is achievable at a far lower cost. New technologies may enable a higher feasible percentage of renewable electricity.
79. If access to dispatchable thermal generation is lost, additional reserve must be held in lakes as reserve for dry years. Higher lake levels lead to an increase in hydro, wind or geothermal 'spill' in which excess energy in wet years is discarded. The effect is substantial: one estimate suggests average annual hydro spill increases from around 200GW/h to 4,000GW/h – over 16% of current annual hydro production, worth more than $1 billion at the current retail price. Spill is not just wasted energy, it is a burden. Energy spilled is energy that must be generated another way. Spill can be reduced by increasing hydro storage capacity, or by increasing the capacity of the HVDC line between the North and South Islands. The loss of coal, gas and diesel stockpiles reduces the diversity of energy sources that currently work in concert to secure supply. Coal at Huntly has acted as a backstop in the event of a failure in gas supply. Methanex, which takes natural gas and converts it into liquid fuel, has been a source of 'swing supply' in dry years. Higher shares of intermittent solar and wind generation will also reduce system inertia (stability of grid frequency), although hydro's significant generation share will help prevent New Zealand being the next South Australia. Another predicted effect of lost thermal is that without a CCGT plant in the North Island, HVDC flows may need to be restricted to meet the N-1 standard for system security. N-1 is a standard for reliability that requires loads can be maintained or restored if any single component fails, leaving N-1 components available.

80. Kenneth Gillingham and James Stock, “The Cost of Reducing Greenhouse Gas Emissions,” *Journal of Economic Perspectives* 32:4 (2018), 53–72.
81. Environmental Protection Agency is an agency of the federal government of the United States.
82. Based on the Obama-era US EPA social cost of carbon estimate of US$46/tonne used in Kenneth Gillingham and James Stock, “The Cost of Reducing Greenhouse Gas Emissions,” op. cit.
83. Dieter Helm, “UK Cost of Energy Review,” op. cit. 91. Helm, who is generally sceptical of the value of government interventions in electricity markets, nevertheless supports the UK’s introduction of government-back capacity contracts due to the lack of large-scale storage and mistakes made in privatisation that made gaming of capacity availability profitable – both factors specific to the UK but not present in New Zealand.
84. There is nothing that is *per se* wrong about decisions rights sitting with the government. The question of how decisions are allocated should be decided on the merits according to the circumstances. A shift in decision-making brought about by the introduction of capacity contracts will make the government responsible for security of supply, a role that will at a minimum require the government to form a view about future demand for electricity as a pre-requisite for the issue of contracts. Governments do not have an unblemished forecasting record in electricity. It was a persistent optimism bias by the government’s planners that led in 1978 to the Marsden B generator being mothballed without ever running. That plant, budgeted at $617 million and built for $923 million in today’s dollars, sat idle for 33 years before finally being dismantled in 2011. Throughout most of the 1970s, the Planning Committee had maintained that the electricity growth rates of the 1950s and 1960s would continue into the 1970s. Not until 1978, years too late, did the Committee finally acknowledge its past forecasts had been high. Between 1969 and 1974, the Committee’s 10-year forecasts exceeded actual demand by an average of 42%. This led directly to malinvestment. Today, there is considerable optimism about the potential for electrification of transport and industry leading to expectations of growth in the demand for electricity. It is not obvious why governments today might be less vulnerable to the optimism biases that so seriously interfered with decision-making in the 1970s in New Zealand. In the present system, decision-makers hold persistent biases at their own expense. See Treasury, “Review of Electricity Planning and Electricity Generation Costs,” op. cit.
85. William Nordhaus, *A Question of Balance: Weighing the Options on Global Warming Policies* (Yale University Press, 2018), 20.
86. Ofgem, “State of the energy market” (London: 2018), 6.
87. Kenneth Gillingham and James Stock, “The Cost of Reducing Greenhouse Gas Emissions,” op. cit.
88. Jean Tirole, “Some Political Economy of Global Warming,” *Economics of Energy and Environmental Policy* 1:1 (2012), 121–132, 123–124. Cap-and-trade gives policymakers direct control of emissions quantities but not price, whereas a carbon tax gives direct control of price but not quantity. Both give effect to a price on carbon. Carbon prices versus picking winners is not a matter of either/or. However, given the performance gap and rent seeking associated with interventions from the top down, the higher the share of abatement efforts through carbon prices the better.
89. Or their downstream users. For example, New Zealand’s ETS requires oil companies to purchase and surrender emissions units on behalf of downstream users of their products where combustion actually occurs. This is an elegant solution to the problem of transaction costs.
90. Catherine Leining and Suzi Kerr, “Guide to the New Zealand Emissions Trading Scheme,” Report for the Ministry for the Environment (Motu, 2018).
91. Ibid.
92. See Julie Anne Genter, “Government announces set of improvements to New Zealand’s Emissions Trading Scheme,” Press release (Wellington: New Zealand Government, 12 December 2018).
93. Jean Tirole “Carbon Pricing for a Climate Coalition,” op. cit. 3. In New Zealand, the Productivity Commission and others have drawn a distinction between the short- and long-lived effects of methane and carbon dioxide. Tirole’s point applies to short- and long-lived gases, considered separately. The quote from Tirole should not be read as saying methane and carbon dioxide have equal effects.
94. This report acknowledges that the technical issues to be considered in the development of the ETS include leakage, optimal emissions target, and optimal time profile for emissions reductions. These matters are not considered further in this report.
95. A price on carbon will increase the share of renewable generation, along other things. Contact estimates a carbon price of $75/tonne will increase the share of renewable generation from 90% to 95% in 2035, relative to a price of $25/tonne. A carbon price also stimulates R&D. See Appendix 2 for references.
96. The term ‘binding ETS’ refers to a cap on emissions tight enough to reduce total emissions below what they would otherwise be without the cap, and implies the cap is enforced.
97. Within the part of the economy covered by the ETS.
98. Of course, that information is not available to market players either. That information is distributed across the economy, and revealed through the interactions brought about by a carbon price.
99. New Zealand’s GST, a universal, flat rate consumption tax, is simple and effective. GST has significant distributional consequences. The tax switch announced at Budget 2010, comprising a rise in GST and an offsetting reduction in income tax, included immediate compensating adjustments to benefits, allowances, family tax credits, and Working For Families. See Bill English, “Fact sheet – GST and compensation,” Press release (Wellington: New Zealand Government, 21 May 2010).
100. See Sam Marden and Ian Gough, “Fiscal Costs of Climate Mitigation Programmes in the UK: A Challenge for Social Policy?” CASE/145 (Centre for Analysis of Social Exclusion, London School of Economics, 2011), 16. This paper suggests that the burden of *ad hoc* climate mitigation policies in the UK disproportionately falls on lower income households.
101. Catherine Leining and Suzi Kerr, “Guide to the New Zealand Emissions Trading Scheme,” op. cit. 31.
102. Intergovernmental Panel on Climate Change (IPCC), “AR5 Climate Change 2014: Mitigation of Climate Change,” op. cit. The IPCC goes on to say other policies “may affect costs and possibly the viability of more stringent future targets”. The next WG3 report, part of AR6, is planned for July 2021.
103. Ofgem, “Financial protections for vulnerable consumers” (London: 2017), 45.

104. Monopolies Commission, “Energy markets at the crossroads of politics and competition” (2009), https://www.energieverbraucher.de/files_db/1249651160_7709__12.pdf, translated with www.DeepL.com/Translator.
105. Scientific Advisory Board, “Promoting Renewable Energies,” Report to the German Federal Ministry of Economics and Technology (Germany), Documentation 534 (2004), https://www.bmwi.de/Redaktion/DE/Publikationen/Ministerium/Veroeffentlichung-Wissenschaftlicher-Beirat/wissenschaftlicher-beirat-erneuerbare-energien-534.pdfs, translated with www.DeepL.com/Translator.
106. Richard Schmalensee, “Evaluating Policies to Increase Electricity Generation from Renewable Energy,” *Review of Environmental Economics and Policies* 6:1 (2012), 45–64, 60.
107. See Ministry for the Environment (MfE), “Improvements to the New Zealand Emissions Trading Scheme,” Consultation document (Wellington: New Zealand Government, 2018), 12, and Shane Jones and James Shaw, “An Emissions Trading Scheme fit for purpose,” Press release (Wellington: New Zealand Government, 13 August 2018).
108. Discussed in the previous chapter.
109. Jacinda Ardern and James Shaw, “$100 million investment fund launched to invest in reducing emissions,” Press release (Wellington: New Zealand Government, 5 December 2018).
110. Jacinda Ardern, “Planning for the future – no new offshore oil and gas exploration permits,” Press release (Wellington: New Zealand Government, 12 April 2018).
111. Megan Woods, “Record investment in low emissions vehicles announced,” Press release (Wellington: New Zealand Government, 22 January 2019).
112. Ignore for a moment geothermal emissions.
113. Earlier in this report, it was suggested that government emissions policies on average spend perhaps $5 to reduce emissions costing $1, whereas an ETS spends up to $1 to reduce emissions costing $1. Combined, these point to a performance gap of perhaps 10:1 between top-down policy and ETS on a cost-per-tonne basis.
114. Intergovernmental Panel on Climate Change (IPCC), “AR5 Climate Change 2014: Mitigation of Climate Change,” op. cit. 1159.
115. The EU ETS price exceeded €20 in August 2018 for the first time since 2009 and remained above €20 for much of the time since. See Sandbag, “EUA Price,” Website, https://sandbag.org.uk/carbon-price-viewer/.
116. For the week ending 14 December 2018, MBIE reported petrol taxes and levies, including ETS and excluding GST, of 78.074 cents per litre of petrol. MfE reported an emission factor for both regular and premium petrol of 2.36kg CO_2-e/litre, equal to 423.7 litres of petrol per tonne of emissions. The tax on that amount of petrol equals 0.78074 x 423.7 = $330.82. Ministry for the Environment (MfE), “Summary of Emissions Factors for the Guidance for Voluntary Corporate Greenhouse Gas Reporting – 2015” (Wellington: New Zealand Government, 2015). Petrol excise is, of course, not a carbon tax. The purpose of expressing excise as a cost per tonne of carbon is to illustrate that a relatively high tax rate on what is currently an essential product can find public acceptance. The structure of the policy matters at least as much as the level of the tax. This suggests public support for carbon pricing through an ETS, even at a high carbon price, depends on policy design.
117. Or near revenue-neutrality if revenue raised via an ETS is partly directed into protecting more vulnerable households from the effects of a carbon price. This is discussed later in this chapter.
118. Revenue neutrality does not mean using the revenues raised from an ETS or carbon tax on emissions reduction or other environmental issues, since this use of revenues increases the overall size of government. Revenue neutrality means returning revenues raised from an ETS or carbon tax via reductions in other taxes, leaving overall government spending unchanged.
119. A significant literature has developed under a “double dividend” rubric, which refers to the potential for revenue neutrality to raise economic welfare first by pricing the carbon externality, and second using revenues raised from carbon pricing to offset other distortionary taxes. Whether a double dividend can be realised in practice depends whether pre-existing taxes on consumption or labour, for example, are so distortionary that the sign of the welfare gain from pricing carbon is negative. For a discussion and references, see Intergovernmental Panel on Climate Change (IPCC), “Assessment Report 5,” Working Group 3 (2014), 234–235.
120. For example, about half the revenues raised by the Australian ETS was to be returned via tax reductions and rebates to households. In Sweden, taxes on NO_x emissions are returned and refunded. The IPCC notes, “Since the fee is refunded (in proportion to output), there is considerably less resistance to the fee and it can be set much higher than what would have been acceptable for a pure tax.” See Intergovernmental Panel on Climate Change (IPCC), “AR5 Climate Change 2014: Mitigation of Climate Change,” op. cit. section 15.5.2.4, 1163.
121. See Ministry for the Environment (MfE), “Improvements to the New Zealand Emissions Trading Scheme,” op. cit.
122. NZIER estimates a substantial economic benefit from access to international permits. See New Zealand Institute of Economic Research (NZIER), “Economic Impact Analysis of 2050 Emissions Targets,” Report to Ministry for the Environment (Wellington: New Zealand Government, 2018), 38–39.
123. Alfred Kahn, *The Economics of Regulation* (MIT Press, 1988), v.
124. Dieter Helm, “UK Cost of Energy Review,” op. cit. xiv.
125. Paul Joskow, “Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies,” op. cit. 9. Joskow’s calculation assumes 100% of wind energy is displacing gas generation and ignores additional costs of intermittency.
126. Reported in Jean Tirole “Carbon Pricing for a Climate Coalition,” op. cit. 3.
127. Ofgem, “State of the energy market,” op. cit. 6, 82.
128. Brian C. Murray, et al. “How Effective Are US Renewable Energy Subsidies in Cutting Greenhouse Gases?” op. cit. 572.
129. Ibid.
130. Meredith Fowlie, Michael Greenstone and Catherine Wolfram, “Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program,” *The Quarterly Journal of Economics* 133:3 (2018), 1597–1644.
131. Youri Chassin, “Do We Need to Subsidize the Purchase of Electric Cars?” (Montreal Economic Institute: 2014), 2.
132. Ibid. 3.
133. Kenneth Gillingham and James Stock, “The Cost of Reducing Greenhouse Gas Emissions,” op. cit. 66.
134. Ibid.
135. Based on Youri Chassin, “Do We Need to Subsidize the Purchase of Electric Cars?” op. cit.
136. Ibid. There is wide variation in the literature of estimates of embedded emissions in EVs and conventional cars.
137. “Driving a Ford Focus electric vehicle in a region in which electricity is generated by coal has approximately the same CO_2 footprint as a Ford Explorer sport utility vehicle that averages 25 miles per gallon.” Kenneth Gillingham and James Stock, “The Cost of Reducing Greenhouse Gas Emissions,” op. cit.

138. Jean Tirole, *Economics for the Common Good* (Princeton University Press, Transl. ed. (2017), 207.
139. Antoine Dechezleprêtre, Ralf Martin and Samuela Bassi, "Climate Change Policy, Innovation and Growth" (Grantham Research Institute, 2016).
140. Examples taken from Intergovernmental Panel on Climate Change (IPCC), "AR5 Climate Change 2014: Mitigation of Climate Change," op. cit.
141. Alongside a range of other US initiatives, including minimum vehicles efficiency standards.
142. Acid rain reduction has localised benefits whereas abatement of carbon dioxide has entirely global benefits. Localised benefits may well increase political support for a policy like cap-and-trade. Notwithstanding differences in support, as a mechanism the fact that cap-and-trade was successfully implemented and effective in reducing sulphur emissions suggests effectiveness in carbon abatement.
143. Allen S. Bellas, "Evidence of Innovation and Diffusion Under Tradable Permit Programs," *International Review of Environmental and Resource Economics* 5:1 (2011), 1–22.
144. Thomas Sterner and Bruno Turnheim, "Innovation and diffusion of environmental technology: Industrial NO_x Abatement in Sweden under Refunded Emission Payments," *Ecological Economics* 68:12 (2009), 2996–3006.

The coalition government has committed New Zealand to a goal of generating 100% of its electricity from renewable energy by 2035.

Renewables already account for 83% of our electricity, and on current trends will generate up to 97% of our electricity in 2035 without any help from policy changes.

However, as Matt Burgess shows in this report, the last 3% through to 100% renewables share will be tremendously expensive, and could raise greenhouse gas emissions.

New Zealand's electricity is secure, affordable and among the cleanest in the OECD countries. Renewable energy has flourished in a system that for more than 30 years has operated at arm's length from elected governments – until now.

Switched on! points out what New Zealand should do – and what it must avoid – to transition to a renewable energy future.

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