Future currents

Electricity scenarios for New Zealand 2005–2050

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata
PO Box 10-241, Wellington, Aotearoa New Zealand
www.pce.govt.nz

Writers

Nick Potter, Iain McAuley, and Doug Clover

Early focus group

Faust Bovenlander, Geoff Bertram, John Peet, Rob Bishop, and Steve Goldthorpe

External reviewers

Alan Pears, Adjunct Professor and Senior Lecturer in Environment and Planning, RMIT University Melbourne; Director Sustainable Solutions Pty Ltd
Bob Frame, Manaaki Whenua Landcare Research, Lincoln
Gerry Te Kapa Coates, Wise Analysis Ltd, Wellington
Ian Shearer, Energy Information Services Ltd, Wellington
Ralph Sims, Professor of Sustainable Energy and Director, Centre for Energy Research, Massey University

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Christine Prebble, Mosaic Consultants Ltd

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Preface

Future currents challenges the way we think about electricity and the services it provides. We have developed two scenarios to highlight how different our futures could be, depending on the decisions we make. Scenarios are not predictions of the future. They are tools to imagine a preferred future and to work out how to get there in a purposeful way.

New Zealand, like other countries, faces some tough energy choices in the years ahead. Our electricity system is in a difficult position, partly due to a lack of strategic planning over the last two decades. Also, we cannot 'plug in' to the electricity networks of other countries. This may make some choices more difficult, but it also provides us with a huge opportunity to head off on new pathways to provide future generations of Kiwis with a more secure future in a carbon-constrained world.

Our electricity system is currently on a pathway that looks very similar to the one we have been on for the last 50 years. To put it simply, too much thinking about electricity is being dominated by the 'supply side' – that is, how can more and more electricity be generated and transmitted around the country? We need to focus more on the 'demand side' – how do we get more value (for example, warmth and light) out of each unit of electricity? New Zealand needs more electricity supplies. We also need a robust transmission system. However, this should *not* be at the cost of forgoing many opportunities to 'get more from less'.

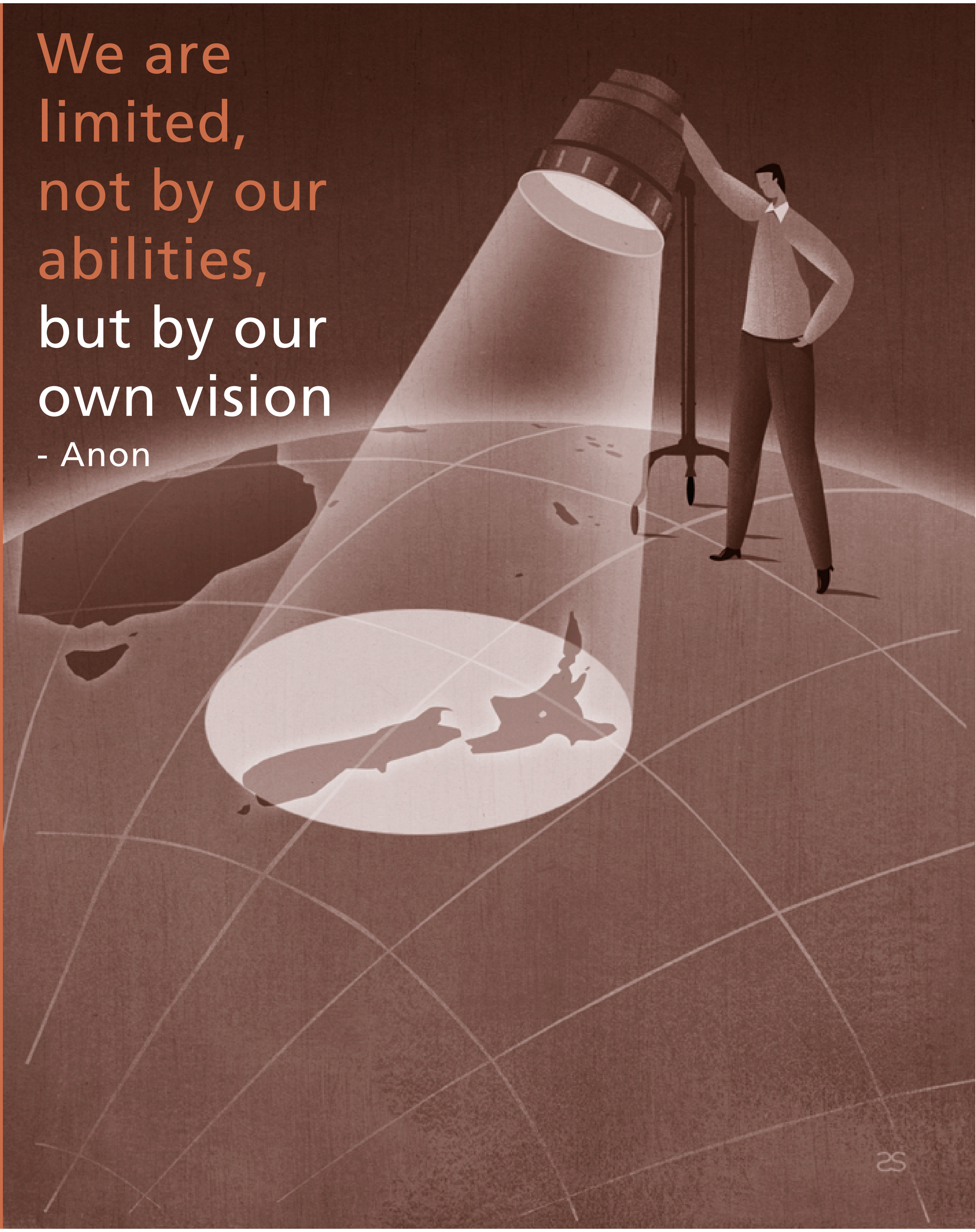
Clearly, opportunities exist for major demand side improvements in New Zealand, so what is holding back change? I suggest three key factors. First, people often resist change and dominant paradigms are difficult to transform. We need to look at who is being appointed to positions of influence on boards, commissions, and advisory groups associated with electricity to make sure that many perspectives are properly represented. Second, we have a market model that is dominated by a few major players on the supply side, with many small players on the demand side. Third, we need to address the irrational way we think about investment returns. When applied to providing more electricity, rates of return of about 10 percent are considered satisfactory. When applied to energy efficiency, a rate of return of up to 40 percent is sought! These factors, and many others, seem to be crippling our ability to think differently about our future options.

Our scenarios are conservative. We've made many of the same assumptions in both scenarios and we believe that both are plausible given today's technologies. The scenarios are presented through the eyes of two fictional characters. Their journeys to the future illustrate how different their lives could be, including their job and career opportunities. That is one aspect that is hardly ever debated in the electricity sector. Demand side initiatives are generally more demanding of human capital (knowledge and expertise). They provide many opportunities for small and medium businesses and can be implemented at individual household and business levels – each of us can be involved in the 'doing'.

New Zealand is in the midst of one of the most challenging and exciting periods of electricity and energy. How we think about electricity, how we define problems and consider options, and what we invest in over the next few years will cast the die for us as a nation for decades to come. We have to be much more innovative on all fronts. *Future currents* is our contribution to more innovative thinking. It will not be our last. I invite all readers to think about our scenarios, challenge our thinking, and develop your own desired visions for the future and share them widely.

J Morgan Williams

Dr J Morgan Williams
Parliamentary Commissioner for the Environment


We are limited, not by our abilities,
but by our own vision
- Anon

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CHAPTER 1

Introduction

Current – 1. belonging to the present time, happening now…
2. the flow of electricity through something or along a wire or cable.
3. a general tendency or course.[1]

New Zealand's electricity system faces a very uncertain future. There are currently concerns about depletion of the Maui gas field, responses to climate change, increasing electricity use, and community resistance to major new power developments. Many more challenges are on the horizon. We can be sure that electricity will continue to play a pivotal role in New Zealand's social and economic development. We also know that many of today's decisions will have consequences for the shape of the future. They will affect many communities, businesses, the environment around us, and the quality of life that people enjoy. It is therefore essential to ask: where are we heading and what sort of future do New Zealanders really want?

1.1 Purpose of this document

This document aims to promote long-term thinking and dialogue about the future of electricity. It uses two scenarios to paint a picture of what New Zealand could look like by 2050. These scenarios are based on very different ways of thinking about and using electricity to meet New Zealanders' aspirations for a great quality of life.

Why it was written

This document is part of broader work the Parliamentary Commissioner for the Environment is doing on electricity, energy and the environment.[2] Each year we assess the environmental performance of New Zealand's electricity sector, independent from the Government and the electricity industry.[3] These assessments include 'focused investigations' that look at some electricity issues in greater depth. This year we are focusing on possible futures for electricity in New Zealand. We decided to take this focus due to:

- **Worries about the depletion of the Maui gas field.** Maui has provided New Zealand with a large supply of gas that has been used on a 'take or pay' basis for generating electricity for over 30 years. It was always expected to reach the end of its economic life around the end of this decade. The electricity industry is concerned about what will happen when Maui runs down around 2007. No other significant gas fields have been found to make up the shortfall.

- **Rising community concerns and resistance to more large-scale electricity infrastructure.** This was clearly highlighted during the conflict over Project Aqua, which was a proposal to develop a series of canals and power stations along the lower Waitaki River. Recent plans have also run into conflict. These include plans for more wind farms, coal-fired power stations, and 200km of new transmission lines from the Central North Island to Auckland.

- **Widespread concerns about the social and economic impacts of rising electricity prices**. More electricity is being used in New Zealand each year and it will be more expensive to generate electricity in the future.

- **Major issues** such as climate change, the looming peak in global oil production, rising energy prices around the world, and New Zealand's growing dependence on oil imported from politically unstable regions like the Middle East.

We believe there has been a lack of futures thinking and strategic planning for electricity and energy issues at an official level in New Zealand since the 1980s. However, there have been some recent efforts (the bibliography lists examples). It is essential to maintain a long-term view because the impacts of important decisions over the next few years will be felt for decades to come.

1.2 What are scenarios?

> ***Scenarios are stories about the way the world might turn out tomorrow, stories that can help us recognise and adapt to changing aspects of our present environment … scenario planning is about making choices today with an understanding of how they might turn out.[4]***

Scenarios are not meant to forecast the future. Instead, they paint pictures of how the future *might* unfold, based on different driving forces in the shifting currents of our society. They explore alternative ways of seeing and acting in the world. They can also highlight what could happen if different courses of action are pursued.

Scenarios provide a very useful tool for *learning*. They can encourage debate and dialogue about the future and assist people to adapt to a changing world that will be very different from the past. They give individuals and groups an opportunity to reflect on what sort of future they would like and to rethink some established practices. They also give society the opportunity to redesign the way it does things if this is likely to lead to a better quality of life.

Some common features of scenarios are that they should be:

- plausible (they describe a future that could happen)

- consistent (they make sense)

- transparent (they are open about assumptions)
- challenging (they stretch thinking about possible alternatives for the future).[5]

1.3 How we developed these scenarios

We began these scenarios in 2004 by involving a small group of people (identified on page 2) in a workshop.[6] These people were selected for their breadth of experience in New Zealand's electricity system and their independence. We decided it would be useful to develop two divergent scenarios that differed in substance, not just in minor details. We then drew on this workshop and our own experiences to create a general storyline for the two scenarios. We developed the storylines by researching a wide range of publications and exploring major trends in electricity and energy systems in New Zealand and internationally. We also developed a quantitative model to consider where some trends could lead in each scenario. Before completing the scenarios we gave them to a group of external reviewers (identified on page 2) for their critique. The scenarios were then refined into their current form.

Ideally, scenario planning should involve a broad range of people from different organisations and backgrounds. The process of gathering people to learn and reflect on the future and to understand different points of view can be just as important as the final product. Although we have drawn on the expertise of a relatively small group of people in our scenarios, it would also be useful to bring together a wide variety of people with an interest in energy, social, and economic development, and the environment in New Zealand. We hope our scenarios will make a useful contribution to any further efforts in this area.

Our focus

Scenarios for electricity and energy futures in New Zealand have been done before (see bibliography for examples). They have often focused on how New Zealand's energy system might respond to social, economic, and environmental changes. Our approach is different. We focus on how New Zealand's environment could be affected by trends and changes in the electricity system, as part of a broader energy system. We also consider in each scenario how communities could be affected by the electricity system. In particular, we look at implications for innovation, regional development, and life in cities and rural areas.

1.4 The scenarios and the structure of this document

The two scenarios in this report are called *Fuelling the future* and *Sparking new designs*. They look 45 years into the future. We chose this length of time to push the boundaries of existing thinking and to explore the long-term impact that many small changes could make.

This document has seven chapters.

Chapter 2 – sets the scene for the rest of this report by exploring what electricity is used for, major energy resources, and forces that are likely to influence the future.

Chapter 3 – introduces the two scenarios by explaining their similarities and differences as well as the dominant mindsets and approaches.

Chapter 4 – explores how New Zealand could change in each scenario from 2005 to 2015. It includes the stories of two fictional characters to explore the changing world through their eyes (also in Chapters 5 and 6).

Chapter 5 – explores how New Zealand could change in each scenario from 2015 to 2030.

Chapter 6 – explores how New Zealand could change in each scenario from 2030 to 2050.

Chapter 7 – summarises key themes from the scenarios and considers the future courses that New Zealanders could take.

Technical report

The scenarios in this report were developed with the aid of a quantitative analysis. This analysis is explained in a separate technical report, which is available at www.pce.govt.nz. The major assumptions from this analysis are summarised in Appendix 1.

CHAPTER 2

Electricity today and in the future

Despite its importance in everyday life, electricity is usually taken for granted. People tend to think about it only when there is a power cut, when their electricity bills increase, or when they see conflicts in the media and hear fears about (yet another) looming power crisis. Little discussion takes place on what people actually want and use electricity for. This chapter unpacks some thinking about electricity to set the scene for the rest of the report. It explains important terms and highlights some influential forces that will shape the future of electricity in New Zealand.

2.1 Thinking about electricity, energy, and smart design

We use electricity to provide us with many things we need and value. We use it for lighting and for powering the electronic equipment that surrounds us. We use it to enjoy comfortable climates in our homes and workplaces. Industries, from farms to factories, use it for heat and power to manufacture products. The benefits of using electricity seem clear. But, when thinking about electricity, it is useful to reflect on a few simple questions.

- What do people really need and want?
- What are the connections between electricity and energy?
- How can people's needs and wants best be met?

What do people really need and want?

Events such as the Auckland inner-city blackouts in 1998 highlight how social and economic mayhem can result if the supply of electricity suddenly stops. If it goes off completely, so do the lights, communication systems, eftpos networks, sewerage systems, fridges, and so on. However, it is essential to distinguish between:

- **energy services** – what people want, such as lighting, heating, cooling, and power to drive machinery
- **electricity** – one form of energy, among many different resources, that people can use to provide the energy services they want.

What are the connections between electricity and energy?

All electricity is generated from *energy sources* in the environment around us. These include finite stocks of fossil fuels (oil, gas, and coal) and renewable flows of energy such as solar energy and the power of the wind, tides, and flowing water.[7] Biomass (organic matter such as plants and wood) can also be used as a renewable fuel source (see glossary for examples). Section 2.5 discusses the main energy sources available in New Zealand.

Energy sources can be used directly (for example, natural gas for heating) or converted into electricity (for example, gas-fired power stations). Whenever *energy conversions* take place, some potential energy in the resource is always 'lost' because it becomes unavailable for future use. This is partly due to the limits of technology and because it always takes some energy to make energy conversions in the first place.

Boundaries between the electricity system and the rest of the energy system are likely to blur over time. For example, cars and trucks currently consume over 40 percent of the primary energy used in New Zealand. When oil becomes much more expensive, electricity and different energy sources will probably be used to provide people with mobility (see Appendix 2).

How can people's needs and wants best be met?

Human needs and wants can be met in many different ways. *Smart design* involves starting with what people want and *then* designing the best ways to meet this. Integrated thinking about environmental, social, and economic goals is needed, as well as a long-term view, to provide the most value to individuals, our society, and the world we live in.

Although electricity is a valuable form of energy that can provide people with energy services, these services can also be provided through:

- **energy efficiency** – getting more benefits from using less energy
- **switching fuels** – using different fuels or energy sources if this is beneficial.

Some examples of energy efficiency and fuel switching are:

- designing buildings to capture and retain free energy from the sun to provide warmth and reduce the need for electricity (see *Future homes now?* and *Better buildings for business* on page 14)
- redesigning industrial processes and electrical appliances to use less electricity (see *Industrial redesign* on page 15)
- using solar water heaters to provide hot water instead of just using electricity
- using forest by-products (for example, woodchips) to generate heat and power in the wood processing industry instead of buying electricity
- improving the energy efficiency of a power station.

Smart design is not just about the equipment and buildings we see around us. It is also about the design of institutions (such as businesses, markets, and regulations) that influence the way people act.

Some examples are:

- financial schemes to help people invest in energy efficiency improvements
- energy performance standards and labels for electrical appliances and new buildings
- electricity companies providing warmth in homes or businesses instead of just selling electricity (for example, investing in energy efficiency improvements that householders pay for over time).

Future homes now?

In New Zealand some houses already exist that use only a little electricity but still provide many more benefits than most homes of today. For example, the *Auckland NOW* home project is showing how today's technologies can be used to create homes that are energy efficient, comfortable, desirable, and healthy to live in. They are also affordable for the average New Zealander. This project also shows how older houses can be improved with retrofits and explores future developments. For more information see www.nowhome.co.nz.

Some architects are also proving that attractive and affordable homes can be designed that save significant amounts of energy and money. For examples, see www.poweredliving.co.nz and www.arhaus.co.nz.

Better buildings for business

When Landcare Research needed a new building in Auckland, they looked for synergies (rather than trade-offs) between economics, the environment, and people's needs. They wanted a building staff would enjoy working in, and that encompassed state-of-the-art environmentally friendly features. They used smart design to promote energy efficiency and the use of innovative technologies. Construction costs were similar to a conventional building, but it is a lot cheaper to run. Power savings are projected to be 60–70 percent and, based on current electricity prices, they will save about $70,000 a year. See www.landcareresearch.co.nz.

Industrial redesign

Electrolux, the world's largest whiteware and appliance company, is demonstrating the benefits of smart design. During the last decade they have integrated environmental thinking into every stage of their design and manufacturing. They aim to develop products with low environmental impact and to help people understand the full costs of their purchases over time. They are helping to change the way many people look at energy and environmental impacts throughout the lifecycle of a product. About 80 percent of the environmental impact of their business occurs when their products are used, such as when appliances use electricity. Energy efficiency is therefore a major priority as well as ensuring that materials can be recycled.

Electrolux's focus on redesigning many products and manufacturing processes has delivered major benefits. A few years after they released their first environmental policy in 1993, they began selling ovens that were 30–60 percent more efficient than those of their competitors. They also developed fridges for supermarkets that used 65 percent less electricity. Between 1998 and 2003, the energy efficiency of their products increased on average by about 20 percent. Their 'green range' of appliances is even more efficient and profitable.

The company works closely with governments and other stakeholders. In the European Union they supported the introduction of energy performance regulations for new appliances. These regulations are becoming progressively more stringent over time. In France, they worked with government environment and energy agencies to promote better understanding of energy labels on appliances and to encourage people to reduce their energy use. This focus has put Electrolux, and its customers, in a very strong position as world energy and material prices continue to rise.

See www.electrolux.com.

2.2 Electricity in New Zealand's past

Before thinking about the future, it is worth reflecting on how radically New Zealand's electricity system has changed since electricity was first used here in 1861.[8] Thinking and technologies that emerged many decades ago have shaped the foundations of our existing electricity system. During much of the twentieth century, the state developed many large-scale power stations and a national grid to provide social and economic benefits to the nation. Major emphasis was placed on generating more electricity to encourage development. Around the end of the century there was a shift away from planning in the electricity system towards a market-based system. Figure 2.1 shows some significant events that have shaped the electricity system over the last 50 years.

Figure 2.1 Significant events in the electricity system 1950–2000

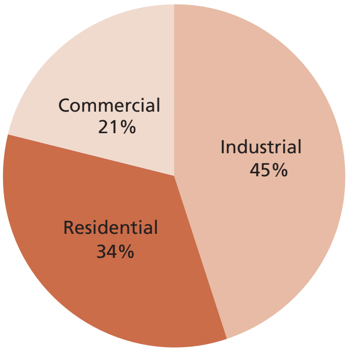
Decade	Events
1950s	• Government strives to connect remote rural settlements to the national grid • World's second geothermal power plant is built at Wairakei
1960s	• The all-electric home, with TV and many electrical appliances, is now the norm, compared with the 1930s when radios were 'newfangled' inventions • Massive public protests over Lake Manapouri development to generate electricity for Comalco's aluminium smelter • Cook Strait power cables laid
1970s	• Energy efficiency and conservation become more important during oil shocks • Royal Commission on Nuclear Power dismisses nuclear power as an option • Government pursues 'Think Big' programme, with major energy projects fast-tracked in the 'national interest' • Maui gas field developed, with gas sold under a 'take or pay' agreement[9]
1980s	• Huntly coal and gas power plant opens in 1983 (five years late) • Shift from central planning to a deregulated market-based system • Ministry of Energy abolished and Electricorp, a state-owned enterprise, established
1990s	• Further major reforms. Local power boards replaced with electricity companies • Electricorp split up. Transpower established. Wholesale electricity market set up • Clyde Dam, New Zealand's biggest dam, opens late and over budget • Major drought affects South Island hydro lakes in 1992 • New Zealand's first wind farm opens in Wairarapa in 1996 • Energy Efficiency and Conservation Authority (EECA) established • Auckland City hit by major power blackouts in 1998 • Ministerial inquiry into the electricity industry leads to further reforms
2000s	• New Zealand signs Kyoto Protocol, which comes into force in 2005 • Electricity Commission established • New challenges emerge …

2.3 Electricity in New Zealand today

Electricity use

Large industries use the biggest share of electricity in New Zealand today (see Figure 2.2), compared to 25 years ago when the residential sector used the most.[10] Most electricity is used in the main urban centres and at Bluff, where Comalco's aluminium smelter is located (see Table 2.1).

Figure 2.2 Electricity use by sector



Source: MED (2005)

Table 2.1 Electricity use: Top five centres

Place	Electricity use
Invercargill/Bluff	15%
Auckland City	10%
Christchurch City	9%
Manukau City	5%
Wellington City	4%

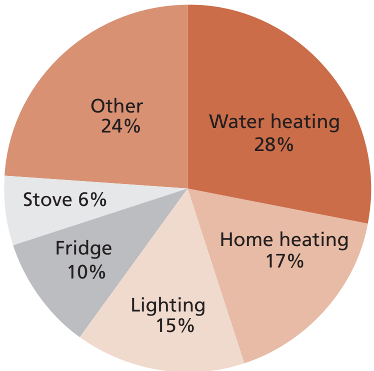
Source: EECA (2002)[11]

The amount of electricity used in New Zealand has almost doubled over the last 25 years. During the last decade it has increased by over 20 percent.[12] The Government predicts that electricity use will keep growing by about 2 percent each year to sustain a growing economy. Some large industrial users and electricity companies claim that it will rise even faster. Others believe that electricity use could be 'decoupled' from economic growth through energy efficiency improvements and other measures.

Although we know how *much* electricity is used, New Zealand lacks knowledge about *how* electricity is actually used to provide people and businesses with the energy services they want. Very little data is being collected in New Zealand beyond some research in the residential sector.

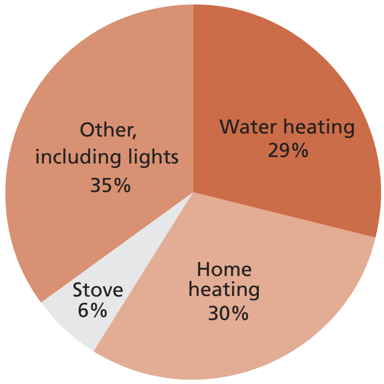
Most homes in urban areas use electricity for heating water and providing people with warm living spaces (see Figure 2.3 for Auckland houses).[13] When other fuels are included (such as natural gas and firewood) water heating and space heating are still the main energy uses (see Figure 2.4).

Figure 2.3 Household electricity use (Auckland only)



Source: Isaacs *et al*. (2004)

Figure 2.4 Estimated household energy use for all fuels (excludes transport energy)



Source: Isaacs *et al*. (2004)

In the industrial sector, electricity and other forms of energy are mostly used to provide heat and power for manufacturing and in electrochemical processes like metal smelting. The commercial sector includes many businesses, government agencies, schools, hospitals, and community organisations. It is difficult to draw conclusions about this sector because it is so diverse. However, the major uses of electricity in commercial buildings are likely to be for heating, ventilation, and lighting to provide a comfortable indoor environment.[14]

Electricity supply

Most New Zealanders are familiar with getting electricity to their homes and businesses through local power lines, which are connected to the national grid (see Figure 2.5). This grid carries electricity from large-scale power plants that are often located far from where most electricity is used.[15] As electricity travels along a power line some of it is lost as heat, and more needs to be generated to make up for this loss. The longer the lines are, the larger the loss. About 15 percent of the electricity generated in New Zealand is 'lost' during these movements.[16] Electricity can also be generated close to where it is used (distributed generation). Some individuals and communities can generate electricity on site and, if connected to local power lines or directly to the national grid, sell any surplus to others.

Most of New Zealand's electricity is generated from renewable sources. Hydro power stations now generate 60–65 percent of the electricity used each year, compared to 85 percent in 1980.[17] Most electricity is generated in the big hydro dams in the South Island and in the dams along the Waikato River. Natural gas and coal are used to generate most of the rest. Geothermal power and other renewable sources, such as wind, play a smaller role (see Table 2.2).

Table 2.2 Electricity generation sources (2004)

Source	Generation	Major locations
Hydro	61%	South Island – Waitaki, Manapouri, Clutha North Island – Waikato, Tongariro
Gas	22%	North Island – Taranaki, Huntly, Auckland
Coal	8%	North Island – Huntly
Geothermal	6%	North Island – Taupo
Other (including wind)	3%	New Zealand-wide

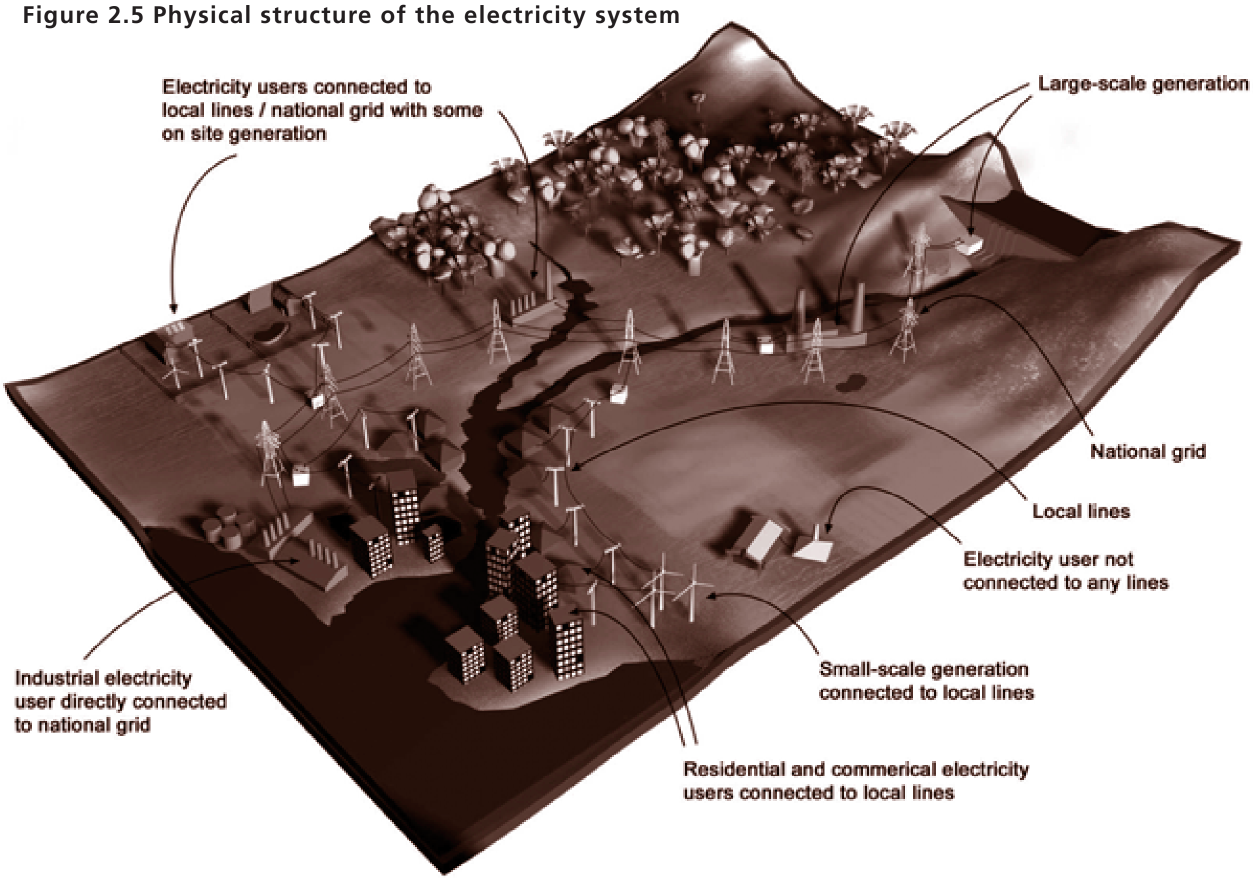
Source: MED (2005)[18]

Unlike most developed countries, New Zealand cannot buy electricity from other countries due to the distance from our nearest neighbours. Although we can import oil and liquified natural gas (LNG) to generate electricity, too much dependence on these imported fuels may make us vulnerable to changes in overseas markets that we have no control over.

Electricity institutions

For an overview of the major organisations, regulations, and strategies in New Zealand's electricity system, see *Electricity, energy and the environment: Making the connections* (PCE, 2003).

Figure 2.5 Physical structure of the electricity system



2.4 Developing a secure electricity system

A secure and reliable electricity system is vital for our society and economy. By 'secure' we mean a system that is resilient to both short- and long-term disruptions to electricity use and supply. Both renewable sources of energy and fossil fuels have pros and cons for providing security. The overall security of an electricity system can also be improved by carefully managing electricity demand.

Most forms of renewable energy are intermittent. This means that they fluctuate during different seasons, months, weeks, days, hours, or even minute by minute. Electricity systems based on renewable energy sources need to be designed to manage these variations. For example, fluctuations in the wind can cause problems for a region if it relies too much on electricity from wind turbines. This can partly be addressed by spreading wind farms over different regions so that there is less reliance on wind in any one area. Different energy sources can also complement each other. For example, wind and hydro power can work well together – hydro lakes act as a 'battery' by storing water when wind turbines are going. This water can then be used to generate electricity when the wind stops blowing.[19] Some renewable resources can also provide very smooth flows of electricity. Biomass and geothermal energy do not generally fluctuate.[20] Tidal energy fluctuates but is easy to predict (although tidal technologies are still unproven and costly – see Section 2.5).

A major benefit of using fossil fuels is that they are not intermittent. However, fossil fuels need to be used carefully to provide security.

- Becoming dependent on a finite resource can lead to major problems when it runs out, especially if it runs out sooner than expected and while further discoveries remain uncertain. The experience with the Maui gas field has clearly shown this.
- Building expensive infrastructure to run on imported fuels such as LNG or oil may make New Zealand more dependent on these fuels and vulnerable to price volatility in international markets.
- The 'cost of carbon' – the additional price New Zealanders will need to pay for burning coal, oil, and gas as part of global efforts to tackle climate change – is uncertain beyond 2012 (see *Climate change: Confronting the biggest global threat* on page 27).

Both large- and small-scale infrastructure can provide security, depending on how systems are designed. Most New Zealanders now rely on large power plants and the national grid to provide electricity. For example, the Huntly power station currently provides Auckland with a very reliable supply of electricity. In the future, many integrated smaller units that are spread over a wide area could spread the risk of major outages from events such as an extreme weather event, act of terrorism, or unforeseen faults.[21] However, these smaller units would also need to be managed carefully.

The security of an electricity system can also be improved by managing electricity use.

- Smart controls on appliances, equipment, and industrial processes can vary the use of electricity when it is scarce (and more expensive) or plentiful.[22]
- Large industries can be offered financial incentives to reduce their use of electricity when it is scarce.[23]
- In the longer term, it may be possible to reduce pressure on infrastructure and provide more security by better managing the overall level of electricity use.

2.5 Resources for the future

New Zealand has many resources that could be developed in the future, including:

- **human resources** – people with the knowledge and capacity to design ways of providing energy services more efficiently
- **energy resources** – renewable sources of energy and stocks of fossil fuels that could be used directly or to generate electricity.

Some resources may also be imported, such as foreign expertise, or fuels like coal or gas (in the form of LNG).

Energy resources that are available in New Zealand and that could be developed or used in the future are identified in Table 2.3. Most energy sources can either be converted into electricity or used directly. It is usually much more energy efficient to use energy sources directly. For example, it is more efficient to use gas to heat rooms or to provide hot water, instead of using gas to generate electricity to provide the same benefits. However, it may not always be cheaper to use resources directly, depending on the cost of the resource and the availability of infrastructure such as gas pipelines. It may also be inappropriate to use some energy sources directly. For example, using coal for heating in urban areas can lead to local problems such as air pollution.

The relative costs of using different resources will change considerably over time. For example, New Zealand receives abundant flows of solar energy. Although the heat from the sun can be used directly, current technologies do not convert solar energy to electricity very efficiently or economically. Usually it is much cheaper to generate electricity from other energy sources. However, as Table 2.4 highlights, 'emerging' technologies such as solar photovoltaics (see glossary) are expected to continue coming down in price over the next 15 years. Experience will lead to further innovations and lower prices as production increases and economies of scale are realised. In contrast, many 'mature' technologies, such as hydro power, are nearing the limits of their development. Any improvements to these technologies over time are likely to be incremental.[24]

Table 2.3 Resources for the future

Resource	Current size	Certainty of estimate	Major locations	Comments
Human resources				
Smart design for energy efficiency	Large	Moderate	NZ-wide	Many reports have highlighted the enormous potential to provide energy services more efficiently but the exact amount is difficult to calculate.[25]
Renewable resources				
Biomass	Large	Moderate	NZ-wide	Wood and organic wastes can be used to provide electricity and heat. For example, forestry by-products such as woodchips could be turned into clean-burning wood pellets. See glossary for description of other biomass resources.
Geothermal	Medium	High	Taupo	Geothermal energy can often provide a very reliable and consistent flow of electricity.
Hydro[26]	Medium	High	NZ-wide	The best large-scale hydro sites have already been developed and most of the remaining big rivers are in conservation areas. Other major rivers that could attract development include the Lower Waitaki, Clutha, Grey, Waiau (in Canterbury), and Ngaruroro rivers. Many smaller scale schemes could also be developed.
Ocean currents	Large	Low	Cook Strait	Movements of large masses of water as ocean currents contain a lot of energy but capturing this with underwater devices is not yet proven.
Solar	Large	High	NZ-wide	An average house rooftop collects more than 20–30 times the house's total energy requirements, but this energy is spread over a wide area and is very intermittent.[27]
Tidal	Small	Moderate	NZ coast	New Zealand's tidal range is probably not very suitable for electricity generation.

Wave	Very large	Moderate	NZ-wide	New Zealand has an exceptionally long and energetic coastline for onshore and offshore wave energy. If all this energy could be captured it would provide New Zealand with more than 40 times the amount of electricity currently used.[28] However, New Zealand's deep offshore waters and wave patterns may hinder development.
Wind				
– Onshore	Medium	High	NZ-wide	New Zealand has relatively strong and consistent winds throughout much of the year, especially in coastal areas, but in a limited number of suitable sites.
– Offshore	Large	Low	NZ-wide	Offshore wind farms would be much more expensive to develop due to the deep seas around New Zealand.
Fossil fuel resources				
Coal	Very large	High	Southland, Otago West Coast, Waikato, Taranaki	Coal contains the most carbon dioxide per unit of energy out of all energy sources and these emissions would need to be dealt with. About 85% of available coal reserves are in the South Island (mostly Southland). Less than 10% of available reserves are bituminous coal (high energy/low moisture content). 22% are sub-bituminous and 70% are lignite (the lowest quality and most dirty burning coal).
Gas	Small to medium	Low	Taranaki, Southland, East Coast, Canterbury	LNG could also be imported, but New Zealand is competing with many other countries in international markets and the cost of LNG will increase. See **The future of oil and gas** on page 25.
Oil	Very small	Low		Oil could also be imported for generating electricity, but the cost is likely to be prohibitive

KEY

Current size: Refers to the technical potential of the resource. The size of most renewable resources could theoretically be much higher.

Small: Less than 10,000GWh/y **Medium:** 10,000–20,000GWh/y **Large:** 20,000–50,000GWh/y **Very large:** More than 50,000GWh/y

New Zealand currently uses about 40,000GWh of electricity each year. NB: Nuclear energy is not included because uranium would need to be imported and nuclear energy is very unlikely to be a practical option for New Zealand. See Appendix 3 for more information.

Key sources: EECA (2001 and 2001a); CAE (2003); MED (2003); EHMS (2002 and 2004); Sims (2005)

Table 2.4 Cost reduction potential of selected generation technologies 2005–2020

Technology	Maturity	Current cost in New Zealand	Cost reduction potential
Coal with CO_2 capture and storage	Emerging, with mature components	High	Moderate to low
Geothermal	Mature	Low	Moderate
Hydro			
– Small scale	Mature	Medium	Low
– Large scale	Mature	Low	Low
Solar photovoltaic			
– Small scale	Maturing	High	Very large
– Large scale	Emerging	High	Very large
Wave and tidal	Emerging	High	Very large[29]
Wind			
– Onshore	Mature	Low	Moderate
– Offshore	Maturing	Medium	Moderate

NB: 'Current cost' refers to the estimated cost of these technologies in New Zealand. It does not include the costs of resource consents or any fuel costs.

Source: Based on ICCEPT (2002) and OECD (2003)

Hydrogen futures

Hydrogen fuel cells are very likely to play a role in New Zealand's electricity system over the next 50 years. However, hydrogen is not an energy source. Hydrogen does not occur naturally as gas on Earth.[30] It is always combined with other elements. Water, for example, contains hydrogen and oxygen. Organic compounds, including fossil fuels, also contain hydrogen. Hydrogen gas needs to be extracted from fossil fuels or by using large amounts of electricity to split the hydrogen from oxygen in water. It may also be possible to use algae or bacteria (probably genetically modified) as a biological means of generating hydrogen gas. Hydrogen is likely to be used in many small-scale applications (for example, in electrical equipment such as laptops or in buildings with integrated energy systems). It may also be used in larger scale applications, such as in the transport system. However, large-scale use would have dramatic implications for the electricity system, energy sources, and land use. See Appendix 2 for more information.

The future of oil and gas

Oil and natural gas are collectively called 'petroleum' and are found together in differing proportions within certain geological formations. Petroleum is a fossil fuel formed from the accumulation and decomposition of biological (plant) material that has decayed over millions of years.[31] From a human perspective, petroleum is a non-renewable energy source.

A characteristic of petroleum production is that once production 'peaks' in a petroleum region, subsequent production never achieves this level again. The rate at which remaining reserves can be pumped out starts to decline, irrespective of the amount of effort put into exploration or recovery.[32]

New Zealand's only current source of oil and gas is in the Taranaki Basin. Gas production has been dominated by the Maui field, which has demonstrated a similar trend in discovery, production, and decline to international fields.[33] It is now becoming increasingly difficult to discover and obtain more natural gas. Although future discoveries are unpredictable, it is highly unlikely that another field the size of Maui will be discovered. The Ministry of Economic Development assumes discoveries will follow the historical average, excluding the anomalously large Maui field. They estimate that there will be new reserves, and long-term average production, of between 30 and 60 petajoules each year. However, even if more gas is discovered, there is no guarantee it will be available for use in New Zealand. If the growing worldwide demand for LNG is as strong as expected, and if one of the new discoveries is sufficiently large, it may be more financially attractive for developers to export the gas rather than sell it domestically.

Globally, the consensus in the petroleum industry is not *if* worldwide oil and gas will peak but *when* it will peak. Estimates for when 'peak oil' will occur range between 2005 and 2040, with the greatest consensus around 2012 to 2020. After it peaks, oil production is expected to decline at a rate of around 3 percent per annum.[34] Oil prices will rise significantly. The available data for global natural gas reserves is even poorer than for oil. However, most estimates give a 'peak gas' date of at least 10 years later than for oil, with the earliest estimate around 2019.[35]

2.6 Forces that will shape the future

> ***There is a tendency in thinking about the future to simply extrapolate past trends … but one of the lessons we can learn from history is that trends do not continue smoothly. There are turning points and discontinuities that were impossible to predict.***[36]

Many energy resources are available in New Zealand. A wide range of influences will affect whether – and how – they are used.

Global influences

International developments that will continue to shape changes in New Zealand include the following factors:

- **Rapidly escalating demands for energy services** – from energy-intensive economies (particularly North America), a growing world population, and further industrialisation (especially in China, India, Russia, Brazil, and Indonesia).
- **Climate change** – from increasing human demands for energy and the burning of fossil fuels. Climate change will affect many communities, ecosystems, and economies and will place pressure on New Zealand's electricity system (see *Climate change: Confronting the biggest global threat* on page 27). International efforts to address the causes and effects of climate change are likely to intensify and flow through to changes in New Zealand.
- **Increasing energy costs** – due to rising consumption and limits to production rates. In particular, oil and gas production limits will almost certainly be reached within the first half of this century and probably sooner rather than later (see *The future of oil and gas* on page 25). Oil and gas prices will rise significantly.
- **Energy security concerns** – will lead to more conflicts over scarce resources, especially in the Middle East and Central Asia, and heightened worries about the reliability and cost of petroleum supplies.
- **New technologies** – will lead to fundamental changes in the way people use energy and generate electricity. Some technologies will enable people to use less energy to get the energy services they want, while others will encourage more energy use.

Many more changes will affect the world as we currently know it. Likely changes include cultural shifts, resolution to some existing conflicts and escalations in others, ongoing waves of economic growth and decline, and countless unforeseen events and new discoveries. New Zealanders have very little influence over these events. However, we can anticipate and prepare for events by responding in innovative ways, such as through our research priorities and choice of technologies.

Climate change: Confronting the biggest global threat

There is no bigger problem than climate change. The threat is quite simple. It's a threat to our civilization. – Sir David King, Chief Scientific Advisor, UK Government.[37]

The earth's climate is changing, mostly because of increasing concentrations of greenhouse gases such as carbon dioxide and methane in the atmosphere. Concentrations of greenhouse gases are increasing from the use of fossil fuels for energy and other human activities like deforestation. We need to make profound changes especially in our use of energy. We also need to prepare for the impacts of climate change that are already unavoidable. Even if we reduce greenhouse gas emissions now, it will be many decades before we can begin reversing the damage (if indeed this is possible).

Most past emissions have come from developed countries, but emissions from developing countries are rising rapidly. This makes it difficult to secure international agreements. Countries are addressing these concerns under the United Nations Framework Convention on Climate Change.[38] The Kyoto Protocol emerged from this process and came into force in 2005. It gives New Zealand a share of 'emission units', often called 'carbon credits', for the protocol's first commitment period (2008–2012). The protocol allows countries with surplus emission units to sell them to countries that require extra units.

New Zealand's target is essentially to reduce the average annual emissions back to 1990 levels during the period 2008–2012.[39] However, our emissions have actually risen by almost 22 percent since 1990.[40] Carbon dioxide emissions in the electricity sector have risen by almost 80 percent.[41] New Zealand is therefore likely to exceed its initial share of emission units for 2008–2012. However, the protocol also has provisions covering land use change and forestry. Forests planted since 1990 can count as 'carbon sinks' and earn additional emission units. In New Zealand's case, new forests are expected to enable us to meet our commitments. After 2012, emissions targets (yet to be negotiated) could get much tougher. Carbon sinks play an important role, but it is vital to address gross emissions, which will eventually need to come down.

Regardless of New Zealand's climate change response, we will also need to adapt to the effects of climate change. These include more frequent and severe droughts and floods (with drier conditions in the east and wetter conditions in the west), rising sea levels, changing rainfall patterns, and higher temperatures in some regions. Many of these changes will impact on the electricity system and need to be anticipated.[42] For example, people may use much more air conditioning during hotter periods unless buildings are designed to prevent overheating.[43]

For more information see www.climatechange.govt.nz or www.4million.org.nz.

New Zealand influences

Within New Zealand, factors that are likely to have a major impact on the electricity system include:

- **Social values, identities, and lifestyles** – will shape the places people wish to live in and the kinds of activities they wish to pursue. What people value most, and the degree to which they see themselves as connected to (or separate from) the communities and environment in which they live, will influence the acceptability of any electricity developments. People's lifestyles will also affect the overall demand for energy services (see *What do Kiwis value most?* on page 29).
- **Economic growth** – will lead to rising demands for energy services and electricity, unless economic growth and energy use can be 'decoupled'.[44] Energy efficiency improvements could help break the link. The impacts of economic growth will partly depend on the kinds of businesses and industries that stay in New Zealand or are established here (see *The future of large energy-intensive industries* on page 30).
- **Political manoeuvring** – by political parties and different interest groups. Energy security concerns are likely to influence many decisions of central government in particular, and short electoral cycles do not facilitate long-term strategic planning.
- **Institutional arrangements** – such as the design of organisations, markets, and governance structures (the social and economic rules we play by). These will influence both the demand for electricity and how it is supplied.
- **Education and research** – will shape people's understanding of energy issues and play a major role in the development and uptake of technologies (see *Research for the future* on page 29).
- **Population size** – as well as household size and where people live, will affect the demand for energy services and the sites of new developments. However, New Zealand's population is not predicted to grow much over the next 50 years.[45]

What do Kiwis value most?

... most of the rewarding enrichments of human life – be it personal freedoms and artistic opportunities, or pastimes of a physical or mental nature – do not claim large amounts of additional fuels or electricity.[46]

According to the Government's Growth and Innovation Advisory Board, New Zealanders currently rate the following factors as most important to them:

- quality of life
- quality of the environment
- quality of education
- quality of health services.

In 2004, 87 percent of people surveyed rated the quality of the environment as 'very important' or 'important' to them. With smart design, many New Zealanders could enjoy a much higher quality of life with social and economic development that does not damage the environment they cherish. Using energy more efficiently offers many benefits. Even so, every time people use energy they have some impact on the world around them. Rising consumption and production may lead to overall increases in energy use. In this case, New Zealanders will still have many difficult decisions to make about the kind of environment and society they want for themselves and the ones they love.

See www.giab.govt.nz for the survey.

Research for the future

Many future investments will be shaped by today's research. In 2003/04, about 40 percent of government funding for energy research was for renewable energy and 40 percent was for fossil fuels, including carbon sequestration (see glossary). Less than 15 percent of funding was for improving energy efficiency.

Source: MED (2004)

The future of large energy-intensive industries

What industries will be in New Zealand in the future? What kinds of businesses do people want? Do energy-intensive industries contribute as much to the economy as service industries? Future economic developments will have a major impact on the demand for energy services, depending on the kinds of businesses and economic structures that exist.

Over 20 percent of the electricity generated in New Zealand is currently used by just seven companies.[47] Electricity prices are very influential for large industries that compete in global markets. Historically, some energy-intensive industries have been attracted to New Zealand by the low price of electricity. If electricity prices rise, these businesses may threaten to move to other countries where the costs of production are lower.[48] Alternatively, it could be more economic for them to switch fuels or improve their energy efficiency. Some industries may redesign their processes to use 'waste' products to provide energy. For example, wood processing plants already use their residues such as bark and woodchips to generate heat and power. Factories could also be located close together to use each other's energy and waste by-products.

A contentious issue is the future of Comalco's aluminium smelter. Comalco uses about 15 percent of New Zealand's electricity. It buys most of its electricity at a cheap rate under a contract that expires in 2012. If a new contract offer is not acceptable to Comalco, they may close the smelter or build a new power plant on site, probably coal-fired. A major supply of electricity from Lake Manapouri would then be available for other uses. However, Lake Manapouri is a long way from the major urban centres in the North Island where most electricity is used. A major upgrade of the national grid would be needed to move this electricity, unless it was instead used locally (for example, to produce hydrogen).[49]

Tensions may rise between different industries about the best use of New Zealand's resources. For example, large-scale electricity developments could have a major impact on New Zealand's environment. This could affect the tourism and food export industries that rely on the quality of the environment for their business.

Readiness to change

New Zealand's electricity system will also be shaped by the degree of readiness to change. People are likely to resist many institutional changes, as ideas and habits often take a long time to change. However, conflicts over specific projects can bring on transformations when people confront their core values and goals.

Major changes may also be slowed by the legacy of previous investments and decisions. Large infrastructure in the electricity system has a very long life. This includes the infrastructure where electricity is used, such as buildings and machinery, and the infrastructure for generating and supplying electricity. For example, some sections of the national grid are over 50 years old. Established technologies and infrastructure can also 'lock out' better alternatives due to their existing market dominance.[50]

Readiness to change will depend on the degree of dialogue, proper consideration of alternatives, long-term vision, and the ability to recognise when a shift in direction is needed. If people are open to change, we may also be better able to meet major challenges, such as global events that are outside our control. While some changes could take a long time, the speed and scale of others could be more dramatic.

Social marketing for change

Good marketing can remarkably change the way people act. In 2003, the Government launched a 'Be better off' marketing campaign to encourage New Zealanders to use electricity more wisely. The campaign by the Energy Efficiency and Conservation Authority lasted two months and cost $200,000. In 2004, the Climate Change Office began a '4 million careful owners' awareness campaign with funding of $500,000 per year. Neither campaign used much television advertising. In contrast, the Government spent over $22 million on drink driving and road safety advertisements in 2003. The Government has also funded major ongoing campaigns to shift smoking habits and to encourage retirement savings.

CHAPTER 3

The scenarios

> *… it is necessary to step out of the normal forecasting mode of energy planning and reflect, review and rethink. Above all, it is necessary to stop thinking about what is likely and to explore what is possible.*[51]

This chapter introduces the two scenarios, called *Fuelling the future* and *Sparking new designs*.

3.1 Similarities and differences

All scenarios are based on assumptions about what *could* happen in the future. While the scenarios in this report are shaped by similar influences, they illustrate how different the future could be by taking different approaches today. In both scenarios we assume that:

- **global influences** – are out of New Zealand's control, but we continue to actively work with other countries to address major issues such as climate change
- **social values, identities, and lifestyles** – continue to shift and change but there is no major transformation in New Zealand society[52]
- **New Zealand's population** – rises from about 4 million people today to 4.6 million people by 2050[53]
- **the demand for energy services** – keeps rising at 2 percent each year, mostly due to economic growth[54]
- **potential energy resources** – start from the same point (see Section 2.5) with the potential to achieve 'Factor Four' improvements in the way people use energy.[55]

Appendix 1 highlights other assumptions that we used in the background technical report (see Section 1.3 for information on this background report).

What's a 'Factor Four'?

A Factor Four potential means we could get *four times* as many benefits out of the resources we use today. Or we could use only a quarter of the energy sources we now use to provide the same services. Major gains in energy efficiency are possible, but not by making incremental (small) improvements. Large leaps in design are needed to reach this potential over time. While it sounds ambitious, many businesses have *already* made cost-effective Factor Four improvements. See von Weizacker *et al*. (1998) for a good introduction.

Some big unknowns that we have not incorporated in either scenario include:

- **Implications of the global petroleum production peaks** – these will have a profound impact on the electricity system, although the actual impacts are very difficult to foresee (see *The future of oil and gas* on page 25). Electricity generation could rise significantly if more electricity is used to provide mobility (see Appendix 2). However, electricity use could decrease if energy-intensive businesses close down due to rising energy and transportation costs. It would be very worthwhile to develop separate scenarios to consider these issues more closely.
- **Revolutionary new technologies** – these are well beyond the limits of existing human knowledge, such as nuclear fusion. Even so, we do expect many new developments and innovations. Most new technologies will be developed elsewhere, but research and development within New Zealand could also lead to local innovations and the emergence of new energy-related industries.

Where the scenarios start to differ

Both scenarios start from today. Electricity use is rising but many communities are against new large-scale power schemes and enlargements of the national grid. Electricity prices are rising. Major industrial users of electricity are particularly concerned because they want to minimise the amount they pay for energy services to stay competitive in international markets. As Maui gas starts to run down, some dominant players in the electricity industry are talking about a 'crisis' if big new electricity projects are not built soon.

Where the scenarios start to differ is in the approaches that people take to address these concerns. There are major differences in the ways people perceive and respond to issues as well as the degree of planning for the future. *Fuelling the future* focuses mainly on building major infrastructure to meet the increasing demand for electricity. *Sparking new designs* emphasises smart design to provide energy services in very efficient and innovative ways.

The following sections explain the dominant mindsets in each scenario and the general approaches taken. Chapters 4 to 6 illustrate what New Zealand could look like under each scenario from now until 2050.

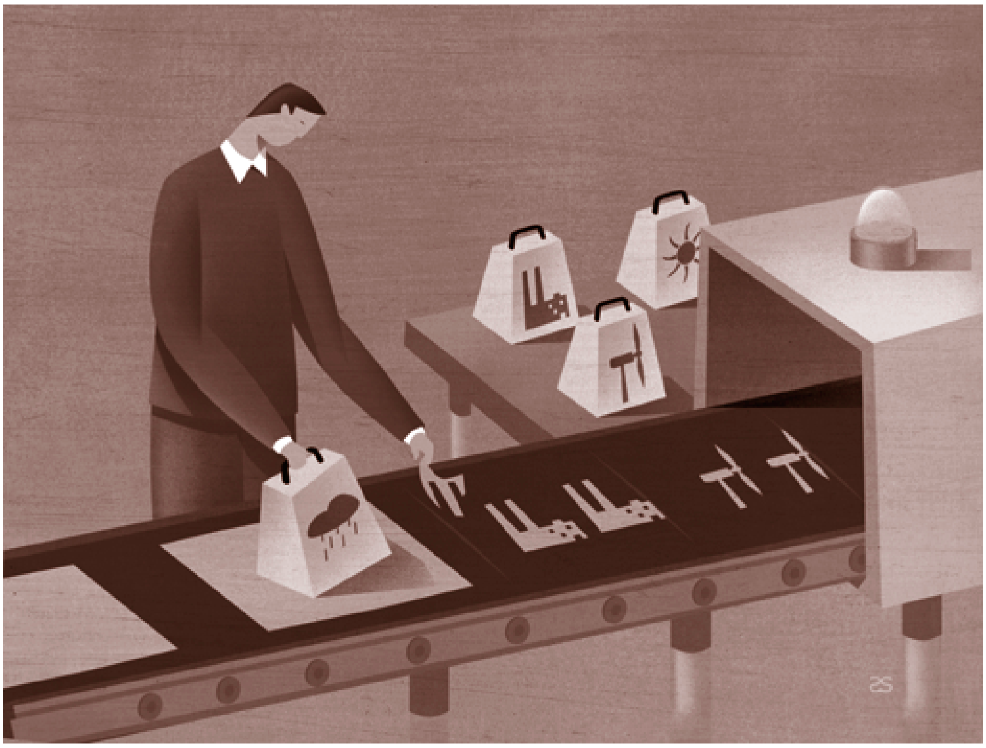
Energy rebounds and amplifications

When energy efficiency improves, people can get the services they want (such as warmth and comfort) for less energy and money. However, energy use sometimes 'rebounds' with energy efficiency improvements, reducing the overall amount of energy that could be saved.[56] On the other hand, energy savings can be 'amplified' to be even larger.

When people save money by improving energy efficiency, or by cutting back their energy use, they have more money to spend. How they spend this money influences whether there is a rebound or an amplification effect, and the size of that effect. For example, if someone spends the money they saved on buying lots of aluminium, which is produced with large amounts of electricity, the rebound effect may be so large that total energy use goes up. However, if that person invested their money into further energy efficiency improvements, the savings would be amplified. Within this spectrum, goods and services vary considerably in the amount of energy needed to provide them.

The size of the 'rebound effect' is debatable. It can differ across countries and varies for different sectors and individuals over time. Overall, rebounds can be significant but are unlikely to rob societies of most energy efficiency benefits. For example, the rebound effect in the United Kingdom has been estimated to lower potential energy savings by about 10 percent.[57] Research on other countries and sectors suggests it can range from 1 to 30 percent.[58] Energy use is still growing in many countries despite improvements in energy efficiency. However, this is mostly being driven by other factors such as the growth in energy-intensive sectors of the economy and consumer trends like the desire for ever bigger houses.

One way to reduce the risk of a rebound effect and make an amplification effect more likely is to encourage people to invest in cost-effective energy efficiency improvements that have very long payback periods. This can be done by using regulations, economic incentives, or other strategies. The financial savings from these improvements are then absorbed by the investment.



3.2 *Fuelling the future* scenario

Fuelling the future is strongly shaped by established ways of thinking. Many government and business leaders assume that the demand for electricity will keep on rising, driven by a growing economy and higher living standards. More power projects need to be built to maintain a secure supply of electricity and to encourage business investment. These projects tend to be large-scale developments that major electricity companies have experience with and find most profitable to build.[59] The national grid also needs to be expanded periodically to distribute the extra electricity.

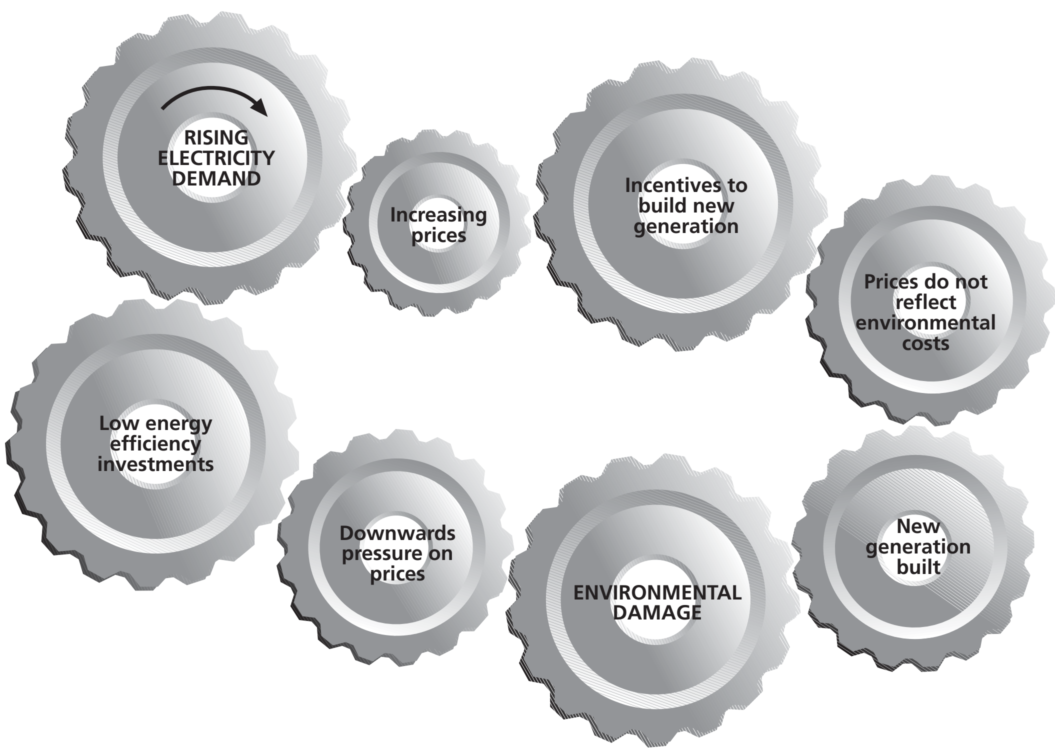
This leads to major tensions. Most New Zealanders are concerned about the quality of their environment, which is under threat. Major projects are often delayed by local opposition. At the same time, some see resource management processes as barriers to progress. Yet most people are also concerned about rising electricity prices and reliable electricity supplies. It seems that the only way to resolve these conflicts is by 'striking a balance' between environmental and economic goals. This means that trade-offs between opposing interests need to be made. Different groups usually find it difficult to cooperate and find some common ground. Fears about electricity shortages and job losses mean that established economic interests tend to hold sway.

Decision making in this scenario tends to be conservative. It favours proven technologies and established approaches that do not fundamentally challenge existing practices. When major projects are delayed, or when people are not prepared for the depletion of energy sources they depend on, important decisions are often made in a reactive way. Decision makers respond quickly to crises (either perceived or real) and the most powerful interests of the day.

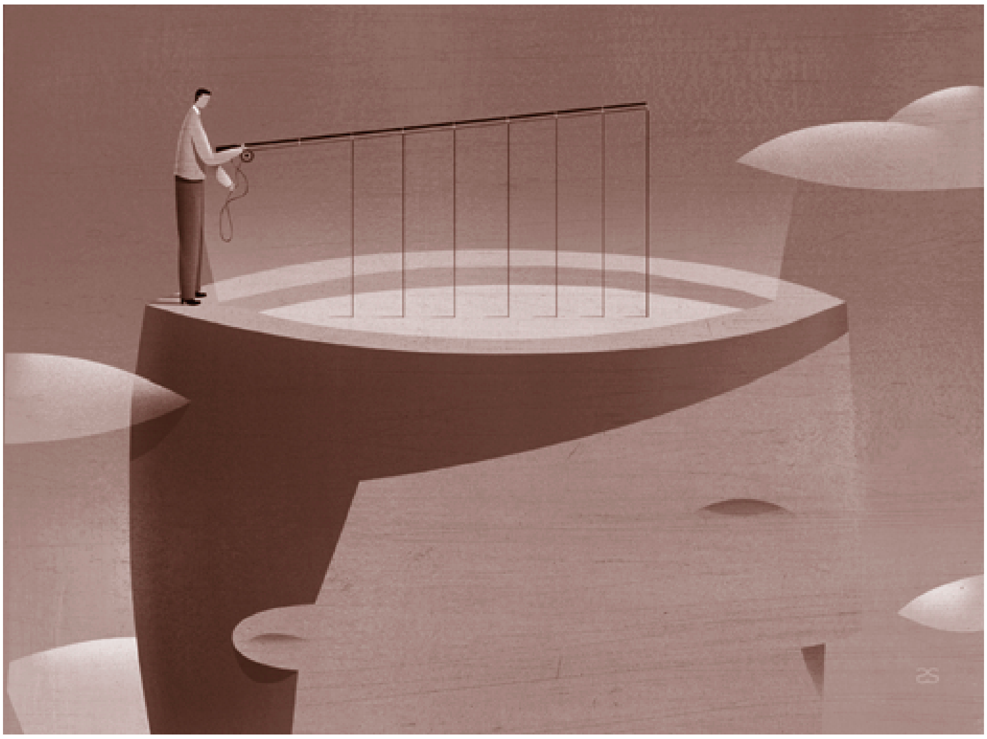
History seems to repeat itself in this scenario (see Figure 3.1).

- The demand for electricity keeps rising and pushes electricity prices up.
- As prices rise, some people avoid paying more for their energy services by using electricity more efficiently or by using other fuels such as gas. However, influential leaders believe it is too hard, and possibly less profitable, to change the way most people use electricity. They believe it is simpler to develop, or lobby for, more infrastructure. More time and money is therefore invested in the latter. Many groups, including businesses and community groups, will increase the pressure to reduce electricity prices.
- Most electricity users do not directly see or pay for the impact of major developments on, for example, climate change or damage to a river that a local community relies on. Otherwise, electricity prices would be higher.
- Large-scale developments are eventually built, easing the pressure on power prices as electricity supplies increase. This provides some certainty for electricity users, particularly large industrial users. With lower electricity prices, people and businesses have less incentive to invest in energy efficiency improvements to reduce energy costs.
- Eventually, demand reaches the point where more electricity is needed again. The cycle then repeats.

Figure 3.1 ***Fuelling the future*** **– conceptual view** [60]



Energy efficiency improves in this scenario, but only modestly from incremental technological improvements. For example, equipment and infrastructure are replaced with more efficient alternatives as they reach the end of their life. New settlements and houses, however, are still planned and built with little consideration given to their energy efficiency. Householders and businesses are expected to pay on their own for any major energy efficiency improvements. Most people do not make these investments because the benefits are not important enough to them, or because they lack money or knowledge of the potential benefits. Ironically, this means that most people eventually end up paying a lot *more* for electricity (to cover the cost of new infrastructure) that provides them with the energy services they want. New Zealand is very slow to develop more widespread expertise in the area of energy efficiency, which could have avoided the need to build many projects. Little disruption occurs in the established electricity system or for most electricity users, apart from ongoing concerns about energy security and delays to major projects.



3.3 *Sparking new designs* scenario

The urban and rural landscapes of New Zealand look very different in *Sparking new designs*. Early in this scenario a flashpoint sparks a big break from the past. A flashpoint could be conflict over a proposed development or rapidly rising energy costs. A major search for new solutions starts when different groups and individuals come together to share common ground.

Although these groups represent different interests, they all want to encourage social and economic development that improves people's quality of life without causing environmental damage. They also agree that everyone should have access to energy services at a reasonable cost. Ongoing dialogue among these groups, as well as with many others, helps them develop their visions for a desirable electricity system.

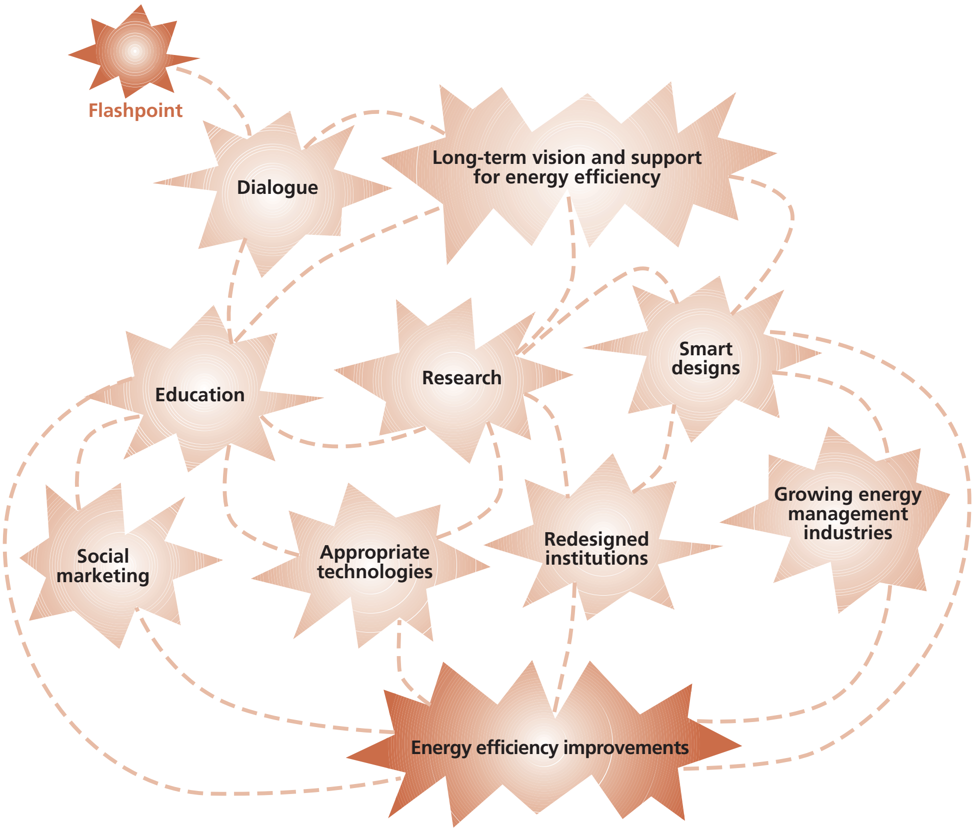
They begin to see that a lot of electricity is not used very efficiently in New Zealand. For example, most buildings, machinery, and electronic equipment have been designed and purchased without considering their energy use. This means there is a huge potential to 'get more from less' by redesigning the ways people use electricity and other forms of energy. Government, businesses, and community groups find broad support for encouraging cost-effective energy efficiency improvements. A government institution, working cooperatively with others, is given a very strong mandate to support this.

Early efforts to improve energy efficiency tend to focus on the easy technical changes that households and businesses can make, such as more efficient lighting. Free energy audits help people to see the benefits of using energy wisely. However, many people will not make changes on their own, despite the benefits. Some people lack the money to make the initial investments in energy efficiency. Most households and businesses are not well placed to influence important decisions like the design of the buildings and equipment they use. Lots of groups – including builders, architects, engineers, appliance retailers, accountants, financial institutions and many others – are encouraged to be involved.

Small changes begin to spark bigger transformations (see Figure 3.2).

- A comprehensive social marketing campaign emphasises the benefits of energy efficiency to the wider community to encourage people to make changes swiftly.
- Public and private investments in education and research help people to improve the way we use energy and to develop appropriate technologies.
- Incentive programmes, agreements, and regulations are developed, for example, to improve the energy performance of buildings and appliances.
- Smart designs, innovation, and locally derived solutions are encouraged. Unexpected results, and sometimes problems, can arise, but they are generally seen as an opportunity for learning better ways.
- While many groups work together, some still resist major changes. Conflicts help to expose the limits of existing institutions, such as regulations and market structures, to benefit society. In the struggle to avoid wasting electricity, many institutions are redesigned to encourage (or at least not hold back) better use of energy.
- Over time, sparks continue to fly in many directions. A strong energy management industry emerges that prospers by helping people to use energy wisely.

Figure 3.2 *Sparking new designs* – conceptual view



Energy efficiency improves remarkably in this scenario. Even so, New Zealand only reaches half its Factor Four potential by 2050 because of the legacy of earlier decisions and investments.

3.4 Summary of the two scenarios

Key similarities and differences between the two scenarios are highlighted in Figure 3.3.[61] Both scenarios start with the same resources, identified in Section 2.5. Most of the global and national influences that were discussed in Section 2.6 are the same. However, over time people's mindsets and approaches, and the influence of different groups, help to shape changes in:

- investments in education, training, and research
- institutional designs
- choice of technologies
- economic developments.

The scenarios diverge significantly over time because of these differences. In *Fuelling the future*, much more infrastructure needs to be built to generate electricity. Many projects are also built in *Sparking new designs*, but cost-effective energy efficiency gains mean that a lot of large-scale developments are not needed.

Figure 3.4 highlights the different demands for electricity in each scenario. Both scenarios start with the same demand for energy services and the same potential for improvements in energy efficiency. The demand for energy services keeps rising at 2 percent each year. In *Fuelling the future,* the demand for electricity grows slightly less than 2 percent each year, as efficiency improves. In *Sparking new designs,* electricity use rises more slowly and eventually levels off when long-term energy efficiency investments take effect.

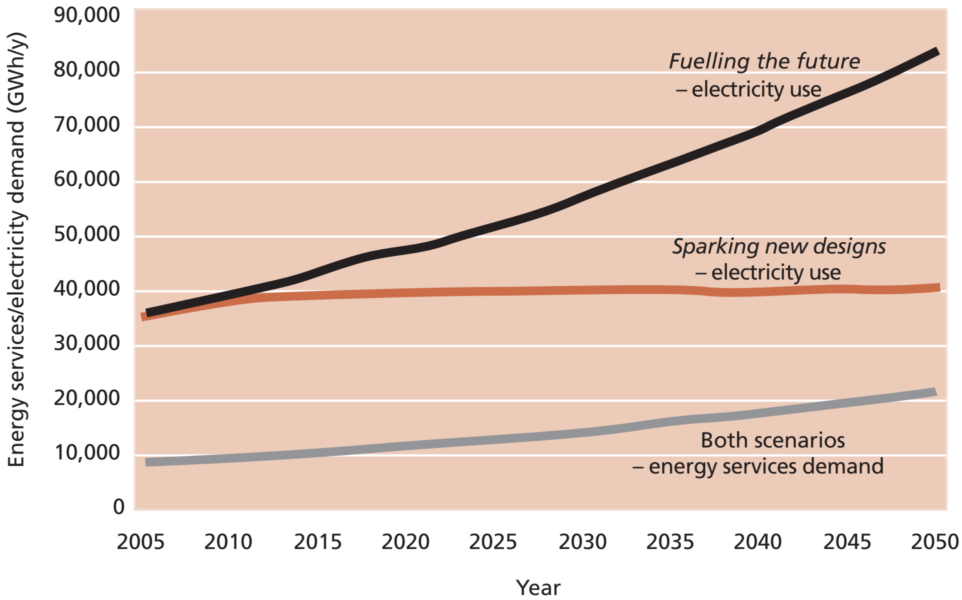
Figure 3.3 Summary of the two scenarios

Both scenarios

- Global context – rising demands for energy services; major concerns about energy security; intensive efforts to address climate change; many new technologies (but no revolutionary breakthroughs)
- New Zealand population – grows to 4.6 million by 2050
- New Zealand values, identities, and lifestyles – continue to change, but no major transformation
- Demand for energy services – rises 2% each year, mostly due to economic growth
- Availability of energy resources – both scenarios start with the same potential.

Fuelling the future		***Sparking new designs***
Meeting the demand for electricity	*What's the aim?*	Meeting the demand for energy services
'A matter of balance' (trade-offs)	*What about environmental concerns?*	'A matter of smart design' (win–wins)
Short-term thinking, top down, and often reactive	*Decision making*	Long-term thinking, participatory, and proactive
Low	*Intervention to improve energy efficiency*[62]	High
Low-cost electricity	*Prices*	Low-cost energy services
Economic capital (physical infrastructure)	*Investment priority*	Human capital (education and expertise)
Mostly energy supply	*Research funding*	Energy efficiency and energy supply
Large, established technologies	*Favoured technologies*	Innovative technologies designed to fit locally
Based around national grid	*New infrastructure*	Distributed close to where electricity is used

Figure 3.4 Demand for energy services and electricity use in each scenario



3.5 Meet the characters

Changes in New Zealand's electricity system will affect many people in vastly different ways over time. We all share some connection to our electricity system, but the impacts of any new developments will not be shared equally. To encourage readers to think about the possible impact on different people, the scenarios in this report are blended with the stories of two characters to explore the changing world through their eyes. The characters are:

- **Shane** – born in 1985, grew up on a farm in the East Cape, and in 2005 completed an agricultural certificate
- **Robyn** – also born in 1985, grew up in the suburbs of Auckland, and in 2005 is studying engineering at university.

Chapters 4 to 6 explore the scenarios in more detail to see what New Zealand could look like from 2005 to 2050.

CHAPTER 4

2005–2015

4.1 Overview of 2015

Fuelling the future

Major new infrastructure 2005–2015

- Wind – New Zealand-wide (1,590MW)
- Gas – Huntly upgrade (385MW)
- Coal – Marsden B (320MW)
- Geothermal – Waikato (285MW)
- Hydro – Marlborough (70MW)
- Hydro – Hawkes Bay (30MW)
- National grid – 400kV lines Waikato to Auckland
- National grid – 400kV lines Waitaki Valley to Christchurch
- National grid – upgrade to HVDC cables across Cook Strait

Retired infrastructure

- New Plymouth gas-fired power plant

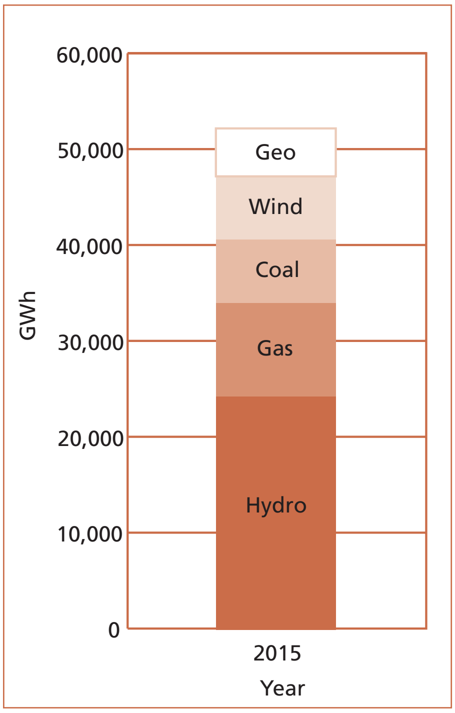
Major research and development investments

- Industrial heat and power cogeneration
- Integrated Coal Gasification Combined Cycle (ICGCC) power plants

Notes

- In 2013 local lines companies were no longer legally required to service remote users of electricity.[63] Gas from New Zealand's landfills is also burned to generate electricity in this period and beyond (70MW not shown on graph).

Figure 4.1 Electricity generation 2015



Electricity use

Up 21% since 2005

Electricity use per capita

Up 16% since 2005

Electricity CO_2 emissions per annum

Up 45% since 2005

Up 155% since 1990

Sparking new designs

Major new infrastructure 2005–2015

- Wind – New Zealand-wide (790MW)
- Gas – Huntly upgrade (385MW)
- Geothermal – Waikato (285MW)
- National grid – 400kV lines from Waikato to Auckland
- National grid – 400kV lines from Waitaki Valley to Christchurch
- National grid – upgrade to HVDC cables across Cook Strait

Retired infrastructure

- New Plymouth gas-fired power plant

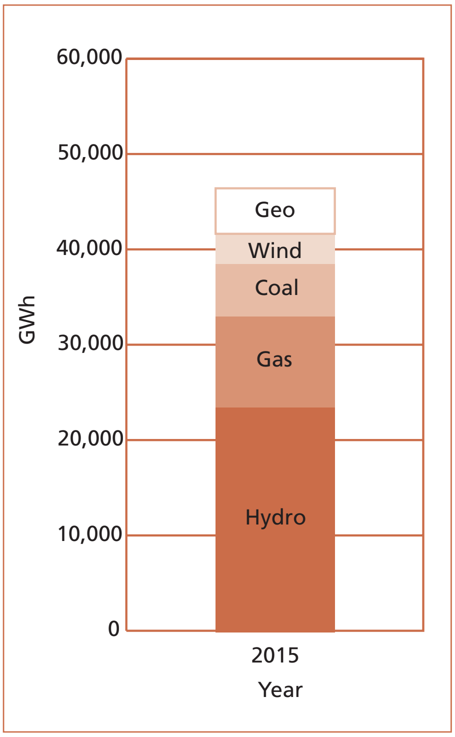
Major research and development investments

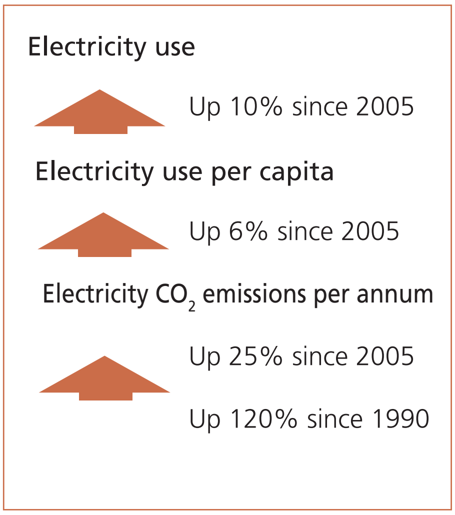
- Energy efficient technologies and their uptake
- Energy use in homes, businesses, and other organisations
- Social benefits of distributed electricity generation
- Wind forecasting

Notes

- Construction of the national grid from Waikato to Auckland was delayed because alternatives were developed. Major sections of the new lines are now being placed underground.
- In 2013 local lines companies were no longer legally required to service remote users of electricity.[64] Gas from New Zealand's landfills is also burned to generate electricity in this period and beyond (70MW not shown on graph).

Figure 4.2 Electricity generation 2015





4.2 *Fuelling the future 2015*

Down on the farm

> ***Shane looked menacingly at the man in the orange suit. It was one of those blokes from the local lines company, fiddling with the wires at the end of his driveway. Ten days ago Shane got a letter telling him he might lose his connection. Apparently his farm was in a low priority zone because it was in a remote rural area of East Cape. He'd already faced a hefty price rise a few years ago to pay for more maintenance of the lines. Now the company was threatening to do nothing if the lines went down in the next storm.***

Back in 2013, local lines companies were no longer obliged to supply electricity to their existing users. Farmers and other people in remote rural areas faced major increases in electricity supply charges and risked losing their connections. Some people spent or borrowed money to generate their own electricity (if they could), while others lobbied the Government to provide more support.

> ***The irony wasn't lost on Shane. A decade ago there were massive protests over plans to build big new power pylons to Auckland, followed by similar protests in the South Island. Many farmers had fought unsuccessfully to prevent the towers being built. Now Shane was struggling to keep the meagre lines to his farm.***

People had growing concerns from 2005 onwards about the supply of electricity into Auckland. The city was still haunted by the 1998 power blackouts, but Aucklanders were using more electricity every day. Local protests were stalling plans to build a new coal-fired power plant at Marsden Point, which could have delayed the construction of the new pylons. The Government was convinced of an impending crisis. They fast-tracked the development of the national grid through the central North Island, claiming it was in the national interest.

City life

> ***Robyn only noticed the hum in the office when the air conditioning stopped. It must be six o'clock, she thought, which was when the heating normally shut down. Her engineering firm had been in their brand new building for only a month, but Robyn was already getting used to it. She gazed at the blazing lights of the office towers around her and decided it was time to go home. Hopefully she had missed the peak traffic mayhem on Auckland's roads. Ten minutes later, however, she was cursing behind the wheel. Averting her eyes from the traffic***

in front of her, she glanced at a new billboard beside the motorway. The words, 'Your next generation: fuelling a bright future' flashed above the glowing face of a green-eyed girl. The face looked familiar to Robyn. She had seen it all over town as part of a marketing campaign for more coal-fired power plants.

Electricity use and generation had increased significantly over the last decade. A new high efficiency gas-fired power plant started generating electricity in Huntly at the end of 2006. Shortly after, as the Maui gas field came to the end of its economic life, an older gas-fired power plant at New Plymouth shut down. In 2010, the Marsden B coal-fired power plant started operating, despite the earlier protests. At first it was fuelled with imported coal from Indonesia but, as world coal prices continued to rise due to soaring economic growth in China and India, it became more economical to ship coal from Southland.

Around this time wind farm construction increased rapidly across the country. People had generally become more accepting of wind turbines, although they often had little trust in large wind farm developers who were reaping major financial rewards. More electricity was also being generated from geothermal energy and two new hydro schemes had been built – one in Marlborough and a smaller one in Hawkes Bay. However, with electricity demand still growing at 2 percent each year, pressure was building for more generation.

Robyn was confused as to why anyone would want to build more coal-fired power plants. She heard things about climate change all the time. But at least burning more coal was better than going nuclear, she thought.

By the end of the first Kyoto commitment period in 2012, New Zealand's climate change emissions were meant to be back to 1990 levels. But because a lot more gas and coal were being burned, carbon dioxide emissions in the electricity sector had more than doubled since this time. The Government used 'carbon credits' from forests grown in New Zealand since 1990 to cover this increase. They also had to buy carbon credits from other countries to cover the increasing greenhouse gas emissions in the transport and farming sectors.

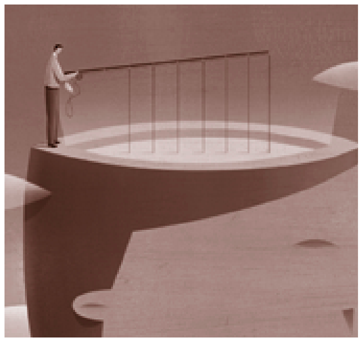
By 2015, most of the best wind farm sites had been developed. People were becoming more hostile towards bigger wind turbines and more wind farms were encroaching on sensitive places. Many major electricity users and some electricity companies were heavily promoting coal to 'bridge the gap' to a more sustainable energy future. They claimed that technologies would soon be developed to address carbon dioxide emissions.

It was dark when Robyn pulled into the driveway and there were no lights on inside the house. At least it would be warm. Robyn was still congratulating herself on her latest investment – a grunty new heater that she had switched on with her cellphone when she was still miles away from home. Sure enough, it was cosy when she got inside. She turned on the kettle and decided to check her mail. Unfortunately there were just a few bills in her inbox, including one from the power company. "Here we go again," she moaned, as she started reading the message that informed her in the politest possible way that electricity prices were about to increase. At least Robyn was expecting a pay rise next month that would more than cover it. She was more worried about her parents. They had recently retired and Robyn hated to think about them going cold to save power and money.

Electricity prices had risen significantly over the decade to pay for new infrastructure. Some householders responded by installing solar water heaters and investing in efficiency improvements if they could afford it. However, most households and commercial businesses simply paid the extra, especially if their incomes or profits had increased.

4.3 *Sparking new designs 2015*

Down on the farm



> ***As the dawn cleared, Shane gazed across the rural East Cape landscape and watched the ageing power line to his house sway in the wind. He cast his mind back to Cyclone Bola, which hit the region nearly 30 years ago. He recalled how his power supply was cut off and the disastrous impact it had on his farm. He now congratulated himself on signing up for the 'DG is easy' programme. He had been faced with a much more expensive contract from his lines company to guarantee a basic level of service. Instead, he took advantage of a favourable financing scheme to install a bio-generator on his property, which could run on a variety of biomass fuels. If there was another major storm, he could crank up the generator at short notice and avoid disruption if his power line was damaged. The local lines company also paid him when he generated extra power during peak electricity periods.***

The 'DG is easy' programme promoted more distributed electricity generation. It was part of a range of measures in response to a decision to delay the upgrade of the national grid into Auckland. Disaffected landowners had fought a long battle over the grid upgrade plans. In 2006, a government agency had been given a strong mandate to develop alternatives to the grid, while dialogue with landowners continued.

Various 'carrot and stick' measures were used to manage the problematic peak electricity periods of the day in Auckland.[65] Households and businesses were offered incentives to alter their electricity use at certain times of day. Combined with higher tariffs at peak times, many found that they could save money by making small changes. For example, they could have their hot water temperature turned down slightly, use heat pumps to heat their living rooms, and set their dishwashers to run late at night. More direct use of gas was also encouraged. Many households took advantage of attractive hire purchase deals and tax deductions for solar hot water heaters. Some industries were offered rebates if they agreed to curb their electricity use at short notice. Businesses and factories were also encouraged to have some emergency backup in the event of a power shortage. At first, people resisted some of these changes, but a social marketing campaign communicated the benefits of alternatives and their acceptability grew.

Cost-effective energy efficiency improvements were now being strongly supported. The Building Code had been strengthened several times to improve the design of new buildings. A major campaign had begun to improve the quality of state houses by making them warmer, healthier, and less expensive to heat. New electrical appliances had to meet strict energy performance requirements. Some appliance retailers were reluctant to support these changes but most could be convinced of the benefits. They shifted their focus to higher value appliances with attractive finance deals and communicated the real long-term costs of different appliances. People were encouraged to trade in their old goods.

Some small firms were now selling comprehensive energy audits, as well as offering basic audits free of charge. The quality of the audits varied at first, but an accreditation scheme for auditors had improved their consistency. For a modest investment, many firms found out how to save money by using energy more efficiently. When construction of the new transmission line into Auckland finally began in 2014, the growth in the region's electricity use had slowed, particularly during peak periods. With recent advances in super-conducting technologies, it was also possible to place major sections of the lines underground.

City life

> ***Robyn sat in her sunny new Auckland office. As a chartered sustainable energy engineer, she marvelled that her building used only a third as much electricity from the power lines as the tinted-window 1980s version across the road. Guided by the new smart design provisions in the district plan, the owners of her building had installed solar water heaters on the roof. They had also configured the building to make the most of free solar energy for heat, ventilation, and light. This proved a wise move, as electricity prices had risen significantly. Robyn had noticed many other new buildings in the central business district that were just as efficient. She hoped plans to extend the smart design provisions to residential districts would proceed.***
>
> ***As Robyn caught the light-rail metro home, she could just see the wind turbines rotating quietly on the tops of the distant hills. She had been one of the first to sign up to the green power scheme. This meant she agreed to buy most of her electricity from the local eco-power company. Wind generation was now much cheaper than a decade ago, so she was actually better off than if she had stuck with her national energy retailer. Some people had objected when Auckland's first wind farm had been proposed. However, as in other parts of the country, the wider community had slowly become more supportive. Technological advances meant the turbines operated well within noise standards, and most people had got used to the visual impact. National guidelines also protected highly valued natural landscapes from development.***

In 2013, New Zealand had signed the updated Kyoto+ Protocol. This sought to reduce emissions even further and included more of the major emitting countries. New Zealand needed to reduce its greenhouse gas emissions to meet its commitments and was pushing for greater energy efficiency and the further development of renewable sources of energy.

A higher carbon charge had been introduced, but its overall impact on the economy was still relatively small. Few energy-intensive industries had moved offshore, as most other countries were imposing a similar charge. Some energy-intensive industries faced greater costs, but the proceeds from carbon charges were used by government to reduce taxes elsewhere. For example, tax breaks were introduced for research and development in energy efficiency and renewable technologies. These incentives effectively replaced those that the petroleum industry had enjoyed over the previous 25 years.

Much more biomass was also being used to provide energy services, mostly from the mountains of wood-waste from the 'wall of wood' (plantation forests) now being harvested. Several industrial plants, including sawmills with drying kilns, now used wood waste to generate heat and electricity for their industrial processes. Many homes and businesses were also using wood pellets for heating.

CHAPTER 5

2015–2030

5.1 Overview of 2030

Fuelling the future

Major new infrastructure 2015–2030

- Coal – Huntly refurbishment (1,000MW)
- Coal – Huntly 2 and 3 (800MW)
- Geothermal – Waikato (475MW)
- Coal – South Auckland (400MW)
- Coal – Southland (400MW)
- Coal – Taranaki (400MW)
- Coal – West Coast (400MW)
- Hydro – Lower Clutha (300MW)
- Hydro – Lower Waitaki (125MW)
- Wind – New Zealand-wide (190MW)
- National grid – 400kV lines Invercargill to Waitaki Valley

Retired infrastructure

- Otahuhu B gas-fired power plant, eventually replaced by coal
- Taranaki gas-fired power plant, eventually replaced by coal

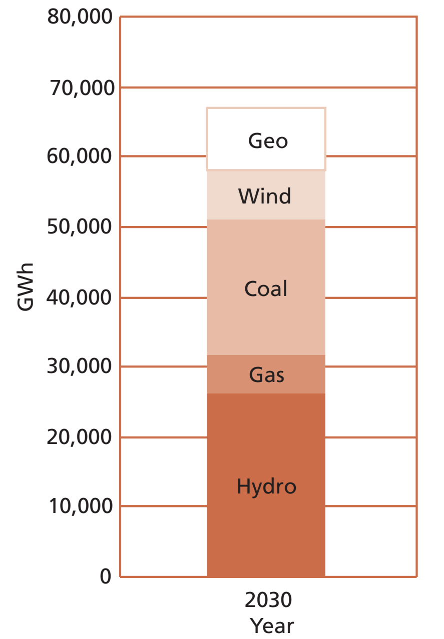
Major research and development investments

- Carbon dioxide capture and sequestration
- 'Clean coal' technologies

Notes

- Huntly West coal mines have been developed.
- 400MW of new industrial cogeneration is also installed.

Figure 5.1 Electricity generation 2030



Electricity use

Up 32% since 2015

Up 60% since 2005

Electricity use per capita

Up 27% since 2015

Up 48% since 2005

Electricity CO_2 emissions per annum

Up 125% since 2005

Up 300% since 1990

Sparking new designs

Major new infrastructure 2015–2030

- Wind – New Zealand-wide (835MW)
- Geothermal – Waikato (475MW)
- Hydro – Marlborough (70MW)
- Hydro – Hawkes Bay (30MW)

Retired infrastructure

- Otahuhu B gas-fired power plant
- Taranaki gas-fired power plant
- National grid – old 220kV lines from Waikato to Auckland

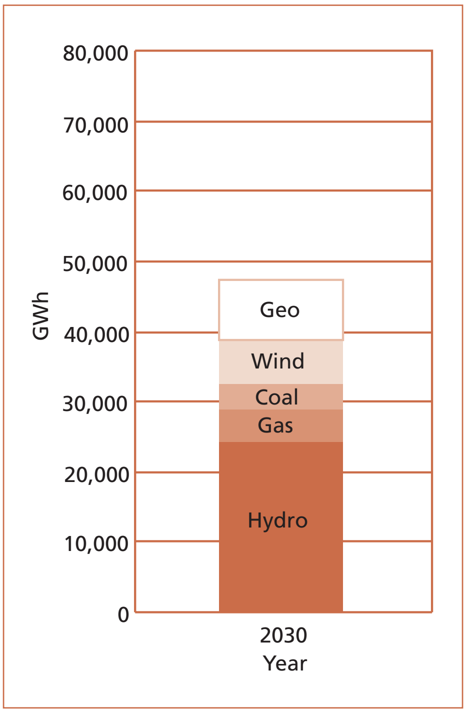
Major research and development investments

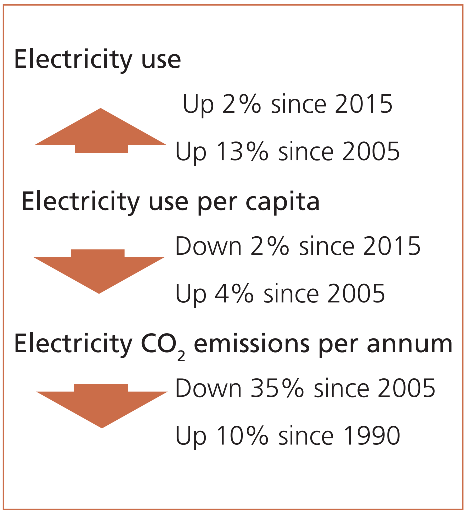
- Distributed electricity generation control systems
- Energy-efficient technologies and their uptake
- Smart energy management systems and metering
- Solar energy systems
- Wave power systems

Notes

- Wave power is also being used to generate minor amounts of electricity (not shown on graph).

Figure 5.2 Electricity generation 2030





5.2 *Fuelling the future 2030*

Down on the farm

Shane sneaked through the corn and saw them demolishing a dam by the river. "Got ya", he muttered. As the dam slid into the murky water, Shane crept up from behind. He liked to see his boys building dams in the creek – most days they were plugged into the gaming system inside the house – but he didn't like to see them too close to the river. Its swift current could still claim a human life or two and it wasn't good for their health, even though water quality had improved in the Waikato region since Shane moved there last decade. Now the river was feeling the heat from some new developments. It wasn't the only river under threat.

Major developments had taken place in the Waikato region over the last 15 years. The Huntly West coal mine opened shortly after the Huntly coal-fired power plant was refurbished in 2015. Local residents had fought against the mine for years, but coal reserves from other nearby mines were starting to dwindle. More coal was needed to power the new Huntly 2 and Huntly 3 coal-fired power plants.

The new Huntly power stations used the latest Integrated Coal Gasification Combined Cycle (ICGCC) technology to generate electricity. Although this technology was considered 'best practice' internationally, the power company was reluctant to invest in it at first because of its added expense. However, they did install it because of public concerns about pollution. Huntly 2 had some teething problems when it first opened in 2017, but Dutch technicians fixed most of these before Huntly 3 was completed. Unfortunately, the power plants needed water for cooling. This was putting pressure on the Waikato River by warming its water. River water was also needed further upstream for cooling more geothermal power plants. However, plans for more geothermal energy were on hold because of concerns about subsidence around Taupo.

More hydro power schemes had been built on rivers elsewhere in New Zealand. Memories of Project Aqua were still alive in many minds when plans for a new development on the lower Waitaki River were revealed. The new scheme was, however, much smaller than earlier proposals. Most of the river's water was now being used for irrigation instead. Farmers depended on irrigation during the increasingly hot and dry summers. The new development on the Lower Clutha River, which had been delayed for over a decade, was much larger. It was built amid heated debates about the increasing costs of burning more coal to generate electricity. Successive governments had argued it was essential to maintain a secure supply of electricity by using coal, and the electricity system was becoming much more dependent on this resource. At the same time, New Zealand was facing increasing pressure from its trading partners not to renege on climate change commitments.

Electricity generators paid only a small carbon charge for burning coal, while the Government paid for most climate change costs. The Government encouraged native forest planting and regeneration, particularly on marginal farmland, to soak up more carbon. They also intervened to reduce greenhouse gas emissions in other sectors. The most controversial move was a series of increasing 'burp taxes' on farm livestock to help reduce methane emissions in the farming sector. Farmers protested, but 90 percent of voters now lived in towns and cities that relied on a secure supply of electricity. Some farmers avoided paying the tax by constructing new 'MethCap' buildings for livestock. These were sealed off from the surrounding environment and allowed farmers to capture all the methane emissions from their animals. Wandering stock were becoming a much less common sight around New Zealand, while more maize and other crops were grown to feed animals in the factory farms. Dairy cow herds were getting smaller anyway. More pastureland was being planted with vegetable oil crops to supply the growing margarine and biodiesel industries. These industries produced far lower greenhouse gas emissions than both dairy farming and diesel sourced from fossil fuels.

City life

> ***Robyn went to the drinks fridge for some bottled water. She'd been at the computer all day, eager to finish the plans she'd been working on for over a year. She was glad to be back in New Zealand, but sometimes she didn't get time to enjoy it. Ten years ago she'd been offered a job in Texas ideally suited to her postgraduate training. She'd jumped at the project that involved capturing carbon dioxide emissions from coal-fired power plants and burying them in old oil wells. Now she was back in Auckland, working on a similar project. The firm she now worked for, Beijing Black Gold, had won a contract to make Taranaki the energy capital of New Zealand once again.***

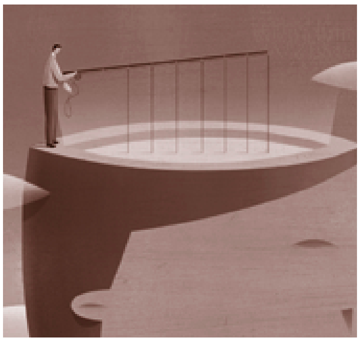
The coal-fired power plants in the Waikato region were not the only ones built from 2015 to 2030. Much more coal was now being used because other energy sources were unavailable. The last major wind farms were developed in Banks Peninsula and the Marlborough Sounds around 2016. Even these only went ahead when new legislation made it easier to get consents. Construction of more hydro developments had also been delayed. The nuclear debate was re-ignited during the early 2020s. However, it now made even less economic sense to build nuclear power plants. The price of uranium and thorium (needed for nuclear power generation) had skyrocketed due to increasing demands from the United States, China, and India. Coal seemed like the best remaining option.

Many West Coasters had welcomed a new power plant fuelled by local coal in their region. A new coal-fired station had also been built in South Auckland, on the site of the Otahuhu B gas-fired power plant that was mothballed when gas prices got too high. Coal for the new power plant was shipped in by barge through the Manukau harbour. Two more coal-fired power plants were also generating electricity. One was in Southland and burned local 'brown coal' stripped from farmland. The second was in Taranaki and burned West Coast coal shipped in by sea barge.

More coal-fired power plants were now planned for Taranaki, the great attraction being the old Maui gas field. Huge public and private investment, overseas and in New Zealand, had gone into finding ways to capture carbon dioxide and pump it underground. New technologies were starting to mature, so tax breaks were offered to encourage the development of Maui as a carbon sequestration site. It was also planned to pump carbon dioxide from the Huntly and Auckland coal-fired power stations to Maui using the old gas pipelines.

5.3 *Sparking new designs 2030*

Down on the farm



> ***Shane looked at the sprinkling of wind turbines across the nearby hills. He was proud that he'd initiated the idea that led to a consortium of farmers and other investors in his district chipping in to finance the turbines that now helped to power his and other local farms. Shane held shares in the cooperative, so he was getting a share of the profits.***
>
> ***Shane's cows were also helping. He had installed a bio-digester system in his dairy shed and the adjacent covered feeding pad to convert his cattle's effluent into electricity. He was using the available energy on his farm more efficiently and, at the same time, reducing the amount of waste that left his property. Shane had recently read that the quality of stream water in his district was improving. He could rightly claim some credit for this. He still let his cattle out to graze each day, but they were kept well away from waterways. Meanwhile, the by-products from the bio-digester system made an excellent odourless soil conditioner.***

By 2030, everybody understood that they needed to use electricity and other forms of energy wisely. Fossil fuel use had declined dramatically over the last couple of decades. This came about because of escalating petroleum prices on world markets and mounting direct evidence of human-induced climate change. New Zealand was also running low on natural gas supplies. It was too expensive to import gas from other countries because of much global competition. The gas-fired power plants at Stratford and Otahuhu had closed down, as it was much more cost-effective to use the remaining gas directly. These factors had a major influence on New Zealand's electricity system, even though many events had been anticipated. More and more, the Government, community groups, businesses, and members of the public were committing to energy efficiency and renewable forms of energy.

Several more rivers had been dammed in the 2020s. There were some medium-sized hydro developments in the Hawkes Bay and the upper South Island, and many more micro-hydro schemes were scattered around the country.

Many new geothermal plants had been constructed and technological improvements meant that geothermal energy was being extracted more efficiently.

Wave energy was also being used to generate electricity in New Zealand, although only in a few micro-sized developments. Sea walls had been constructed to protect many rural communities from rising sea levels and more severe weather events. Wave power generators were incorporated into the design of the walls to feed electricity into local power networks.

The majority of new electricity supplies, however, came from wind energy. Most people found wind farms more acceptable than large coal-fired power plants or major hydro schemes. The latest turbines were also quieter, so people were happy to live even closer to turbines than in the past. As with hydropower though, people wanted sensitive natural areas to remain off-limits.

No major additions had been made to the national grid since the new lines to Auckland had been completed, with major sections of it underground. People were still concerned about the security of the electricity system, but many safeguards were in place. Diverse energy sources were being used and more electricity was being generated near to major urban centres. Any electricity supply problems tended to be localised. Wind turbines were now spread over a wider area and hydro power was used when the wind stopped blowing. After some reluctance at first, energy companies were also actively involved in electricity demand management initiatives. They were finding the new market arrangements profitable.

City life

Robyn looked out her office window at the clear Auckland sky. She mused over a city map, looking in particular at the few remaining districts that her energy services company had not yet covered. The business she'd started with two old university pals was flourishing. They'd all gained postgraduate degrees in sustainable energy management. After working for major energy companies for a few years they realised that huge opportunities existed in the energy efficiency sector. They now worked with organisations such as district health boards, local councils, schools, and community groups. They also had numerous contacts with local business groups and electrical equipment companies. They were able to identify huge savings in energy costs for their clients and show them where they could find and install energy-efficient equipment.

Energy efficiency in New Zealand was improving in leaps and bounds. Many people were now trained in smart design systems and ongoing research and development went into energy efficiency as well as new and improved renewable energy technologies. This expertise had flowed through to regional developments. Local people were trained and employed to install new equipment and offer energy efficiency packages to households and businesses.

Robyn got off the hybrid bus to stop off at her local market on the way home. She chose her food for the week and organised a delivery time. When she got home she enjoyed a long hot shower thanks to her solar powered water heater. She then sat down with her children

while they went over their schoolwork. She marvelled at how much her kids knew about energy these days. She had also read a recent study that showed fewer children than ever before now suffered acute health problems attributable to cold, damp, and draughty houses. Yet her family almost never had to use a heater.

New electrical appliances and motors were now much more energy efficient and ongoing schemes were available to replace older models. Energy use was a paramount consideration in the design of all new buildings. Urban form in many cities had also begun to change. Many mega shopping malls, with their huge carparks, were closing and being replaced with smaller scale mixed-use developments. Most new commercial buildings used passive solar energy to provide lighting and a comfortable working environment. Many older buildings had also been fitted with solar panels for heating hot water, and a few had their own small wind turbines.

CHAPTER 6

2030–2050

6.1 Overview of 2050

Fuelling the future

Major new infrastructure 2030–2050

- Solar photovoltaic – New Zealand-wide (7,000MW)
- Coal – Taranaki (1,600MW)
- Coal – Southland (900MW)
- Coal – Marsden B upgrade (300MW)
- Hydro – Lower Grey (210MW)
- Hydro – Mohaka (Hawkes Bay) (75MW)
- Geothermal – Waikato (160MW)
- National grid – 400kV lines Taranaki to Central North Island

Retired infrastructure

- Gas – all remaining gas-fired power plants closed down
- Oil – Whirinaki power plant closed down
- Wind – many old turbines replaced at the end of their life by newer, more efficient designs

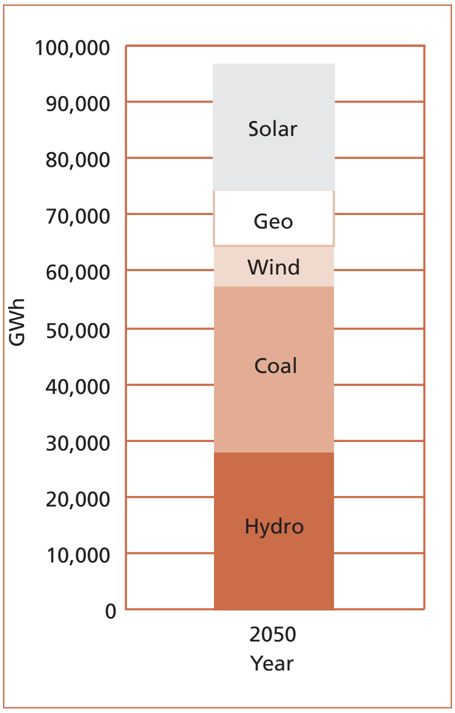
Major research and development investments

- Large-scale coal to hydrogen plants

Notes

- Carbon dioxide emissions from some coal-fired power plants are being sequestered into the old Maui gas field in Taranaki.

Figure 6.1 Electricity generation 2050



Electricity use

Up 48% since 2030
Up 137% since 2005

Electricity use per capita

Up 42% since 2030
Up 110% since 2005

Electricity CO_2 emissions per annum

Up 195% since 2005
Up 520% since 1990
NB: Some CO_2 capture and sequestration

Sparking new designs

Major new infrastructure 2030–2050

- Solar photovoltaic – New Zealand-wide (1,200MW)
- Wind – New Zealand-wide (250MW)
- Geothermal – Waikato (160MW)
- Wave – New Zealand-wide (100MW)

Retired infrastructure

- Coal – all remaining coal-fired power plants
- Gas – all remaining gas-fired power plants
- Wind – many old turbines replaced at the end of their life by newer, more efficient designs

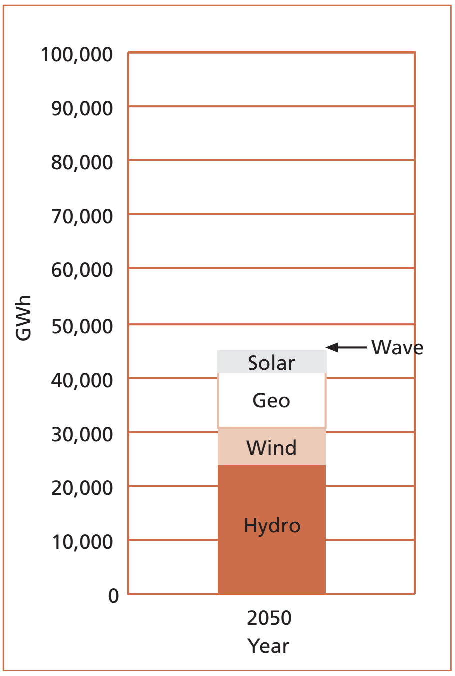
Major research and development investments

- Integrated energy, waste, and water systems
- Solar energy systems
- Wave power systems

Notes

- Fuel cells are being used in many small-scale applications, using hydrogen gas produced from renewable energy sources during off-peak electricity periods.

Figure 6.2 Electricity generation 2050



Electricity use

Steady since 2030

Electricity use per capita

Down 4% since 2030
Same as 2005

Electricity CO_2 emissions per annum

Down to no emissions

6.2 *Fuelling the future 2050*

Down on the farm

> ***A shiver ran up and down Shane's spine as he surveyed the scene in front of him. The old farmland that his grandparents once worked was scarred beyond recognition. Towering over him, a massive machine scraped earth from the coal seams. The air, once filled with the 'quardle oodle ardle' of magpies, now throbbed to the hum of huge trucks and occasional blasts in the background. The coal company talked about 'remediation' work when they were done, but it was hard to picture now. Shane had just arrived down south to meet Ani, his newest grandchild. He wondered what would become of the land during her lifetime.***

More coal-fired power plants were built in Southland during the 2030s. Some people still hoped this region would rival Taranaki's energy fame, but there were no more plans for major power plants on the horizon. Taranaki was also home to more coal-fired power plants. Just before the Maui sequestration project was developed there were problems over the liability for carbon charges if any gas escaped. No insurance companies were prepared to underwrite the project. The Government eventually accepted any liability to allow the project to proceed. Many taxpayers were disgruntled to learn that they were, in effect, subsidising the fossil fuel industry yet again. Fortunately, everything appeared to be working.

By the 2040s, coal was generating 15 times more electricity than in 2005 and the coal industry was flourishing. Hugh amounts of coal were needed to fuel all the power plants around Auckland, Huntly, Taranaki, the West Coast, and Southland. Coal was also being used to produce hydrogen gas for fuel cells in the transport sector. Plenty of coal remained in the ground, but large areas of productive farmland needed to be carved up for mining. In spite of ongoing environmental improvements to mining techniques, mining had polluted many streams. People continued to be concerned about annual injuries and fatalities in the mines.

Two more major rivers had also been dammed for extra power generation. A series of power stations was developed along the Mohaka River in Hawkes Bay and a much bigger dam was built on the lower Grey River. West Coasters had enjoyed the boost to the local economy during construction of the dam, but the benefits dried up when the contractors left town. Some residents were also forced to relocate when small settlements up the valley were flooded.

By 2050, more geothermal power stations had been built in the Waikato. Many new transmission towers and power lines now framed the landscapes of New Zealand. However, the biggest change over the last decade had been the rapid development of solar power following an international breakthrough in new materials development with nano-technology science.

City life

> ***Robyn admired her new roof. What a bargain! Her turn-of-the-century townhouse had always been a bit leaky, especially during recent storms. Now there'd be no more drips and a new stream of money as well – or lower electricity bills at least. A few other houses in her street also had new solar roofs, although they were more common in the commercial parts of town. What she couldn't understand was why solar homes weren't more common in New Zealand. They were widespread in Europe and even Africa. Perhaps it was because their governments had been supporting solar power systems for at least 30 years, while New Zealand's government was only starting to think about incentives here.***

International research into solar power had led to major technological advances over the last 50 years. The price of generating electricity from solar cells dropped dramatically when production of the new cells took off. By the late 2030s, the technology was starting to become an economically viable option for wider use in New Zealand. However, major difficulties were encountered. The existing electricity system had been designed around the national grid and large-scale developments. In contrast, many other countries, especially in Europe, had redesigned their systems over previous decades to favour more distributed electricity generation.

Most local lines companies in New Zealand were reluctant to accept the new technology. They still argued it would be extremely difficult to integrate the intermittent flows of electricity from solar cells into their networks. They were happy for some large-scale developments to go ahead – such as huge solar towers in Northland and near Nelson – that fed electricity directly into the national grid. But they did not favour more widespread use of solar cells in urban centres.

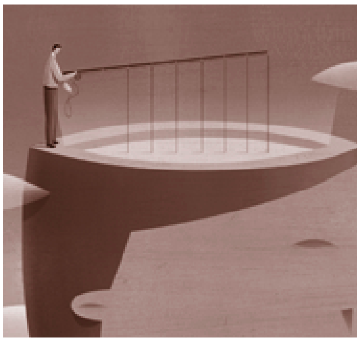
This started to change during the 2040s. Electricity prices had risen sharply again because of increasing costs for managing carbon dioxide emissions from burning so much coal. Many businesses, and some enthusiastic homeowners, soon realised how much money they could save by investing in solar cells on their buildings. At first, local lines companies charged enormous fees to anyone who wanted to use their lines to sell surplus electricity. In the end, however, public pressure forced them to accept the changes and they decided it would be better to 'go with the flow'.

As Robyn turned to go inside she saw Keiko, her granddaughter, crawling towards her. Robyn looked into her bright green eyes and briefly thought about the brave new world she would inherit.

For the time being, it looked as though no more coal-fired power plants would be built. However, with almost a third of New Zealand's electricity now generated from coal, difficult questions remained. What would happen to the existing coal-fired power plants and their employees? What would happen to the coal mines and those who worked there? With soaring world demand for solar cells, and limited resources needed to make them, would the price of solar power continue to fall? The demand for electricity was still growing at 2 percent each year. Compared with 50 years ago, more than twice as much electricity was now needed to provide a secure supply of electricity. Households and businesses enjoyed a secure supply of electricity, but could New Zealand's electricity system continue to cope with such rapidly rising demand?

6.3 *Sparking new designs* 2050

Down on the farm



> ***Shane stepped off the electric bullet train in Invercargill and was greeted by his niece, Shui. He had not seen her for a few years. It was such a long journey from his Waikato farm before the Cook Strait rail tunnel was completed. Shane was excited. Shui was going to show him around a large-scale wave power station that she'd helped to design. As they made their way past several wind farms, Shane reflected on how much the Southland landscape had changed over the last 50 years. Many citrus orchards and grapevines were now thriving in the warmer climate.***

Electricity generation in New Zealand had peaked in 2030. Massive gains in energy efficiency meant that it had remained relatively constant for two decades. More renewable energy projects had been developed and the last gas- and coal-fired power plants were closed in 2040. Greenhouse gas emissions from electricity generation in New Zealand had been consigned to the history books.

This period of relative stability was warmly welcomed, as generating electricity had become more difficult. While many people supported renewable projects, most of the best wind and hydro sites had already been developed. People were resisting further developments in cherished landscapes. All the known geothermal fields were being used to the full and a few were showing signs of depletion due to over-exploitation. Fortunately, solar photovoltaics became cost competitive in the late 2030s when a breakthrough occurred in new materials development. Wave power had also advanced significantly. A major wave power generator was now operating in Southland and others were in advanced prototype trials. In addition, New Zealand had several wind farms off the Taranaki coast and in the Hauraki Gulf. Plans were underway to integrate future offshore wind farms with wave power devices and mussel farming.

No major upgrades had been made to the national grid for several decades, apart from some further placement of lines underground. It was much cheaper to provide electricity using small- to medium-sized distributed electricity systems. The diverse range of renewable energy sources complemented each other and boosted the security of the electricity system. Interactive smart metering systems were installed in almost every home. These systems adjusted electricity use according to the cost and availability of electricity at any particular time.

City life

> ***Robyn sat in her living room and watched her grandson, Caine, play on the warm sun-lit floor. She marvelled at how her home could provide such comfort at such a low energy cost. The solar panels on her roof heated her water and provided electricity. The Building Code ensured that the house was built to maximise the use of passive solar energy too, so she almost never used a heater. She also had a connection to her subdivision's bio-digester. This used methane gas collected from the wetland waste treatment system on the edge of the subdivision and converted it to electricity for homes. Any surplus electricity from the bio-digester and the solar shingles on the rooftops was used in the micro-hydrogen gas production system to power fuel cells.***

Zero-energy and ultra-low-energy buildings were becoming more common in New Zealand. Many buildings were virtually self-sufficient for energy services. They used micro-sized renewable energy technologies such as solar photovoltaics and wind turbines. Hydrogen fuel cells were also integrated into some buildings, including many large commercial premises. The fuel cells were powered by hydrogen gas. The hydrogen was produced during off-peak periods from renewable energy sources, such as small solar-powered devices on rooftops that worked efficiently even with low light levels.

Some new houses and apartments were also self-sufficient in water and waste treatment systems. New residential subdivisions had fully integrated waste recycling schemes. This transformation had not been smooth. Many established interests resisted change and some communities experienced difficult times. However, the public exerted ongoing pressure for governments to have the foresight and commitment to persevere with change.

> ***As Robyn cast her eye across the subdivision she noticed her daughter, Maarama, adjusting her neighbour's micro wind turbine. Micro wind turbines had fascinated Maarama ever since the day her school had installed its own all those years ago. Maarama had even gone on to complete her university degree in sustainable energy technologies. With so many turbines now in place around the country, her skills were in high demand. Robyn was also proud that a core part of Maarama's degree was learning the complex energy systems model that she herself had perfected back in 2010.***

Many initiatives to promote education for sustainability supported the strong focus on energy efficiency since 2005. Education programmes were run in schools, tertiary institutes, workplaces, professional organisations, and the community. Research and development investment continued into technologies as well as into social benefits and barriers to change. New Zealand's expertise on sustainable energy systems was now sought worldwide. New Zealanders participated in various international research and development initiatives. The most recent of these aimed to advance the development of technologies using offshore wave and ocean currents.

Many local businesses had flourished in New Zealand as the electricity system became more dispersed and smaller in scale. This fuelled social and economic development in many regions. Moreover, communities were active participants in shaping their energy futures, assisted by a skilled local workforce. New Zealand's economy was more resilient to changes in world energy prices and employment in the energy efficiency and renewable energy industries was booming.

CHAPTER 7

Navigating the currents

> ***He moana pukepuke e ekengia e te waka.***
> ***A choppy sea can be navigated.***

This chapter summarises key themes from the scenarios and considers the future courses that New Zealand's electricity system could take.

7.1 Key themes from the scenarios

Many different resources could be developed

Many resources could be used or developed in New Zealand. In *Fuelling the future,* most changes are experienced beyond the major urban centres and much more infrastructure is built to exploit New Zealand's environmental resources. In contrast, more of the changes in *Sparking new designs* are experienced in urban settlements. Human resources (knowledge, skills, and expertise) are developed along with the capacity for new approaches.

No easy way ahead

In *Fuelling the future*, 'business as usual' is hardly threatened. Some people may find this comforting. Alternative approaches, such as radical improvements in energy efficiency, are dismissed as too challenging or difficult. However, many conflicts arise over large developments. Energy developments are likely to be delayed when they encounter public resistance. This is likely to threaten any remaining trust that people have in electricity companies and the Government.

In *Sparking new designs*, alternative approaches are actively pursued. This requires venturing into unfamiliar territory. With innovation comes the risk of failure, but people are encouraged to adapt and learn from mistakes.

Diversity and dependence

A secure electricity system is very important for New Zealand and a diverse mix of energy sources should be used to generate electricity. In *Fuelling the future*, a variety of energy sources is used, but coal provides most of the desired security. New Zealand becomes more dependent on coal over time. Any attempts to close down coal-fired power plants once they are built may be resisted. This resistance may come from the communities that depend on the plants for jobs, the businesses that own and operate them, or electricity customers concerned about the risk of power shortages.

In *Sparking new designs*, a range of renewable energy sources is used. Most electricity projects are small in scale. Major efforts are required to better integrate systems so that renewable energy sources can complement each other. Demand management initiatives are also pursued to improve the overall security of the electricity system.

A question of costs

Both scenarios need major investments, and electricity prices rise in both of them. In *Fuelling the future*, much more infrastructure is built to supply electricity. Electricity users ultimately pay for this infrastructure, but the costs are not necessarily shared equally. Some electricity users may try to avoid paying for the social and environmental costs of new developments, for example, climate change costs. Rising electricity prices in this scenario might also contribute to many hidden costs, such as health care and days off work for people who get sick from living in cold, damp houses that they cannot afford to heat.

In *Sparking new designs*, the price of electricity reflects more of these social and environmental costs. Many financial schemes and community initiatives are implemented to encourage cost-effective energy efficiency investments. These initiatives might be funded by a levy on electricity users. Although the price of electricity is also higher in this scenario, this does not necessarily mean that everyone pays more for their energy services. Electricity may cost more per unit, but people do not need to use as much electricity because of energy efficiency improvements and other demand management initiatives. Some people may actually pay less for their energy services overall.

Generating big money

State-owned electricity companies made profits of more than $400 million during 2003/04. Over $150 million of this went to the Government. In contrast, public funding for the Energy Efficiency and Conservation Authority (EECA) over the same year was less than $11 million.

Designing for the future can save time and money

Today's investments will continue to incur costs or pay dividends far into the future. Many buildings designed and built before 2015 in *Fuelling the future* will still require lots of electricity to provide warmth in future decades. Individuals pay a lot for electricity over the lifetime of these buildings and the rest of society bears many of the associated costs. A lack of long-term thinking can also lead to crises and 'quick fixes' that are poorly thought through.

In *Sparking new designs*, early investments in energy efficiency produce benefits over the long term. By managing the demand for electricity, people can buy time and avoid many crises. They may also be able to choose from better technologies that have been developed in the interim.

Who participates?

In *Fuelling the future*, individuals and communities are not expected, or encouraged, to take an active role in the electricity system. People are often on the receiving end of decisions made elsewhere, even if there is some consultation.

In *Sparking new designs*, individuals and groups are expected to become more actively involved in their electricity system. Diverse perspectives are represented in decision-making processes and many people have a stake in the success of new initiatives.

What about energy conservation?

> *On one hand there is a multitude of technically mature and hence readily available and indisputably cost-effective options to reduce energy demand. On the other hand there are quotidian [everyday] realities of the affluent world dominated by casual waste of resources, growing displays of ostentatious consumption, and a palpable absence of concerns about the impact of high energy use on the fate of the biosphere.*[66]

In both our scenarios we assume that the demand for energy services keeps growing by 2 percent each year. The demand for electricity rises at a slightly slower rate in *Fuelling the future* and slows down dramatically in *Sparking new designs*. This is mainly due to energy efficiency improvements – that is, changing the way we do things to get the same energy services with less energy.[67] We did not consider any role for energy conservation – that is, wanting fewer energy services in the first place. For example, we discussed the potential for more energy-efficient homes but we did not question consumer trends for larger houses and ever more electronic devices.[68] Similarly, we did not raise the possibility of energy conservation campaigns during special circumstances, for example, encouraging people to turn heated towel rails off when hydro lake levels are low. However, energy conservation could also play an important role. Energy conservation campaigns could help to overcome short-term problems, such as potential electricity shortages. Some people may also wish to lead less consumptive lifestyles if it improves their quality of life and this would lead to longer term changes.

7.2 Which courses will New Zealanders take?

> ***In order to effectively envision, it is necessary to focus on what one really wants, not what one will settle for.***[69]

At the beginning of this report we asked: where are we currently heading, and what sort of future do New Zealanders really want? We described two possible scenarios. New Zealand will not simply follow the course of one of the scenarios in this report. However, if someone looks back in 10, 20, or 50 years' time, could one scenario seem more familiar than the other?

New Zealand's electricity system has changed remarkably over time (see Section 2.2). Even so, if we look back 25 years, New Zealand was already facing many of the issues we still see today. For example, an old Ministry of Energy strategy commented that:

> ***New Zealanders in industry, commerce, and at home need to become more informed on energy matters… Such an appreciation would result in better designs of facilities, more discrimination in the choice of equipment and appliances, and a more thorough allowance for the effect of future energy costs on the cost of both constructing and operating long-lasting assets such as buildings.***[70]

Electricity use has almost doubled since then and prices have risen significantly.[71] It is very unlikely that most New Zealanders are any more informed about energy issues than they were 25 years ago.[72] Most go about their daily lives with very little sense of the growing impact of electricity use on the environment and other people. Electricity has powered economic growth and it undoubtedly provides many benefits. However, it is still often used in very inefficient ways. We continue to build more dams, burn more coal and gas to generate electricity, and make many inefficient investments in infrastructure. Major issues such as climate change and competition for limited water resources have also emerged and will not go away.

What kind of vision do people want for New Zealand and their electricity system in 25 years and beyond? As Chapter 2 highlighted, we need to focus on what people *really* want when asking this question. For example, if people want warm and healthy homes, affordable energy services, successful businesses, a secure livelihood for themselves and the ones they love, and a 'clean and green' environment, what could be done to achieve this? It is not simply a matter of making trade-offs between environmental and economic objectives in some sort of balancing act. A broader perspective is needed – one that involves many people in the search for smart designs.

Some people will claim that increasing electricity use is inevitable, and indeed desirable, for New Zealand's development. For example, the Government and most electricity companies claim that the demand for electricity will keep on rising by about 2 percent or more each year, well into the future. Some electricity companies also believe that the Government's existing targets for energy efficiency are unrealistically high.[73] We could accept these claims and do nothing to change the future. Or New Zealanders could take the initiative and use different visions to shape a future that they desire.

Learning from other countries

Although New Zealanders need to develop approaches that suit local needs, it is worth looking at initiatives in other countries. Here are a few examples:

United Kingdom –

The UK Government is doubling funding for energy efficiency improvements over the next six years. They are improving energy standards for buildings and introducing further economic incentives to encourage energy efficiency. They are tackling poverty with a 'decent homes' programme to ensure that all state houses have effective insulation and heating by 2010. They are also providing tax relief for landlords who install insulation. Energy efficiency is being promoted in schools, but not just as a separate topic. It is part of a 'whole school' approach to education for sustainability. Children participate in the energy management of their schools. Some schools are even generating their own electricity.[74]

Germany –

The German Government is providing strong support for energy efficiency to help fulfil their vision for a completely renewable energy system. About 100,000 new jobs have been created in industries related to energy efficiency since environmental tax reforms began in 1999. Germany is now the world's leading producer of wind power, with strong community involvement. 90 percent of wind turbines are owned by community cooperatives. The wind industry has provided 45,000 permanent jobs – about 10 times as many jobs per unit of electricity as in the nuclear industry. Germany also has one of the fastest growing markets for solar photovoltaics, stimulated by interest-free loans. The Government has established firm goals for renewable energy and energy efficiency for 2010 and 2020. Their policy horizon extends to 2030, when nuclear power is to be fully phased out, and to 2050 when a dominant share of Germany's energy (not just electricity) is expected to come from renewable energy sources. To meet their vision, total energy use will need to be about 30 percent lower in 2050 than it is today.[75]

United States of America –

In the 1980s, the citizens of Sacramento, California voted to close down the local nuclear power reactor that supplied them with a major share of their electricity. They wanted cleaner and safer forms of energy. This forced their local power utility (owned by its customers and governed by an elected board of directors) to seek alternatives. They diversified their energy sources and aggressively pursued improvements in energy efficiency. Sacramento has now become a leader in the United States for developing and using renewable energy sources. They provide energy audits and employ architects, engineers, scientists, and lighting specialists to help customers improve their energy management. They invest in education and new technologies and aim to be the 'Silicon Valley' of energy efficiency and advanced renewable energy developments.[76]

7.3 Time to spark some changes?

> ***A great flame follows a little spark.***[77]

If New Zealanders want a different vision for their electricity system – one that breaks the links between economic development and environmental damage – enormous changes will be needed. New Zealand does, however, have many strengths that could contribute to a shift in direction. Unlike most other countries, most of our electricity is already generated from renewable sources. We take pride in 'Kiwi ingenuity' and talk about the need for innovation. Furthermore, the low priority given to energy efficiency in the past means that we have the potential to use electricity much more wisely in the future.

Ultimately, any changes will be shaped by what people value and their commitment to making a difference. As the Government recently acknowledged in its *Sustainable Energy* report:

> ***New Zealand has made a good beginning in promoting better use of energy through the National Energy Efficiency and Conservation Strategy, but progress could be accelerated through a wide range of possible measures, depending on the level of ambition applied.***[78]

The former Minister of Energy also commented in this report:

> ***Humankind has changed its energy system radically in the past, and can do so again. The place to begin is not with supply, but with demand. We have been preoccupied with expanding supply to meet our growing energy needs, which have increased steadily with our population and our economy. But our energy needs are ours to control.***[79]

Major changes, if they occur, will depend on many people. They will require visionary leadership, an openness of mind, and the willingness to challenge and be ready for change. Significant changes could also be sparked by looming global events that are outside New Zealand's control (see Chapter 2). The sooner we prepare for these challenges the better.

Will there be a major shift in direction in New Zealand's electricity system? Only time will tell. However, it is worth keeping in mind that large-scale electricity developments have sparked major changes before. In the 1960s and 1970s public resistance to the Lake Manapouri power development provided a flashpoint for the birth of the environmental movement in New Zealand. Has the time now come to spark further changes?

Glossary and acronyms

Word	Definition
Biomass	Any organic matter that is available on a renewable or recurring basis (excluding original indigenous forests), including dedicated energy crops and trees, agricultural food and feed crop residues, wood and wood wastes, animal wastes, and other 'waste' materials.
Brown coal	The lowest quality and most dirty burning coal, also known as lignite coal. 70 percent of New Zealand's available coal reserves are in this category.
Clean coal technologies	Technologies to reduce emissions of carbon dioxide, sulphur dioxide, nitrogen dioxide, ash, and other pollutants that can contaminate the air and water when coal is burned.
Cogeneration	The simultaneous generation of electricity and heat for industrial processes, or the use of waste heat from electricity generation in an industrial process.
Demand side management	Methods to manage the use of electricity, such as energy efficiency, load management, and fuel switching.
Distributed generation	Electricity that is generated close to where it is used either stand-alone or connected to local power lines, but not the national grid.
Electricity system	All people, organisations and institutions that use, manage, sell and/or generate electricity to provide people with energy services. It includes those who design and build the infrastructure (such as buildings) and appliances that use electricity or other forms of energy.
Energy efficiency	An improvement in the way energy is used that leads to more benefits per unit of energy. See Section 2.1.
Energy services	Services such as lighting, heating, cooling, and mobility that people value that involve the use of energy. See Section 2.1.
Fuel switching	Using a different fuel (for example, wood pellets instead of electricity for heating a home) to provide the same energy services.

Gigajoule	One billion joules (see 'joule' below).
Gigawatt hour	One million kilowatt hours (or 'units' of electricity as they appear on domestic electricity bills – see 'kilowatt'). A Gigawatt hour is the amount of electricity used to run a million single bar (1 kilowatt) heaters for one hour.
Joule	A unit used to measure energy or work. It takes about one joule to lift an apple over your head and about one million joules to make a pot of coffee.
Kilowatt	A measure of electricity, or 'unit' of electricity as they appear on electricity bills. A 100-watt light bulb turned on for 10 hours uses one kilowatt hour (100 watts x 10 hours) of electricity.
Load shedding	Measures to reduce electricity use at peak times (when most electricity is used). For example, large industries can be offered financial incentives to reduce their electricity use when it is scarce.
Load shifting	Measures to shift electricity use away from peak times (when most electricity is used). For example, smart controls on appliances, equipment, and industrial processes can vary the use of electricity when it is scarce or plentiful.
Megawatt	One thousand kilowatts (see above). A large wind turbine at maximum output generates about 2 megawatts of electricity.
National grid	The high voltage power cables that transmit electricity from where it is generated to local lines networks or directly to industrial users.
Petajoule	One million gigajoules (see 'gigajoule' and 'joule' above).
Renewable energy	Energy from sources such as the sun, wind, waves, tides, ocean currents, the hydrological cycle, and biomass that are sustainable and naturally replaced within a short time period.
Retrofits	Adapting existing infrastructure (for example, buildings) to make it more energy efficient.
Ripple control	A ripple relay is an electrical switch that is 'remote controlled' by an electricity provider.

	Ripple control is used for load shedding. For example, many homes have electric hot water cylinders that can be switched off or on by electricity providers during peak and off-peak electricity periods.
Sequestration (carbon)	The capture and long term storage of carbon, often in the form of carbon dioxide, to prevent a further increase in the atmospheric concentration of carbon dioxide. It may also be possible to use carbon sequestration to reduce the atmospheric concentration of carbon dioxide.
Smart design	Designing processes and systems to meet people's needs and wants to provide the most value to themselves, their society, and the world they live in. This requires long-term thinking and integration of environmental, social and economic goals.
Solar photovoltaics (PV)	A technology based on solar cells that convert light directly into electricity.
Supply side	In the electricity system, refers to the generation and distribution of electricity to where it is used.

Acronyms

CAE	Centre for Advanced Engineering
EECA	Energy Efficiency and Conservation Authority
EHMS	East Harbour Management Services
GWh	Gigawatt hour
GWh/y	Gigawatt hours per year
HVDC	High voltage direct current
ICCEPT	Imperial College Centre for Energy Policy and Technology
ICGCC	Integrated Coal Gasification Combined Cycle
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kV	Kilovolts
LNG	Liquified natural gas
MED	Ministry of Economic Development
MW	Megawatts
OECD	Organisation for Economic Co-operation and Development
PCE	Parliamentary Commissioner for the Environment
PJ	Petajoule

Appendix 1: Assumptions in the technical report

This appendix summarises the main assumptions from the technical report that we used to develop the scenarios. A free copy of the technical report is available at www.pce.govt.nz or by contacting the PCE directly.

Table A1.1 Major assumptions in the technical report – both scenarios

Assumption	Both scenarios
Technologies and costs	Only technologies that are already technically proven, with sufficient operational experience to estimate future capital and operating costs, were considered.
Gas discoveries or imports	On average 60 PJ of gas is discovered, or imported, and available for use each year. However, even if this much gas can be discovered or imported at a viable cost, we assume that additional gas-fired electricity generation is unlikely. This is because over time it becomes increasingly more cost effective to use gas directly.
Carbon charge	A $15/tonne charge for carbon dioxide emissions is implemented in 2007.
Electricity use by sector	The proportion of electricity use between the residential, commercial, and industrial sectors remains constant over the period. We do not consider the kinds of industries that will stay or set up in New Zealand.
Demand for energy services	Grows at 2 percent each year (based on the recent historical trend).

Table A1.2 Major assumptions in the technical report – different scenarios

Assumption	*Fuelling the future*	*Sparking new designs*
Annual energy efficiency improvement	0.215% each year (based on the recent historical trend)	Starts at 0.215% each year and increases by 0.035% each year. This means that improvements gather momentum over time
Efficiency of converting electricity into energy services	25% in 2005 26% by 2050	25% in 2005 50% by 2050
Reduced residential electricity demand for space heating by 2050	No reduction. Same demand as present	10% reduction due to better insulation and use of modern wood/pellet burners
Houses with solar water heating in 2050	25% (based on the recent historical trend)	67%
Use of woody biomass to generate electricity in the forestry sector	No additional uptake	By 2040, electricity generation from biomass meets 20% of the electricity requirements of the forestry sector

Appendix 2: Transport and the electricity system

The electricity and transport sectors are usually considered separate parts of our energy system. New Zealand's transport system is heavily dependent on fossil fuels, as 98 percent of energy comes from petroleum (oil and natural gas). Only 1 percent of transport energy consists of electricity. It is used in the main railway of the North Island and Wellington's trolley bus system. No electricity was sourced from oil in 2003.

In the future, the boundaries between the transport and electricity sectors are likely to blur as competition increases for access to energy sources. Hydrogen fuel cells and various bio-fuels are likely to play an increasing role in the transport sector.

Hydrogen fuel cells

Hydrogen fuel cells operate by producing electricity from hydrogen and oxygen. They have been hailed as the future of land transport. However, major technical and economic hurdles need to be overcome to make this a reality.[80] These include:

- **Production** – hydrogen does not occur naturally as a gas on Earth.[81] It is always combined with other elements. Water, for example, contains hydrogen and oxygen. Many organic compounds also contain hydrogen, including fossil fuels. Hydrogen gas therefore needs to be produced from fossil fuels, or by using large amounts of electricity to split hydrogen from other elements. It may also be possible to use algae or bacteria (likely to be genetically modified) to produce hydrogen gas. If fossil fuels were used, the carbon dioxide emissions would need to be captured and stored, adding further costs.

- **Distribution and storage** – major infrastructure investments would be needed to distribute hydrogen from where it is produced to where it is used. Hydrogen gas is very difficult to store because it is so light. It could be produced at central facilities and then distributed, or produced at smaller facilities located directly at filling stations.

- **Conversion of hydrogen into energy** – fuel cells were invented over a century ago, but the current cost of manufacturing and using them to provide power is extremely high.

If the demand for hydrogen rises, this will need to be met by using existing energy sources. Most of the world's hydrogen is currently sourced from natural gas. Natural gas is already a premium fuel, with its demand and price increasing around the world. Coal has also been proposed as a fuel source option.[82] The technology to convert the coal into hydrogen has not yet been perfected. Both natural gas and coal are key sources of energy for generating electricity. Competition between traditional electricity uses and transport would lead to higher prices and accelerated depletion of these resources.

As noted above, electricity can also be used to split hydrogen from oxygen in water. To replace the amount of oil that New Zealand currently uses for transport, about 185 PJ of electrical energy would be needed each year.[83] To put this into context, about 145 PJ of energy is currently generated in New Zealand's electricity system.

Another possible source of hydrogen is the use of specially bred hydrogen fixing algae.[84] To produce sufficient hydrogen to fuel the existing vehicle fleet, 21,000 hectares would be required. The actual area would be much larger as algal farms would have non-producing areas undergoing maintenance or algal restocking. The final area could be in the order of over half the size of Lake Taupo (60,000 hectares).

Bioenergy

Bioenergy is renewable energy sourced from biomass. The sources of this material are diverse but fall into two broad categories. Biomass can be a by-product of other processes and includes agricultural and wood waste residues, used vegetable and animal fats, and wet waste (includes domestic, agricultural, and industrial sludge and animal manure). Alternatively, biomass can be grown as energy crops specifically for the purpose of producing bioenergy. These could be annual crops such as oilseed rape for bio-diesel fuel or longer term perennials such as short rotation forests harvested every four to six years.

The processes for converting biomass into bioenergy are extensive, depending on the type of feedstock and the form and function of the bioenergy to be produced. Table A2.1 summarises the main processes used.

The role of bioenergy in the future of New Zealand's electricity system will depend on:

- New Zealand's biomass production capacity from the various sources
- the quantity of resources (for example, land) that can be used to produce biomass and the impact this has on existing uses
- the amount of useful (net) energy that can be produced from these processes[85]
- the cost of bioenergy relative to other sources of energy
- how much of the bioenergy resource is diverted to non-electricity energy production (for example, for direct heat use and production of bio-fuels)
- the sustainability of biomass production, that is, its impact on soil fertility and reliance on non-sustainable inputs (for example, nitrogen fertiliser derived from fossil fuel).

At this time there is no robust information to address many of these questions. However, as with other forms of renewable energy, bioenergy has much lower energy densities in comparison with fossil fuels.

Table A2.1 Main processes used for converting biomass into bioenergy

Process	Probable end use	Preferred biomass type
Direct combustion Heat used directly or to produce steam to drive turbines	Direct heat Bio-power (electricity from biomass)	Dry material, for example, woody crops (energy crops, wood waste) or agricultural by-products (for example, tree prunings, straw)
Fermentation Use of biological processes to produce carbohydrates (alcohols)	Bio-fuel (transport fuel from biomass)	Biomass containing sugars or carbohydrates easily converted to sugars
Anaerobic digestion Low temperature biological process to produce biogas (mainly methane)	Bio-power, bio-fuel, or bio-heat	Non-woody wet material (often animal and human waste)
Gasification A range of high-temperature thermochemical conversions in the partial absence of oxygen to produce a combustible gas or liquid	Bio-power or bio-fuel	Dry and consistent material
Pyrolysis Heating carbonaceous material in the absence of oxygen to produce a liquid bio-oil	Bio-power or bio-fuel	Dry material, sewerage, drudge
Transesterification Conversion of vegetable oils or animal fats to produce bio-diesel	Bio-fuel	Vegetable oils and animal fats

Appendix 3: Nuclear power and New Zealand

Nuclear power generation was seriously considered for New Zealand's electricity system during the 1970s. However, the public was greatly concerned about the social and environmental impact of nuclear power plants and their economic viability. A Royal Commission on Nuclear Power Generation was established to enable New Zealanders to express their views and to provide independent recommendations to the Government on nuclear energy. The Commission's report effectively dismissed nuclear power generation as a desirable option for New Zealand.[86] During the 1980s, many New Zealanders also protested against visits by foreign military vessels that were nuclear-powered and armed with nuclear weapons. Most New Zealanders take pride in the 'nuclear free' status of their country, and for many people it has become a defining characteristic of national identity. Nuclear power generation is therefore likely to remain unacceptable in New Zealand for the foreseeable future. Even so, it is occasionally proposed as a viable option.

Internationally, nuclear power generation is also controversial. Public concerns tend to focus on the dangers of radioactive waste and the major risks if a fault occurs in the nuclear energy production chain. These are real concerns and would need to be thoroughly investigated if nuclear energy was seriously considered in New Zealand again. Uncertainties also exist about:

- the practicality of nuclear power generation in New Zealand
- the economic viability
- the claimed environmental benefits.

This appendix summarises some of these uncertainties.

A3.1 Practicality of nuclear power generation in New Zealand

The practicality of nuclear power generation in New Zealand would largely depend on:

- access to fuel over the life of the nuclear programme
- the limitations of proven nuclear generation technologies
- the availability of suitable waste disposal sites.

Access to fuel

The future availability and cost of nuclear fuel depends on worldwide demand for the required mineral resources (particularly uranium). It is estimated that 4.5 million tonnes of economically recoverable uranium exist. If current growth trends continue, all known and proven uranium resources may be used up by 2050.[87] Higher prices should encourage the search for new resources and it should become more cost effective to enrich lower quality resources.[88] However, all projected remaining uranium resources could still be depleted by 2100. If the nuclear industry grows more quickly, these resources could be depleted sooner.

Limitations of the technology

Any increase in nuclear power generation depends on the development of commercially viable, fast breeder reactors. This technology is designed to generate electricity and create new fissionable material out of non-fissionable forms of uranium and thorium. After 40 years of development, this technology remains commercially unproven. Almost all existing fast breeder reactors have either been shut down or are about to be decommissioned. If this technology ever becomes proven, its widespread use would also present significant security risks. The fissionable materials created during this process are suitable for use in nuclear weapons.[89]

Leading-edge nuclear technology is classified as 'Generation III'. Advances of this technology, called 'Generation III+', are planned and it is anticipated that these will lower costs. These technologies are expected to be available after 2010.[90] Current nuclear technologies rely on economies of scale (and usually government support) to be profitable, with most around 1,000 Megawatts equivalent in scale. The smallest commercial plant in the United States is around 550 Megawatts equivalent. Experts doubt whether New Zealand's electricity system could accommodate a reactor even of this size. One concern is the need to have reserve capacity available for planned and unplanned outages and regular refuelling. Refuelling occurs every one to two years, during which time a power plant is off-line for one to three months.[91]

Nuclear power technologies are complex and require access to a sufficient pool of people with the relevant expertise. A 1,000 Megawatt equivalent plant would require about 400 engineers and technicians to operate. It is unclear whether New Zealand is large enough to sustain the necessary critical mass of expertise to ensure that 'best practice' could be achieved.

Waste disposal

Radioactive waste from the operation and decommissioning of nuclear power plants needs to be stored until its radioactivity declines to safe levels. The time this takes can range from days to hundreds of thousands of years. Storage procedures vary, but it is currently considered best practice to store highly radioactive waste in deep and stable geological formations such as igneous rock, salt deposits, or clay.[92] New Zealand's geology may not be suitable for this sort of disposal. If so, New Zealand would need to find somewhere else in the world to send highly radioactive waste.

A3.2 Economic viability

To compare the costs of different electricity generation options, it is common practice to assess the capital costs and the operating costs (fuel costs, cost of short-term or low-grade waste disposal and storage). However, a proper assessment of the economic viability of nuclear power generation would also need to include:

- The cost of long-term storage of highly radioactive waste. The actual cost is unknown, as all existing waste is being stored in temporary facilities.[93]
- The full cost of insuring against risk. In all countries where nuclear power is currently used, liability is limited by international conventions and/or legislation where the taxpayer underwrites the risk. In the United States, the Price Anderson Act limits total liability to US$10 billion, which is much less than the potential cost of a major accident.[94]
- The long-term and ongoing costs associated with decommissioning plants. This is estimated to be between US$300 – US$500 million per plant.[95] It is common practice to have the operators pay for decommissioning. For example, operators in the United Stated are required to pay into a trust fund administered by the Nuclear Regulatory Commission.[96]
- Government oversight institutions. This includes safety and security oversight and the management of trust funds.

A3.3 Environmental aspects

Nuclear energy is non-renewable and ultimately, in the long term, unsustainable. At most, it could be considered a 'transitional' energy source.[97] New Zealand would very probably need to import uranium to generate nuclear power. However, if accessible uranium resources exist within New Zealand, the environmental impact of uranium mining and processing would also need to be addressed. Specific concerns related to uranium mining are contamination of ground water by radioactive material and the safe long-term disposal of mining wastes.[98]

Nuclear power plants do not produce carbon dioxide while they are operating. However, other critical parts of the nuclear process do produce carbon dioxide, including:

- mining and fuel processing
- power plant construction
- management and storage of waste
- decommissioning of power plants (including cool down periods, dismantling, and storage).

As uranium reserves become depleted, ore emissions of carbon dioxide are likely to increase. Once the best quality ores are used up, lower quality ores will need to be mined and processed (enriched). These processes require more and more energy. A controversial analysis suggests that at some point the carbon dioxide emissions could even exceed those from an equivalent fossil fuel power plant throughout its lifecycle.[99]

The environmental risks associated with the safe containment of radioactive waste are still unanswered. In the United States, poor temporary storage practices have led to groundwater contamination at the Hanford Nuclear Facility in Washington State. In the United Kingdom, contamination from Sellafield has resulted in increased levels of plutonium in the teeth of children across the country.[100] The longer term effects on humans and our environment from radioactive waste remain unclear.

Endnotes

[1] *New Zealand Oxford Paperback Dictionary* (1998, page 187).

[2] For more information about this work see PCE (2003 and 2004).

[3] For more information about the role of the PCE see www.pce.govt.nz.

[4] Schwartz (1996, page 4).

[5] Some suggested reading on scenarios is included in the bibliography. For a recent example of scenarios in a New Zealand context see Landcare Research Scenarios Working Group (2005).

[6] These people participated as individuals and not as spokespeople for any particular agency.

[7] All energy, except geothermal energy and nuclear energy, ultimately comes from the sun. Non-renewable fossil fuels are accumulated stocks of previous energy flows. They are stores of ancient plant matter that grew with energy from the sun and decomposed into a rich energy source over millions of years. Biomass, wind, waves, and ocean currents are also indirect forms of solar energy.

[8] The first use of electricity was for an electric telegraph line from Dunedin to Port Chalmers.

[9] A 'take or pay' agreement means buyers have to either take the gas and use it, or pay for it anyway.

[10] MED (2005).

[11] These figures are estimates for local territorial authorities for the year ending March 2002 and are based on EECA's end-use database.

[12] MED (2005).

[13] Research into other regions of New Zealand is still ongoing.

[14] An unpublished report by EECA in 2003 suggests a quarter of electricity in the commercial sector is used for space heating and cooling and approximately 20 percent (each) is used for lighting and refrigeration.

[15] The major exception is the close proximity of Comalco's aluminium smelter in Bluff to the Manapouri power station. Other schemes where electricity is generated close to where it is used are marginal to the dominant structure of the current system.

[16] This includes losses across both the national grid and local lines.

[17] MED (2005).

[18] Figures in all tables have been rounded.

[19] Electricity systems can be designed to manage fluctuations at a small cost compared with the costs of generation (Performance and Innovation Unit, 2002b).

[20] However, geothermal and biomass resources do need to be managed carefully to maintain their 'renewability' and avoid depletion.

[21] For examples see Lovins *et al*. (2002).

[22] This is an example of electricity load shifting.

[23] This is an example of electricity load shedding.

[24] OECD/IEA (2003); Performance and Innovation Unit (2002b).

[25] For example, see MED (2004) and EECA (2000). An energy report for the UK Government suggested that the cost-effective potential for energy efficiency was 30 percent of final energy demand (Performance and Innovation Unit, 2002b). This is broadly consistent with estimates for other countries summarised by Working Group III for the Intergovernmental Panel on Climate Change (2001). The UK Government (2005) recently revised their figures. They now believe the potential for energy efficiency improvements is 20 percent higher than they first thought possible. In our report, we assume New Zealand has a Factor Four potential for improving energy efficiency (see Section 3.1 and Appendix 2).

[26] Refers to hydro developments over 1MW.

[27] Annual sunshine hours in New Zealand range from about 1,600 in Invercargill to over 2,400 in Blenheim. The main centres receive about 2,000 hours. The annual amount of sunshine falling on the roof of a typical NZ house is about 220MWh.

[28] See Sanders *et al*. (2004) for more information.

[29] There is a lot of uncertainty about the cost reduction potentials of wave and tidal technologies because many competing devices are currently at an early stage of development. For some examples see Redding Energy Management (1999) and Sanders *et al*. (2004).

[30] Small quantities of hydrogen are released into the air in trace amounts, for example, from volcanoes, but the density of the gas is so low that it rises into the upper atmosphere and most of it escapes into space. Uncertainty remains about the effects of hydrogen in the atmosphere because scientists still have a limited understanding of the hydrogen cycle.

[31] These biological and geological conditions appear to have occurred, at any significant scale, only during certain times and locations in the past.

[32] This observation was initially made for the lower 48 of the United States, the most heavily explored area in the world, but similar trends have been detected in 18 petroleum production regions. See Laherrere (2004) and Skrebowski (2004).

[33] At its height in 2001 Maui produced 203 PJ. In that same year, over 265 PJ of gas was produced. In 2003, the total amount of gas produced had reduced to 235 PJ and by 2008 it is forecast that it will be down to 135 PJ. Without future discoveries, gas production will be reduced to around 20 PJ by 2020 (MED, 2003).

[34] Laherrere (2004).

[35] Laherrere (2004).

[36] Costanza (2000, page 5).

[37] Quoted from www.theclimategroup.org/index.php?pid=455.

[38] See the Intergovernmental Panel on Climate Change: www.ipcc.ch.

[39] More specifically, our initial allocation of units is five times our 1990 emission levels (to cover the five years from 2008 to 2012).

[40] For the most recent data see www.climatechange.govt.nz.

[41] Carbon dioxide emissions from the electricity sector were 3.9 million tonnes in 1990 and 7 million tonnes during 2003 (MED, 2005).

[42] The National Institute of Water and Atmospheric Research (NIWA), Infometrics Ltd and MED are undertaking research to better understand the impacts of current climate variability and potential climate change on the supply and demand of electricity for New Zealand.

[43] 'Passive cooling' in building designs is based on reducing solar gains (for example, using shade and reducing north-facing window sizes), improving ventilation, and good insulation.

[44] The current government aims to decouple economic growth from pressures on the environment. See New Zealand Government (2003b, page 10).

[45] New Zealand Government (2003a).

[46] Smil (2003, page 353).

[47] MED (2005).

[48] Industries that use little energy are less sensitive to changes in energy prices because the total cost of energy is a relatively smaller part of their total costs.

[49] Research into the net social and economic benefits or costs of providing power to Comalco would be needed for an informed debate on this topic. We have not addressed these issues in our scenarios.

[50] Intergovernmental Panel on Climate Change (2001); Performance and Innovation Unit (2002b).

[51] Boshier *et al*. (1986, page 9).

[52] We assume, based on the research carried out by the Growth and Innovation Advisory Board (see Section 2.6) as well as recent protests over large-scale electricity projects, that environmental values and quality of life concerns are likely to remain important in New Zealand in the future. There will, of course, be many social changes but we have simplified our analysis in this report.

[53] Current government projections suggest our population will grow to 4.4 million by 2021 and to 4.6 million by 2051 (New Zealand Government 2003a). The great majority of people are likely to live in urban centres. See http://www.population.govt.nz for more information.

[54] It is commonly assumed by most electricity companies and government agencies that the demand for electricity will keep growing by about 2 percent each year. This is based on projecting past trends into the future. Indeed, electricity use has grown by about 2 percent each year over the last decade. However, we make a distinction between the demand for electricity and the demand for energy services – or, more specifically, the demand for energy services usually provided by electricity. Furthermore, we do not consider what *kinds* of industries stay or set up in New Zealand. We only assume that the demand for energy services keeps rising at 2 percent each year.

[55] See von Weizsacker *et al*. (1998) for a good introduction to Factor Four improvements. Some people argue that Factor Four improvements are actually conservative and that Factor Ten improvements are possible. Examples can be found on the Internet.

[56] See *Energy Policy* (Volume 28, 2000) for research on the rebound effect and the various micro (individual) and macro (structural) changes that can result from investments in energy efficiency.

[57] Performance and Innovation Unit (2002b).

[58] See *Energy Policy* (Volume 28, 2000).

[59] This is mostly due to the economies of scale of building large projects.

[60] This diagram, like all diagrams, simplifies a complex system. Many other 'drivers' and 'feedback loops' influence electricity demand, prices, investments in energy efficiency, and environmental damage. There is not a simple chain of causation, but this diagram does highlight some very influential drivers and their relationships with each other.

[61] This diagram accentuates the differences between each scenario to make the distinctions clearer to see. For example, some emerging technologies are also adopted in *Fuelling the future* (although they perform a marginal role) and some large projects are also developed in *Sparking new designs.*

[62] 'Intervention' means purposefully changing or adapting practices, and the broader systems that shape those practices, to improve energy efficiency. Government agencies, businesses, and community groups can intervene in many different ways, with approaches such as education, partnerships, regulations, policies, strategies, and economic incentives.

[63] Under the Electricity Act 1992 (Part 6, section 62), the obligations of electricity distributors to supply electricity to all existing users expire on March 31, 2013.

[64] Under the Electricity Act 1992 (Part 6, section 62), the obligations of electricity distributors to supply electricity to all existing users expire on March 31, 2013.

[65] In technical terms, this included ripple control, load shedding, and load shifting to reduce peaks, as well as changes to the wholesale and retail markets to encourage more distributed generation.

[66] Smil (2003, page 331).

[67] It is also due to more direct use of solar energy – for example, using passive solar energy to heat buildings instead of burning fuels or using other resources to generate electricity.

[68] In a global context, increasing materialistic consumption raises many issues. For example, if coal from New Zealand is shipped to China for powering factories that manufacture electronic appliances that New Zealanders buy, New Zealand would not be held responsible for the carbon dioxide emissions from burning the coal. The consumer does not see, or pay for, most of the social and environmental impacts of production.

[69] Costanza (2000).

[70] Ministry of Energy (1978, page 21).

[71] MED (2005).

[72] Furthermore, even if people are 'informed' about energy issues, this will not simply lead to a better outcome. Many other issues need to be considered, such as what people value and what shapes our actions and perceptions, the limited choices and conflicting incentives that people often face, who to trust, and how much time people have to learn about energy issues.

[73] For example, according to Frazer (2004, page 11) electricity industry participants in a Sustainable Energy Futures Project "fundamentally do not believe that the [Ministry of Economic Development's] Energy Outlook view based on the National Energy Efficiency and Conservation Strategy is realistic based on the current implementation approach".

[74] United Kingdom Government (2005, chapter 4).

[75] These figures are all estimates. See Aitken (2005).

[76] See www.smud.org.

[77] Dante Alighieri (1265–1321), Italian poet and statesman. Quoted from *The Divine Comedy*, Paradiso, canto 1, line 34.

[78] MED (2004, page 65).

[79] Pete Hodgson in MED (2004, page 2).

[80] See, for example, Doty (2004) and Newell (2005). Many social hurdles would have to be overcome.

[81] Small quantities of hydrogen are released into the air by volcanoes but the density of the gas is so low that it rises into the upper atmosphere and most of it escapes into space. Uncertainty remains about the effects of hydrogen in the atmosphere because scientists still have a limited understanding of the hydrogen cycle. Scientists are also concerned that a build-up of hydrogen in the atmosphere from human activities could contribute to a moistening and cooling of the upper atmosphere and, indirectly, destruction of ozone.

[82] It is estimated that South Island lignite coal resources might be able to provide hydrogen to meet transport demand for 200–300 years. IRL in conjunction with Solid Energy have a project to look at this technology (Goldthorpe, 2004). A problem is that the CO_2 produced during conversion from lignite to hydrogen would be around 400kg of CO_2 per Gigajoule. This compares to the 80kg of CO_2 produced by conventional transport fuels.

[83] This assumes fuel cells are more efficient than conventional engines (otherwise 290 PJ of electrical energy would be required). It also assumes electrolysis conversion efficiency of 72 percent, fuel cells conversion efficiency of around 55 percent, and conventional engines of around 35 percent. This assessment ignores the differences in drivetrain efficiencies and energy losses that occur in hydrogen distribution and storage.

[84] See Food and Agricultural Organisation (1997, chapter 5). The theoretical maximum production of hydrogen by algae is estimated by Melis and Happe (2001) to be around ~20g $m^{-2} d^{-1}$.

[85] There is controversy over whether bioenergy from high intensity agriculture results in a net energy gain (produces more energy than the process requires). See Patzek (2004).

[86] Royal Commission on Nuclear Power Generation in New Zealand (1978).

[87] This is based on the industry practice of a once-through use of the fuel and tailings fuel enrichment based on a 0.3 percent assay (Wakabayashi, 1998).

[88] Vera *et al*. (1998). Natural uranium contains two forms: ^{238}uranium and ^{235}uranium. ^{235}Uranium is the fissionable fuel and occurs naturally. It is usually enriched. Uranium tailings are also enriched.

[89] These are ^{239}plutonium and ^{233}uranium.

[90] The nuclear industry is basing its long-term viability on the development of 'Generation IV' nuclear technologies. However, these technologies have yet to be tested as prototypes. The stated goals of the development programme are to have power plants that are highly efficient, low waste, low cost, safe, and reliable, and with low proliferation/security risk potentials. The nuclear industry hopes that these technologies will reach technical maturity by 2030. Fast breeder technologies are envisaged as a core element of Generation IV. See United States of America Department of Energy (2002).

[91] The world record for the fastest refuelling is 20 days at the Arkansas Nuclear One plant.

[92] It should be noted that no country has started their deep disposal programmes. The United States Yucca Mountain facility will be the first if it goes ahead in 2010 (Anderson *et al*., 2004).

[93] Rothwell (2004). In the United States, this cost is being covered by the taxpayer. For concerns about the adequacy of funding see www.nei.org/index.asp?catnum=3&catid=1039.

[94] The Energy Act 2003 would raise the limit to $15 billion for any one year, although the actual cost of a major accident has been estimated at $300 billion. See also Heyes and Liston-Heyes (1998). The European Union funds research into storage options.

[95] See www.nei.org/index.asp?catnum=3&catid=1039.

[96] In 1992, Congress realised that the funds were not accumulating fast enough. They approved a legislative change to help utilities build up nuclear plant decommissioning funds more rapidly. They changed the federal tax on the funds to be lowered in steps: from 34 percent to 22 percent in 1994 and to 20 percent in 1996.

[97] The duration of the transition will depend on the development of fast breeder reactors.

[98] Metzler (2004).

[99] van Leeuwen and Smith (2004).

[100] Barnett (2003).

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The references in this bibliography are arranged in these categories:

- New Zealand electricity and energy futures
- World energy futures
- General reading on scenarios
- Other references

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