Future Currents:
Electricity Scenarios for New Zealand
2005–2050
Technical Report

Office of the
Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata
PO Box 10-241, Wellington

June 2005

Writers
Mike Webb and Doug Clover

External reviewers
Gerry Te Kapa Coates, Wise Analysis Ltd, Wellington
Ian Shearer, Energy Information Services Ltd, Wellington
Alan Pears, Adjunct Professor and Senior Lecturer in Environment and Planning, RMIT University Melbourne; Director Sustainable Solutions Pty Ltd

Acknowledgements
Iain McAuley, Nick Potter, and Helen Beaumont for comments and feedback

Editing
Write Group Limited, PO Box 9840, Wellington

Design and layout
Write Group Limited, PO Box 9840, Wellington

Bibliographic reference
Parliamentary Commissioner for the Environment (PCE). 2005. Future Currents: Electricity scenarios for New Zealand 2005–2050: Technical Report. Wellington: PCE.

ISBN: 1-877274-57-7

Contents

1 About this report 5

1.1 Introduction 5
1.2 The scenarios – key assumptions 5
1.3 Structure of this report 7

2 Demand-side analysis 8

2.1 Demand for energy services and the efficiency of conversion 8
2.2 Annual efficiency improvements 9
2.3 Average efficiency under the two scenarios 10
2.4 Some comments about the differences between the two scenarios 12
2.5 Alternative means of providing energy services 13
2.6 Biomass use in the forestry sector 14
2.7 Residential sector 15
2.8 Demand projections 17

3 Treatment of losses, reserves, and retirement 19

3.1 Transmission and distribution losses 19
3.2 Reserve capacity 20
3.3 Retirement of plants 20

4 Future generation 21

4.1 Key assumptions about generating technologies 21
4.2 Methodology for determining investment in generation 22
4.3 Resource availability 22
4.4 Key assumptions about generation costs 24
4.5 Comparison of costs 28

5 Results 29

5.1 Scenario A – *Fuelling the future* 29
5.2 Scenario B – *Sparking new designs* 34

6 Comparison of Scenarios A and B 39

References 40

Tables

Table 3.1 Estimated transmission and distribution losses 19
Table 4.1 Potential renewable resources (MW and GWh pa) 23
Table 5.1 Demand and generation 2015 29
Table 5.2 Demand and generation 2030 30
Table 5.3 Demand and generation 2050 31
Table 5.4 Demand and generation 2015 34
Table 5.5 Demand and generation 2030 35
Table 5.6 Demand and generation 2050 36

Figures

Figure 2.1 Calculated growth in demand for electricity services (assuming 2% growth in demand for electricity services and with an estimated AEI of 0.000215) 10
Figure 2.2 Average efficiency of conversion in Scenario A 2005–2050 11
Figure 2.3 Average efficiency of conversion in Scenario B 2005–2050 12
Figure 2.4 Projected demand for electricity under Scenario A 17
Figure 2.5 Projected demand for electricity under Scenario B 18
Figure 3.1 Electricity consumption and generation 2005–2050 ... 20
Figure 4.1 Forecast lifecycle costs for coal, wind, and photovoltaics 2005–2050 28
Figure 5.1 Scenario A – Installed capacity 2004 (actual), 2015, 2030, and 2050 33
Figure 5.2 Scenario A – Generation by source 2004 (actual), 2015, 2030, and 2050 33
Figure 5.3 Scenario B – Installed capacity 2004 (actual), 2015, 2030, and 2050 38
Figure 5.4 Scenario B – Generation by source 2004 (actual), 2015, 2030, and 2050 38
Figure 6.1 Scenarios A and B – Comparison of installed capacity 2004 (actual), 2015, 2030, and 2050 39
Figure 6.2 Scenarios A and B – Comparison of generation by source 2004 (actual), 2015, 2030, and 2050 39

1 About this report

1.1 Introduction

This report describes a constrained quantitative analysis of New Zealand's future electricity demand and supply. This analysis is the basis of the scenarios described in Future Currents: Electricity scenarios for New Zealand 2005–2050 (PCE, 2005).

The analysis explores electricity demand and supply using two fundamentally different sets of assumptions. These are briefly outlined in Section 1.2.

The two scenarios based on the sets of assumptions are:

- Scenario A (*Fuelling the future*)
- Scenario B (*Sparking new designs*)

This analysis models future electricity use and supply under the different assumptions. It should not, however, be confused with a statistical forecast or prediction. The study uses the best available data to determine the most cost-effective way of generating enough electricity to meet two estimated demands for electricity. We have not explicitly included economic responses to price signals in this analysis. The analysis does not assess the energy services in other sectors, such as the transport sector.[1]

The analysis includes a conservative range of technologies. Over the 45-year period new technologies will certainly appear. However, we have considered only technologies that are technically proven today, with enough operational experience for us to derive robust economic data.[2]

The advantage of this constrained methodology is that it allows the analysis to be explicit about the underlying variables.

1.2 The scenarios – key assumptions

The scenarios are fully described in the main report *Future Currents: Electricity scenarios for New Zealand 2005–2050* (PCE, 2005). This section sets out the key assumptions that were used to define future electricity demand and supply for the two scenarios *Fuelling the future* and *Sparking new designs*.

1.2.1 Assumptions Scenario A (*Fuelling the future*)

Scenario A assumes a relatively small increase in the uptake of measures to reduce the residential sector's demand for electricity, such as the installation of solar hot water heating. Scenario A assumes a small investment in energy efficiency measures in all sectors. These assumptions are consistent with past experience. Increasing demand for energy services continues to be provided for by increased generation capacity.

---

1 Note: In this document 'energy services' means those services usually provided by electricity unless otherwise stated.

2 For example, New Zealand potentially has a significant wave power resource. However, with these technologies at a very early stage of development, it is impossible to fully determine the role this resource will play by 2050.

Demand

Assumption A1 – The uptake of energy efficiency improvements (or 'annual efficiency improvement' (AEI)) remains at the estimated historic level of 0.00215 until 2050.

Assumption A2 – Twenty-five percent of the 1,623,000 houses in New Zealand have solar hot water systems by 2050. The increase is linear and starts from a base of 16,000 systems.

Supply

Assumption A3 – No additional uptake of biomass in the forestry sector.

1.2.2 Assumptions Scenario B (*Sparking new designs*)

Scenario B assumes a greater improvement in energy efficiency through smart design. Substantial investment is made in energy efficiency measures such as efficient lighting, air conditioning, and machinery. Moreover, in this scenario the residential sector uses technologies such as solar hot water heating, and measures such as improved insulation and house design to a greater extent. As a consequence less electricity is required to provide the same level of comfort and services.

Demand

Assumption B1 – Greater investment in energy efficiency measures will result in an average efficiency of conversion (AAEC) of 0.5 by 2050 (a 100 percent improvement) by 2050.

The increase in the uptake of energy efficiency improvements will occur gradually over the study period (AEI is constant at 0.00035 per year).

Assumption B2 – Sixty-seven percent of the 1,623,000 houses in New Zealand have solar hot water systems by 2050. The increase is linear from a base of 16,000, and it is assumed that 22,677 new solar hot water systems are added each year.

Supply

Assumption B3 – The forestry sector is more willing to embrace biomass technologies. Generation from biomass meets 20 percent of the electricity requirements of the forestry sector by 2040.

1.2.3 Assumptions common to Scenarios A and B

We assume that the functional level of energy services is the same under both scenarios, so our analysis does not cover the role of energy conservation.[3] We also assume that external factors such as the global price of natural gas and the prices of various generating technologies are the same. This assumption is consistent with the fact that New Zealand's economy is small so our decisions have very little effect on international prices.

---

3 One way of improving energy efficiency and energy conservation is to have appropriate market-based incentives in place, such as those that encourage peak-load conservation (e.g. ripple control and load shedding). However, we do not draw a distinction between our scenarios based on energy conservation.

The approach used in this report requires two essential assumptions about current electricity use in New Zealand so that we can then estimate future demand to 2050. These are Assumptions #1 and #2.

Assumption #1 gives an estimate of the current technical potential for energy efficiency improvements in the electricity sector. Assumption #2 is the estimate of the rate that the demand for energy services (provided by electricity) will increase in the future.

Assumption #1 – New Zealand's average annual efficiency of conversion (AAEC) in 2003 was 0.25.

Assumption #2 – Long-term growth in the demand for energy services is 2 percent per annum. The demand for energy services is assumed to be the same under both scenarios.

1.3 Structure of this report

This report has six main sections.

- Section 2 outlines the methodology used and the assumptions made about electricity demand for each of the scenarios. This section also outlines how the scenarios take account of the effect of:
  - different rates of uptake of biomass in the forestry sector (as an alternative to remote electricity generation)
  - residential use of solar hot water heating and wood burners (as alternatives to electricity).
- Section 3 looks at the impact of transmission and distribution losses, reserve capacity, and the retirement of existing generation plants.
- Section 4 discusses future investment in generation, including resource availability, and capital and operating costs.
- Section 5 presents demand and supply estimates for both scenarios in 2015, 2030, and 2050.
- Section 6 presents tables and graphs that compare the two scenarios.

2 Demand-side analysis

2.1 Demand for energy services and the efficiency of conversion

We use electricity for the energy services it provides. The amount of electricity needed to provide these energy services is determined by conversion efficiency. Average annual efficiency of conversion (AAEC) denotes the theoretical maximum technical efficiency with which energy can be used. This maximum is consistent with thermodynamic limits to energy conversion and the limits imposed by:

- practical sizes of heat exchange equipment
- practical thickness of insulation
- practical electrical conductivity.

What is practical and cost effective is, of course, strongly shaped by the technologies available.

The total demand for electricity is determined by the demand for energy services and the AAEC:

$$\text{Demand for electricity} = \frac{\text{Demand for energy services met by electricity}}{\text{AAEC}}$$

This analysis assumes an AAEC of 0.25 in 2003 [Assumption #1]. This means that if we were to use electricity as efficiently as technically and practically as possible, we would need to use only a quarter of the electricity we currently use to provide the desired energy services. This is known as a Factor Four potential for improvement. The justification for using this estimate of potential is based on several international and local studies.[4]

The demand for electricity was 34889 GWh in the year ended March 2003.[5] Using Assumption #1 we can calculate that the level of energy services provided by electricity was 8722 GWh for the year ended March 2003.

---

4 For discussion of the potential for energy efficiency, see: Rosenfeld A, et al, 'Energy efficiency and climate change' in *Encyclopaedia of Energy: Volume 2,* 2004; Lovins A, 'Energy efficiency, taxonomic overview' in *Encyclopaedia of Energy: Volume 2*, 2004. The long-term potential from retrofitting has been identified as 30–50 percent. Turner W, *Energy Management Handbook*, 2004, Fairmont Press, Lilburn. IPENZ in May 1997 identified 70–80 percent savings as least cost in new buildings. RMI in 1988 identified 80 percent savings as possible. In 1972 the theoretical improvement in the 1972 energy/production ratio was calculated as 87.5 percent (American Physical Society Summer Study on Technical Aspects of Efficient Energy Utilisation, 1974. Available as W H Carnahan, et al, *Efficient use of energy, a physics perspective*, 1974).

5 Ministry of Economic Development, *Energy data file* (July 2004), table G12, page 126. The year ended March 2003 is the most recent year for which comprehensive information is provided.

Demand for energy services increases over time. Rising production and consumption tend to lead to greater use of energy services provided by electricity. Our analysis assumes that over the long term the demand for energy services grows at 2 percent per year [Assumption #2].

2.2 Annual efficiency improvements

Conversion efficiency improves as obsolete equipment is replaced with more efficient equipment and as greater efforts are made to improve energy efficiency. We capture this improvement with a parameter called the 'annual efficiency improvement' (AEI). Mathematically, it is defined by the following expression:

AAEC (year n) = AAEC (year n-1) + AEI*(1 – AAEC (year n-1))

We therefore have two counteracting effects:

- increasing demand for energy services (increases the demand for electricity)
- increasing conversion efficiency (decreases the demand for electricity).

The AEI is not directly observable, so it needs to be estimated. The best estimate should minimise the difference between the *observed* (actual) demand for electricity and the *estimated* demand for electricity.[6] We used historical data to do this. In our analysis, we used *observed* electricity demand for the period March 1994 to March 2003. This data is available in the *Energy data file*.[7]

We *estimated* electricity demand over this period, using the assumptions identified above:

- an AAEC of 0.25 in 2003 (Assumption #1)
- energy services demand increasing by 2 percent per year (Assumption #2).

By minimising the difference between the observed demand for electricity and the estimated demand for electricity, we calculated that the AEI over this period was 0.000215.[8]

The difference between actual and estimated electricity demand between 1994 and 2003 is shown in Figure 2.1.

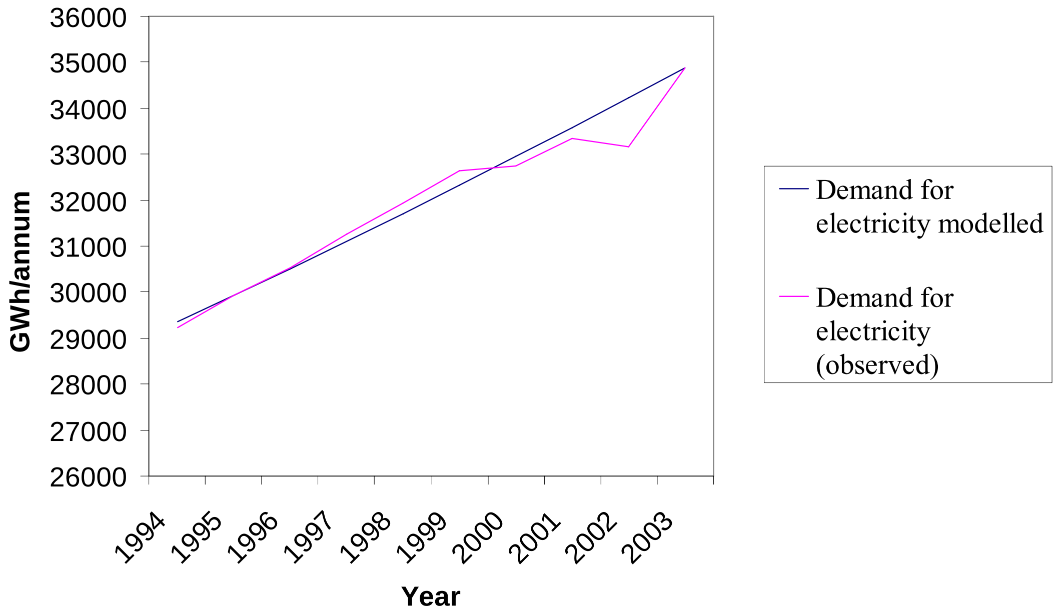
---

6 This is found by minimising the sum of the squared differences between the actual electricity demand and estimated electricity demand.

7 Ministry of Economic Development, *Energy data file* (July 2004), table G 12, page 126.

8 Note that there is evidence to indicate that some sectors currently have higher AEIs than this figure.

Figure 2.1 Calculated growth in demand for electricity services (assuming 2% growth in demand for electricity services and with an estimated AEI of 0.000215)

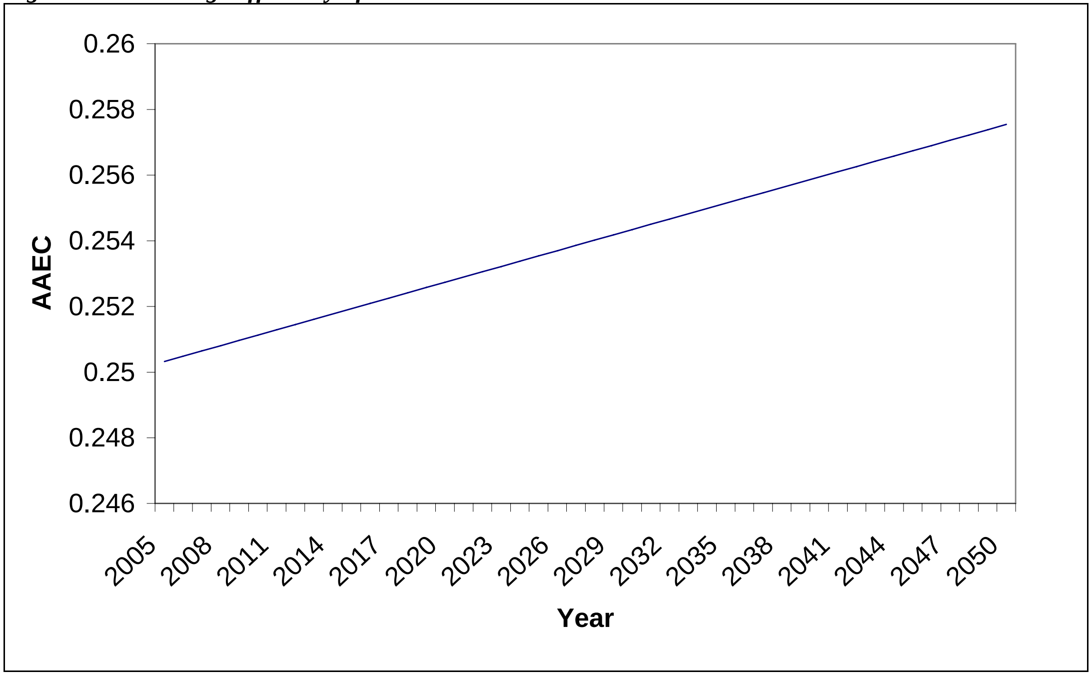


2.3 Average efficiency under the two scenarios

A fundamental difference between our two scenarios is in the rates of uptake of energy efficient technology and processes as reflected in the AEI.

Under Scenario A, the uptake of energy efficiency remains constant at the calculated historical AEI level of 0.00215 until 2050 [Assumption A1]. This is shown in Figure 2.2.

Figure 2.2 Average efficiency of conversion in Scenario A 2005–2050



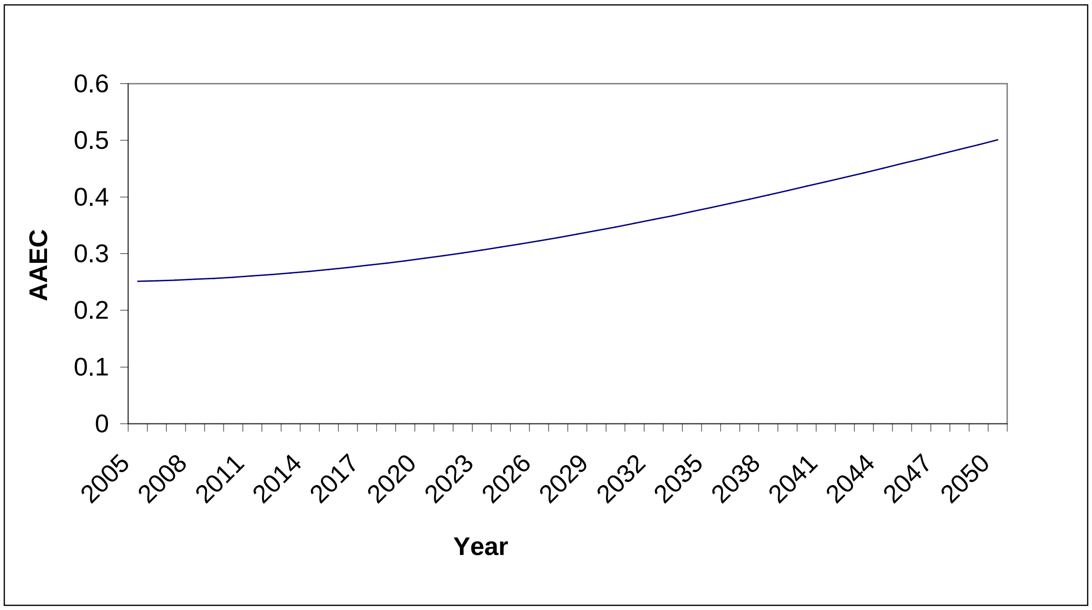
Under Scenario B greater investment is made in energy efficiency measures. These result in 100 percent improvement in our average efficiency of conversion by 2050. This gives an AAEC of 0.5 by 2050 (a Factor Two improvement). To be more realistic we assume that the increase in the uptake of energy efficiency improvements will occur gradually, gathering momentum over the study period. To achieve an AAEC of 0.5 in 2050 we assume that the AEI will increase by a constant 0.00035 per year [Assumption B1].[9] Thus our analysis has a gradually increasing AEI reflecting the increasing commitment to and capacity to provide energy efficiency improvements.[10]

9 Although the scenarios cover the period from 2005 to 2050, the last year of data available for the analysis was 2003. This means that for the 47-year period 2003–2050 the AEI rose from a base value of 0.000215 to a value of 0.016665.

10 See Section 2.2.

Figure 2.3 shows the increase in the AAEC using Assumption #1 (AAEC was 0.25 in 2003) and Assumption B1 (AEI will increase by a constant 0.00035 per year to reach an AAEC of 0.5 by 2050.

Figure 2.3 Average efficiency of conversion in Scenario B 2005–2050



2.4 Some comments about the differences between the two scenarios

2.4.1 Annual improvements in energy efficiency

The AEI is multiplied by the difference between the previous year's AAEC and 1. This means that for any given level of AEI, the annual improvement in energy efficiency will be greater the smaller the initial AAEC. This is because efficiency improvements become more difficult as the theoretical maximum efficiency is approached, reflecting the law of diminishing returns.

2.4.2 Different attitudes to energy improvements

The different AEIs under the two scenarios reveal a fundamental difference in attitude to energy efficiency. Under Scenario A, the historical trend for the uptake of energy efficiency improvements is perpetuated. In Scenario B, attitudes to the role of energy efficiency change significantly. In this scenario sustained efforts are made to enhance and expand programmes that deliver ongoing energy efficiency improvements.

2.4.3 Factor Two improvement achieved in Scenario B

Although the analysis is based on the possibility of eventually achieving a Factor Four improvement, this analysis achieves only a Factor Two improvement in Scenario B over the next 45 years. We consider that this fairly conservative result is appropriate: an AAEC is premised on achieving maximum possible efficiency. This in turn depends on factors such as the rate at which technology develops and is accepted, and the level of ongoing political and social commitment to energy efficiency improvements.

2.5 Alternative means of providing energy services

Generating electricity in large power stations in remote locations, and then transporting it through the grid, is only one way of meeting the demand for energy services.

Electricity can be generated and used on site. Alternatively, electricity may not be required at all to provide the desired level of energy service. For example:

- natural gas can be directly used for heating and cooking
- wood burners can be used for heating
- solar energy can be used to heat hot water.

Changes in the direct use of natural gas are treated as implicit in the 2 percent growth in demand for energy services.[11] In other words, the two scenarios are based on the same levels of natural gas usage. This ensures that factors that are largely outside the control of New Zealand are treated equally.[12]

In Scenario B, the demand for electricity from remotely generated sources is reduced because of:

- increased use of biomass in the forestry sector
- increased uptake of solar water heating
- improvements in home insulation
- increased use of modern wood burners.

These changes are consistent with the behavioural paradigm of Scenario B. This scenario envisages a greater uptake of energy systems that are designed to minimise energy consumption while at the same time meeting the demand for energy services ('smart design').

---

[11] Electricity is a very flexible means of providing energy services. However, the second law of thermodynamics states that this conversion from another energy source results in a loss of energy available. This means that the direct use of an energy source such as gas should be cheaper than electricity generated from that source. However, electricity is used by customers where flexibility is desired.

[12] We assume in this analysis that future availability of natural gas in New Zealand will be largely dependent on geology and the influences of the world petroleum market.

2.6 Biomass use in the forestry sector

Large-scale biomass is unlikely to be cost competitive with coal for use in dedicated electricity generation plants under either scenario (where biomass is the only fuel used).[13] However, biomass has the potential to be incorporated as part of forestry sector operations, using by-products and wood residues converted to electricity through cogeneration or gasification.[14] Because biomass is likely to be used as distributed generation, and uptake is disassociated from its explicit costs, this analysis treats it as a demand-side response displacing traditional forms of electricity generation.[15]

The uptake of biomass depends on the willingness of the forestry sector to embrace these technologies. It is, therefore, justifiable to draw a distinction between its uptake under the two scenarios. In Scenario A we assume that there is no additional uptake of biomass in the forestry sector [Assumption A3].

Under Scenario B the forestry sector is more willing to embrace biomass technologies. This is consistent with the premise that in this scenario New Zealand is more aggressive in promoting and adopting innovative electricity solutions.

By 2040 generation from biomass will meet 20 percent of the electricity requirements of the forestry sector [Assumption B3].[16] This assumption is incorporated into the model in the following way. In the year ended March 2003, the demand for electricity in the forestry sector was 3733 GWh. Assuming that the AAEC in the forestry sector is the same as for New Zealand overall (0.25 in 2003), demand for energy services in the forestry sector is estimated to be 933 GWh pa. The growth in demand for energy services and the potential for efficiency improvements are assumed to be the same in the forestry sector as New Zealand overall. Demand for electricity in this sector is calculated from the demand for energy services and the AAEC in the same way as for New Zealand overall.[17] Each year, from 2005 to 2040, the proportion of electricity requirements of the forestry sector met by biomass increases by $\frac{1}{175}$. This is multiplied by the demand for electricity in the forestry sector in each year and subtracted from total demand for electricity in the respective year.

---

13 However, this situation could change with significant increases in carbon charges.

14 See East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, and Energy Efficiency and Conservation Authority, *Energy from woody biomass in New Zealand*, 2001a.

15 This disassociation means that its uptake will depend on the sector's willingness to innovate, which is not easily quantifiable.

16 2040 was chosen because we expect that photovoltaics will be a cheaper alternative after that date. This is discussed later in the report.

17 See Section 2.1.

2.7 Residential sector

2.7.1 Why the residential sector is treated differently

Alternative ways of meeting the demand for energy services are most evident in the residential sector. This is because hot water and space heating constitute such a large component of the demand for energy services met by electricity. Heating is an area where better design or alternative sources can significantly reduce electricity demand while providing the same level of energy service. Because we take account of improvements in heating only in the residential sector this analysis can be considered to be conservative. However, drawing similar conclusions about other sectors would be unwise due to the paucity of energy use data. (Energy use in other sectors is an area that would benefit from further research.)

Displacements of the demand for energy services through alternative sources are incorporated into our model by defining demand for electricity as:

$$\text{Electricity Demand} = \frac{\text{Demand for electricity services } \textit{less} \text{ Displacement by alternative sources}}{\text{Average annual efficiency of conversion (AAEC)}}$$

2.7.2 Solar water heating

Each solar hot water system displaces 450 kWh of demand for energy services. With an AAEC of 0.25 this corresponds to a reduction in electricity use of 1800 kWh per year.[18] The efficiency improvement (AEI) in electric hot water cylinders is assumed to be the same as the overall AEI. As the AAEC increases over time, additional solar hot water systems will have less effect on the overall demand for electricity.[19]

---

[18] This is based on solar hot water heating replacing 70 percent of hot water electricity needs. Residential electricity needs were based on the Year 7 result of the Building Research Association of New Zealand's *Household energy end-use project* (HEEP).

[19] This is because the least efficient hot water systems are replaced first, so it becomes progressively more difficult to extract the same efficiency improvements.

In Scenario A, 25 percent of the 1,623,000 houses in New Zealand have solar hot water systems by 2050 [Assumption A2].[20] This increase is linear and starts from a base of 16,000 systems.[21] In other words, 11,168 new solar hot water systems are added each year. Although this level of uptake represents a significant increase on historical trends, we consider that an increase of this size is possible. We assume a constant increase for this analysis. While the demand for solar water heating is likely to increase over time, the smaller number of electric heating systems available to be replaced counteracts this effect. Consumers are likely to make greater use of solar hot water systems as the industry develops and the systems are seen as economical and desirable.

In Scenario B, we assume that 67 percent of the 1,623,000 houses in New Zealand have solar hot water systems by 2050 [Assumption B2]. As with Scenario A, the increase is linear from a base of 16,000. Under Scenario B, 22,677 new solar hot water systems are added each year.

2.7.3 Reduction in electricity demand for space heating

In Scenario B the demand for energy services in the residential sector is reduced through:

- improvements in house design, construction, and insulation
- increased use of modern wood burners.

These factors reduce home space heating requirements. By 2050 this will have reduced residential electricity demand by 10 percent.[22]

---

[20] We estimate the number of houses in 2050 by multiplying the number of permanent private households in New Zealand from the 2001 Census (1,287,888) by Statistics New Zealand's percentage growth in households by 2021 (26%) (Statistics New Zealand. 2003. *New Zealand family and household projections 2001 (base)–2021*, page 2). http://www.stats.govt.nz/analytical-reports/nz-family-hholds-projections.htm [Last accessed March 2005]

[21] An estimate of the number of solar hot water systems is provided in Energy Efficiency and Conservation Authority, *Solar Energy Use and Potential in New Zealand*, May 2001c.

[22] A 10 percent reduction in total use through reduced space heating may be a conservative estimate. BRANZ's HEEP project Year 6 report has 42.9 percent of household electricity unassigned after measuring fixed-wire lighting, ovens and hobs, hot water systems, refrigerators, dryers, and washing machines. Space heating is likely to account for a significant portion of this use. *Build* magazine estimates the space heating electricity requirements (without double glazing) to be 3991 kWh pa in Auckland, 5812 kWh in Wellington, 10203 kWh in Christchurch, and 12895 kWh in Invercargill (*Build,* September 2004). This can be compared with the average household electricity use of 10500 kWh (BRANZ, 2002).

We include the reduced demand by subtracting an increasing proportion of the residential demand for electricity from the total demand for electricity. This proportion increases by $\frac{1}{450}$ each year so as to be 10 percent by 2050. Residential demand for electricity, excluding the effect of better design, remains constant at 34 percent of the total demand for electricity.[23] Displacements from solar water heating are not subtracted from the total demand for electricity because these are part of the residential demand for energy services. These measures do not result in any decrease in the level of warmth and comfort in a home.

2.8 Demand projections

Demand for electricity under our *Fuelling the Future* scenario is shown in Figure 2.4.

Figure 2.4 Projected demand for electricity under Scenario A

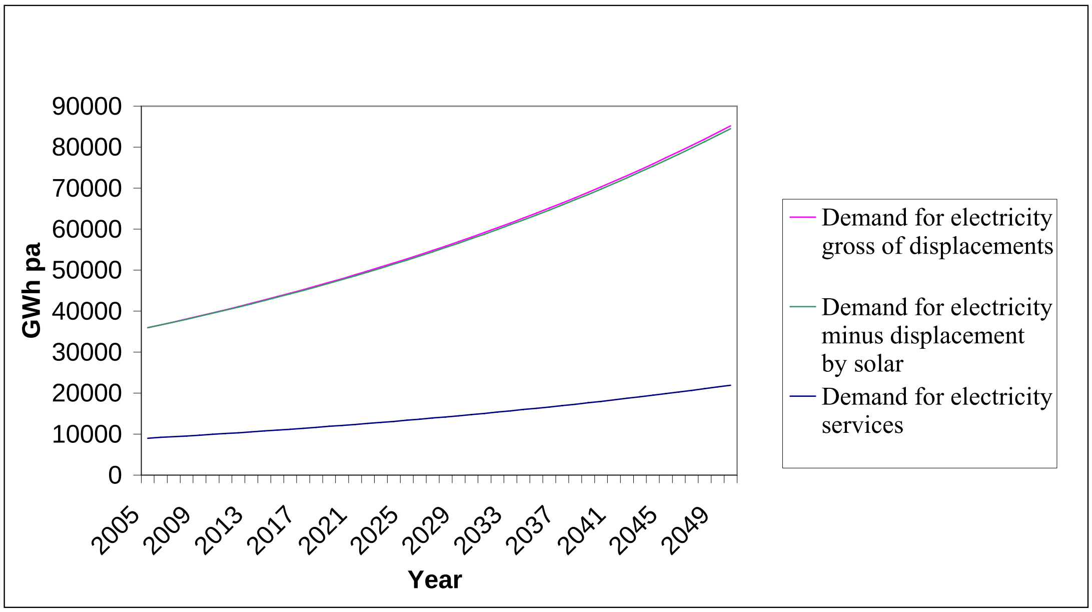
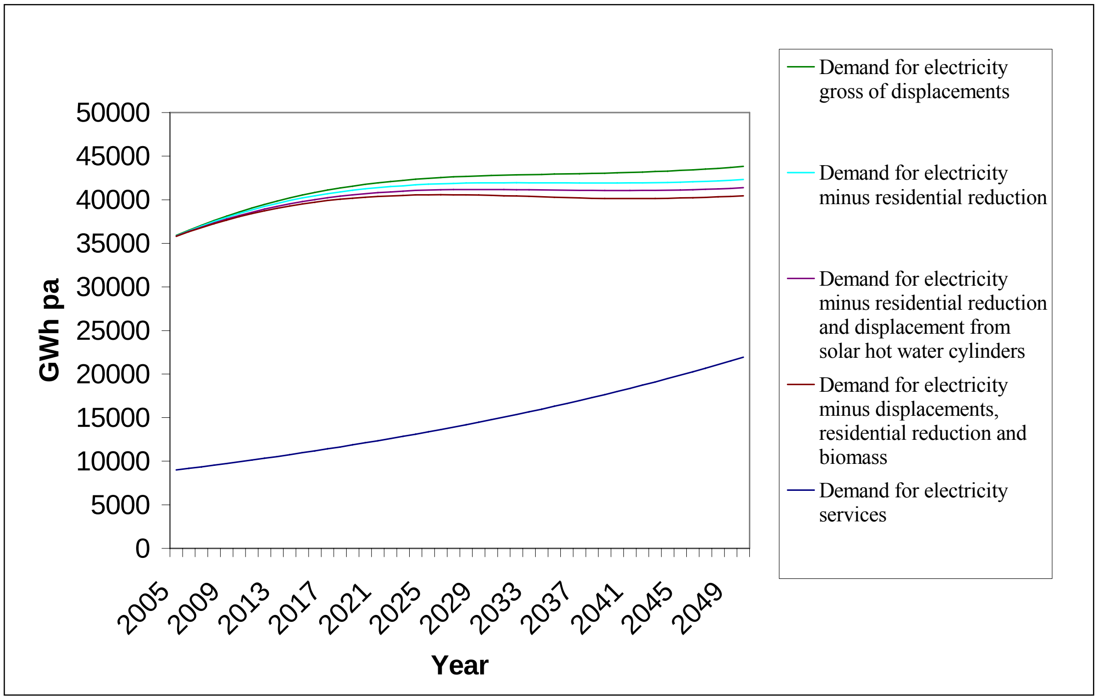


Figure 2.5 shows demand for electricity under our *Sparking new designs* scenario.

[23] Ministry of Economic Development, *Energy data file* (July 2004), chart G 7c, page 127.

Figure 2.5 Projected demand for electricity under Scenario B



3 Treatment of losses, reserves, and retirement

3.1 Transmission and distribution losses

Losses from transmission and distribution mean that more electricity must be generated than is actually consumed. The volume of electricity transmitted, the distance it travels, the type of lines used, and environmental factors (such as ambient temperature) affect these losses. One way of determining these losses is to compare historical electricity generation and use, as shown in Table 3.1.[24]

Table 3.1 Estimated transmission and distribution losses

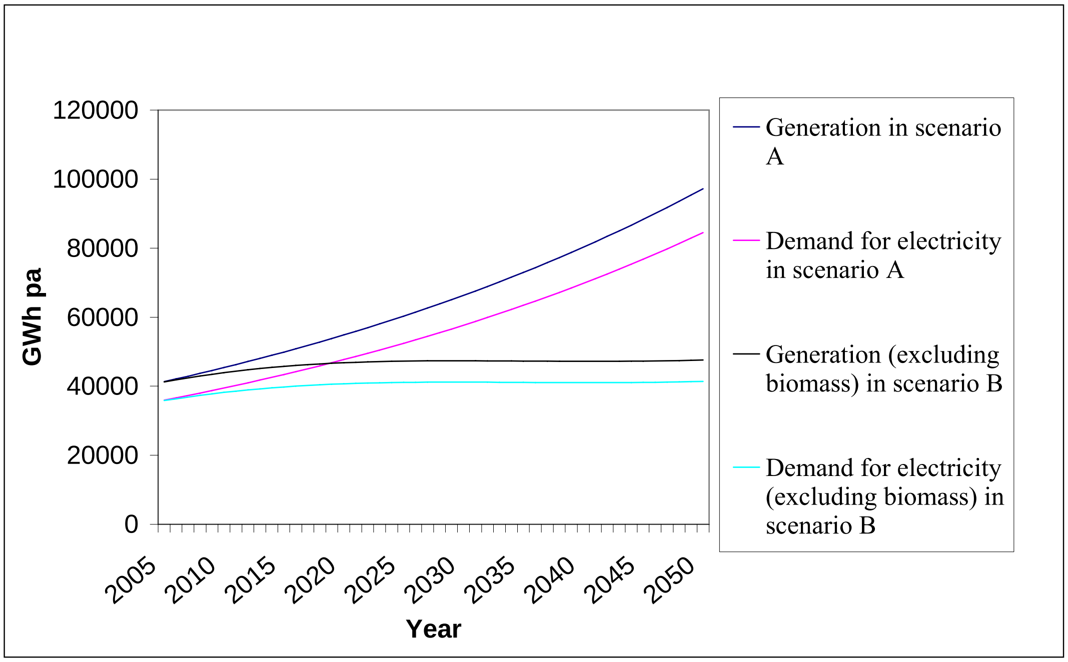
Year ended	Electricity use GWh	Generation GWh	Losses as a percentage of electricity use
March 2001	33347.9	38645.5	15.9%
March 2002	33149.8	38340.9	15.6%
March 2003	34888.5	40150.0	15.1%

Using these figures we calculate that transmission and distribution losses are 15 percent of electricity use under both scenarios. Pressures on the transmission grid are likely to increase due to increased demand, which will increase losses. Moreover, climate change may lead to higher air temperatures, which will further increase losses. So, by assuming losses at the historical level we are implicitly assuming that transmission and distribution networks will be upgraded. Due to the higher load under Scenario A, upgrades will be have to be larger, and therefore more extensive and expensive.

We multiply demand by 1.15 to get the total annual generation required as shown in Figure 3.1.

24 Ministry of Economic Development, *Energy data file* (July 2004), tables G12 and G3.

Figure 3.1 Electricity consumption and generation 2005–2050



3.2 Reserve capacity

In addition to installing generation to meet load growth, we need to ensure that the power system has sufficient reserve capacity to cover for maintenance and breakdowns. Thus, additional generation required to be built in future years has been multiplied by 20 percent.[25]

3.3 Retirement of plants

New generation must be installed to replace plants that have reached the end of their operational life. Under both scenarios the 400 MW New Plymouth gas station, which generated 1813 GWh of electricity in 2003, is retired in 2010. The large gas-fired stations Otahuhu B and Taranaki Combined Cycle (TCC) (which together accounted for 737 MW and generated 4452 GWh pa in 2003) are retired in 2020. The Huntly Energy Efficiency Enhancement Project (E3P) gas station is generating by 2010 and retired in 2035. Smaller gas stations are gradually phased out.[26] Because of its location,[27] under Scenario A, Huntly is overhauled or replaced by a coal station of the same size (1000 MW). No hydro or geothermal stations are retired.

The generation lost because of retirement is added to the extra generation required.[28]

---

[25] This is consistent with Bryan Leyland, *New Zealand's load growth from 1974 and expected demand to 2025*, page 9.

[26] It is possible that some of these stations may be retained in some form in an emergency short-term role. Such stations would not use much natural gas and due to their emergency role would be able to afford the high price of the gas.

[27] Such as its proximity to supplies of coal and closeness to Auckland. It should be noted that there is always the possibility the sites of retired stations is where new stations will be built.

[28] Reserve capacity is already implicit in existing plants.

4 Future generation

4.1 Key assumptions about generating technologies

Both scenarios are based on key assumptions about the various generating technologies.

The discount factor used in investment decisions is 1.1 for all large-scale plant and 1.15 for photovoltaics (see 4.4.5 for more about photovoltaics).[29] This reflects investors' differing investment criteria.

- A carbon charge of $15/tonne of carbon dioxide (CO_2) is implemented to meet New Zealand's obligations under the Kyoto Protocol.[30] This carbon charge could be considered to be conservative. Moreover, we assume that investors have correct (rational) expectations of this charge – perhaps through a credible government policy to cap the charge.
- We do not assume any carbon charge rebates for wind generation.
- The CO_2 emissions level for thermal generation is discussed in Section 4.4.4. However, there is a substantial difference in cost between the most cost-effective coal stations and the least productive wind sites, as we demonstrate in Section 4.4. Consequently, the analysis is relatively insensitive to this parameter.

The average load factor of new thermal stations is 75 percent.[31]

Although demand fluctuates throughout the day and over the year, the load factor of thermal stations and the flexible operation of hydro stations together ensure that peak demand is met. The reserve capacity installed also provides security of supply (see Section 3.2).

---

[29] The discount rate for large-scale plant is consistent with Ministry of Economic Development, *Availabilities and costs of sources of energy for generating electricity: Technical note*, October 2003.

[30] This is consistent with Ministry of Economic Development, *New Zealand energy outlook to 2025*, October 2003

[31] This assumption is consistent with MED *Availabilities and costs of renewable sources of energy for generating electricity and heat: Technical note*, and Bryan Leyland, *New Zealand's load growth from 1974 and expected demand to 2025*, August 2004, which uses a load factor of 75 percent. The New Zealand Business Council for Sustainable Development and Frazer Lindstrom report, *Sustainable energy futures report*, September 2004 and Solid Energy, Concept Consulting, and NZIER report, *Energy options: Securing supply in New Zealand*, 2004, both use a load factor of 85 percent for gas- and coal-fired stations. One justification for using a load factor of 75 percent is that a plant is operating at a mean capacity of 80 percent and is available approximately 95 percent of the time.

4.2 Methodology for determining investment in generation

The approach taken to determine the level of new generation required can be defined as:

(generation required in that year – generation in previous year) *x* (reserve margin + retirement of existing plants in that year)

New generation is installed on a year-by-year basis to ensure that in every year there is sufficient capacity to meet the demand for electricity.

In a deregulated electricity sector, decisions over the technology used to meet any additional generation required are presumed to be rational economic ones. Therefore the model allocates generation purely on the basis of lifecycle costs, as assessed in the year before the station is needed. Lifecycle cost is defined as:

$$\text{Lifecycle cost} = \frac{\sum_{t=1}^{T} \delta^t \cdot \text{Operating cost year t}}{\sum_{t=1}^{T} \delta^t \cdot \text{Generation in year t}} + \frac{\text{Capital cost per kWh capacity}}{\sum_{t=1}^{T} \delta^t \cdot \text{Generation per kWh capacity in year t}}$$

If we assume that generation and operating costs are constant across years, this expression simplifies to:

$$\text{Lifecycle cost} = \text{Operating cost per kWh} + \frac{\text{Capital cost per kWh capacity}}{\text{Generation per kWh capacity} \cdot \sum_{t=1}^{T} \delta^t}$$ [32]

4.3 Resource availability

All generating technologies have a limited resource base. For instance, a limited number of sites are suitable (and cost competitive) for renewable generation such as hydro-electric, geothermal, and wind. A key limitation on hydro development is society’s resistance to the environmental impacts from these projects. Under Scenario A future hydro development is limited to three large-scale projects over 100 MW and a number of relatively small-scale developments (on 10 river systems). If public resistance resulted in less hydro development, demand would need to be accommodated by building more coal-based thermal plants.

Thermal stations, on the other hand, are limited by the availability of fuel; these are discussed later.

The potential resource base of renewable energy is summarised in Table 4.1.

---

[32] For operating costs that cannot be assumed as constant over time (for example, carbon charges) an average of the discounted value can be used, i.e.

$$\frac{1}{T} \cdot \sum_{t=1}^{T} \delta^t \cdot \text{Carbon charge in Year t}$$

Table 4.1 Potential renewable resources (MW and GWh pa)

Additional renewable resources	Maximum capacity available (MW)	Capacity assumed available (MW)	Maximum generation available (GWh pa)	Generation assumed available (GWh pa)
Landfill gas[33]			70	70
Geothermal[34]	2507	951	19750	7500
Wind locations A (Wellington hills and coast; Manawatu Gorge; Mossburn)[35]	420	420	1742	1742
Wind locations B (Wairarapa hills and coast; Foveaux Strait and SE hills)	650	650	2340	2340
Wind locations C (Coromandel/Kaimai Ranges)	40	40	140	140
Wind locations D (West Coast Auckland; Marlborough Sounds hills; Banks Peninsula)	260	220	806	682
Wind locations E (North Island East Coast and hills; Far North)	650	450	2002	1386
Wind locations F (Cape Egmont/Taranaki Coast; Inland Otago; Canterbury river gorges)	1120	820	2632	1927
Hydro[36]	3590	800	18500	4200

[33] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 9. As plants have other objectives (such as the reduction of methane emissions) costs are of less relevance.

[34] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002. Geothermal fields that are assumed to be available for development are: Horohoro, Mokai, Ohaaki, Wairakei, Mangakini, and Ngatamariki. These are all designated development fields in Environment Waikato's *Proposed Variation No. 2 (Geothermal) to proposed WRP Decisions version, 12 June 2004*, page 16. The proposed variation defines development geothermal systems as those "where the sustainable taking and use of geothermal water will be allowed while avoiding, remedying or mitigating adverse effects on the geothermal system including: geothermal features, overlying structures (the built environment); and other natural and physical resources." Fields assumed unavailable are: Kawerau, Ngawha, Rotoma, Tauhaea, Tikitere-Tahake, Reporoa, and Tokaanu. Additional fields are assumed to become steadily available over the next 20 years. It should be noted that our estimates are more conservative than the latest MED estimates available at http://www.med.govt.nz/ers/environment/water-bodies/geothermal/geothermal.pdf

[35] For information about wind resources see: Energy Efficiency and Conservation Authority, *Review of New Zealand's wind energy potential to 2015*, 2001b, page 31.

[36] This is based on estimates of hydroelectric schemes on the Lower Clutha (Tuapeka Mouth), lower Waitaki (due to water allocation issues capacity constrained to 100 MW), and the Lower Grey that are considered to be large scale. Projects on the Mata River; Waingakia Stream; Waitahaia Stream; Kirowehu Stream; Tukituki River; Wairehu Canal; Waipapa River; Waipa River and the Wairoa River, and Mohaka are relatively small scale (<100 MW). From East Harbour Management Services, *Waters of national importance – Identification of potential hydro electric resources*, 2004.

4.4 Key assumptions about generation costs

4.4.1 Wind generation

The cost of wind turbines has been estimated in 2002 at $2,000/kW for stations between 25 and 50 MW in size, with a forecast reduction of 1.5 percent per year. The minimum cost of $1,225/kW will be reached in 2025.[37]The cost of linking wind farms with the national grid is likely to be greater than for other sources of electricity. This is because wind farms are dispersed and located in more remote areas. On the other hand, most prime wind sites are in the North Island so they would incur lower transmission losses than generation from the South Island. Even so, the cost of wind turbines has been increased in the scenarios by $111,111 per MW to reflect the costs of additional lines and substations needed for connection to the national grid.[38]

Operational and maintenance costs are calculated as $28000 per MW installed capacity per year plus 0.6 cents per kWh generated.[39]

Offshore wind generation has not been incorporated into this analysis because of the lack of research into its potential in New Zealand. It is unclear when wind generation might be cost competitive. European experience suggests that capital costs are around 30–70 percent higher than for onshore generation. Higher capital costs are offset to some extent by energy yields that are about 30 percent higher.[40] We expect the development of turbines suitable for New Zealand conditions to be expensive because the New Zealand offshore environment is very different to Europe.[41]

4.4.2 Geothermal generation

The capital cost of retrofitting a binary cycle plant to a geothermal field that has already been adjusted by the installation of condensing sets has been estimated at $3,200/kW.[42] As plants are modular no economies of scale are possible.

The costs of field development have been estimated to add between $600 and $2,000 per kW to the cost of the binary plant. It is worth noting that since a Crown drilling programme has quantified many of New Zealand's geothermal fields, they may be able to be developed at a lower cost. In the longer term, costs are expected to remain relatively constant due to the counteracting effects of technological improvements and higher well costs.[43]

---

37 East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 86.

38 This is consistent with Bryan Leyland, *New Zealand's load growth from 1974 and expected demand to 2025*, 2004, page 10.

39 East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 87.

40 Concerted Action on Offshore Wind Energy in Europe (CA-OWEE).*Offshore wind energy – Ready to power a sustainable Europe.* December 2001. Page 6-1.

41 One of the main reasons for this is that unlike other countries, New Zealand does not have a relatively shallow continental shelf, so the technical challenges will be greater.

42 East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 68.

43 East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 69.

Operational and maintenance costs are dominated by the cost of drilling the make-up wells. They have been estimated at:

- $93/kW per year for a station larger than 50 MW
- ${177-3.66*[size(MW)] + 0.04*[size(MW)]2}/kW/year for a station less than 50 MW.[44]

Carbon dioxide emissions are estimated at approximately 100 tonnes per GWh.[45]

The lifecycle cost of geothermal power is considerably lower than all other types of generation. This means that geothermal uptake is likely to be constrained by resource availability rather than cost.

Up to 2040, 951 MW of geothermal power will become available in a linear manner. In other words, 31.7 MW of geothermal plant generating 250 GWh per year will become available every year until 2040.

4.4.3 Generation from natural gas

We have included the 385 MW E3P project at Huntly in our modelling. We also assume that the steam turbine station at New Plymouth is retired before 2015. Likewise, the large gas-fired stations (Otahuhu B and Taranaki Combined Cycle) are retired in 2020. All existing gas stations are retired before 2050. Even with additional gas discoveries, or imports of liquefied natural gas (LNG) maintaining supply at 60 PJ per year,[46] 2 percent growth in the direct use of gas will make the development of new gas stations uneconomic. As direct use of gas is more efficient than conversion to electricity, direct users will be prepared to pay a higher price for gas. Consequently, new gas-fired generation will eventually be squeezed out of the market.[47]

4.4.4 Generation from coal

Under both scenarios Huntly runs completely on coal. When it reaches the end of its life, another 1000 MW station is constructed on its site. Under Scenario A the presently uncommissioned Marsden B station has been refitted to a 320 MW coal-fired station.

Coal costs $3/GJ and is of sub-bituminous quality.

---

[44] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 68.

[45] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 56. This varies across fields but is not a significant cost of geothermal generation.

[46] Ministry of Economic Development, *New Zealand's energy outlook to 2025*, 2003, page vii, assumes 60 PJ of discoveries per year.

[47] This point is developed in detail in Solid Energy, Concept Consulting, and NZIER, *Energy options: Securing supply in New Zealand*, 2004.

The capital cost of a 400 MW conventional coal station has been estimated at $2,032 per kW (in 2001).[48] This has been estimated to decrease to $1,971 per kW in 2012; $1,921 per kW in 2025, and $1,751 per kW in 2050.[49] Efficiency of conversion has been estimated at 36.2 percent in 2001, 37.5 percent by 2012, 37.5percent by 2025, and 45 percent by 2050.[50] Efficiency improvements are generally through increasing steam temperature and boiler pressure.[51] Operations and maintenance costs are estimated at 1.308 cents per kWh and other costs are estimated at 1.3 cents per kWh.[52] Carbon dioxide emissions are estimated at 955 tonnes per GWh.[53]

Integrated Coal Gasification Combined Cycle (ICGCC) stations burn a fuel gas created by the gasification of coal. Waste heat from the gasification of coal is used to generate steam that then drives a steam turbine.[54] The world's first commercial ICGCC is in operation in Buggenum in the Netherlands.

The capital cost of a 400 MW ICGCC plant has been estimated at $2,476 per kW (in 2001).[55] This has been estimated to decrease to $2,189 per kW in 2012; $1,891 per kW in 2025, and $1,591 per kW in 2050.[56] Efficiency of conversion has been estimated at 42.8 percent in 2001, 49 percent in 2012, and 60 percent in 2050.[57] Operational and maintenance costs are estimated at 0.98208 cents per kWh and other costs are estimated at 1.7 cents per kWh.[58] Carbon dioxide emissions are estimated at 700 tonnes per GWh generated.[59] This is between the 794 tonnes per GWh emission level at Buggenum and the projected emission level for this technology of 660 tonnes per GWh.[60]

---

48 East Harbour Management Services, *Costs of fossil fuel generating plant,* 2002, as adjusted in MED technical note.

49 East Harbour Management Services, *Costs of fossil fuel generating plant,* 2002, as adjusted in MED technical note. Changes in the intervening years have been calculated on a straight-line basis.

50 East Harbour Management Services, *Costs of fossil fuel generating plant,* 2002. Changes in the intervening years have been calculated on a straight-line basis.

51 Saddler H, Diesendorf M, and Denniss R, *A clean energy future for Australia*, March 2004, page 106.

52 East Harbour Management Services, *Costs of fossil fuel generating plant*, 2002, as adjusted in MED technical note.

53 Motu and East Harbour Management Services, *Renewable energy and the efficient implementation of New Zealand's current and potential future greenhouse gas commitments*, 2002, page 34. This is around the average estimate of most New Zealand reports.

54 Saddler H, Diesendorf M, and Denniss R, *A clean energy future for Australia*, March 2004, page 108.

55 East Harbour Management Services, *Costs of fossil fuel generating plant*, 2002 as adjusted in MED technical note.

56 East Harbour Management Services, *Costs of fossil fuel generating plant*, 2002 as adjusted in MED technical note. Changes in the intervening years have been calculated on a straight-line basis.

57 East Harbour Management Services, *Costs of fossil fuel generating plant*, 2002. This is consistent with figures from the IEA that predict efficiencies of 50 percent in the next 10–15 years. Changes in the intervening years have been calculated on a straight-line basis.

58 East Harbour Management Services, *Costs of fossil fuel generating plant*, 2002 as adjusted in MED technical note.

59 Saddler H, Diesendorf M, and Denniss R, *A clean energy future for Australia*, March 2004, page 108.

60 www.ieagreen.org.uk/emis6.htm, accessed 4 November 2004.

4.4.5 Photovoltaic generation

Photovoltaic generation is based on a technology that uses solar cells, which convert light directly into electricity. At present photovoltaics are relatively expensive but considerable development to increase conversion efficiencies and reduce costs has already occurred and this trend is expected to continue.

The capital cost of photovoltaics is estimated as $\text{NZ\$}2.98*1057*e^{-0.065}*\text{year}$.[61] This reflects the expected exponential decrease in costs resulting from technological innovations and learning effects. We assume a capacity factor of 0.185[62] and operational and maintenance costs of 1.8 cents per kWh.[63]

4.4.6 Wave power

New Zealand has significant potential for wave generation. This technology is less understood compared to other emerging renewable technologies. Data on the potential resource and cost curves are much less certain.

However, we thought that it was unrealistic to ignore this resource under a high renewables uptake scenario. We assumed, somewhat conservatively, that 100 MW of wave generation capacity will have been installed by 2050. This has a capacity factor of 40 percent (Industrial Research Limited (IRL) estimates capacity factors of up to 50 percent for New Zealand) that in turn produces around 350 GWh per year.[64] This capacity will displace the uptake of some photovoltaic energy.

---

[61] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, page 148.

[62] Energy Efficiency and Conservation Authority, *Solar energy use and potential in New Zealand*, May 2001c.

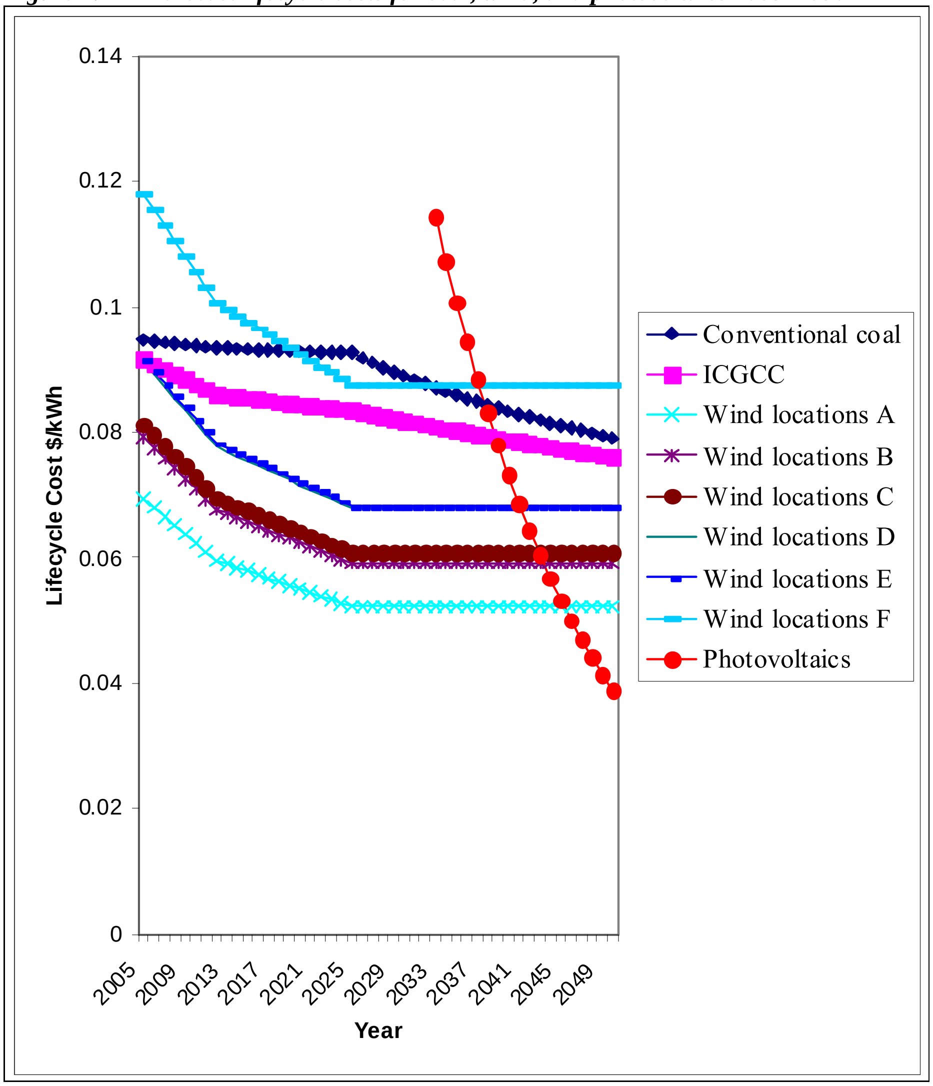
[63] East Harbour Management Services, *Availabilities and costs of renewable sources of energy for generating electricity and heat*, 2002, as adjusted for capacity factor.

[64] Iain Sanders, Alister Gardiner, Guy Penny, and Richard Gorman. 2003. *New Zealand wave energy potential: Riding the crest of a wave or gone with the wind?* Industrial Research Limited and National Institute for Water and Atmospheric Research, page 3.

4.5 Comparison of costs

Figure 4.1 illustrates the evolution of lifecycle costs calculated using the cost estimates outlined in Section 4.4 and the methodology in Section 4.2.

Figure 4.1 Forecast lifecycle costs for coal, wind, and photovoltaics 2005–2050



5 Results

5.1 Scenario A – *Fuelling the future*

Table 5.1 Demand and generation 2015

	MW capacity	GWh / year
Projected demand in 2015		43542
Generation required to meet this demand		50073
Generation in 2003		40029
Additional generation required		10044
Plus: 20% reserve margin		2009
		12053
Plus: Plants retired		
New Plymouth Gas	400	1813
New generation to be installed		13867
Sources of new generation:		
Landfill gas		70
Wind	1589	6443
Geothermal	285	2250
Hydro	100	472
Coal	320	2102
Gas	385	2529
Total new generation	2679	13866

Note:
The coal development is the conversion of the currently uncommissioned Marsden B station. Since the infrastructure is largely in place this is likely to be a cost-effective source of generation.[65] The gas station developed is the E3P project at Huntly. According to the lifecycle cost methodology outlined in Section 3 and cost assumptions specified in Section 4, wind generation is the most cost-effective means of providing the additional generation. This is augmented by small-scale hydro as detailed in Section 4.

65 See www.mightyriverpower.co.nz/news_events/news/18-08-04_marsden_point.asp (last accessed 23 September 2004).

Table 5.2 Demand and generation 2030

	MW capacity	GWh/year
Projected demand in 2030		57517
Generation required to meet this demand		66145
Generation in 2003		40029
Additional generation required		
2004–2015		10044
2016–2029		16072
		26116
Plus: 20% reserve margin		5223
		31339
Plus: Plants retired		
2005–2015: New Plymouth Gas	400	1813
2016–2030: TCC and Otahuhu B	737	4842
Total retirement	1137	6655
New generation to be installed		
2004–2014		13867
2015–2029		24128
Total new generation to be installed		37995
Sources of generation:		
Landfill gas		70
Wind		
Installed 2004–2014	1589	6443
Installed 2015–2029	191	587
Total new wind generation	1780	7030
Geothermal		
Installed 2004–2014	285	2250
Installed 2015–2029	476	4000
Total new geothermal generation	951	6250
Hydro		
Installed 2004–2014	100	472
Installed 2015–2029	425	1880
Total new hydro generation	525	2352
Coal		
Installed 2004–2014	320	2102
Installed 2015–2029	2400	15768
Total new coal generation	2720	17870
Gas		
Installed 2004–2014	385	2529
Installed 2015–2029	0	0
Total new gas generation	385	2529

	MW capacity	GWh / year
Cogeneration		
Installed 2015–2029	400	2628
Total new generation		38729

Note:
Once the economic limit of wind generation is reached, 400 MW Integrated Coal Gasification Combined Cycle stations are the most cost-effective means of providing additional generation. However, one 400 MW coal station could be replaced with a large-scale hydro development of the magnitude of Project Aqua. Whether further large-scale hydro development occurs will depend on societal judgements as reflected in resource consent processes.

Table 5.3 Demand and generation 2050

	MW capacity	GWh / year
Projected demand in 2050		85182
Generation required to meet this demand		97960
Generation in 2003		40029
Additional generation required		
2004–2015		10044
2016–2030		16072
2036–2050		31815
		57931
Plus: 20 % reserve margin		11586
		69517
Plus: plants retired		
2005-2015: New Plymouth Gas	400	1813
2016-2030: TCC and Otahuhu B	737	4452
2031-2050: All gas stations incl. Huntly E3P	716	4704
Total retirement	1853	10969
New generation to be installed		
2004–2014		13867
2015–2029		24128
2030–2049		42491
Total new generation to be installed		80486
Sources of generation:		
Landfill gas		70
Wind		
Installed 2004–2014	1589	6443
Installed 2015–2029	191	587
Installed 2030–2050	0	0
Total new wind generation	1780	7030

	MW capacity	GWh / year
Geothermal		
Installed 2004–2014	285	2250
Installed 2015–2029	476	4000
Installed 2030–2050	158	1250
Total new geothermal generation	919	7500
Hydro		
Installed 2004–2014	100	472
Installed 2015–2029	425	1880
Installed 2030–2050	285	1872
Total new hydro generation	810	4224
Coal		
Installed 2004–2014	320	2102
Installed 2015–2029	2400	15768
Installed 2030–2050	2600	17082
Total new coal generation	5320	34952
Gas		
Installed 2004–2014 (retired 2030–2050)	385	2529
Installed 2015–2029	0	0
Installed 2030–2050	0	0
Total new gas generation	385	2529
Cogeneration		
Installed 2015–2029	400	2628
Photovoltaics		
Installed 2030–2050		21552
Total new generation		80486

Note:

As discussed in Section 4, all gas-fired stations are retired by 2050. Integrated Coal Gasification Combined Cycle stations continue to be developed until photovoltaics become a cost-competitive source of supply around 2040. If the costs of photovoltaics have not decreased as much as assumed; then, unless an alternative source of generation such as offshore wind is cost-competitive in the New Zealand context, there will be significantly more investment in coal.

5.1.1 Comparison of 2004, 2015, 2035, and 2050[66]

Figure 5.1 Scenario A – Installed capacity 2004 (actual), 2015, 2030, and 2050

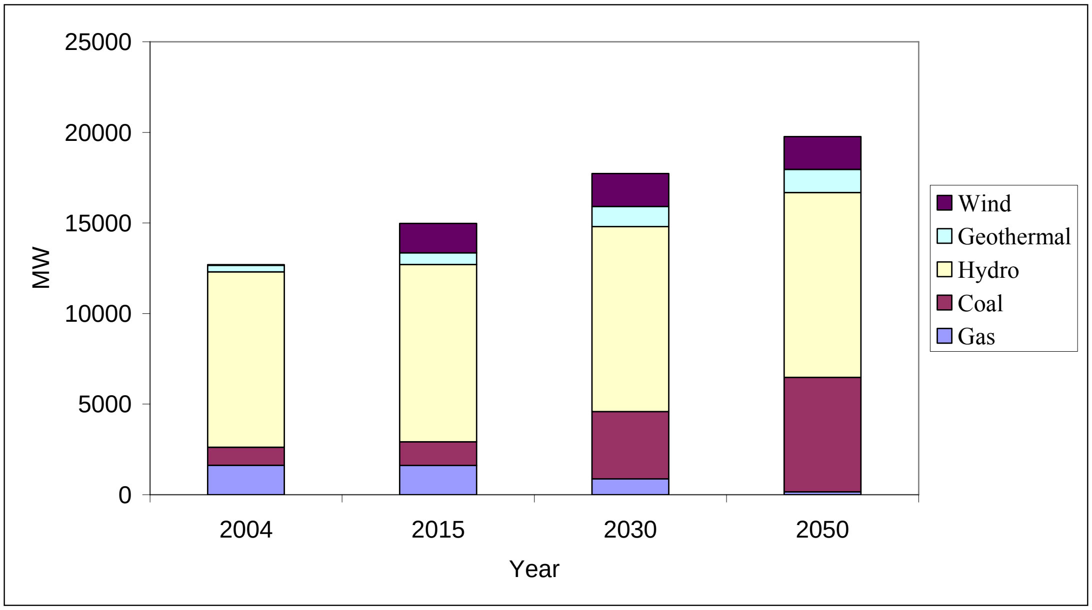
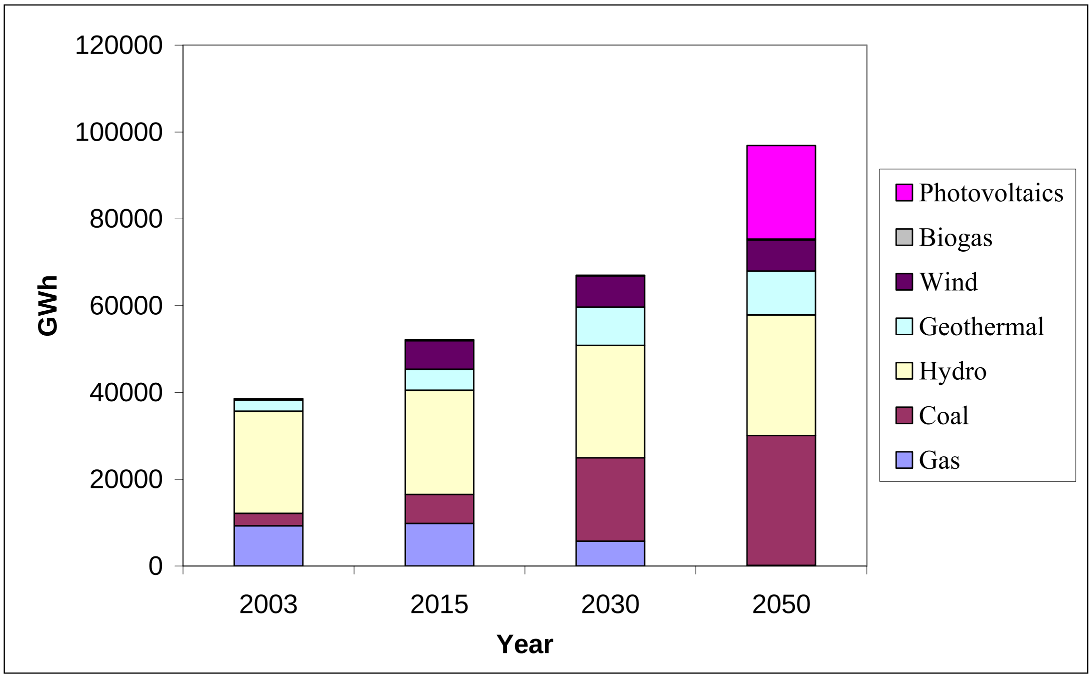


Figure 5.2 Scenario A – Generation by source 2004 (actual), 2015, 2030, and 2050



66 Reserve generation (which is assumed to be coal) and Whirinaki are included in the graph showing capacity but not in the graph showing generation.

5.2 Scenario B – *Sparking new designs*

Table 5.4 Demand and generation 2015

	MW capacity	GWh / year
Projected demand in 2015		39513
Less: Demand met through biomass use in the forestry sector		272
		39241
Generation required to meet this demand		45127
Generation in 2003		40029
Additional generation required		5099
Plus: 20 % reserve margin		1020
		6118
Plus: Plants retired		
New Plymouth Gas	400	1813
New generation to be installed		7932
Sources of new generation:		
Landfill gas		70
Wind	792	3083
Geothermal	285	2250
Hydro	0	0
Coal	0	0
Gas	385	2529
Total new generation	1462	7932

Note:

The gas station developed is the E3P project at Huntly. With greater community resistance and less pressure for supply, Marsden B is not converted into a coal station. Wind is the most cost-competitive source of further generation; however, the amount of construction required is significantly less than in Scenario A. Moreover, with less pressure for supply, the small-scale hydro development that has taken place in Scenario A is postponed.

Table 5.5 Demand and generation 2030

	MW Capacity	GWh / year
Projected demand in 2030		40499
Less: Demand met through biomass use in the forestry sector		679
		39820
Generation required to meet this demand		45794
Generation in 2003		40029
Additional generation required		
2004–2015		5099
2016–2030		667
		5765
Plus: 20 % reserve margin		1153
		6918
Plus: Plants retired		
2004–2015: New Plymouth Gas	400	1813
2016–2030: TCC and Otahuhu B	737	4842
Reduced use of Huntly (coal)	250	1643
Total retirement	1387	8298
New generation to be installed		
2004–2014		7932
2015–2029		7285
Total new generation to be installed		15217
Sources of generation:		
Landfill gas		70
Wind		
Installed 2004–2014	792	3083
Installed 2015–2029	835	2814
Total new wind generation	1627	5897
Geothermal		
Installed 2004–2014	285	2250
Installed 2015–2029	476	4000
Total new geothermal generation	761	6250
Hydro		
Installed 2004–2014	0	0
Installed 2015–2029	100	470
Total new hydro generation	100	470
Coal		
Installed 2004–2014	0	0
Installed 2015–2029	0	0
Total new coal generation	0	0

	MW Capacity	GWh / year
Gas		
Installed 2004–2014	385	2529
Installed 2015–2029	0	0
Total new gas generation	385	2529
Total new generation		15216

Note:
The hydro generation that was postponed is undertaken in this period. Wind development continues to be the most cost-effective source of generation. With less pressure for supply, coal-fired operations at Huntly are reduced, and an overhaul of the plant restores it to only 750 MW capacity.

Table 5.6 Demand and generation 2050

	MW capacity	GWh / year
Projected demand in 2050		40462
Less: Demand met through biomass use in the forestry sector		921
		39541
Generation required to meet this demand		45472
Generation in 2003		40029
Additional generation required		
2004–2015		5099
2016–2030		667
2030–2050		-322
		5444
Plus: 20 % reserve margin		1089
		6532
Plus: Plants retired		
2004–2015: New Plymouth Gas	400	1813
2016–2030: TCC, Otahuhu B, and reduced use of Huntly (coal)	987	6485
2031–2050: All remaining thermal stations	1536	6701
Total retirement	2923	14999
New generation to be installed		
2004–2014		7932
2015–2029		7285
2030–2049		6314
Total new generation to be installed		21531

	MW capacity	GWh / year
Sources of generation:		
Landfill gas		70
Wind		
Installed 2004–2014	792	3083
Installed 2015–2029	835	2814
Installed 2030–2050	250	716
Total new wind generation	1877	6613
Geothermal		
Installed 2004–2014	285	2250
Installed 2015–2029	476	4000
Installed 2030–2050	158	1250
Total new geothermal generation	919	7500
Hydro		
Installed 2004–2014	0	0
Installed 2015–2029	100	470
Installed 2030–2050	0	0
Total new hydro generation	100	470
Coal		
Installed 2004–2014	0	0
Installed 2015–2029	0	0
Installed 2030–2050	0	0
Total new coal generation	0	0
Gas		
Installed 2004–2014 (retired between 2030-2050)	385	2529
Installed 2015–2029	0	0
Installed 2030–2050	0	0
Total new gas generation	385	2529
Wave power	100	350
Photovoltaics		
Installed 2030–2050		3998
Total new generation		21530

Note:

Landfill gas, geothermal, and hydro development are dictated by the resource availabilities described in Section 3. As discussed in Section 4, thermal stations are gradually phased out during this period. Additional generation needed later in this period is from photovoltaics, replacing old thermal stations. If the cost of photovoltaics has not decreased by as much as assumed, then New Zealand is in a stronger position than in Scenario A to use other cost-effective sources. By 2050 a diverse range of renewable sources provides all of New Zealand's electricity generation.

5.2.1 Comparison of 2004, 2015, 2030, and 2050[67]

Figure 5.3 Scenario B – Installed capacity 2004 (actual), 2015, 2030, and 2050

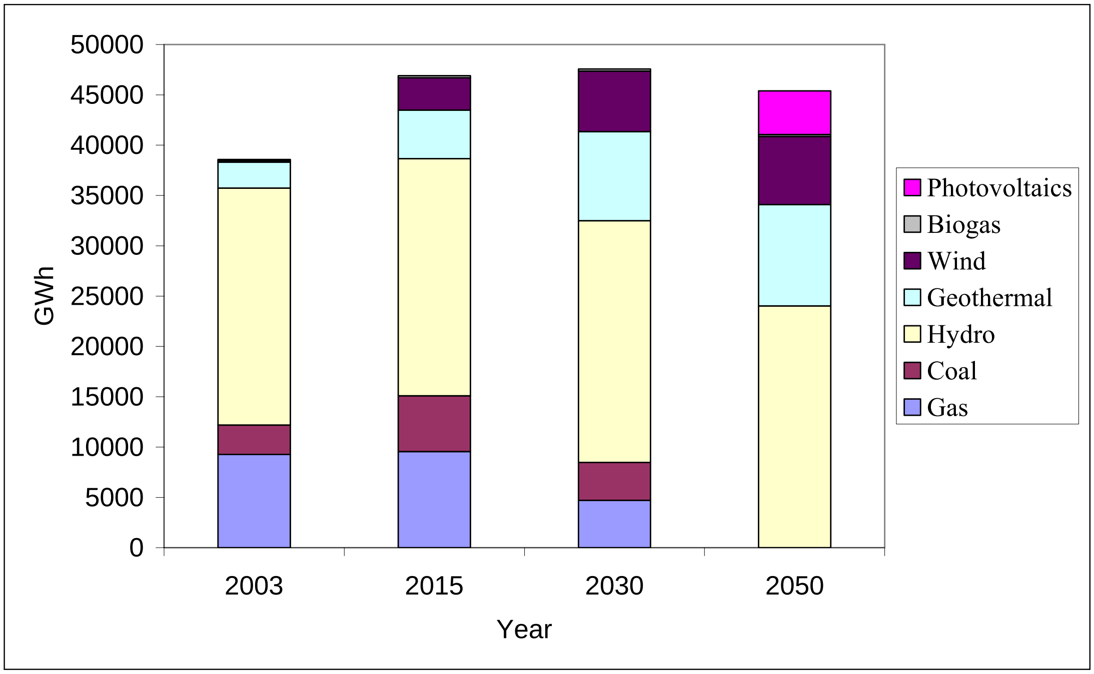
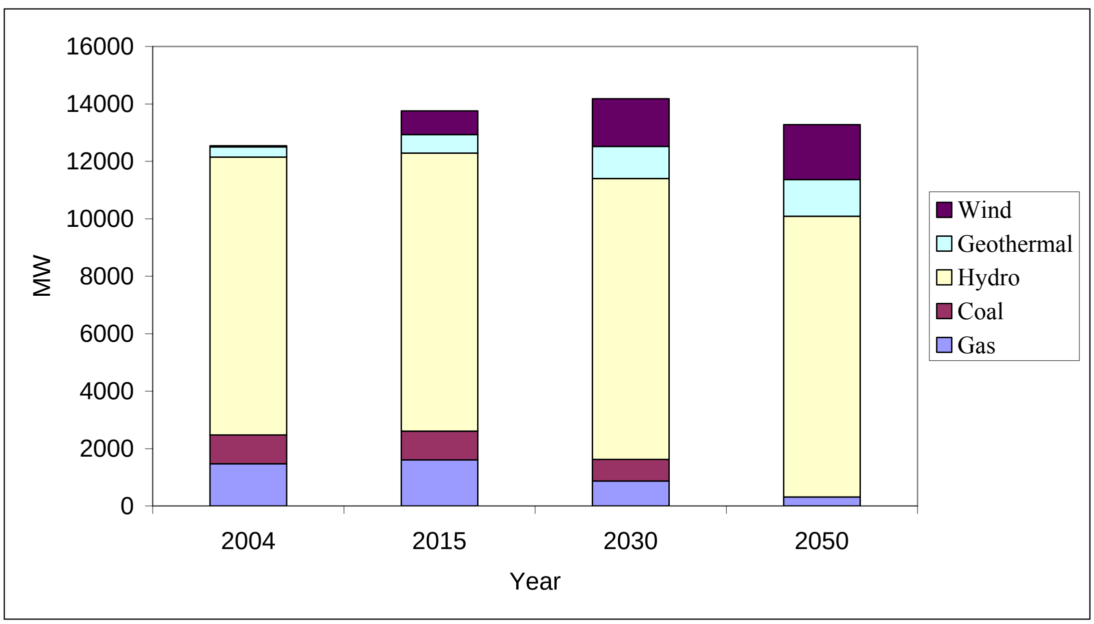


Figure 5.4 Scenario B – Generation by source 2004 (actual), 2015, 2030, and 2050



[67] Reserve generation (which is assumed to be coal) and Whirinaki are included in the graph showing capacity but not in the graph showing generation.

6 Comparison of Scenarios A and B[68]

Figure 6.1 Scenarios A and B – Comparison of installed capacity 2004 (actual), 2015, 2030, and 2050

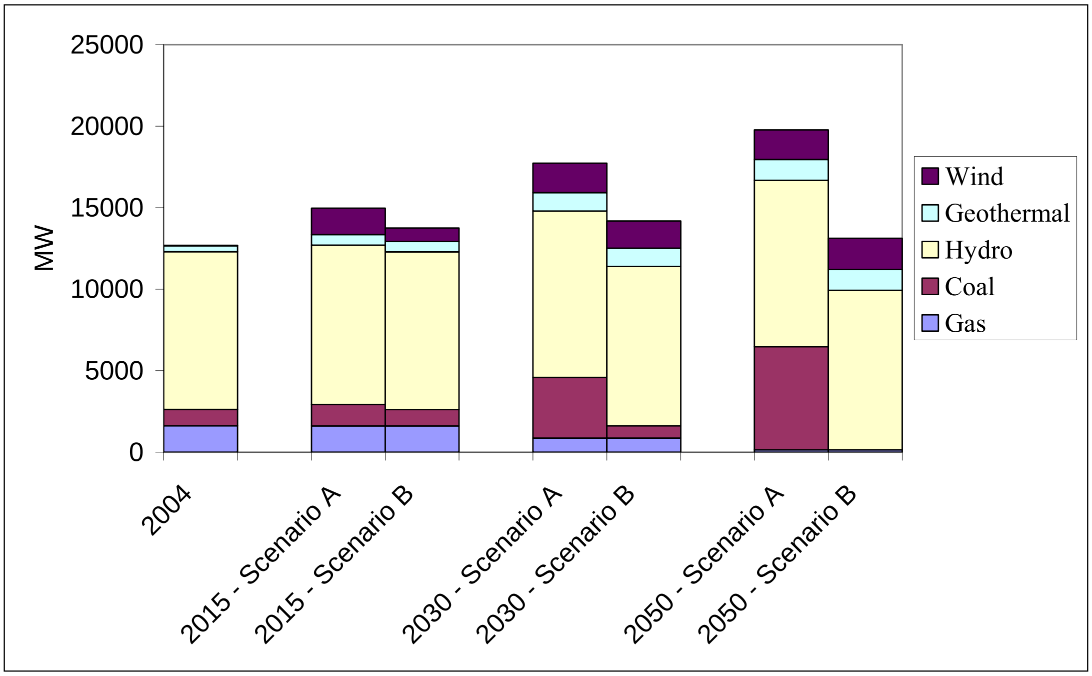
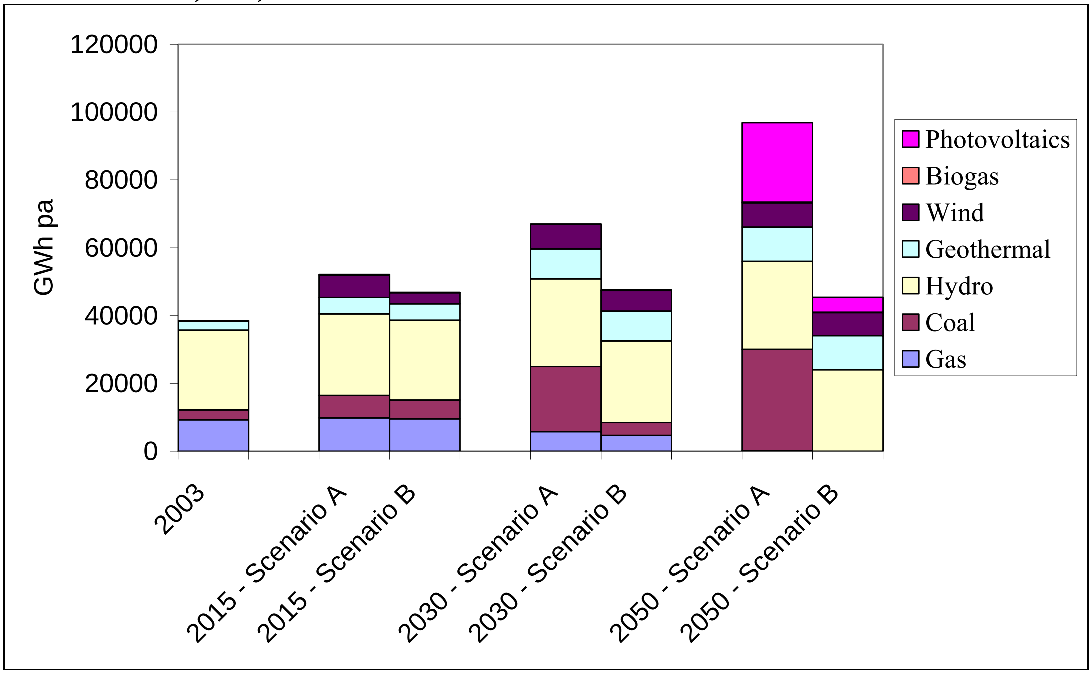


Figure 6.2 Scenarios A and B – Comparison of generation by source 2004 (actual), 2015, 2030, and 2050



[68] Reserve generation (which is assumed to be coal) and Whirinaki are included in the graph showing capacity but not in the graph showing generation.

References

Build Magazine, September 2004.

Building Research Association of New Zealand. 2002. *Report on the year 6 analysis for the Household Energy End-use Project (HEEP)*. SR115.Wellington: BRANZ.

Building Research Association of New Zealand. 2003. *Energy use in New Zealand households – Report on year 7 of the Household Energy End-use Project (HEEP)*. SR122. Wellington: BRANZ.

Carnahan, W H, et al. 1974. *Efficient Use of Energy, a Physics Perspective Use*. Efficient Energy Use Vol. 25 of the American Institute of Physics Conference Proceedings.

Concerted Action on Offshore Wind Energy in Europe (CA-OWEE). 2001. *Offshore wind energy – Ready to power a sustainable Europe, Final Report*. Delft University of Technology, The Netherlands. http://www.offshorewindenergy.org/ca-owee/indexpages/downloads/CA-OWEE_Resources_Economics.pdf [Last accessed 17 March 2005].

East Harbour Management Services. 2002. *Availabilities and costs of renewable sources of energy for generating electricity and heat*. Wellington: Ministry of Economic Development.

East Harbour Management Services. 2002. *Costs of fossil fuel generating plant*. Wellington: Ministry of Economic Development.

East Harbour Management Services. 2004. *Waters of national importance – Identification of potential hydro electric resources*. Wellington: Ministry of Economic Development.

Energy Efficiency and Conservation Authority (EECA). 2001a. *Energy from woody biomass in New Zealand*. Wellington: EECA.

Energy Efficiency and Conservation Authority (EECA). 2001b. *Review of New Zealand's wind energy potential to 2015*. Wellington: EECA.

Energy Efficiency and Conservation Authority (EECA). 2001c. *Solar energy use and potential in New Zealand*. Wellington: EECA.

Environment Waikato, *Proposed variation No. 2 (geothermal) to proposed WRP decisions version*, 12 June 2004. Hamilton: Environment Waikato.

Frazer, S. 2004. *Sustainable Energy Futures Project Stage 1 Report*. Wellington: New Zealand Business Council for Sustainable Development and Frazer Lindstrom Limited.

Hall, M. 2004. *Existing and potential geothermal resource for electricity generation*. Wellington: MED. http://www.med.govt.nz/ers/environment/water-bodies/geothermal/geothermal.pdf [Accessed: 24 February 2005].

International Energy Authority (IEA) Coal Industry Advisory Board. 2003. *Meeting with IEA Governing Board, Wednesday 10 December 2003, Background Paper*. Paris: IEA. http://www.iea.org/Textbase/Papers/2003/ciab_cct.pdf [Last accessed 17 March 2005].

Leyland, Bryan. 2004. *New Zealand's load growth from 1974 and expected demand to 2025*. Christchurch: Centre for Advanced Engineering.

Lovins A. 2004. 'Energy efficiency, taxonomic overview' in *Encyclopedia of Energy: Volume 2*. Oxford: Elsevier.

Mighty River Power Limited Press Release. Available at www.mightyriverpower.co.nz/news_events/news/18-08-04_marsden_point.asp [Last accessed 23 September 2004].

Ministry of Economic Development (MED). 2003. *Availabilities and costs of sources of energy for generating electricity: Technical note, October 2003*. Wellington: MED. http://www.med.govt.nz/ers/electric/generation-sources/ [Last accessed 21 June 2005].

Ministry of Economic Development (MED). 2004. *Energy data file, July 2004*. Wellington: MED.

Ministry of Economic Development (MED). 2004. *Existing and potential geothermal resource for electricity generation*. Available at http://www.med.govt.nz/ers/environment/water-bodies/geothermal/geothermal.pdf [Last accessed 23 June 2005].

Ministry of Economic Development (MED). 2003. *New Zealand energy outlook to 2025*. Wellington: MED.

Motu and East Harbour Management Services. 2002. *Renewable energy and the efficient implementation of New Zealand's current and potential future greenhouse gas commitments*. Wellington: Motu. http://www.motu.org.nz/pdf/Dynamic_Efficiency_1.pdf [Accessed 17 March 2005].

Parliamentary Commissioner for the Environment (PCE). 2005. *Future Currents: Electricity scenarios for New Zealand 2005–2050*. Wellington: PCE.

Rosenfeld A, et al. 2004. *'Energy efficiency and climate change' in Encyclopedia of energy: Volume 2*. Oxford: Elsevier.

Saddler H, Diesendorf M, and Denniss R. 2004. *A clean energy future for Australia*. Sydney: WWF Australia.

Sanders I, Gardiner A, Penny G, and Gorman R. 2003. *New Zealand wave energy potential: Riding the crest of a wave or gone with the wind?* Christchurch: Industrial Research Limited and National Institute for Water and Atmospheric Research. http://www.irl.cri.nz/electrotec/downloads/IDES%20Applications/NZ-Wave-Energy-Potential.pdf [Last accessed 23 June 2005].

Solid Energy, Concept Consulting, and NZIER. 2004. Energy options: *Securing supply in New Zealand*. Christchurch: Solid Energy Limited.

Statistics New Zealand. 2003. *New Zealand family and household projections 2001 (base)–2021*.Wellington: Statistics New Zealand. http://www.stats.govt.nz/analytical-reports/nz-family-hholds-projections.htm [Last accessed March 2005].

Turner W. 2004. *Energy Management Handbook*. Lilburn: Fairmont Press.