Prepared for

Parliamentary Commissioner for the Environment

Microgeneration Potential in New Zealand

A Study of Small-scale Energy Generation Potential

by

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Executive summary

The study of the New Zealand's potential for micro electricity generation technologies (defined as local generation for local use) in the period up to 2035 shows that a total of approximately 580GWh per annum is possible within current Government policies. If electricity demand modifiers (solar water heating, passive solar design, and energy efficiency) are included, there is approximately an additional 15,800GWh per annum available. In total, around 16,400GWh of electricity can be either generated on-site, or avoided by adopting microgeneration of energy services.

The study has considered every technology that the authors are aware of. However, sifting the technologies reduced the list to those most likely to be adopted to a measurable scale during the period of the study. The definition of micro electricity generation technologies includes

- those that generate electricity to meet local on-site energy services, and
- those that convert energy resources directly into local energy services, such as the supply of hot water or space heating, without the intermediate need for electricity.

The study has considered the potential uptake of each technology within each of the periods to 2010, 2020, and 2035. It also covers residential energy services and those services for small- to medium-sized enterprises (SMEs) that can be obtained by on-site generation of electricity or substitution of electricity.

The study assumes that all current energy related Government policies and strategies are implemented and the expected outcomes are achieved. This includes the National Energy Efficiency and Conservation Strategy (NEECS) and, more specifically, the expectation that a Home Energy Rating Scheme (HERS) of some form will be in place by 2010. These policies have been announced and therefore we have assumed that they will be implemented and the expected outcomes will be achieved.

Other policies could be introduced that could increase the uptake of microgeneration, but such analysis is beyond the scope of this project.

For the purposes of this assessment, microgeneration was assumed to be any positive generation (or 'fuel' substitution) from zero to upper limits in the one-megawatt thermal (1-MW_{th}) region for heat, and in approximately the 300–500-kilowatt (300–500-kW_e) region for electricity (1MW = 1,000kW). Both grid-connected and stand-alone technology options were considered.

The study provides a baseline profile of current expectations for the uptake of each technology. It considers the economies of scale that will eventuate and the position of each technology in its development phases, but it does not analyse what the potential may be under different Government policies. It also assumes that the energy price increases that may affect the actual level of uptake during the 30-year period are consistent with today's price relativities. Clearly, during the 30 years there will be significant real price increases that will affect specific technologies and thus individual investment decisions.

Table 1 summarises the results of the study by technology for both residential and commercial/industrial applications.

Table 1 Energy from microgeneration services (GWh) – residential

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
Photovoltaic (PV)	0.1	5.1	42
Combined heat Power (CHP)	0.3	0.8	23
Micro hydro	0.2	0.7	14
Wind	3.0	10	64
Wind rooftop	0.2	7.0	29
Total electricity generation	**3.6**	**23.2**	**172**
Pellet burner	27	143	401
Wood burner	61	179	366
Heat pump	182	440	1,304
Heat-pump water heaters	3	112	603
Direct geothermal heating	?	?	?
Solar water heaters	115	927	1,893
Total heat generation	**387**	**1,800**	**4,568**
Ceiling insulation	120	177	243
Water heating efficiency	11	33	152
Passive solar design (retrofit)	54	107	321
Passive solar design (new)	116	231	693
Double glazing (retrofit)	11	21	64
Double glazing (new)	71	282	679
Total energy efficiency	**382**	**852**	**2,152**
Residential total	**772**	**2,675**	**6,891**

Within the residential sector it would appear that microgeneration of electricity will have less uptake than the provision of local energy services by substitutes for electricity. The most significant technologies are heat pumps for space heating, solar water heating, heat pumps for water heating, and the incorporation of passive solar design in new dwellings.

In the SME sector the provision of heat services from solar, geothermal or bioenergy resources allows substitution for the use of electricity, but the gains from improvements to equipment in the efficiency of energy use are most significant.

Within both residential and SME sectors the common trend is for the substitution of electricity for the delivery of heat services. This is consistent with recent similar studies[1] in Europe where heat is the principal driver for microgeneration.

Table 2 Energy from microgeneration services (GWh pa) – industrial/commercial

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
PV	0.3	15.4	127
CHP	0.5	1.6	68
Micro hydro	0.5	1.4	27
Wind	5.7	20.0	127
Wind rooftop	0.4	13.2	58
Total electricity generation	**7.7**	**51.4**	**408**
Pellet burner	2	5	13
Industrial combustors	4	4	25
Heat pump	380	950	2,836
Direct geothermal heating	?	?	?
Heat-pump water heaters	2	15	51
Solar water heaters	123	290	508
Organic Rankin cycle	0	6	18
Anaerobic digesters	0	1	2
Total heat generation	**510**	**1,270**	**3,453**
Wind pumping	2	7	21
Hydro pumping	?	?	?
Total motive power	**2**	**7**	**21**
Energy management and equipment efficiency	719	2,388	5,603
Total energy efficiency	**719**	**2,388**	**5,603**
SME total	**1,237**	**3,712**	**9,485**

[1] Reference DTI – 2006

Table 3 shows the total potential supply of local energy services by microgeneration of electricity and electricity demand modification.

Table 3 Total potential supply of local energy services by microgeneration (GWh pa)

	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
Micro electricity generation: residential	4	23	172
Micro electricity generation: SMEs	7	51	408
Total micro electricity generation	**11**	**74**	**580**
Micro heat generation: residential	387	1,800	4,568
Micro heat generation: SMEs	510	1,270	3,453
Total micro heat generation	**897**	**3,070**	**8,021**
Energy efficiency: residential	382	852	2,152
Energy efficiency: SMEs	719	2,388	5,603
Total energy efficiency	**1,101**	**3,240**	**7,755**
Total motive power	**2**	**7**	**21**
Total	**2,009**	**6,387**	**16,375**

Contents

1 Introduction

1.1 Purpose and context

The Parliamentary Commissioner for the Environment (PCE) has commissioned an assessment of the potential for microgeneration of energy services in New Zealand.

The Commissioner is focusing on microgeneration because of advances in these technologies, together with advances in the metering and monitoring systems, all of which may assist with future electricity supply.

The Commissioner considers that microgeneration systems can also make a significant contribution to improving New Zealand's environmental sustainability.

The objectives of this project are to assess the potential of microgeneration in New Zealand by:

- identifying which microgeneration technologies could currently be applied
- calculating realistic and defendable estimates of the potential for microgeneration in the short (0–5 years), medium (5–10 years), and long term (up to 30 years).

The study covers residential energy services and those services for SMEs that can be obtained by on-site generation of electricity or substitution of electricity.

The study of the New Zealand–wide potential for micro electricity generation technologies is based on current Government policies. It assumes critical policies including that current Government National Energy Efficiency and Conservation Strategy (NEECS) initiatives are achieved and, in particular, that a Home Energy Rating Scheme (HERS) of some form is adopted by 2010. These policies have been announced policies and are believed to be achievable.

The study provides a baseline profile of current expectations for the uptake of each technology. It considers the economies of scale that will eventuate and the position of each technology in its development phases, but it does not analyse what the potential may be under different Government policies. It also assumes that the energy price increases that may affect the actual level of uptake during the 30-year period are consistent with today's price relativities. Clearly, during the 30 years there will be significant real price increases that will affect specific technologies and thus individual investment decisions.

1.2 Definition of microgeneration

For the purposes of this study, microgeneration is defined in a broad sense based on delivery of energy services and includes generation of electricity, heat, or motive power on a small scale. This covers a range of applications and technologies, some of which are really modifiers of local electricity demand. This definition is consistent with those used in similar studies in Europe[2].

The scale has been defined based on the application rather than a fixed size. The applications to be considered include:

- single households and neighbourhood networks
- small rural communities
- farms and other rural businesses
- small- to medium-sized enterprises and community facilities.

The study focuses on modular technologies that can be installed close to the point of demand. Although both renewable and non-renewable energy resources have been included, the Commissioner is especially interested in systems that can use local renewable energy resources to deliver local energy services, or have the potential to enable a transition from non-renewable to renewable energy resources at a similar scale.

Both grid-connected and stand-alone technology options have been considered.

For the purposes of this assessment, microgeneration was assumed to be any positive generation (or 'fuel' substitution) from zero to upper limits in the one-megawatt thermal (1-MW_{th}) region for heat, and in approximately the 300–500-kilowatt (300–500-kW_e) region for electricity (1MW = 1,000kW).

In the case of renewable energy (e.g. geothermal, hydro, and wind), the location of resources can drive microgeneration e.g. Local use is also a driver (e.g. using geothermal energy for space and water heating in houses and commercial premises in parts of Taupo and Rotorua).

Microgeneration can be either grid connected or operate off grid. Associated storage of either the 'fuel' (e.g. a reservoir upstream of a micro hydro) or the output (e.g. batteries, an ice bank for refrigeration) is likely to be much more significant for off-grid microgeneration where renewable resources are used.

In some cases, microgeneration will include a systems approach to ensure the viability of microgeneration meeting the need of the host (e.g. using photovoltaic [PV] technology invariably requires a battery bank or other storage unit to provide an on-demand availability of electrical power or the product being pumped by the PV output). In some other circumstances, storage, although not essential to meet the needs of the host, may add to the value of the microgeneration by optimising unit sizes.

[2] Reference DTI – 2006

1.3 Methodology

The project was divided into two distinct stages, with intermediate phases to allow for close discussion on findings with PCE staff throughout the project. A project such as this requires involvement of all interested parties so that effort is expended on appropriate technologies within the budget for each part. This required East Harbour staff to work closely with PCE staff.

The effort also needed to be managed within the agreed budget for each stage. This was achieved by consultation at the end of each phase on the priorities for the subsequent stages.

Stage 1 – Technology identification

Stage 1 involved identifying all known microgeneration technologies/systems that are feasible in New Zealand. The technologies were evaluated from the perspective of expected uptake for technologies that are currently feasible; expected technology uptake in 5–10 years time; and expected technology uptake in 30 years time.

The assessment is based on technical feasibility; cost and scale of potential applications; and current and announced Government policies. It is assumed that NEECS initiatives were achieved; in particular, that a HERS was adopted and became effective from 2010. No policies on climate change were assumed, because at the time of this study no decisions on the climate change policy review had been announced.

A list of the technologies identified is provided in Appendix A. This list was discussed with PCE staff to confirm which technologies to include in stage 2. It includes technologies that have been excluded from the study, and an explanation of why they have been excluded.

The microgeneration technologies are grouped as follows:

- efficiency – technologies or concepts that mostly focus on reducing primary energy use
- electricity – specific technologies along with some brands considered representative of a particular technology
- heat (also cooling/refrigeration) – heat generation technologies such as solar water heaters and passive solar design
- combined heat and power (CHP) – technologies for delivering CHP are included in the electricity group
- pumping – technologies that deliver energy directly used for pumping fluids (essentially motive power that is not transport related). Specific non-pumping mechanical applications (e.g. wind- or water-powered flour mills) are not included as these are considered ‘boutique’ applications.

Technologies that were not assessed include:

- marine (considered not viable on a systems basis at outputs less than a 500-kW_e limit)
- transport (microgeneration assumes a host site with a fixed location).

Stage 2 – Technology assessment

A selected number of technologies were analysed in detail to test the methodology. The installed cost for each technology was determined based on present-day costs.

The estimated cost of energy from each system was then calculated. This calculation included the initial capital cost, running costs (maintenance and fuel), efficiency, and expected system lifetime based in part on warranty details.

The energy cost data was then compared with current and projected energy prices to inform estimates of the expected technology uptake for each of the specified time frames.

The technology uptake estimates are also based on:

- available primary energy resources
- number of suitable applications
- expected technology improvements and cost reductions over time.

Assumptions about the level of intervention by Government and other parties will influence the probable rate of uptake.

A key factor that is expected to influence this uptake is the expiry of the current requirement for electricity distribution/network companies to supply line-function services to all existing customers. Section 62 of the Electricity Act 1992 requires electricity distributors to continue to supply existing customers, except by written agreement with the affected customer or customers. Currently this section of the Act will expire on 1 April 2013. It is expected that the Ministry of Economic Development will review the expiry of this requirement this year. But for the purposes of this assessment we have assumed that this section of the Act will remain unchanged.

The technologies were applied to residential, commercial, and industrial applications of the appropriate scale.

1.4 Key assumptions

1. Experience or learning curves from other studies were used to determine the expected cost reduction of technologies over time. This was based primarily on figures from the ‘Potential for Microgeneration Study and Analysis’ 2005 United Kingdom. This was supplemented with data available from the International Energy Agency (IEA) and other sources.
2. Capital costs were annualised for the lifetime of the technology; the warranty period was used to influence the estimated lifetime of the equipment.
3. A discount rate of 5% was used to analyse each technology where applicable.
4. An inflation of 2% was assumed.
5. A tax rate of 0% was applied because it was assumed that most of the technologies would be used in residential applications.
6. A depreciation rate of 5% was applied to all capital expenditure.
7. Energy costs (electricity, gas, and coal) were based on data from the Ministry of Economic Development’s Energy Data File and Energy Outlook.

8. To determine the value of surplus energy generated it was assumed
   - that the value of surplus heat is zero.
   - that the value of surplus electricity generated is the same as the purchase price.
9. Details of the number of households in New Zealand were determined from Statistics New Zealand data.
10. The number of houses is assumed to increase at a rate of 1.14% per year (this is based on the average percentage increase over the past 10 years)
11. It is assumed that 90% of new houses are owner occupied, while the remaining 10% are rental properties.
12. It is assumed that the rate of demolition, or removal of dwellings from use in housing, is 25% of the rate of new builds.

2 Technology identification

All microgeneration technologies identified are listed in Appendix A.

2.1 Electricity generation technologies

The electricity generation technologies selected for further investigation in stage 2 are listed in Table 4 below.

Table 4 Electricity generation technologies selected for assessment

Source	Technology
Wind	Rooftop turbines
	Pole-mounted micro turbines
Hydro	Micro hydro (impulse turbines)
Solar	Photovoltaic (on-grid)
	Photovoltaic (off-grid)
Gas CHP	Stirling engine (Whispertech)
	Fuel cells
Petrol	Reciprocating engine (Honda)
Biofuels	Organic Rankine cycle (Adoratec[3])

[3] Adoratec ORC units are supplied by Key Energy in New Zealand

2.2 Heat generation technologies

The heat generation technologies selected for further investigation in stage 2 are listed in Table 5 below.

Table 5 Heat generation technologies selected for assessment

Source	Technology
Solar	Solar water heaters
Heat pumps	Water heating (air-source)
	Space heating
Geothermal	Direct use
Biofuels	Wood burners
	Pellet burners (Nature's Flame)
	Industrial combustors (Bio T-Burner[4])
	Anaerobic digestion

2.3 Motive power technologies

The motive power technologies selected for further investigation in stage 2 are listed in Table 6 below.

Table 6 Motive power technologies selected for assessment

Source	Technology
Wind	Direct water pumping
Hydro	Direct water pumping

2.4 Energy efficiency opportunities

The energy efficiency technologies selected for further investigation in stage 2 are listed in Table 7 below.

Table 7 Energy efficiency technologies selected for assessment

Source	Technology
Solar	Passive solar design improvements
Electricity	Water heating efficiency improvements
	Motors and equipment efficiency improvements
All fuels	Ceiling insulation improvements
	Double glazing

2.5 Energy storage technologies

Energy storage technologies are described in Section 4 of this report. These have not been assessed in the same way as the microgeneration technologies because they are enabling technologies, which mean they can have an impact on the rate of uptake of several different microgeneration technologies.

[4] Bio T-Burner units are supplied by Living Energy in New Zealand

3 Technology assessment

3.1 Rooftop wind turbines

Description

A rooftop wind turbine involves mounting a propeller unit on a house with direct connection to the internal electricity supply. The unit comprises the turbine, a power inverter to convert to AC supply, and appropriate electronics to match the frequency of the grid-supplied electricity. Simply plugging into a normal household outlet connects some units. The difference in these designs from other wind turbines available for boats etc is that these are a total plug-in package.

It is unlikely that such a small turbine would provide sufficient electricity to meet a household's needs. It would usually be used as a grid-connected option acting as an on-site electricity demand modifier.

At times when additional electricity is required, the household would purchase it from the local distribution network. When surplus electricity is available, the household might be able to export this surplus back into the network.

The main development of rooftop wind turbines has been in Scotland. Two companies are now selling units for domestic use:

- Renewable Devices Ltd, Edinburgh, who manufacture the Swift unit with a blade diameter of 2m and a maximum rated output of 1.5kW[5]

- Windsave Ltd, Glasgow, whose unit has a blade diameter of 1.75m and a maximum output of 1kW.

Both units claim to be 'quiet' with vibration-free mountings.

Application details

Some people would welcome the opportunity to mount wind turbines on their houses. There is potential for widespread uptakes if district plans allow it, the units are reliable, and they can be supplied and installed cost-effectively.

Both the Scottish turbines were launched in 2004 and have received a lot of publicity and increasing sales. Applications to date have included individual residential installations and multiple turbine sites. The largest of these is in Manchester where Co-operative Financial Services are mounting 19 Windsave turbines around the roof of their 13-storey office building.

Rooftop turbines are currently being manufactured and installed in the United Kingdom, but they are not yet available for import to New Zealand.

[5] Reference http://www.renewabledevices.com/swift/SWIFT%20Rooftop%20Wind%20Energy%20System.pdf

Noise

Special consideration must be given to the noise levels that rooftop wind turbines produce. The Swift turbine claims noise levels are less than 35dB at all operational wind speeds. The Windsave unit produces noise at 52dB at 5m from the turbine in 7m/s winds. Under New Zealand's Resource Management Act 1991 (RMA), people are not allowed to make 'excessive' noise and must ensure that noise from their property does not reach an 'unreasonable' level. The allowable noise levels are not specified in the RMA but they may be specified in local by-laws. A reasonable daytime level is generally regarded as below 40dB at a residential boundary as an average, with lower levels at night. Noise from the Swift unit may be acceptable, but there could be problems using the Windsave turbine in urban residential areas.

Capital cost

Published prices for the Swift and Windsave units show that they have an installed cost of about one pound per watt, so the cost in New Zealand could be as low as $3 per watt. Grants schemes are available in the United Kingdom that cover 30–100% of the installed cost.

Operating costs

Manufacturers claim that there are no annual operating costs other than maintenance, and that these costs will be minimal. However, experience of small turbines in New Zealand wind conditions indicates that some significant maintenance could be necessary in some situations. Turbulence in close proximity to buildings may also cause high structural stresses with resulting increased maintenance.

Lifetime

The expected lifetime for these units is stated as between 10 and 20 years. Fifteen years has been assumed in the present study.

Assumptions

1. Estimated annual output of 2,000kWh
2. Installed cost $4,500
3. Estimate economic lifetime of 15 years
4. Maintenance costs 2%.

Summary

Table 8 Summary information on roof-mounted wind turbines

Technology/measure	Roof-mounted wind turbine
Capital cost	$4,500
Annual operating cost	2% of capital cost ($90/year)
Annual energy savings	2,000kWh
Economic lifetime	15 years
Unit cost	25.8 cents/kWh

Barriers

The need to obtain resource consent to install a roof-mounted wind turbine will limit uptake, particularly in residential areas. Obtaining acceptable resource consents for wind turbines is regarded as a significant barrier to future development.

Noise from the Windsave unit may be considered excessive in urban areas. Their use may need to be restricted in higher wind speeds and this is likely to significantly affect their economics.

Despite being cheaper, the maintenance on wind turbines will most likely be significantly greater than other on-site electricity demand modifiers such as PV cells. This may limit uptake to those homeowners prepared to maintain them.

This technology has not yet been proven over the turbines' full economic lifetime.

Payment for electricity exported from site would be needed to encourage the uptake of this technology.

Assessed uptake

A real possibility to widely apply this technology exists if the identified barriers can be addressed. The most significant barrier is that the technology is not currently available in New Zealand. This application of micro wind power is in the early stages of its product life cycle. If reliable, quiet, low-cost units do become available in New Zealand, the number of installations is expected to be significant.

It is possible that cheaper technology will be developed soon. The Chinese are already producing similar-sized low-voltage turbines for installation on remote masts at about one-third of the above costs. However, the turbines' long-term reliability has not yet been proven and they currently do not have the technology required for connection to the mains.

It has been assumed that the uptake for rooftop wind turbines will be significant as soon as the price, availability, and installation issues can be resolved. In terms of the number of installed systems, it has been assumed they will have a medium level of uptake.

Several installs of rooftop wind turbines have been completed in the United Kingdom, but these units are not yet available for export.

Because of the environmental issues surrounding their installation and their cost compared to the retail electricity price, we have assumed that this technology will be taken up mainly in rural areas. It is not yet available here, so we have also assumed that its uptake would be low in the next 5 years. This will change as the technology becomes readily available and its reliability is proven.

In the residential sector, we have assumed there will be 11,200 installations during the next 30 years, supplying 29GWh per annum. This assumes that rural residential areas will be a significant location for uptake, but that there will be little uptake in high-density urban areas.

We have estimated that the uptake in the SME sector will be twice that of the residential sector. This is because of tax benefits to SMEs, and the location of turbines in commercial/industrial areas where noise and other consent aspects are less of an issue. SMEs also have electricity load patterns that will allow site-generated electricity to be embedded to meet strong economic drivers.

3.2 Stand-alone micro wind

Description

The use of stand-alone turbines larger than those suitable for mounting on houses has a long history, both in New Zealand and overseas. Most installations are at remote sites and often off-grid. The ability to be grid-connected and to supplement the existing electricity supply requires electronic inverters. Unlike the larger grid-connected wind turbines that generate electricity with voltage and frequency control, small wind turbines for remote applications are usually optimised for battery charging. Inverters to generate AC electricity can in turn use this battery power.

Units are available in many sizes. In North America, 10kW is a common size and only in recent months have units down to 1kW been developed for these markets. In a remote location, noise is unlikely to be a significant problem, with the owners often the only residence affected.

Most micro turbines are of the horizontal axis, propeller type; however, horizontal scroll and vertical axis turbines (VAWT) are also produced. Solwind in Whangarei manufactures vertical axis units using the Darrieus principle with outputs up to 30kW on a 12-m-high tower. There are few VAWT machines still manufactured.

Eco Innovation in Taranaki has developed a small propeller wind turbine using the Smart Drive motor. It is also importing turbines from China. A number of other manufacturers are represented in New Zealand. The efficiency of these units is higher than for roof-mounted units, as they will be mounted higher and in optimal wind locations less affected by turbulence than those on buildings.

Wind energy output is very strongly influenced by the height of the hub above the ground. Durability is affected by turbulence and wind shear, although this is not such a problem with machines with small diameter blades.

Application details

Remote installations are likely to be in conjunction with other renewable generation means such as PV or micro hydro, or with diesel generation backup. There is the possibility of supplying electricity to multiple sites from larger wind turbines and this could introduce increased benefits from the larger scale. Bergey, an established US manufacturer who claims to be the world's largest supplier of small turbines, reports average efficiencies of about 20% on their website - http://www.bergey.com/. It is possible that better results could be achieved in some exposed sites in New Zealand.

Capital cost

Installed prices are higher than those of domestic-scale turbines because of the cost of providing a support structure, which may be 50% of the total, and because more reticulation might be required. Costs are presently in the range of NZ$5.00–$8.00 per watt capacity (based on Bergey and EECA figures).

Operating costs

Manufacturers claim that there are no annual operating costs other than maintenance. Under New Zealand conditions it should be expected that bearings would need to be replaced every 5 years. Blade damage is also likely during this period. Annual maintenance should be carried out with the unit lowered to the ground for inspection and repair.

Lifetime

The larger, pole-mounted turbines should be more durable than the rooftop units; however, some turbines installed previously have not fared well under New Zealand's extreme wind conditions. An economic lifetime of 15 years has been assumed. In practice, the economic lifetime will vary depending on location and the maintenance schedule.

Assumptions

1. A conventional propeller turbine with maximum 5kW output
2. Annual yield of 7,500kWh, based on figures published by Bergey in the USA (20% efficiency)
3. Installed cost $54,000
4. Cost of batteries not included for the grid-connected option
5. Fifteen per cent added to the capital costs to allow for batteries for the off-grid option
6. Estimated lifetime of 15 years
7. All electricity generated is used
8. Maintenance costs 1.5% of installed cost.

Summary

Table 9 Summary information on mast-mounted wind turbines

Technology/measure	5-kW mast-mounted wind turbine
Capital cost	$54,000
Annual operating cost	1.5 % ($1,350/year)
Annual energy savings	7,500kWh
Economic lifetime	15 years
Unit cost (on-grid)	78.5 cents/kWh
Unit cost (off-grid)	90.3 cents/kWh

Barriers

Costs now and into the foreseeable future do not justify installation at grid-connected sites. This study assumes mainly off-grid applications. This could change in the period 2020–2035 but that cannot be assumed.

Predictable wind power is not continuous and therefore cannot be relied upon solely. Wind generation works most effectively when incorporated into a system with other generation or supply options, often in conjunction with energy storage systems.

The ability to obtain resource consents for wind turbines is regarded as a significant barrier to future development. Consents can take 2 years or more if there are appeals.

Assessed uptake

Micro wind is a mature technology that forms a key part of many remote area power systems. The costs for on-grid applications are high when compared with other grid-connected options.

In some American states, rebates improve cost-effectiveness. Rebates vary from 30% to 70% depending on the local state policy and the application.

Because of the environmental issues (primarily noise) and the high cost compared to both the retail electricity price and other microgeneration options, it has been assumed that this technology will be taken up in low numbers and mainly in rural areas in New Zealand.

In the residential sector, it has been assumed there will be 7,150 off-grid installations during the next 30 years, supplying 127GWh per annum.

We have estimated that the uptake in the SME sector will be twice that of the residential sector. Resource consent issues are likely to be easier in remote locations and industrial areas. Small wind turbines may also be more cost-effective than extending the grid supply in some situations. In addition, businesses are likely to get tax benefits that are not available to residential customers.

3.3 Micro hydro

Description

Impulse turbines convert the water's kinetic energy into movement using a jet of water in the air. The jet of water strikes the turbine's buckets or blades and unlike other types of turbine there is no pressure reduction, as the water pressure is atmospheric on both sides of the impeller. Technologies include Pelton Wheels and Turgo turbines. Higher heads tend to be required for impulse turbines but they can be effective with lower water flows.

For the purpose of this report we have considered the EcoInnovation Smart Drive Turgo turbine unit. This New Zealand–built unit is at the low-priced end of the market, with imported units of comparable size costing three or four times as much. This unit is able to operate with head heights as low as 3m, although more than 5m is recommended. Installation costs will vary significantly depending on the location and stream conditions. Flow rates of 8–25 litres per second are required.

EcoInnovation also manufacturers a Pelton Wheel turbine, which will operate with flows as low as 0.25 litres per second but requires a head height of at least 10m.

For the purposes of this study. other technologies such as those of Hydro Venturi, are considered to be alternatives to the impulse turbine so are not included separately.

Application details

Remote installations are likely to be in conjunction with other renewable generation such as PV or wind power, or with diesel generation backup. Supplying electricity to multiple sites from hydro turbines is possible, and this could introduce increased benefits on a larger scale. The big advantage over wind is that water flow is almost always available so there is not the same need for electricity storage and other forms of backup.

The amount of electricity generated depends on the height and flow rate of the water. We have assumed an efficiency of 50% for this assessment.

Capital costs

The basic EcoInnovation 24-volt Pelton Wheel turbine sells for $1,100. A package including battery bank, inverter, and regulator costs $4,000 plus GST[6]. Installed prices will depend on the site's location and geography.

Operating costs

Operating costs should be minimal, but regular inspection and maintenance will be required. Maintenance costs are estimated to be 2% of the installed cost.

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[6] EcoInnovation website http://www.ecoinnovation.co.nz/

Lifetime

Equipment should have an operating life of 25 years.

Assumptions

1. Using EcoInnovation's Pelton Wheel turbine with maximum 1,000-W output
2. Average output 500W
3. Base load is more than 500W
4. Annual yield of 4,000kWh
5. Installed cost of $15,000
6. Cost of batteries are not included for the grid-connected option
7. We have added 15% to the capital costs to allow for batteries for the off-grid option
8. Estimated lifetime of 25 years
9. All electricity generated is used
10. Maintenance costs 2%.

Summary

Table 10 Summary information on micro hydro

Technology/measure	1-kW Pelton Wheel Micro Hydro
Capital cost	$15,000
Annual operating cost	2%
Annual energy savings	4,000kWh
Economic lifetime	25 years
Unit costs (on-grid)	34.6 cents/kWh
Unit costs (off-grid)	39.8 cents/kWh

Barriers

Restricted to rural sites where a suitable stream or river with adequate head is available.

Assessed uptake

If an off-grid location has a suitable water source available, micro hydro generation can provide a cost-effective source of electricity. It is unlikely to have many on-grid applications, although it can be integrated into a site electricity set-up and provide electricity demand modification.

In the rural residential sector we have assumed 3,200 installations during the next 30 years, supplying 14GWh per annum.

We have estimated that the uptake in the SME sector will be twice that of the residential sector. Micro hydro may be more cost-effective than extending grid supply in some rural locations. Businesses are also likely to get tax benefits that are not available to residential customers.

3.4 Photovoltaics

Description

Solar energy can currently be converted into electricity at a cost suitable for many small niche off-grid uses. PV electricity is already well established as a cost-effective solution in stand-alone applications in remote areas. The technology is advancing and is likely to be used increasingly for other applications during the next two decades.

Direct solar to electricity conversion can be carried out with PV cells. These are usually solid-state semiconductors that generate an electrical potential when exposed to light.

For complete functionality, PV modules require various components such as structural supports, charge controllers, inverters, batteries, and safety disconnects. There may be special metering requirements where export from site may occur.

PV systems are easily integrated into new or existing buildings for on-site generation; they are unobtrusive, can enhance the aesthetics and architectural appeal of buildings, and are often considered a positive asset due to their green image.

PV systems have a wide range of off-grid uses in rural areas. These include pumping, lighting, fencing, farm amenity building services etc. In recent decades, it became the norm to run electricity to remote locations; with changing economics (and the question of who pays for lines), on-site generation becomes the more viable option.

Capital costs

As a rule of thumb, the solar module represents 40–50% of the total installed cost of a 'solar system'. This percentage will vary according to the nature of the application. A complete solar system includes all the other components required to create a functioning system, whether it is be to feed energy into the grid or to use in stand-alone off-grid applications. A residential solar system costs about $18,000–$25,000 per kilowatt peak (kWp)[7] installed. On-grid systems may require equipment to integrate the electricity produced into the local supply network, whereas off-grid systems may require batteries and inverters. EECA provided the costs used in this report. Efficiency of 15% has been assumed for an average New Zealand installation.

Operating costs

These should be minimal, with regular inspections required. Likely replacement of electronic equipment during its lifetime is allowed for in assuming an average maintenance cost of 1%.

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[7] A measure of the peak output of a photovoltaic system

Lifetime

Equipment manufacturers claim PV should have an operating life of up to 35 years. An economic life of 30 years has been assumed.

Assumptions

1. Photovoltaic array of 2,000W capacity
2. Average daily output 7.25kWh
3. Annual yield of 2,600kWh
4. Installed cost of $40,000
5. Cost of batteries are not included for the grid-connected option
6. We have added 15% to the capital costs to allow for batteries for the off-grid option
7. Estimated lifetime of 30 years
8. All electricity generated is used
9. Maintenance costs 1%.

Summary

Table 11 Summary information on photovoltaics

Technology/measure	Photovoltaic 2,000-W array
Capital cost	$40,000
Annual operating cost	1%
Annual energy savings	2,600kWh
Economic lifetime	30 years
Unit costs (on-grid)	115 cents/kWh
Unit cost (off-grid)	132 cents/kWh

Barriers

The main impediment to further uptake of PV technology in on-grid applications has been its cost compared to grid electricity prices. Costs are predicted to fall at a greater rate for PV equipment than for other microgeneration technologies, but it seems unlikely that they will match grid prices in the time frame of this study.

Suitable applications where there are few barriers include remote installations where battery storage can provide continuous power.

Assessed uptake

Due to the high costs of PVs, it is likely this technology will continue to be reserved for off-grid niche applications where other options are either not available or not practical. For the purposes of this study it has been assumed that, compared to off-grid applications and other microgeneration technologies, the potential for PVs for on-grid applications is very small, particularly for residential applications.

Because of low maintenance needs, PVs are likely to be taken up, despite their high cost, in higher numbers than wind and micro hydro. These have significant maintenance requirements that are difficult for residential homeowners.

In the residential sector, we have assumed there will be 14,300 installations during the next 30 years, supplying 42GWh per annum.

The uptake in the SME sector is estimated to be three times that of the residential sector. PVs are commonly used where they are cheaper than connecting to the grid, which is often the case in remote locations. In addition, businesses are likely to get tax benefits that are not available to residential customers.

3.5 Fuel cells

Description

Fuel cells use hydrogen to produce both electricity and heat. It is possible to combine fuel cells with hydrogen production units at the same site or to use hydrogen produced elsewhere.

Fuel cells can produce equal amounts of electricity and heat. This power/heat ratio could make fuel cells more suitable for microgeneration applications in New Zealand homes than other combined heat and power technologies, due to the fact that heat loads in New Zealand households are often small compared to those in the United Kingdom.

Major research is being carried out on using fuel cells to power vehicles, but there is also considerable work on developing larger stationary cells for commercial/industrial applications.

The fuel cell market is in its infancy. Applications are currently in niche applications at a prototype level. The technology is still being developed for widespread application.

Capital costs

Currently, fuel cells are extremely expensive to produce. For vehicle applications, it has been estimated they cost around 50 times an equivalent petrol or diesel engine. As development progresses and production rates increase, fuel-cell costs are likely to reduce significantly. For this reason, fuel cells must be considered a technology of the future. A recent report produced for the Energy Savings Trust in the United Kingdom predicted that the price of a solid oxide fuel cell with a heat/power ratio of 1:1, producing 1,000W of heat and 1,000W of electricity, which costs $10,000 now, will drop to about $4,000 within 20 years[8]. This report found that fuel cells were the only system of microgeneration that looks likely to compete financially with conventional generation within the next 20 years without the need for a subsidy or grant.

[8] Potential for Microgeneration Study and Analysis, Energy Saving Trust, 2005

Operating costs

Due to the recent development of this technology and the expectation of much improved performance, it is difficult to establish likely operating costs in the future. The cost and availability of hydrogen is also difficult to accurately determine. It has been assumed that hydrogen will be generated by reformation of natural gas and will be available at a cost of $26/GJ[9]. This assumes efficiency of 40%.

Maintenance costs are estimated to be 10% of the capital costs. These costs may reduce as the technology is developed.

Lifetime

Equipment should have an operating life of 15 years. The electrolyte membrane may need to be replaced at more regular periods.

Assumptions

1. Fuel cell of 1,000-W capacity (heat/power ratio 50:50)
2. Average daily output 9.5kWh
3. Annual yield of 3,500kWhe
4. Installed cost $15,000
5. Cost of hydrogen is $26/GJ
6. Cost of batteries are not included for the grid-connected option
7. We have added 15% to the capital costs to allow for batteries for the off-grid option
8. All electricity and heat generated is used
9. Maintenance costs 10%.

Summary

Table 12 Summary information on fuel cells

Technology/measure	**1-kW solid oxide fuel cell**
Capital cost	$15,000
Annual operating cost	10% for maintenance (plus fuel)
Annual energy savings	7,000kWh (electricity and heat)
Economic lifetime	15 years
Unit cost (on-grid)	57.9 cents/kWh
Unit cost (off-grid)	71.9 cents/kWh

Barriers

The main barriers are that the technology has not matured for general applications and that the predicted price drops have not yet occurred.

[9] BP cleaner energies/Hydrogen

Supply of hydrogen as a feedstock is uncertain but this may be overcome by using reforming devices to convert natural gas or other fuels to hydrogen on-site. Gas availability is likely to be a big consideration in the uptake of fuel cells.

Predicted high maintenance costs will be a major factor in reducing the uptake of this technology. These costs may reduce as the technology develops.

In spite of present barriers, fuel-cell technology could have a positive future as a form of microgeneration. The potential of fuel cellsdepends on the technology being developed further to reduce capital costs and maintenance costs. It also depends on the cost and availability of hydrogen.

Assessed uptake

Fuel-cell technology is not yet mature, so uptake is expected to be low initially. The technology may become more cost-effective and reliable over time; however, the cost and availability of hydrogen is expected to limit the widespread uptake in New Zealand.

In assessing the uptake, we have combined fuel cells and the Stirling engine as CHP because the typical applications are similar.

In the residential sector, we have assumed there will be 3,200 CHP installations during the next 30 years, supplying 23GWh per annum.

We have estimated that the uptake in the SME sector will be twice that of the residential sector. Businesses are more likely to have a continuous requirement for heat. In addition, businesses are likely to get tax benefits not available to residential customers.

3.6 Reciprocating engine

Description

Reciprocating engines often form a useful component of off-grid power systems. These generators can be used intermittently to recharge battery banks when other forms of generation are not available, such as wind and solar power. They are quick start and their reliability means they are attractive for standby generation.

Application details

The incorporation of reciprocating engines into on- and off-grid systems enhances the reliability of stand-alone power systems, without the need for a large amount of battery storage.

Capital costs

The capital costs are based on the current retail price of a 4.5-kW Honda petrol generator (EM50is).

Operating costs

We have allowed 1% of the capital costs for maintenance and assumed that unleaded petrol will cost $1.50 per litre.

Lifetime

We have assumed a 15-year economic lifetime.

Assumptions

1. That the generator will provide 2,000kWh/year. Based on the specification, this will require 1,326 litres of petrol per year
2. The fuel costs are $1.50 per litre for 91 octane petrol
3. The maintenance costs are 1% of the capital costs.

Annual energy output/savings

We have assumed that the petrol generator will be used to supplement power from other sources (ie wind or solar power) and therefore will be used to recharge batteries when other forms of energy are not available.

Utilisation of this equipment is expected to be low, because the primary use is assumed to be for standby or backup for other microgeneration or grid-connected systems.

Summary

Table 13 Summary information on petrol generators

Technology/measure	Petrol generator (Honda)
Capital cost	$5,700
Annual operating cost	$2,000
Annual energy savings	2000kWh
Economic lifetime	15 years
Unit costs	144 cents/kWh

Assessed uptake

The uptake in capacity terms is expected to be very high, but low in actual operation terms. As this study is primarily to consider uptake in energy terms, the amount of annual output is considered too low to be assessed. Petrol generators are seen as an enabling technology to complement other microgeneration technologies by improving the reliability of the system, or for standby generation. Petrol generators were included in this study to provide a useful reference point to compare costs.

The annual energy output is expected to be low because of the limited operation of the plant; however, petrol generator installation numbers will be high as they can provide a useful backup for off-grid microgeneration systems.

3.7 Stirling engine

Description

The WhisperGen is a domestic scale CHP unit developed in New Zealand. It is designed to replace a central heating boiler and to supplement domestic electricity supply. First released commercially in 1998, the unit is based on a small four-cylinder external combustion engine using the Stirling cycle. The engine operates on the basic principle that heated gas expands and cooled gas contracts. This expansion and contraction within a cylinder will force a piston to move in and out, which can be harnessed to a transmission and alternator to generate useful power.

Although natural gas is the most common fuel source, the burner design allows different models to operate on a variety of fuels including diesel, kerosene, natural gas or LPG.

The unit is similar in size and appearance to a dishwasher.

Application details

The WhisperGen is used as a combined source of heat to provide space and water heating, and electricity for household use. A model has also been developed specifically for use on small boats. There has been considerable interest and uptake of this equipment in Europe, with steady sales in Britain. These are markets where it is traditional to have a home boiler to provide heating. This application is where the WhisperGen is being used, either in new homes or as replacements for existing boilers. The system is being promoted as a \drop-in replacement for existing boilers and is most effective for a house with a heat loss of 8kWh.

The Stirling engine–based CHP units have a much higher heat/electricity ratio (typically 3:1) than fuel cells (typically 1:1).

Overall efficiency is 90% (GCV), compared to 70–80% for a conventional new boiler. In many instances, micro-CHP will be replacing an old boiler with conversion efficiencies between 50 and 65%.

Capital costs

In England, the installed cost of a WhisperGen system is 3,000 pounds[10], which is equivalent to NZ$8,500.

Lifetime

Units are supplied with a 2-year warranty and should have an economic life of 15–20 years.

Barriers

The greatest barrier to uptake in New Zealand is the high heat/electricity ratio. The average New Zealand household does not use the quantity of heat produced by these units and the electricity savings alone would not justify its installation.

Annual energy output/savings

Outputs are: Electrical: 1kW AC at 220–240V

Thermal: heat output from 7.5–13kW

[10] http://www.greenconsumerguide.com/powergenminisite/whispergenunit.htm

It has been assumed that the unit's operating hours will be controlled by the heating requirement. For households, the heat load is assumed to be 3,500kWh/year. Therefore the unit would operate for 350 hours per year when installed in a typical home. The annual energy output has been calculated as 3,850kWh (being made up of 3,500kWh of heat and 350kWh of electricity).

The outputs are likely to increase for SME applications; this will reduce the unit cost for energy and improve the economics.

Summary

Table 14 Summary information on Stirling engines

Technology/measure	Stirling engine/Whispertech
Capital cost	$8,500
Annual operating cost	$650
Annual energy savings	3,850kWh
Economic lifetime	15 years

Assessed uptake

The electricity to heat ratio of this technology means that it is likely only to be applied in households in New Zealand's colder climates, as most regions are too temperate. Therefore, it is expected that it will have very limited uptake in the residential sector.

In making this assessment, we have combined fuel cells and the Stirling engine as CHP because of the similarity of typical applications.

In the residential sector we have assumed there will be 3,200 CHP installations during the next 30 years, supplying 23GWh per annum.

This technology can be productively applied in several SME applications. Low uptake has been assumed in the short term, but this will increase as the technology matures and energy costs increase.

3.8 Heat pumps (space heating)

Description

A heat pump works on the same principle as a refrigerator, but in reverse. It takes heat from outside and pumps it into the room. For space heating, the most common type is a split system, where the evaporator is mounted outside the house wall, and a condenser is mounted inside on the floor, or wall. Heat pumps installed for space heating can also be used for cooling in summer.

Inverter-type heat pumps are even more efficient than conventional types, especially when outside temperatures are lower. These inverter heat pumps are more expensive than the conventional type.

Heat pumps can provide more than three times as much heat output as they consume in electricity.

Ground-source heat pumps are expected to be increasingly available through the next three decades, but for this study the analysis was based on air-source heat pumps for which there is currently more sales data available. It is expected that over time much of the assumed uptake will come from ground-source heat pumps.

Application details

Heat pumps can be installed in homes, offices, and small industrial buildings. Heat pumps are starting to become common on dairy farms where the cooling can also be used for milk storage.

The performance of a heat pump reduces as the difference between the outside and inside temperature increases (i.e. as the outside temperature gets colder, the heat pump performance decreases). Because ground temperatures stay approximately constant, the performance of ground-source heat pumps is often better than that of air-source heat pumps, especially in colder locations.

The use of heat pumps for space heating is growing rapidly. About 7% of houses now have them compared with very few 5 years ago[11].

Capital costs

Costs for heat-pump systems vary depending on capacity, performance, and ease of installation. For households, the installed cost of an air-source unit ranges from $1,500 to $4,500 per unit. A capital cost of $2,500 has been assumed for this assessment.

Operating costs

The maintenance costs for both space and water heating are minimal; therefore, the main operating cost is electricity. A marginal cost for electricity of 19 cents/kWh and an average coefficient of performance (COP) of 3 has been assumed for space-heating systems. Water-heating systems are a little lower because of the need to heat water to 60^{o}C.

Lifetime

Fifteen years has been assumed for both space-heating and water-heating systems.

Assumptions

1. Space-heating heat pumps used 4.5 months of the year for heating, and 0.5 months for cooling
2. Space heating requirement of 3,142kWh/year; hot water requirement of 3,200kWh/year
3. COP of 3 for space heating

[11] New Zealand House Condition Surveys, BRANZ 2000 & 2005

4. Electricity price of 19 cents/kWh
5. Linear growth of 2% per annum for SMEs.

Annual energy output/savings

The annual energy output for air-source heat-pump space heating has been calculated for four regions throughout New Zealand. This ranges from 1,750kWh/year in Auckland to 5,100kWh/year in Southland. A weighted average energy output of 3,142kWh/year has been assumed[12].

Summary

Table 15 Summary information on air-source heat pumps for heating

Technology/measure	Air-source heat pump (space heating)
Capital cost	$2,500
Annual operating cost	$200
Annual energy savings	3,142kWh
Economic lifetime	15 years
Unit cost	14.6 cents/kWh

Assessed uptake

The technology uptake was estimated for each climatic region in New Zealand. Based on the heating requirement for each region, the total space-heating output was calculated. The percentage uptake for new houses is assumed to be higher than for existing homes. The estimate uptake is also based on current sales estimates and the low cost of heating from applying heat-pump technology.

The driver for future space- and water-heating heat pumps will be energy prices and the introduction of a HERS.

The uptake of heat pumps varies between regions, time period, and new and existing houses. The weighted average percentage uptake is shown in Table 16.

Table 16 Percentage uptake of heat pumps (air)

Heat pump (air)	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
New houses	10.2%	15.3%	30.7%
Existing houses	2.5%	4.7%	9.4%

Applying these percentages to new and existing homes gives the assessed uptake shown in Tables 17 and 18.

[12] Source http://www.mfe.govt.nz/publications/energy/warm-homes-heating-options-phase1-nov05/html/page4.html

Table 17 Assumed uptake of heat pumps in residential applications

Short term (0–5 years) Number	Medium term (5–10 years) Number	Long term (10–30 years) Number
59,000	81,000	280,000

Table 18 Assumed energy uptake of heat pumps in residential applications

Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
182	260	860

The potential for heat pump applications to provide low grade heat in the commercial and industrial sectors is also significant. Tables 19 and 20 show the estimated uptake of heat pumps for new and existing businesses. Table 21 shows the energy output (heat) from these applications.

Table 19 Uptake for new businesses (percentage of heat load)

Region	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
Auckland	10%	15%	25%
Wellington	7.5%	11%	19%
Christchurch	7.5%	11%	19%
Invercargill	5.0%	7.5%	13%

Table 20 Uptake for existing businesses (percentage of heat load)

Region	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 Years)
Auckland	3.3%	5.0%	8.3%
Wellington	1.9%	2.8%	4.7%
Christchurch	2.5%	3.8%	6.3%
Invercargill	1.0%	1.5%	2.5%

Table 21 Energy uptake from commercial/industrial heat-pump applications (GWh pa)

	Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
Auckland	235	353	1,130
Wellington	71	107	383
Christchurch	55	83	265
Invercargill	19	28	108
Total	**380**	**570**	**1,886**

3.9 Wood burners

Description

Enclosed efficient-burning low-emissions wood fire.

Application details

Wood burners can be installed in homes, offices, and small industrial buildings. They need a supply of wood, storage facilities, and manual refuelling at regular intervals.

Fuel may be required to comply with local regulations (e.g. Environment Canterbury says the water content of wood must be less than 25% by weight).

Burners have to meet standards for burning efficiency, which is taken as a measure of emissions.

Capital costs

Range: $1,500–$6,000. Most mainstream models can be supplied and installed for about $2,300–$2,600.

Operating costs

These will vary according to the source of wood and the efficiency of the fire. Costs range from 4 to 10 cents/kWh (Ministry for the Environment: 4–8 cents/kWh; Christchurch City Council: 6–8 cents/kWh; EnergyConsult Pty Ltd and Strategic Energy Ltd: 5–10 cents/kWh delivered). (Figures are based on retail prices of wood in December 2004.)

Lifetime

We have assumed an economic lifetime of 30 years.

Assumptions

1. Most mainstream models put out between 11 and 20kW. They can be run at reduced output (e.g. 11kW can be run at 4kW).

2. Fuel consumption ranges from 0.07 to 0.1m^3/100kWh; or from 25 to 36kg/100kWh.
3. Efficiency ranges from 55 to 75%. Actual efficiency depends on whether the heater is free-standing, built in, or has a wetback. Results of wood-burner efficiency tests carried out for Environment Canterbury indicate that built in appliances are typically 3–5% less efficient than the equivalent freestanding models.
4. Heating is used for 4.5 months of the year.
5. Annual heat output required is 3,456kWh.

Summary

Table 22 Summary information on enclosed wood fires

Technology/measure	**Enclosed wood fire**
Number of potential applications	90,000 over 30 years
Capital cost	$2,500
Annual operating cost	$290 (4.5 months at $65/month)
Annual energy savings	3,456kWh
Economic lifetime	20 years
Unit cost	19.2 cents/kWh

Barrier

Sourcing and storing wood for winter use can be a problem on residential or commercial/industrial sites. It is labour intensive, and fuelling requires constant attention during operation. Wood has to be cut and processed so that it is in a useable form.

Assessed uptake

The technology uptake was estimated for each climatic region in New Zealand. Based on the heating requirement for each region, the total heat output has been calculated. The percentage uptake for new houses is assumed to be higher than that for existing homes. The estimated uptake is based on current sales estimates, and is also influenced by the National Air Quality Standard and the cost of heating compared with other available options.

Wood burner uptake varies between regions, time period, and new and existing houses. The weighted average percentage uptake is shown in Table 23.

Table 23 Percentage uptake of wood burners

Wood burner	**Short term (0–5 years)**	**Medium term (5–10 years)**	**Long term (10–30 years)**
New houses	2.6%	5.2%	5.2%
Existing houses	0.6%	1.6%	1.6%

Applying these percentages to new and existing homes gives the assessed uptake and energy output shown in Tables 24 and 25.

Table 24 Assessed uptake of wood burners (number of installations)

Short term (0–5 years) Number	Medium term (5–10 years) Number	Long term (10–30 years) Number
15,000	28,000	47,000

Table 25 Assumed energy uptake of wood burners in residential applications

Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
61	118	190

3.10 Pellet burners

Description

A pellet burner is a specialised enclosed wood fire that burns wood pellets only. Pellets are fed into the fire from a hopper.

Most models have two or three electric motors to drive fans, fuel feeders, etc, so they depend on electricity to work. A battery backup option is available for some models.

This fuel is currently only available from a limited number of sources such as the BBQ Factory and Solid Energy merchants. However, as pellet fires become more common, the number of pellet-manufacturing facilities in New Zealand will increase.

Application details

Pellet burners can be installed in homes, small warehouses, schools, manufacturing plants, and hospitals/rest homes – in fact, anywhere where coal is currently used.[13] They require a reliable supply of pellets and storage facilities.

Capital costs

Pellet fires for domestic applications are priced at about $2,700 to $4,500 installed.

Costs for commercial/industrial applications vary according to the application.

[13] References
http://www.mfe.govt.nz/publications/energy/warm-homes-home-heating-methods-fuels-nz-nov05/html/page4.html
http://www.mfe.govt.nz/publications/energy/warm-homes-heating-options-phase1-nov05/html/page4.html
BRANZ Study report No 142 Chapter 11
BRANZ Study report No 115 Executive Summary

Operating costs

Costs for residential applications range from 4 to 10 cents/kWh (Ministry for the Environment: 4–8 cents/kWh; Christchurch City Council: 8–10 cents/kWh; Nature's Flame: 7 cents/kWh; EnergyConsult Pty Ltd and Strategic Energy Ltd: 7–9 cents/kWh delivered).

Lifetime

We have assumed an economic lifetime of 30 years.

Assumptions

1. Heat output for residential applications is between 10 and 11kW.
2. Fuel consumption for residential applications is estimated at 0.07–0.1m^3/100kWh, or 25–36kg/100kWh.
3. Efficiency ranges for residential applications are from 75 to 92% (higher than the better wood burners).
4. Heating for residential applications is used for an average of 4.5 months of the year.

Summary

Table 26 Summary information on wood pellet fires

Technology/measure	Wood pellet fire (residential)
Capital cost	$3,600
Annual operating cost	$360
Annual energy savings	3,456kWh
Economic lifetime	20 years
Unit cost	21.6 cents/kWh

Information on commercial/industrial pellet burner applications is specific to each application.

Assessed uptake

The technology uptake for residential applications was estimated for each climatic region in New Zealand. The total heat output was calculated based on each region's residential heating requirement. The percentage uptake of pellet burners for new houses is assumed to be higher than that for existing homes. The estimated uptake is also based on current sales estimates, the National Air Quality Standard, the cost of wood pellet heating compared with other available options, the availability of wood pellets, capital cost, and the fact that this technology is not yet widely used in New Zealand.

Pellet burner uptake varies between regions, time period, and new and existing houses. The weighted average percentage uptake is shown in Table 27.

Table 27 Percentage uptake of pellet burners

Pellet burner	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
New houses	1.3%	5.2%	7.8%
Existing houses	0.3%	1.3%	2.0%

Applying these percentages to new and existing homes gives the assessed uptake shown in Table 28.

Table 28 Assumed number of pellet burners in residential applications

Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
Number	Number	Number
7,000	28,000	65,000

Table 29 Assumed energy uptake of pellet burners in residential applications

Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
GWh pa	GWh pa	GWh pa
27	116	260

Pellet burners are an ideal substitute for coal. In many cases, coal handling facilities may be used for pellets with little modification. Estimates of the number of commercial applications are shown in Table 30.

Table 30 Number of commercial/industrial pellet-burner applications

	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
	Number	Number	Number
Schools	6	11	24
Rest homes	1	2	5
Private hospitals	0	1	5
Other	1	1	6
Total	**8**	**15**	**39**

Table 31 Energy uptake from commercial/industrial pellet-burner applications (GWh pa)

	Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 Years) GWh pa
Schools	1.1	2.3	4.8
Rest homes	0.3	0.7	1.4
Private hospitals	0.1	0.2	1.5
Other	0.1	0.1	0.4
Total	**1.6**	**3.3**	**8.1**

3.11 Biofuels – organic Rankine cycle

Description

The organic Rankine cycle (ORC) is a non-superheating thermodynamic cycle that uses an organic working fluid to generate electricity. The working fluid is heated to boiling, and the expanding vapour is used to drive a turbine. This turbine can be used to drive a generator to convert the work into electricity. The working-fluid vapour is condensed back into a liquid and fed back through the system to do work again.

This technology provides a combined source of heat and power and has been included in this report because of this dual generation role. There is also likely to be a relatively low electricity output, so it can be regarded as a microgeneration application although it is at the top end of the scale.

Application details

Unlike conventional steam turbine generation systems, ORC can make use of low-temperature waste heat to generate electricity. At these low temperatures a steam cycle would be inefficient, due to the enormous volumes of low-pressure steam required. Turbine speeds are much lower than those of high-pressure steam turbines and can allow direct drive of the electricity generator.

ORC units are suitable for using heat from waste wood in sawmills/timber-processing plants where there is sufficient waste wood to provide heat at a competitive price, and where the residual heat can be applied to kiln drying of timber – or for any other situation where waste wood is available in sufficient quantities and at virtually zero cost, and where the residual heat can be used for production purposes.

ORC's potential use in New Zealand lies in this waste wood application. Using the waste heat in timber drying kilns provides an ideal combination to maximise the system's output.

An ORC plant can also be retrofitted to an existing heat plant to extract surplus low-grade heat for electricity generation. This would have applications for the wood- and food-processing industries, where large heat plants with excess capacity could have an ORC plant attached to generate electricity.

A modular ORC biomass, combined heat and power plant has the following advantages.

- It will allow modular staged expansion, thereby reducing upfront capital costs and debt that might otherwise be needed for one super-sized high-pressure steam boiler. Risks are reduced accordingly.
- It will enable easier control and distribution of heat loads.

ORC efficiency is estimated to be between 10 and 20%, depending on temperature levels.

The ability of the ORC technology to use low-grade heat means that it could potentially be applied in geothermal use but this has not been considered in this report.

The small scale of the ORC plant considered in this study is below current economic size and would not normally be considered. The most economic size would have an electrical output of about $1.3MW_e$.

The smallest economic sized ORC plant is about $400kW_e$; a plant of this size has been assumed in this study.

Capital costs

Costing has been obtained from the New Zealand agents for the German Adoratec ORC equipment[14]. This would be combined with a specialised wood waste combustion system such as the Bio T-Burner,[15] which was developed in New Zealand and is now manufactured in Malaysia.

It is assumed that an ORC producing $400kW_e$ would cost about $1.85 million if retrofitted to an existing boiler, or $2.9 million if connected to a $2.4\text{-}MW_{th}$ wood-waste boiler (including a Bio T-burner and fuel-handling equipment).

(Larger ORC units outside the scope of this report are approximately half the capital cost per kW of the 400-kW unit.)

Operating costs

Using waste-wood residue as the fuel source for an ORC system means that the feedstock costs are very low. In some situations, fuel may even have a negative cost as using it on-site may remove the need for otherwise expensive disposal.

[14] Key Energy keyenergy@clear.net.nz
http://www.adoratec.com/productnav.html
http://eshop.bizenjinn.com/visdamax/cust/cPkgDetail.asp?pkgId=3
[15] LivingEnergy www.livingenergy.co.nz

Lifetime

A minimum life of 25 years is considered for this equipment although wearing parts will need to be replaced during this time.

Assumptions

1. ORC technology in New Zealand will be applied principally in the wood- and food-processing sectors.
2. There will be both completely new installations, and the retrofitting of ORC generation plants to existing combustion equipment.

Annual energy output/savings

Output will be governed by the fuel availability and the need for heat at the plant. This technology does, however, have the ability for the ORC unit to run at full load when kilns are on light load.

Assessed uptake

For this project it is estimated that during the next 30 years there will be three new ORC systems installed for heat and power, and three more ORC generation systems fitted to existing heat plants.

Summary

Table 32 Summary information on organic Rankine cycle generators

Technology/measure	**Organic Rankine cycle generation**
Number of potential applications	Six installed over 30 years
Capital cost	$1.85 million (excluding GST)
Annual operating cost	$40,000
Annual energy savings	18GWh (total)
Economic lifetime	25 years

3.12 Direct geothermal use

Description

Low/medium-temperature geothermal energy can be used for direct heating for residential and commercial/industrial users.

Application details

Geothermal energy[16] has traditionally been used for heating dwellings, community swimming pools and commercial/industrial facilities. Because of overuse in some areas, such as Rotorua, some previous applications have been closed down.

With well-designed, well-constructed bores the energy can be extracted in a sustainable manner and piped to a household or business. The applications can be similar to any other hot-water heating sources.

Ground-source heat pumps (GSHPs) are an alternative method of using geothermal energy at almost any location, but there are still very few in New Zealand.

Capital costs

The costs will depend on the specific costs of drilling and piping. There are clear economies of scale from a number of users tapping a single bore. On the other hand a number of smaller bores can spread the draw-off. A regulatory environment can ensure that the total extraction is sustainable.

In one recent example of a GSHP application in Hamilton, the total load was 15kW of output heat for a capital cost of $15,000, including all in-building costs.

Operating costs

Geothermal bores are potentially operating in a corrosive environment or are subject to scaling, so maintenance is required. In addition, the bores require regular inspection and field monitoring.

Lifetime

A bore can be operated in a sustainable manner so that it has a virtually endless life.

Annual energy output/savings

No information is available on the cost of energy and the savings from the use of other energy forms, as each is specific to the application.

Assessed uptake

It is difficult to assess the amount of uptake that could occur for direct use of geothermal energy to deliver energy services. The uptake will also depend on resource management issues, and the desire of local regional councils to encourage use rather than preservation. Some specific proposals have been developed, whereas general use has been static or receding for several years. Uptake under current policies could be low. But with different policies, significant uptake is possible while a sustainable resource is maintained.

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16 www.nzgeothermal.org.nz

3.13 Biofuels industrial combustors

Description

As the cost of energy rises, the use of waste wood becomes more economically viable. For many wood-based enterprises, waste wood will come from several sources, each with their own handling and combustion characteristics. Burners that can cope with these varying conditions are available now in the scale covered by this project. These have been traditional low-efficiency pile burners, but more efficient burners such as the Bio T-Burner are now available.

The Bio T-Burner is an under-stoked refactory-lined pile bed wood waste burner. It can handle a wide range of fuel sizes and moisture contents, including sawdust, wood shavings, woodchips, chip fines, and bark.

Application details

Small-scale heat plants are commonly used on wood-processing sites to dispose of wood biomass processing residues and to produce heat for low-temperature wood-drying kilns.

Capital costs

The installed cost of a 1.2-MW_{th} burner is about $730,000 (excluding GST), plus the cost of a concrete pad and a fuel system to feed the included fuel silo.

Assumptions

There are more than 300 forestry and logging firms with 6–19 employees. It has been assumed that during a 30-year period, 2% of these firms would install one 1.2-MW_{th} burner. An 80% load factor has been assumed.

Summary

Table 33 Summary information on industrial burners

Technology/measure	Industrial burner
Number of potential applications	Six installations in 30 years
Capital cost	$0.73 million (excluding GST)
Economic lifetime	20 years

Assessed uptake

It is assumed that about six of these burners will be installed by 2035. In addition, a number of larger plants will be installed but these are beyond the scope of this project.

Table 34 Assessed energy uptake from biofuel combustors (GWh pa)

Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
4.2	4.2	16.8

3.14 Anaerobic digestion

Description

Biogas is commonly produced by anaerobic digestion of wet organic waste. Microgeneration applications can occur at industrial plants (food and dairy processing) that have liquid wastes containing organic material, and on farms where animal dung can be easily collected and processed, such as on dairy, pig, or poultry farms.

The anaerobic process can take place in contained vessels or covered ponds. Industrial applications usually use contained vessels, and dairy farms may use either.

Biogas is a mixture of mainly methane (50–80% on a volumetric basis). The gas can be used on-site for direct firing in heat plants or engines, or to produce electricity for local consumption on the site.

In many industrial and farming cases, treatment of the waste to produce biogas is not economical, but is carried out for other reasons, such as waste management. Also, small-scale generation of biogas is rarely economic because of the high labour requirements and dilute nature of the effluent being treated.

Biogas from anaerobic digestion can be used directly as a fuel in a number of different types of plant such as reciprocating gas engines, mini-gas turbines, Stirling engines, and fuel cells, or by direct combustion in boilers or other CHP heat plants.

Anaerobic digestion is a mature technology and is used worldwide, particularly for municipal waste-water treatment. Here the scale of treatment can justify the costs of installing and operating the equipment. If the organic content of a wet-waste stream is too dilute, energy recovery will be more expensive. Excess moisture may cause handling problems for gasification processes.

Anaerobic digestion is essentially a continuous process so it requires a reliable continuous feed of material. This is often difficult to achieve on small sites. The process cannot be stopped for a holiday or maintenance period as it takes a long time to stabilise. Many potential opportunities have a period in the year when there is no waste to process, and additional make-up feedstock has to be brought in.

Capital costs

The economies of scale for building an efficient anaerobic digestion facility indicate that a small microgeneration plant is often uneconomic.

A dairy farm closed-vessel digester can cost about $1000 per cow to build and install. A covered pond system can be significantly cheaper if sealing the pond is easy.

Operating costs

A digester is very labour-intensive, in that the waste to be processed must be continually collected and fed to the digester. Continuous monitoring is also necessary to ensure that everything is working smoothly. Bringing in additional feedstock to cover periods when there is no waste from the site significantly adds to the operating cost.

Lifetime

A 10-year lifetime has been assumed.

Assumptions

Despite biodigester technology having been around for many years there are few international examples where food waste is processed in digesters. Internationally, a greater number of digesters are fuelled by farm-stock waste (effluent), although the total number in this category is still very small. The emphasis on processing farm-stock waste is driven principally by environmental objectives, whereas fruit and vegetable waste is generally less of a problem.

Producing methane gas from fruit and vegetable waste is anecdotally considered about three to seven times more efficient than using farm-stock waste, or 50m^3 per 150kg of dry matter.

It is assumed that digesters would not be economic for dairy farms with less than approximately 1000 cows.

A digester's smooth operation depends on a continuous flow of feedstock of uniform consistency. The bacteria in the digester cannot handle sharp changes in feedstock composition.

Annual energy output/savings

The savings for dairy farms are based on biogas produced by the digester fuelling a 30-kW generator. Factories will be able to sustain larger plants.

Summary

Table 35 Summary information on anaerobic digesters

Technology/measure	**Anaerobic digesters**
Number of potential applications	24
Capital cost	$250,000+
Annual operating cost	$2500+
Annual energy savings	3.0GWh in 2030
Economic lifetime	25 years

Assessed uptake

Fruit- and vegetable-processing residues

Methane gas from a bio-digester fuelled on fruit and vegetable waste is a suitable fuel for boilers. This would be the preferred use in the Hastings area, where large quantities of heat are used, rather than using gas to generate electricity.

The study has shown that producing biogas from fruit and vegetable waste is close to being commercially viable. Under certain scenarios, biogas fuel could possibly be produced and delivered to boilers for heating at costs of 8–11 cents/kWh compared to natural gas supplied to commercial users at about 6.9 cents/kWh. Cogeneration of electricity from biogas was calculated at 17 cents/kWh compared to the marginal cost of grid-connected electricity at 11–13 cents/kWh. These costs are based on the best assumptions available, which in practice may vary significantly according to how the projects are implemented. However, these results indicate that, if the assumptions are accurate, further work on the use of digesters for converting food- and vegetable-processing waste to energy (and associated by-products) is justified.

Dairy farms

Uptake potential is based on 0.25% of dairy farms with herds greater than 500 head throughout New Zealand[17], with double this uptake for the Waikato, Hawkes Bay and Southland regions.

Meat processing

The potential uptake is based on 10% of the meat processors, which employ 20–49 employees installing digesters.

The timing and uptake of anaerobic digesters is shown in Table 36.

Table 36 Number of digesters installed

	Digester uptake (number)		
Industry	**0–5 years**	**5–10 years**	**10–30 years**
Dairy farms	1	4	14
Meat processing		1	2
Dairy processing			1
Fruit and vegetable processing			1
Total	**1**	**5**	**18**

[17] Statistics New Zealand
Ministry of Agriculture and Forestry

Table 37 Assessed energy uptake from anaerobic digesters (MWh pa)

	Annual savings (MWh pa)		
Industry	**0–5 years**	**5–10 years**	**10–30 years**
Dairy farms	75	300	1050
Meat processing		500	1000
Dairy processing			650
Fruit and vegetable processing			150
Total	**75**	**800**	**2950**

3.15 Solar and heat-pump water heating

Description

Solar energy and heat-pump technology can be used to heat water for residential or commercial applications.

Application details

Solar and heat-pump water-heating systems can be installed in new residential dwellings or retrofitted to existing conventional electric water-heating systems.

Potentially there is an enormous range of applications for larger scale SWH in New Zealand, with possible candidates including low-temperature hot water, or pre-heaters for higher temperature hot-water (Table 38).

Heat pumps have a growing application on dairy farms for heating water and cooling milk.

Table 38 Potential opportunities for large-scale SWH in New Zealand

Industry sector	**Potential opportunities for large-scale solar water heating**				
Food industry	Milk factories	Confectionaries/ bakery	Tinned goods	Meatworks	Desalination of seawater
Forestry/agriculture	Timber/food drying	Greenhouses	Nurseries	Dairy farms	Fish farms
Textiles	Tanneries	Leather treatment	Cloth refineries	Dyeing/finishing	Textile processing
Chemical industry	Cosmetics	Detergents	Pharmaceuticals	Wax	Distilleries
Beverages	Wineries	Liquor distilleries	Breweries	Soft drinks	Fruit juices
Service industry	Hotel/motel	Takeaway restaurant	Gymnasium/swimming pool	Events centres	Sports stadium
Institutions	Hospitals	Prisons/military barracks	Boarding establishments	Retirement homes	Schools

Capital costs

The cost of supply and installation of residential solar and heat-pump systems is assumed to be similar to current costs ($5,000–$7000). Some reduction in the cost can be expected as a result of increased competition from new imported products, and economies of scale from more installation activity. A cost of $4,300 is based on the assumption that the storage tank is necessary anyway.

Bulk purchase for installation for group housing developments, Government facilities, or Housing New Zealand Corporation retrofitting of rental accommodation will also provide economies of scale for solar and heat-pump systems leading to reduced cost over time.

The costs of supply and installation of commercial solar installations are likely to reduce as building specifiers and system suppliers become more proficient in the design and tendering of systems. Large commercial solar applications such as for the Department of Corrections, and hotels and food processors, will have economies of scale.

Heat-pump system installation costs are expected to remain near to present costs as the effort required to install these systems is similar to that of conventional electric hot-water heating systems.

Operating costs

Both solar and heat-pump systems have minimal annual operating costs, with savings of about 75% of conventional electricity supply for solar and an assumed COP of about 2–3 for heat pumps.

Lifetime

The lifetime for both solar and heat-pump systems is assumed to be 20 years. Some replacement of systems can be expected in the period 2020–2035 but these do little to increase use of solar energy or heat pumps for water heating.

Assumptions

1. The suppliers of solar water heating systems establish adequate and strong quality delivery networks before the end of 2006.
2. By 2007, SWH and HPWH are available from plumbing merchants for installation by approved installers.
3. Average solar energy gain for dwellings is 2400kWh per annum.
4. Residential assumptions:
    - Annual increase in new dwellings is 1.15% (average annual increase for the past 5 years).
    - Ninety per cent of new households are owner-occupied and 10% are rental.
    - The rate of demolition or removal from dwelling use is 25% of the rate of new buildings (BRANZ).
    - Ninety per cent of demolitions or removals from dwelling use are owner-occupied and 10% are rentals.

Table 39 Number of dwellings with solar or heat-pump water heating

	Dwelling Number			**Dwellings with SWH**			**Dwellings with HPWH**		
	Jun-04	2035	2005	2005-2010	2010-2020	2020-2035	2005-2010	2010-2020	2020-2035
Existing owned home	1022900	882946	28286	22986	148638	106760	460	14864	21352
New owned home	23,200 pa	718371		22894	156907	271942	916	23536	81582
Rented home	438200	508402	250	1830	32823	24152	183	3282	4830
TOTAL				47710	338368	402854	1559	41682	107764

5. EECA's report 'The Dynamics of Energy Efficiency Trends in NZ' states that in 1998 (the last year recorded):
   - thirteen per cent of commercial-sector end-use energy (35PJ/year), and 3% of industrial end-use energy (140PJ/year), is for water heating. This indicates that in 1998, 8.75PJ/year of water heating was used in commercial and industrial applications
   - between 1998 and 2004, total consumer energy increased 17.2%, which indicates that in 2004 10.3PJ/year of water heating was used in commercial and industrial applications.
6. The cost of commercial solar applications (in particular, accommodation, restaurants, food outlets) will become cost competitive with other water-heating energy sources before 2010.
7. Solar energy is used principally as a pre-heater in commercial applications.
8. The proposed Government solar programme is based on:
   a. high profile Government promotion of SWH
   b. government facilitating SWH profile by acting as role model
   c. targeted Government healthy homes scheme for low energy-performance homes
   d. Government leadership through Housing New Zealand Corporation installation of rental accommodation
   e. Introduction of Home Energy Rating Scheme for new homes from 2010 (60% of new homes to install SWH per annum from 2015)
   f. Government agencies (Corrections, Education, health, CYPS etc) are encouraged to install SWH for large hot-water applications
   g. local Government is encouraged to install SWH for large hot-water applications.

Barriers

The principal barrier relates to a lack of familiarity with SWH and heat-pump systems. In commercial and industrial applications, the comparative cost of alternative energy sources for heating water during the decade also creates a price barrier.

Summary

Table 40 Summary information on solar water heaters

Technology/measure	Solar water heating (residential)
Capital cost	$4,200 (marginal cost)
Annual operating cost	$20
Annual energy savings	2,400GWh
Economic lifetime	20 years
Unit cost	14.4 cents/kWh

Commercial solar system costs depend on each application.

Assessed uptake

The expected uptake for each of the periods is shown in Table 41 and is based on:

1. Twenty-nine per cent of current existing homes have SWH by 2035
2. Sixty per cent of new homes have SWH by 2015
3. Thirteen per cent of existing rental homes have SWH by 2035
4. Significant increase in installation of SWH and HPWH in new dwellings derives from introduction of a HERS from 2010
5. Healthy Homes programme leads to significant increase in installation in rental accommodation of SWH and HPWH
6. Increase in installation of SWH and HPWH from role modelling from Government programmes.

Table 41 Energy provided by solar energy or heat pump for water heating (GWh pa)

	Solar Water Heating			Heat Pump Water Heating		
	2005–2010	2010–2020	2020–2035	2005–2010	2010–2020	2020–2035
Existing owned home	55	357	256	1	36	51
New owned home	55	377	653	2	56	196
Rented home	4	79	58	0	8	12
Subtotal (residential)	114	813	967	3	100	259
Dairy farm	4	11	21	0.1	1	4
Commercial including restaurants	48	72	72	1	7	14
Industrial	47	35	35			
Accommodation	15	29	48	0.3	3	10
Institutional	4	11	21			
Local Govt	4	11	21			
Subtotal (commercial)	122	169	218	1.4	11	28
TOTAL	236	982	1185	4.4	111	287

3.16 Direct wind pumping

Description

Windmills for the direct pumping of water were once very extensive throughout New Zealand. These very forgiving pieces of equipment proved to be robust and could be installed nearly anywhere. They are generally installed directly over the bore or very near to the stream or river from which the water is drawn, so they are often in locations that are not optimal for wind energy. The simplicity of this equipment was enhanced by the fact that the windmills operated when the wind occurred rather than when the water was needed. This is a characteristic of pumping that suits it to the variability of wind – it is generally not time critical as, in most cases, the associated storage (e.g. water troughs) provides a buffer.

Small wind pumps can replace small diesel pumps from 7kW to 20kW for either drinking-water supply, or irrigation.

Capital costs

Prices for a 10-kW system range from about $70,000 to $85,000. This includes a voltage regulator, inverter, meter, a guyed lattice tower, or tilt-up tower (for sites without crane access), which is available in heights of 18–37m..

Pumping costs from a modern 10-kW wind turbine and pump are about 30 cents/kWh with an average wind speed of 7m/s. This drops to 22c/kWh if the average wind speed rises to 8m/s. Costs would be higher for more common lower wind speeds.

Direct pumping can also be undertaken with traditional systems still available such as windmills supplied by Ferguson Windmills Company (approximately $3000). These traditional systems may be about one-third of the cost of the new wind turbines, but a fuller evaluation is required.

Operating costs

Windmills for direct pumping of water require very little maintenance and can operate for years without any significant attention.

Lifetime

A lifetime of 25 years has been assumed.

Assumptions

1. Two per cent of farms with livestock install a wind-based pumping system.

Annual energy output/savings

Assuming each installation has an average output of 0.5kW and operates 20% of the time, the total saving in avoided electricity could be about 1,000,000kWh per annum.

Summary

Table 42 Summary information on wind pumping

Technology/measure	Wind pumping
Capital cost	$9/kW
Annual operating cost	Small
Annual energy savings	1GWh
Economic lifetime	25 years

Assessed uptake

It is difficult to assess the possible uptake of windmills for direct pumping of water as they are currently unfashionable; however, in the period to 2035, it has been assessed that 2% of farms with livestock could potentially install wind-powered pumps, giving a total of more than 1100 installations.

Table 43 Assessed energy uptake from wind pumping (GWh pa)

Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
0.05	0.26	0.96

3.17 Hydro pumping

Description

Hydro pumping uses the hydraulic ram as a means of pumping water to a higher elevation. Rams can be referred to as automatic water-driven pumps.

Application details

The hydraulic ram has been a feature of New Zealand's rural water supply options for decades. It operates automatically by using the energy in the flow of water that the 'pumped' water is extracted from (the energy of large flow under a small head can be utilised to raise relatively small quantities of water to a greater head) and does not need an 'external' energy source. Siting can be very flexible, because locations can be remote from electric lines and can operate without bringing fuel (e.g. petrol) to the pumping site.

Wherever there is a flow of water with a gradual fall and only a small amount of that flow is required for use at a higher elevation, a ram can provide this (smaller) flow at the higher elevation. Pumping energy can be obtained in a sustainable way from the potential/kinetic energy of the stream or river the water is pumped from.

A number of rams operate throughout New Zealand. A representative delivery from a ram with a 10-m supply head (elevation) and a delivery-pipe diameter of approximately 100mm using 655 litres per minute would be about 40 litres per minute (approximately 2500 litres each hour) at a 100-m head or 85 litres per minute at 50-m head.

Capital costs

Indicative costs for rams range from approximately $1,600 to $17,000 (including GST), depending on capacity. This generally does not include packaging, freight, all piping, fittings, intakes, feed tank, surge tanks, and foundation materials. The cost of constructing the pumping system is site specific and also needs to be taken into account.

The representative ram with a delivery-pipe diameter of approximately 100mm costs about NZ$5,000 excluding GST (July 2004 prices) - packaging, freight, all piping, fittings, feed tank, and foundation materials are not included.

Operating costs

With no motor a pulse valve is the only moving part. Therefore, the only operating costs are those associated with maintenance of the valve, pipes, and other parts of the system that are normally associated with a water-pumping facility. This includes keeping the intakes clear of debris.

Lifetime

A ram can be operated in a sustainable manner so that it has virtually an endless life.

Annual energy output/savings

No information is available on the cost of energy and the savings from use of other energy forms as each is specific to the application. In some cases ‘do nothing’ may be the chosen option, particularly if the opportunity is to provide more water to increase the stock carrying capacity of the land.

Assessed uptake

The uptake of hydraulic rams is not likely to change significantly in the short and medium term. While they can provide a reliable water source for stock and rural domestic purposes where gravity feed is not able to, they occupy a niche where the supply of water from an electrical or fossil-fuelled system is more expensive. If water-powered pumping is not feasible, wind- or diesel-powered pumps are alternatives. Electric pumps are commonly used but, depending largely on the distance from existing distribution lines, laying in a power supply can be expensive.

It is difficult to assess the uptake that could occur for hydro pumping. It will largely depend on specific water requirements where a hydro pumping system can run at the lowest economic cost. This is likely to be where there is water with sufficient head and flow to meet the delivery and system requirements. These opportunities are likely to be located in hilly terrain.

Uptake is of the order of tens of rams each year, mostly at the lower end of the range of sizes. Removing the requirement for lines companies to maintain supply to all areas, which will come into effect in 2013, is likely to affect their uptake in rural areas.

The energy is difficult to assess because it will depend on head and flow.

3.18 Energy management, motors, and equipment efficiency

Description

Over time, the energy efficiency of all sectors increases as energy management techniques and equipment efficiency improves.

Application details

Some businesses will achieve significant (10–15%) energy savings as a result of energy-efficiency improvements, while others will achieve little. We have estimated that the average improvement in energy efficiency will be similar to historical averages.

This saving incorporates an assumption of an annual increase in SME energy use of 2% per annum.

Capital costs

The capital cost incurred to achieve this efficiency improvement has not been estimated as part of this study.

Operating costs

The annual operating cost for energy efficiency improvements is assumed to be nil.

Lifetime

These efficiency improvements are expected to be ongoing.

Assumptions

It has been assumed there will be an average annual improvement in energy efficiency of 1%. This estimate is based on:

1. current world best practice of 2% per year
2. the National Energy Efficiency and Conservation Strategy target of a 20% improvement in energy efficiency over 10 years
3. a history of improvements in energy efficiency of between 0% and 1%[18].

The amount of annual energy use for SMEs is estimated to be currently 13,800GWh (about 75% of the total energy used by the entire commercial and light-industrial sector).

[18] Situation Assessment Report on the National Energy Efficiency and Conservation Strategy, March 2006

It has been assumed that energy use in the SME sector will increase by 2% every year.

Annual energy output/savings

An annual energy saving of 1% due to various energy efficiency improvements within the SME sector has been assumed.

Summary

Table 44 Summary information on energy management

Technology/measure	**Energy management and energy efficiency improvements**
Capital cost	Not estimated
Annual operating cost	Nil
Annual energy savings	1% of
Economic lifetime	Continuous
Unit cost	Not estimated

Assessed uptake

The expected uptake of a 1% improvement in energy efficiency is based on the assumptions above.

The long-term energy savings are calculated to be 5,800GWh.

3.19 Ceiling insulation

Description

In 1977 a national standard was introduced for house insulation. In 1978 this standard became mandatory for new houses. A further new national standard was introduced in 1996, although this did not become mandatory until 2004.

A significant proportion of houses built after these mandatory standards came into place do not comply with them. Over 30% of houses built from 1980 to 2000 do not meet the 1977 standard, and over 60% of houses built since 2000 do not meet the 1996 standard for ceiling insulation.

The ceiling space is the most common part of existing houses to be insulated, because it is the easiest space to insulate and it results in the most significant reduction in heat loss. Very few houses have no ceiling insulation (6%); almost 70% have fully insulated ceilings. The remaining 24% represents houses with inadequate ceiling insulation; for most (almost 60%), the insulation is of insufficient thickness.

Application details

Insulation improvements have been limited to ceiling insulation improvements because the ceiling space is usually accessible. It is also the most significant area of heat loss in an un-insulated house.

Figures available from the New Zealand House Condition Survey 2005 have been used to determine the number of houses where ceiling insulation can be improved. This survey indicates that 6% of New Zealand houses (81,600) have no ceiling insulation, while a further 24% (340,000) have inadequate ceiling insulation.

Capital costs

The cost to install ceiling insulation in a house without it is based on the average price for installing ceiling insulation for EECA's EnergyWise Home Grants scheme ($11.54/m^2). A figure of $12/m^2 has been assumed, which is equivalent to $1,440 for a 120-m^2 house.

The cost to install ceiling insulation in a house with some insulation is based on the average price for installing ceiling insulation for EECA's EnergyWise Home Grants scheme ($9.25/m^2). A figure of $10/m^2, which is equivalent to $1,200 for a 120-m^2 house, has been assumed.

Operating costs

There are no annual operating costs (fuel or maintenance) for this intervention.

Lifetime

The lifetime for this intervention is assumed to be 20 years, based on EECA's Residential Grants Technical Manual, although the New Zealand Building Code now includes a durability requirement for insulation of not less than 50 years[19].

Assumptions

1. Average house size of 120m^2
2. Installed cost for ceiling insulation $12/m^2 (non existing)
3. Installed cost for ceiling insulation $10/m^2 (some existing)
4. Estimated lifetime of 20 years
5. Estimated energy savings based on EECA's Technical Manual
6. Estimate potential based on New Zealand House Condition Survey 2005

[19] Approved Document for New Zealand Building Code Durability Clause B2, Effective 1 April 2004

7. Number of houses based on data from Statistics New Zealand (Permanent Private Occupied Dwellings 2001 – i.e. 1.36 million houses)
8. The distribution of both un-insulated houses and inadequately insulated houses throughout New Zealand is similar to the distribution of all houses.

Annual energy output/savings

Calculating the annual energy saving from improvements in ceiling insulation is difficult. Many households in New Zealand are inadequately heated (30% of homes have an average winter evening temperature of less than 16^{o}C)[20]. If a house is not heated the installation of ceiling insulation will not result in any energy savings, but will raise the internal temperature.

The energy savings from installing ceiling insulation are based on EECA's Residential Grants Technical Manual. This manual is currently being updated and improved. It was considered to be the best available resource to calculate the energy savings from energy efficiency measures at this time.

Annual energy savings from insulating houses with no ceiling insulation range from 967kWh/year for a house in Auckland to 2,598kWh/year for a house in Southland.

Annual energy savings from insulating houses with some ceiling insulation range from 265kWh/year for a house in Auckland to 721kWh/year for a house in Southland.

Barriers

Some ceiling cavities are not accessible. These have not been included in this analysis. The key barriers are:

1. Knowledge of the benefits in comfort and energy savings
2. Ease of implementation. It is often difficult to access the ceiling cavity and to install the insulation. It is also difficult in some areas to find experienced insulation installers to complete the work to an acceptable standard.

Assessed uptake

Although the number of houses with inadequate ceiling insulation is significant, as are the benefits in terms of comfort and cost savings, the current rate of improvement is estimated at 16,000 houses per year, even though the total potential is 421,600 houses.

[20] Energy Use in New Zealand Households – Report on the Year 6 Analysis for the Household Energy End-use Project, (2002), Isaacs et al.

It has been assumed that the current rate of improvement will increase so that, within 5 years, 100,000 more houses will have ceiling insulation (an annual rate of improvement of 20,000 houses). It is assumed that after this period most houses with accessible ceiling cavities will have some insulation installed.

In the 5–10-year time frame, the annual rate of improvement increases to 30,000 houses per year – about twice the current rate of improvements.

All houses in New Zealand with accessible ceiling cavities are expected to have adequate ceiling insulation installed within a 30-year time frame.

Table 45 Uptake of ceiling insulation

Time frame (years)	Number of installations	Annual savings GWh pa
0–5	100,000	120.1
5–10	150,000	57.2
10–30	172,000	62.2

Summary

Table 46 Summary information on ceiling insulation

Technology/measure	Ceiling insulation
Number of potential applications	78,000 houses (no existing insulation)
	325,000 houses (some existing insulation)
Capital cost	$526 million (total)
Annual operating cost	Nil
Annual energy savings	243GWh (total)
Economic lifetime	20
Unit cost (no existing insulation)	9.5 cents/kWh
Unit cost (some existing insulation)	28.9 cents/kWh
Unit cost (all houses)	19.9 cents/kWh

3.20 Water heating efficiency improvements

Description

Electric water heating is New Zealand's most common form of water heating. Approximately 75% of houses have an electric hot-water cylinder. The dominance of these systems means efficiency is important in terms of national energy use for water heating.

A wide range of electric hot-water cylinders are currently in use. Cylinder age is a key factor in determining the heat loss from hot-water cylinders and therefore the thermal efficiency of hot-water systems.

Table 47 Energy improvements from water-heating efficiency[21]

[21] New Zealand House Condition Survey, BRANZ 2006

Grade	Age	Percentage	Number of houses	Energy savings per cylinder	Potential national savings
				(kWh/year)	(GWh/year)
A		12%	124,000	140	17
B	Post 1986	52%	537,000	140	75
C	1976–1986	15%	155,000	430	67
D	Pre–1976	21%	217,000	440	95

Application details

Data available from the New Zealand House Condition Survey 2005 has been used to determine the number of houses where cylinder wraps can be cost-effectively installed. It has been assumed that it is only cost-effective to install wraps on C&D grade cylinders.

Capital costs

An assumption of $100 per house to supply and install a hot-water cylinder wrap has been assumed. Because there is potential to install 350,000 hot-water cylinder wraps, the total capital cost is $35 million.

Operating costs

There are no annual operating costs (fuel or maintenance).

Lifetime

The lifetime for this intervention is assumed to be 10 years based on EECA's Residential Grants Technical Manual (see 3.19 'Ceiling Insulation').

Assumptions

1. Number of houses based on data from Statistics New Zealand (Permanent Private Occupied Dwellings 2001 – ie 1.36 million houses).
2. Seventy-six per cent of dwellings have an electric hot-water cylinder (BRANZ, New Zealand House Condition Survey 2005).
3. Approximately 35% of houses have older inefficient hot-water cylinders.
4. Ninety-four per cent of C&D grade cylinders can be cost-effectively wrapped (i.e. the 6% of hot-water cylinders that are inaccessible are C&D grade cylinders).
5. No allowance for energy savings from reducing thermostat settings on hot-water cylinders.
6. The cost of installing a hot-water-cylinder wrap is $100.
7. Hot-water pipes will be insulated at the same time.
8. The cylinder wrap will stay in place for 10 years.

9. Sixty per cent of all electricity storage water heaters are 180 litres, and 40% of all electricity storage water heaters are 135 litres.

Annual energy output/savings

Calculating the annual energy saving from improvements in insulation of hot-water-cylinder wraps is straightforward. The only areas of uncertainty are the number of cylinders where a wrap can be fitted, and the length of time the wrap will remain in place.

Based on EECA's Residential Grants Technical Manual (currently being updated), the annual energy savings from insulating cylinder wraps on all accessible C&D grade cylinders is 152GWh/year.

Barriers

Some hot-water cylinders are not accessible. Some that are do not have enough space to fit a cylinder wrap. We have assumed that 6% of hot-water cylinders are not accessible and that all of these are C&D grade cylinders. For the purposes of this study, accessible hot-water cylinders are assumed to have sufficient space to install a hot-water cylinder wrap.

The key barriers are:

1. Knowledge of the benefits in terms of both energy savings and cost savings
2. Ease of implementation.

The barriers appear to be significant, because several campaigns to improve the efficiency of existing hot water systems have not resulted in a significant uptake.

Assessed uptake

Only 5% of electricity hot-water cylinders have cylinder wraps fitted. This represents approximately 52,000 houses.

The number of houses with inefficient hot-water cylinders is significant, as are the benefits of improvement in terms of cost and energy savings.

Accurate sales figures for cylinder wraps are difficult to obtain. However, sales increase significantly when there are concerns about electricity supply. We have assumed that the current rate of improvement is 5,000 houses and that the total potential is 350,000 houses.

We have assumed that 5,000 hot-water-cylinder wraps are installed each year; that this will increase to 10,000 per year in the medium term; and that all accessible hot-water cylinders will be fitted with cylinder wraps or replaced in the long term.

Table 48 Energy improvements for each period

Time frame (years)	Number of installations	Annual savings GWh pa
0–5	25,000	11
5–10	50,000	22

10–30	275,000	119

Summary

Table 49 Summary information on hot-water-cylinder wraps

Technology/measure	**Hot-water-cylinder wraps**
Number of potential applications	350,000 houses (accessible C&D grade cylinders)
Capital cost	$35 million (total)
Annual operating cost	Nil
Annual energy savings	152 GWh (total)
Economic lifetime	10
Unit cost (all houses)	2.11 cents/kWh

3.21 Passive solar design

Description

Passive solar design involves a combination of design strategies to use energy from the sun to contribute to heating, cooling, and lighting a building. That is, a building's windows, walls, roof, and floor are designed to collect, store, and distribute warmth during winter, and to reject solar heat in summer.

The key factors taken into consideration are:

- Site planning and building orientation
- Collecting solar heat (window sizing and placement)
- Storing solar heat (use of thermal mass)
- Conserving solar heat (use of insulation)
- Avoiding overheating (through shading and natural ventilation).

Applying passive solar design principles will result in significant improvements in comfort as well as energy savings. The principles can be applied to new buildings and, to a lesser extent, to renovations.

These benefits can often be obtained with little (or no) additional cost; however, attention to the details of design and construction is required.

Application details

The principles of passive solar design can be most easily applied when a house is first built, although some can be applied during alterations.

Figures from the Designing Comfortable Homes booklet have been used to estimate the potential energy savings from the application of passive solar design principles.

For new buildings the analysis compares the energy use of a 200-m^2 house, which has low thermal mass, medium glazing, and code levels of insulation to that of a house of the same size but with high thermal mass, high glazing, and the best level of insulation. This latter design has been taken as the maximum energy benefit that can be achieved. It has been assumed that, on average, new houses will only realise

50% of these potential energy savings. It has also been assumed that approximately 27,000 new dwellings are built each year.

For existing buildings, the energy use of a 200-m^2 house that has low thermal mass, low glazing, and code levels of insulation has been compared to the same house with low mass, high glazing, and the best level of insulation. It is assumed that it is too difficult to change the level of thermal mass in an existing house. However, the size and type of windows can be altered so as to maximise the thermal performance. Insulation levels will be improved to best levels. These changes design have been taken to give the maximum energy saving achievable in an existing house. It is assumed that, on average, only 25% of these energy savings will be realised, and that approximately 28,000 significant house alterations are completed each year.

Capital costs

The capital costs for passive solar design are expected to be small. However, it is acknowledged that more care may be required in design and construction details. Better insulation will come at a higher cost, but this is not expected to be significant. Similarly, more thermal mass is likely to be more expensive, but this too is not expected to be significant.

For the purposes of this study, the additional capital costs for the design, construction, and quality control of passive solar design features for both new dwellings and alterations are estimated to be $2000. This represents approximately 1% of the total construction costs for a new dwelling.

Operating costs

There are no annual operating costs (fuel or maintenance) for this intervention.

Lifetime

The lifetime for this intervention is assumed to be 50 years.

Assumptions

1. 27,000 new houses will be built every year.
2. 28,000 house alterations will be completed each year.
3. The energy savings from applying passive solar design principles are based on the building simulations contained in “Designing comfortable homes”.
4. 50% of the total potential energy savings will be achieved for new houses, and 25% of the total potential energy savings will be achieved for alterations.
5. The additional capital costs for incorporating passive solar design principles will be $2,000 per house.

Annual energy output/savings

The achievable energy savings have been calculated based on published figures from the results of building simulations. From this, the annual energy savings from using passive solar design principles in new buildings and alterations are estimated to be 71.6GWh/year.

Barriers

Passive solar design principles are not new. It is assumed that these principles are well known within the construction industry but it appears that the benefits are not well understood.

Improvements to the status quo are unlikely without some form of prompt. This could take the form of changes/improvements to the New Zealand Building Code to increase insulation levels in new buildings and alterations, and to improve quality control to ensure the relevant standards are being achieved.

The key barrier is often time. Design decisions frequently need to be made quickly, so the tendency is to resort to previous solutions with known outcomes.

The barriers appear to be significant, but can be overcome with improved awareness, knowledge, analysis tools, and building standards.

Assessed uptake

It has been assumed that passive solar design principles will be incorporated in half of all new homes and half of all alterations (ie 13,500 new houses a year and 14,000 alterations).

Table 50 Estimated uptake and energy savings from passive solar design

Time frame (years)	# of installations thousands	Annual savings GWh pa
0–5	275	358
5–10	275	358
10–30	1,100	1,432

Summary

Table 51 Summary information on passive solar design

Technology/measure	Passive solar design
Capital cost (new houses)	$54 million (total)
Capital cost (alterations)	$56 million (total)
Annual operating cost	Nil
Annual energy savings (new houses)	49.9 GWh (total)
Annual energy savings (alterations)	21.7 GWh (total)
Economic lifetime	50 years
Unit cost (new houses)	5.6 cents/kWh
Unit cost (alterations)	13.5 cents/kWh
Unit cost (all houses)	8.0 cents/kWh

3.22 Double glazing

Description

A double glazing unit consists of two panes of glass separated by an air gap. The air between the panes acts as an insulator. The optimum air gap for insulation purposes is approximately 16mm, but this is often not practical for many windows. The air gap is usually between 6mm and 12mm.

Double glazing can significantly reduce the heat loss from windows. We have assumed that double glazing will reduce the heat loss from an average house by 25%, based on information from consumers.[22]

Application details

Double glazing is more expensive than single glazing, but results in significantly reduced heat losses.

Currently double glazing is installed in 60% of new homes built in Christchurch, even without a legal requirement. As the use of double glazing becomes more commonplace in New Zealand, the costs are expected to reduce and the uptake to continue to increase.

Capital cost

We have obtained material costs for Smith and Smith glass for both double glazing and single glazing. We have also estimated installation costs of $30/m^2.

Operating cost

There are no operating costs for double glazing.

Lifetime

Double glazing has an economic lifetime of 25 years.

Assumptions

1. A low level of uptake for existing homes, equivalent to 0.5% over 5 years.
2. A higher uptake in new homes starting in the short term with 10% in Auckland, 30% in Wellington, and 60% in Christchurch; this uptake is expected to increase in the long term to 30% in Auckland, 50% in Wellington, and 100% in Christchurch.
3. Energy savings from installing double glazing are estimated to range from 814kWh/year in Auckland to 2,781kWh/year in Christchurch, with a national weighted average of 1,572kWh/year.
4. The average house has 40m^2 of glazing.
5. The material costs for double glazing are estimated to be $275/m^2.

[22] Consumer Report: Double Glazing, March 2001

6. In the case of installation in new homes, we have taken into account the saving from not requiring single glazing (at $123/m^2).
7. In the case of installation in existing homes, we have allowed $30/m^2 for installation.

Annual energy savings/outputs

Energy savings are based on the assumption that double glazing can reduce the heat loss from a well-insulated house by 25%.

Summary

Table 52 Summary information on double glazing

Technology/measure	**Double glazing**
Capital cost (new houses)	$6,110 (per house)
Capital cost (alterations)	$12,200 (per house)
Annual operating cost	Nil
Annual energy savings (new houses)	1,572kWh/year
Annual energy savings (alterations)	1,572kWh/year
Economic lifetime	50 years
Unit cost (new houses)	26.2 cents/kWh
Unit cost (alterations)	52.3 cents/kWh

Barriers

The main barrier to the widespread uptake of double glazing in New Zealand is the initial capital cost.

In colder regions and/or in cases where homes are well heated it is likely to be cost-effective. However, based on the current heating patterns in New Zealand homes it is not as cost-effective as other alternatives, particularly in retrofit situations.

Other barriers include availability and industry knowledge about marketing the features and benefits. These barriers have considerably reduced in recent years in Christchurch, resulting in significant uptake for new homes.

Assessed uptake

Double glazing is more likely to be cost-effective for new buildings; therefore, we have assumed a much higher uptake for them. We have assumed in colder regions that uptake will increase from 60% in the short term to 100% in the long term for new buildings. Uptake in the warmer regions will also increase, but from a lower base and at a slower rate.

For retrofits, we have assumed a very low uptake (0.5% every 5 years).

In the long term we have estimated 41,000 existing homes will install double glazing, resulting in energy savings of 41GWh.

In the long term we have estimated 330,000 new homes will install double glazing, resulting in energy savings of 679GWh.

Table 53 Estimated uptake and energy savings from double glazing

Time frame (years)	# of installations thousands	Annual savings GWh
0–5	40,000	82
5–10	105,000	221
10–30	226,000	440

4 Enabling technologies

4.1 Energy storage

A critical factor in any form of microgeneration is the ability to capture and to reuse the electricity or heat produced when supply is greater than demand. Electricity generation from wind and solar sources is only available when the wind is blowing or the sun is shining; therefore, alternative supplies of power are required at other times. This is particularly important for off-grid applications. In most cases, some form of storage system will reduce the dependence on other generation technologies.

A number of energy storage technologies are available. Considerable research is being carried out to improve existing ones and to develop new forms of storage. Much of this is aimed at large-scale storage and may not be relevant at the micro level of generation. However, it is possible these outcomes may be applied at a smaller scale. This report provides a brief overview of the forms of storage presently available and considers likely future advances. Information from the Electricity Storage Association in California, USA, has been used to provide some comparisons between capital and operating costs of different technologies. While costs are in US dollars, the relationships between the storage methods are the same in New Zealand. New Zealand costs have been used, where possible, to allow for comparisons.

On-grid

Where microgeneration is being used at a location that is connected to an electricity supply network, it is unlikely that the cost of providing additional electricity storage equipment is cost-effective. At the moment, the combined cost of generation and storage equipment will result in higher electricity costs than those from the retailer. If payment can be received for any exported power this will make the storage option even less favourable. Using the grid as the virtual storage technology will give the best combination of on- and off-site generation.

Off-grid

It is in the off-grid application that the need for energy storage becomes important. Only when ‘on demand’ generation, such as a diesel generator, is available will storage be unnecessary. Some storage technologies are reviewed below.

Batteries

These have been the traditional form of electricity storage and much work is being carried out to improve their cost and efficiency. New battery technologies are continually being developed to get the best combination of cost, operating life, weight, and storage capacity. All these factors must be considered when selecting the most suitable storage for a particular application. A major disadvantage of batteries is that they store energy in direct-current format while most applications require alternating-current electricity. This requires an inverter and voltage regulator to supply the power in the required form.

Lead-acid batteries

Lead-acid is one of the oldest and most developed battery technologies. It is a low-cost and popular storage choice for power quality and UPS applications. Its application for energy storage, however, has been very limited due to its short cycle life. The amount of energy (kWh) that a lead-acid battery can deliver is not fixed and depends on its rate of discharge. Most microgeneration power storage systems in New Zealand now use some form of heavy-duty lead-acid battery. While these may not be the best technology, their ready availability and relatively low cost offset their short life. This trend is unlikely to change in the next 5 years.

Other battery technologies

Considerable research has been carried out to provide increasingly effective batteries for use in portable electronic equipment such as computers. Applying these technologies on a larger scale provides the most likely opportunity for energy storage on the microgeneration scale.

Lithium-ion has rapidly overtaken nickel-cadmium and nickel metal hydride batteries, and has secured over 50% of the small portable market in a few years. There are some challenges for making large-scale Li-ion batteries. The main hurdle is the high cost due to special packaging and internal overcharge protection circuits. Several companies, particularly in the auto industry, are working to reduce the manufacturing cost of lithium-ion batteries to capture large energy markets (multi-kW, kWh sizes for residential and commercial markets). A lesser problem is that these batteries perform best at low temperatures and may need to be cooled for some applications.

Lithium polymer batteries (Li-Poly or LiPo) have technologically evolved from lithium-ion batteries. Ultimately, the lithium salt electrolyte is not held in an organic solvent as in the proven lithium-ion design, but in a solid polymer composite. The many advantages to this design over the classic lithium-ion design include the fact that the solid polymer electrolyte is not flammable (unlike the organic solvent that the lithium-ion cell uses); thus, these batteries are less hazardous if mistreated. Lithium-ion polymer batteries started appearing in consumer electronics in about 1996.

Other advanced battery technologies are being developed but are not detailed in this report.

Battery selection is based on a combination of capital and lifetime costs. Figures 1 and 2 from the Energy Storage Association illustrate that lead-acid batteries have the lowest capital cost but high operating costs.

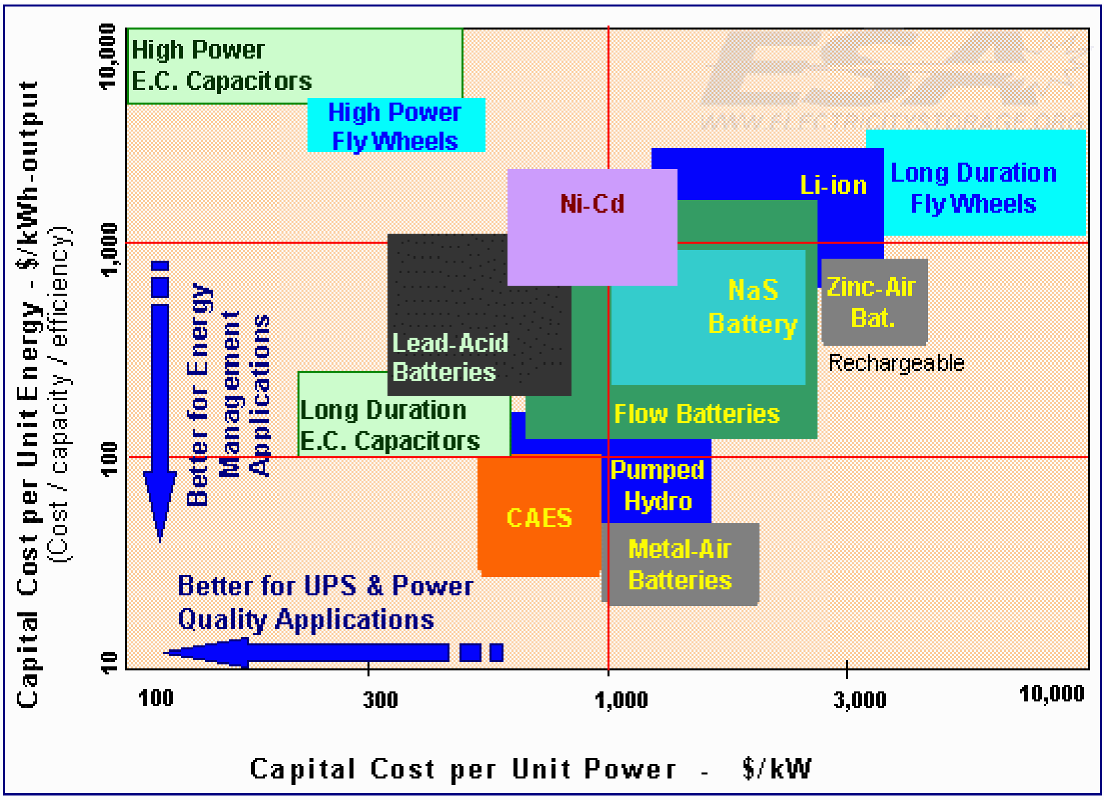


Figure 1 Costs of energy storage technologies

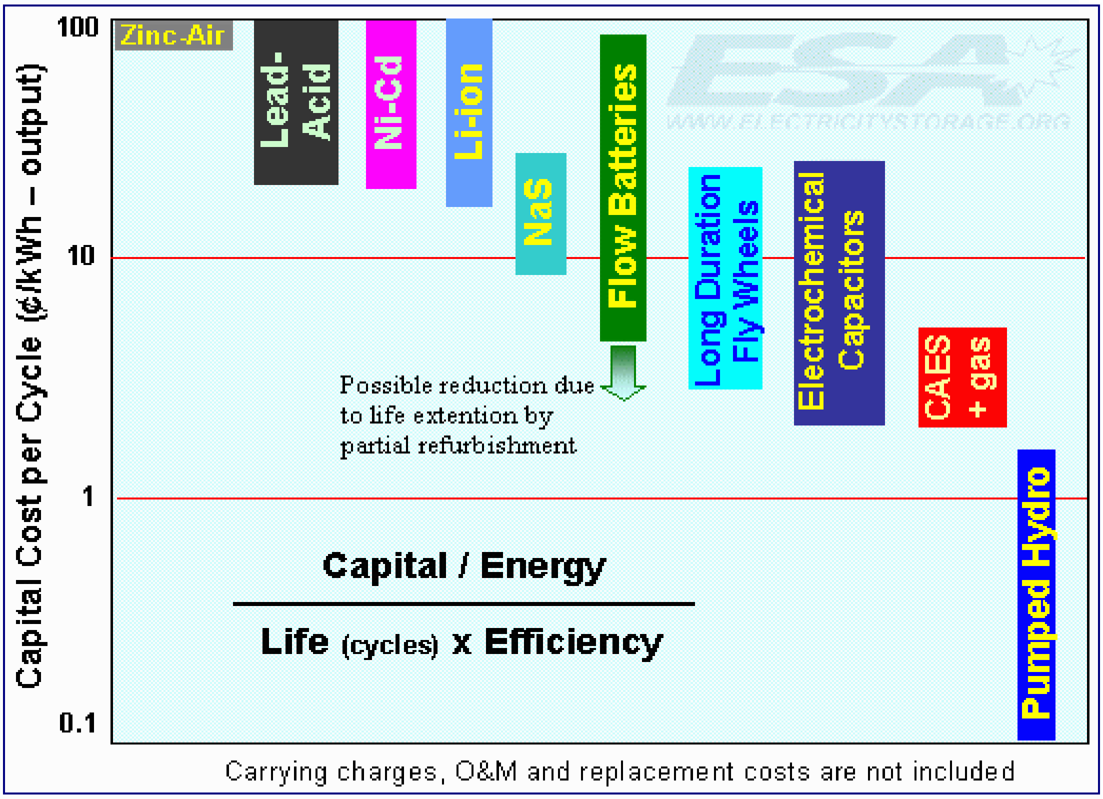


Figure 2 Capital costs and life cycles of energy storage technologies

Other forms of energy storage

While technologies such as compressed air energy storage (CAES), flywheels, and capacitors are available, it is unlikely that these would be applied for storage at the scale being looked at in this report. Most are being developed for storage on a much greater scale. Hydro storage is most likely of the present forms to be used in New Zealand.

Pumped hydro storage can be used to even out the daily electricity generating load, by pumping water to a high storage reservoir during periods of over generation. This water can then be used for hydroelectric generation to cover transient peaks in demand. The chief problem with pumped storage is that it usually requires two nearby reservoirs at considerably different heights; however, it enables potential generation capacity to be captured when demand is low but wind or solar energy is available. This application is practical only when micro hydro and wind or solar generation are in use at the same location.

Using electricity to produce hydrogen can be seen as a form of energy storage in that the hydrogen can be stored for later use as an energy source. As technology in this area advances, using excess renewable energy generation capacity in this way may become increasingly popular in 15 to 20 years time.

Anaerobic digestion of organic matter produces biogas that can be stored for later use.

Costs

The cost of energy storage can be greater than that of the generation equipment, and it can also have higher operating costs. These costs must be a major consideration when considering the suitability of microgeneration in off-grid applications.

To indicate the impact of storage, costs from the EcoInnovation website have been used. For 240W of PV panels, the price is NZ$2,160. The combined cost of batteries, inverter, and voltage regulator is $2,925. A small wind turbine installation has similar costs. This shows that nearly 60% of the cost of an installation can be due to the ancillary equipment required to cope with off-grid supply.

Mobile storage

An intriguing possibility for the future is using batteries in a vehicle as a mobile storage system. Not only could the microgeneration be used to charge the batteries for transport needs, but the batteries could supply additional energy storage to cover household peaks and times of low generation.

4.2 Smart metering

Smart meters not only measure the total amount of electricity used, but also incorporate data storage and communication functions. These meters can enable electricity meters to be read remotely and often incorporate two-way communication systems.

With smart-metering technology, customers can have more information about their energy consumption patterns. The technology can also be used to switch appliances remotely. It could be used to control microgeneration equipment and to meter both the output from a microgeneration plant, and the total electricity used by the premises.

Smart metering is an enabling technology that will make more widespread use of microgeneration technology possible. The cost of smart-metering is decreasing, and its widespread installation is becoming more common. Smart meters are being installed on a large scale in Ontario, Canada, and some states in Australia. Meridian Energy has recently initiated a large-scale pilot project in the Hawkes Bay.

5 Potential for microgeneration of energy services in New Zealand

This section provides a cumulative assessment of the microgeneration technologies providing energy services that are expected to be the most significant in the next 30 years.

5.1 Electricity prices – current and projected

A key factor in estimating the expected uptake of all microgeneration technologies is the current and projected price of energy. Uptake of microgeneration technologies will depend on these prices for on-site electricity.

In order to simplify the number of different electricity tariffs available throughout New Zealand, the households likely to be most interested in microgeneration are those with some concern about the cost of their energy use. These will be principally rural electricity users.

To establish benchmark electricity prices, five urban areas and five rural areas were identified from the Ministry of Economic Development's Schedule of Domestic Electricity Prices – Updated to 15 November 2005. Electricity tariffs for these areas were obtained from the Consumers Powerswitch website to determine the daily fixed charge and the variable tariff for customers based on the incumbent retailer's electricity tariff. The results are shown in Tables 54 and 55.

Table 54 Rural residential electricity cost (cents/kWh)

Rural	Daily charge c/kWh	Variable charge c/kWh
Northland	80.9	20.9
Bay of Plenty	59.6	24.5
Wairarapa	78.8	24.4
Taranaki	78.8	24.4
West Coast	179.0	19.7
Average (rural)	**95**	**23**

Table 55 Urban residential electricity costs (cents/kWh)

Urban	Daily charge c/kWh	Variable charge c/kWh
Auckland (North Harbour)	78.8	19.1
Auckland (Central)	79.8	17.0
Waikato	75.0	20.4
Wellington	78.8	19.1
Christchurch	63.9	20.0
Average (urban)	**75**	**19**

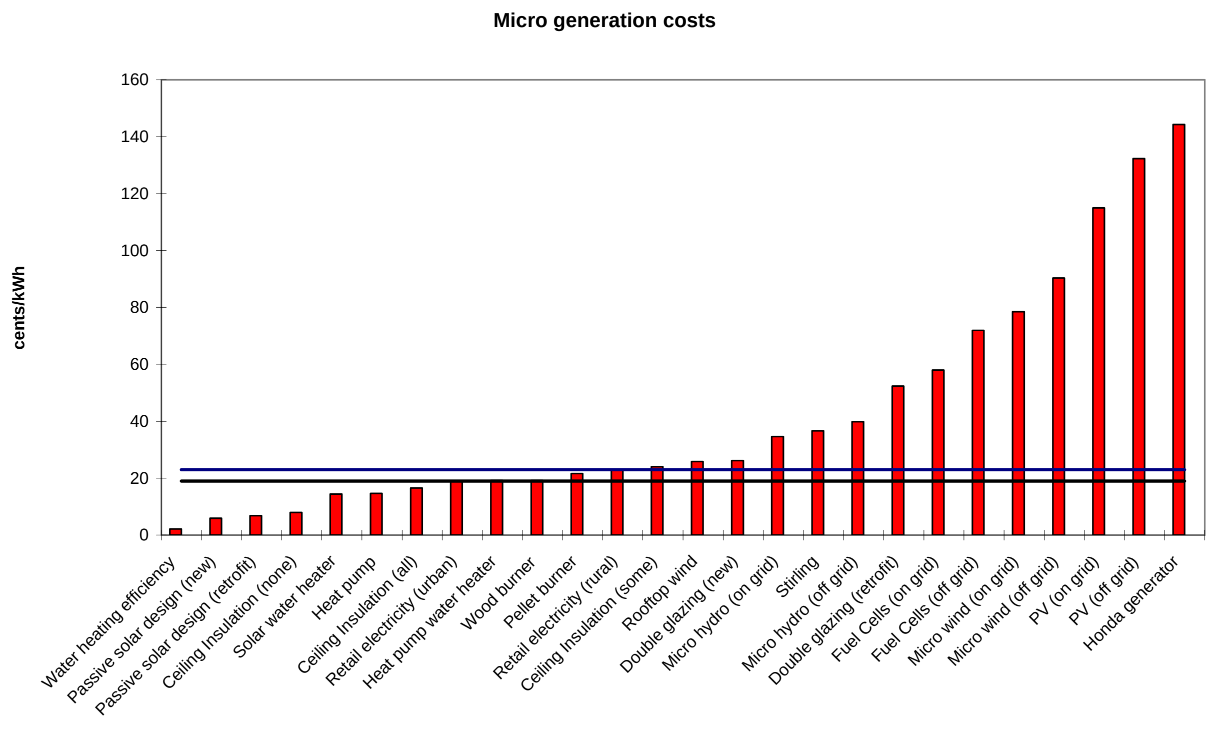
Marginal prices for electricity range considerably from 24 cents/kWh in some rural areas to 15 cents/kWh in urban areas. An average variable rate of 19 cents/kWh for urban areas and 23 cents/kWh for rural areas has been assumed. These rates are compared to the costs for microgeneration technology. Electricity's marginal cost is expected to significantly influence the uptake of microgeneration technologies.

Therefore, electrical microgeneration technologies are most likely to be implemented in rural areas first while solar water heating is likely to be taken up quicker in sunny regions.

5.2 Microgeneration cost estimates

The cost of energy from the microgeneration technologies covered by this project has been calculated and compared in Figure 3 with the current marginal price to influence estimates of technology uptake.

Figure 3 Energy costs from microgeneration technologies



5.3 Assessed cumulative potential – electricity generation technologies

Many of the electricity generation technologies are not currently economic and their uptake is expected to be limited in the short and medium term. However, as energy costs increase after the 2010–2020 period, uptake could increase significantly. It is expected to be higher in rural areas where electricity costs are higher and electricity distribution systems are less concentrated, and therefore more expensive to maintain and sometimes less reliable. Of the 1.36 million households in New Zealand, approximately 190,000 are in rural areas. This data has been used as an upper boundary of the possible uptake for electricity-based micro technologies in the short term (0–5 years) and medium term (5–10 years). In the long term (10–30 years), minor urban areas have also been included in the total potential (i.e. 313,000 households).

A significant uptake of microgeneration technologies focused on electricity production in main urban areas in New Zealand is not expected within the next 30 years. However, some uptake may occur in rural areas. More significantly, electricity demand modifiers such as solar and heat-pump water heating, space-heating heat pumps, and passive solar design will have a large uptake in both rural and urban areas. This is due to several factors.

1. The price of electricity is significantly lower in urban areas due to the more concentrated nature of electricity distribution systems.
2. The local environmental effects from microgeneration are expected to be more significant in main urban areas due to the population density and environmental effects from other activities such as transport, home heating, industry etc.
3. The reliability of supply in main urban areas is expected to be significantly better for grid-connected houses than for any microgeneration options now or in the future.
4. The cost for microgeneration options is significantly higher than the cost of electricity from the national grid. This is expected to continue at least for the short and medium terms.
5. Due to the low level of current activity within the microgeneration equipment supply sector in New Zealand, there is a lack of skills and experience among designers and installers.

Table 56 Assumed distribution of rural and urban residential dwellings

Description	Example	Number of dwellings
Main urban areas	Whangarei, Auckland, Hamilton, Tauranga etc	955,806
Secondary urban areas	Pukekohe, Tokoroa, Taupo, Whakatane etc	90,189
Minor urban areas	Taipa Bay-Mangonui, Kaitaia, Kerikeri etc	121,104
Rural areas		192,231
Inland water/inlet/oceanic		513
Total New Zealand		**1,359,843**

The removal of the requirement for lines companies to maintain electricity supply to all areas, which comes into effect in 2013, was also taken into account when estimating the uptake of microgeneration technologies. The Ministry of Economic Development is expected to review this change by June 2006. If it does come into effect, it is likely to have a significant impact on the uptake of microgeneration technologies in many rural areas.

For residential applications, each electricity generation technology has been ranked in terms of the expected potential uptake. The total residential potential has then been assessed along with an estimation of the percentage uptake for each technology. This estimated uptake is based on the cost of energy from the microgeneration technology compared to current electricity prices, ease of installation and maintenance, and availability of fuel or natural resource. From this work, the number of potential installations is determined.

Table 57 Residential uptake percentage

Technology	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
PV	0.02%	1.00%	4%
CHP	0.02%	0.02%	1%
Micro hydro	0.03%	0.03%	1%
Wind	0.20%	0.30%	2%
Wind rooftop	0.05%	1%	2%

Table 58 Maximum theoretical residential potential

Technology	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)
PV	190,000	190,000	310,000
CHP	190,000	190,000	310,000
Micro hydro	190,000	190,000	310,000
Wind	190,000	190,000	310,000
Wind rooftop	190,000	310,000	400,000

Table 59 Number of residential applications

Technology	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)	Percentage
PV	38	1,900	12,400	38%
CHP	38	38	3,100	9%
Micro hydro	57	57	3,100	9%
Wind	380	570	6,200	19%
Wind rooftop	95	3,100	8,000	24%
Total	**608**	**5,665**	**32,800**	**100%**

Using these assumptions, the energy potential for all residential applications is calculated and presented in Table 60, based on the estimated energy output from each installation.

Table 60 Residential electricity generation potential (GWh pa)

Technology	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)	Percentage
PV	0.1	5.0	37	25%
CHP	0.3	0.5	22	15%
Micro hydro	0.2	0.5	13	9%
Wind	3.0	7.1	54	36%
Wind rooftop	0.2	6.4	22	15%
Total residential	**4**	**20**	**148**	**100%**

Commercial and industrial applications have been assessed on an analysis of specific applications that may occur at local on-site situations.

Table 61 SME electricity generation potential (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
PV	0.3	15.4	127
CHP	0.5	1.6	68
Micro hydro	0.5	1.4	27
Wind	5.7	20.0	127
Wind rooftop	0.4	13.2	58
SME total electricity generation	**7.4**	**51.4**	**408**

5.4 Assessed cumulative potential – heat generation technologies

Heat generation technologies are generally implemented at a more significant rate, so the expected uptake can be estimated more accurately . Many of the residential heat generation technologies are household space heaters or water heaters. The maximum potential is based on the number of households in New Zealand, now and in the future.

The assumptions made about the housing stock are detailed in Section 1.4.

Details of the energy savings from heat generation technologies in residential applications are summarised in Table 62.

Table 62 Residential heat generation potential (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
Pellet burner	27	143	401
Wood burner	61	179	366
Heat pump	182	440	1,304
Heat-pump water heater	3	112	603
Solar water heater	115	927	1,893
Total residential heat generation	**387**	**1,800**	**4,568**

Commercial/industrial use is driven by the need for process heat, particularly in the food- and wood-processing sectors, and is presented in Table 63.

Table 63 SME heat generation potential (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
Pellet burner	2	5	13
Industrial combustor	4	4	25
Heat pump	380	950	2,836
Heat-pump water heater	2	15	51
Solar water heater	123	290	508
Organic Rankine cycle	0	6	18
Anaerobic digestor	0	1	2
Total SME heat generation	**510**	**1,270**	**3,453**

5.5 Assessed potential – motive power technologies

It is assumed that motive power technologies such as wind and hydro pumping will only apply to commercial/industrial applications such as farming. The estimated energy potential of motive power technologies is shown in Table 64.

Table 64 Energy potential of commercial/industrial motive power applications (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
Wind pumping	1	2	21
Hydro pumping	?	?	?
Total	**1**	**2**	**21**

5.6 Assessed potential – energy efficiency

The potential for energy efficiency improvements has been determined from the available knowledge about New Zealand's current housing stock. The number of houses with no ceiling insulation, inadequate ceiling insulation, old hot-water cylinders etc has been assessed, so the potential energy savings from energy efficiency measures can be determined.

Table 65 shows the number of houses where each energy efficiency technology included in this project can be applied.

Table 65 Estimated number of energy efficiency improvements in houses

Technology	Short term (0–5 years)	Medium term (5–10 years)	Long term (10–30 years)	Percentage
Residential				
Ceiling insulation	100,000	250,000	421,000	35%
Water heating efficiency	25,000	75,000	350,000	29%
Passive solar design (retrofit)	70,000	140,000	420,000	35%
Passive solar design (new)	65,000	130,000	390,000	33%
Double glazing (retrofit)	34,000	68,000	340,000	29%
Double glazing (new)	37,000	74,000	222,000	19%
Total	**195,000**	**465,000**	**1,191,000**	**100%**

Table 66 shows the estimated energy savings from these energy efficiency measures.

Table 66 Residential energy efficiency potential (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
Ceiling insulation	120	177	243
Water-heating efficiency	11	33	152
Passive solar design (retrofit)	54	107	321
Passive solar design (new)	116	231	693
Double glazing (retrofit)	11	21	64
Double glazing (new)	71	282	679
Total residential energy efficiency	**382**	**852**	**2,152**

Table 67 SME energy-efficiency potential (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (5–10 years) GWh pa	Long term (10–30 years) GWh pa
Energy management and equipment efficiency	719	2,388	5,603
Total SME energy efficiency	**719**	**2,388**	**5,603**

5.7 Total potential

Figures 4 and 5 show the estimated energy savings from each microgeneration technology investigated.

Figure 4 Estimated microgeneration technology uptake in the residential sector to 2035

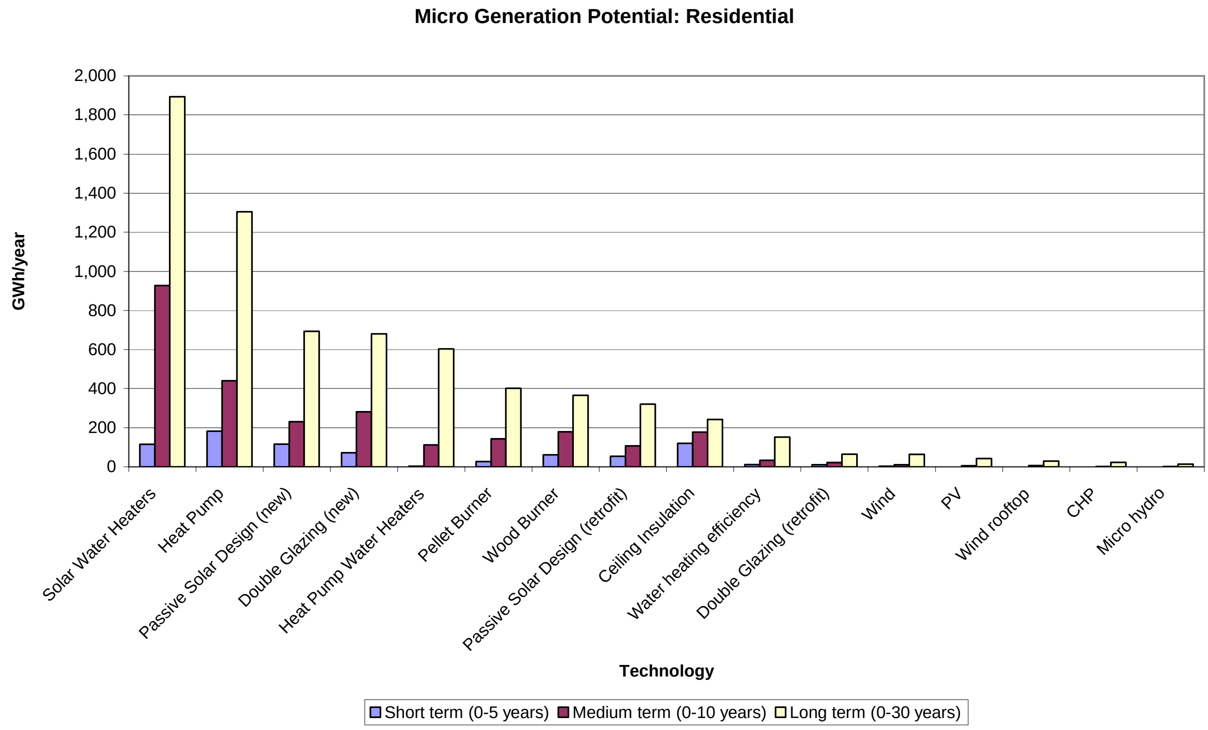
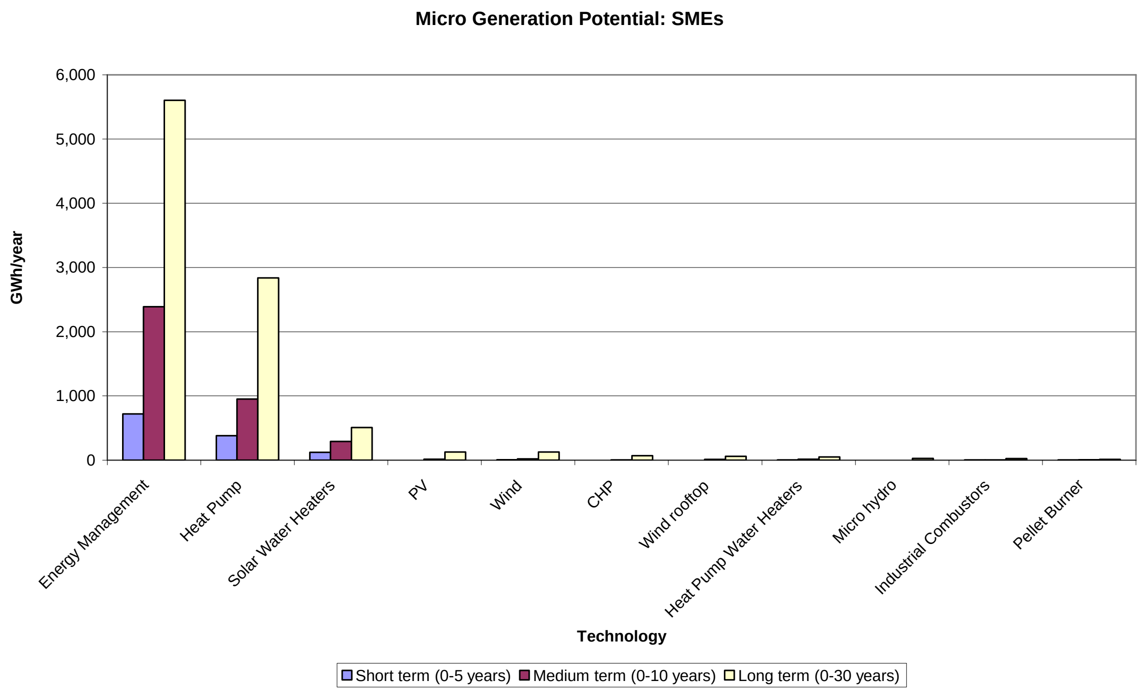


Figure 5 Estimated microgeneration technology uptake in the commercial/industrial sector to 2035



Tables 68 and 69 show this data in a tabular form.

Table 68 Total potential for residential applications (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa	Percentage
PV	0.1	5.1	42	0.6%
CHP	0.3	0.8	23	0.3%
Micro hydro	0.2	0.7	14	0.2%
Wind	3	10	64	0.9%
Wind rooftop	0.2	7	29	0.4%
Total electricity generation	**3.6**	**23.2**	**172**	**2.5%**
Pellet burner	27	143	401	5.8%
Wood burner	61	179	366	5.3%
Heat pump	182	440	1,304	18.9%
Heat-pump water heaters	3	112	603	8.8%
Solar water heaters	115	927	1,893	27.5%
Total heat generation	**387**	**1,800**	**4,568**	**66.3%**
Ceiling insulation	120	177	243	3.5%
Water-heating efficiency	11	33	152	2.2%
Passive solar design (retrofit)	54	107	321	4.7%
Passive solar design (new)	116	231	693	10.1%
Double glazing (retrofit)	11	21	64	0.9%
Double glazing (new)	71	282	679	9.9%
Total energy efficiency	**382**	**852**	**2,152**	**31.2%**
Total	**772**	**2,675**	**6,891**	**100.0%**
Total residential electricity use 2004	12,255	12,255	12,255	
Percentage of total residential	6.3%	21.8%	56.2%	
Projected residential electricity use assuming an annual increase of 2% pa (2010, 2015, 2035)	12,500	13,800	22,600	
Percentage of projected residential electricity use	6.2%*	19.4%*	30.5%*	

*Note that this compares the total uptake of micro technologies in the residential sector with the sector's projected electricity consumption. The microgeneration potential includes electricity, heat, and energy-efficiency technologies.

Table 69 Total potential for industrial/commercial applications (GWh pa)

Technology	Short term (0–5 years) GWh pa	Medium term (0–10 years) GWh pa	Long term (0–30 years) GWh pa
PV	0.3	15.4	127
CHP	0.5	1.6	68
Micro hydro	0.5	1.4	27
Wind	5.7	20.0	127
Wind rooftop	0.4	13.2	58
Total electricity generation	**7.4**	**51.4**	**408**
Pellet burner	2	5	13
Industrial combustors	4	4	25
Heat pump	380	950	2,836
Heat-pump water heater	2	15	51
Solar water heater	123	290	508
Organic Rankine cycle	0	6	18
Anaerobic digesters	0	1	2
Total heat generation	**510**	**1,270**	**3,453**
Wind pumping	2	7	21
Hydro pumping	?	?	?
Total motive power	**2**	**7**	**21**
Energy management and equipment efficiency	719	2,388	5,603
Total energy efficiency	**719**	**2,388**	**5,603**
SME total	**1,237**	**3,712**	**9,484**
Total SME electricity use 2004	6,999	6,999	6,999
Percentage of total SME	18%	53%	135%
Projected SME electricity use assuming an annual increase of 2% pa (2010, 2015, 2035)	7,900	8,700	12,900
Percentage of projected SME electricity use	15.6%**	42.6%**	73.4%**

**Note that this compares the total uptake of micro technologies in the residential sector with the sector's projected electricity consumption. The microgeneration potential includes electricity, heat, and energy efficiency technologies.

The analysis shows that the most potential for microgeneration lies in heat generation technologies. Energy-efficiency improvements also have significant potential.

The potential for electricity generation technologies is expected to be low. This is based on the gap between electricity prices from conventional sources, and the costs for microgeneration options.

6 Barriers to widespread uptake

Except for heating related technologies that modify electricity demand, the most significant barrier to the widespread uptake of microgeneration technologies is the cost.

Other barriers include:

- the lack of data on how energy is used in residential and commercial/industrial applications, and on the benefits of microgeneration technologies
- possible environmental impacts in urban applications
- maintenance requirements
- regulation and model supply and interconnection agreements to enable easy connection
- customer awareness of the available technologies and where they can be best applied
- availability of suppliers and skilled installers to design, install, and maintain microgeneration systems.

7 Recommendations for further work

The study identifies that, for many technologies, there has been little analysis undertaken by others during the last two decades. Little reliable data exists on how energy is used in commercial and industrial applications. The lack of information results in a lack of debate on the assumptions included in this study, and subsequent action.

Energy use in commercial/industrial applications by SME is poorly understood. Data published by EECA in 'The Dynamics of Energy Efficiency Trends in New Zealand, 2000' is dated and may no longer be applicable. It is recommended that this work be updated and revised.

In the residential area, the very valuable research by BRANZ in the HEEP project should be continued. The project provides an important database of residential energy use that gives a good understanding of where microgeneration can contribute to future energy supply.

This study provides a baseline for further analysis. This should be based on scenarios exploring policy options that would improve the uptake of microgeneration technologies.

Microgeneration's potential to assist future energy services would most likely be greater than assessed in this study if a programme of microgeneration market initiatives were established. It is recommended that a project focused on improving the quality and reliability of the data on which this study is based be convened. The project should include the various industry associations, EECA, Electricity Commission, Parliamentary Commissioner for the Environment, Ministry of Economic Development, Victoria University Architecture School, BRANZ, and other parties with an interest in microgeneration technologies.

Lack of public knowledge on microgeneration technologies partly reflects little government support for such technologies. Because of the large transaction costs in researching and promoting microgeneration technologies, and the lack of significant industry players to fund such work, it is beholden on government to assist if long-term public benefits are to be achieved.

Specific further work to include:

- evaluation of the expected impact of a feed-in tariff to provide a trigger for the uptake of electric microgeneration technologies
- quantification of the national benefits of microgeneration and how their value compares to the private benefits. This evaluation should include quantification of benefits to lines companies and the wider community as well as environmental benefits
- investigation of methods to build capability and increase understanding of the application and potential of microgeneration technologies in New Zealand
- investigation of regulatory changes to encourage increased uptake of microgeneration technologies in New Zealand.

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Appendix A – Technology identification

Electricity generation technologies

Source/ category	Technology	Brands	Included in stage 2	Comments
Wind	Rooftop turbines	Swift, Windsave	Yes +++	The technical potential is expected to be significant and able to be quantified with available data sources. We will assume that the characteristics of the Swift turbine are representative of all rooftop wind turbines.
	Pole-mounted turbines – grid-connected	Eco Innovation, Bergey, Soma, Air Marine, Windflow	Yes +++	The technical potential is expected to be significant and able to be quantified with available data sources. We plan to select key brands and models that are representative to evaluate this option.
	Pole-mounted turbines – not grid-connected	Eco Innovation, Bergey, Soma, Air Marine, Windflow	Yes +++	The technical potential is expected to be significant and able to be quantified with available data sources. We plan to select key brands and models that are representative to evaluate this option.
Hydro	Reaction		No	The blades of a reaction turbine are totally immersed in the flow of water and the pressure of water leaving the runner is reduced to atmospheric or lower. This technology is typically applied to larger hydro applications; therefore, it will not be assessed in this study.
	Impulse	Eco Innovation, Nomad, Inertia-less systems	Yes +++	Impulse turbines convert the kinetic energy of a jet of water in air into movement by striking turbine buckets or blades – there is no pressure reduction as the water pressure is atmospheric on both sides of the impeller. Technologies include Pelton Wheels and Turgo turbines. Higher heads tend to be required for impulse turbines but they can be effective with lower water flows. The technical potential is expected to be significant. It is expected that the potential will be difficult to accurately quantify.

	Micro venturi	Generic	Yes +	The use of a venturi to reduce pressure can used to pull water or air from another location into the primary flow. It is this secondary flow that allows generation of electrical power. The application of this technology in run-of-river or tidal situations may have significant potential in the future. It is expected that the potential will be difficult to accurately quantify.
	Archimedes screw		No	There has recently been revived interest in the use of Archimedes screw technology in Europe with installations in Germany and Switzerland. These units require only low flow and allow fish to pass up them. Potential is expected to be difficult to quantify and smaller than other technologies assessed.
Solar	PV – on-grid		Yes	Technical potential is expected to be significant. Currently the cost is very high compared to other options.
	PV – off-grid		Yes	Technical potential is expected to be significant. Currently the cost is very high compared to other options, but remains a practical solution for many remote locations.
	Solar thermal		No	Not expected to be economic in New Zealand because of high level of cloud cover.
Gas CHP	Stirling engine	WhisperGen	Yes	The technical potential is expected to be significant and able to be quantified with available data sources. We will assume that the characteristics (price and output) of the WhisperGen turbine are representative of all micro Stirling engine applications.
	Modular organic Rankine cycle		Yes	Because this is a low-temperature and low-pressure system there are opportunities to retrofit onto existing heat plants as well as potential to connect with new heat plants.
	Fuel cells		Yes	Worldwide there is major research being carried out on fuel-cell development. Fuel cells have a higher electricity than heat output; therefore, their application in New Zealand is expected to be greater than Stirling engines
Coal	Conventional combustion plant		No	Requires a large heat plant for generation. Generally not considered economic below 1Mwe

	Modular organic Rankine cycle		Yes	Because this is a low-temperature and low-pressure system there are opportunities to retrofit onto existing heat plants as well as potential to connect with new heat plants.
Diesel	Engines	Generic	Yes	The technical potential is expected to be significant and able to be quantified with available data sources.
Petrol	Engines	Honda	Yes	Potential is expected to be limited. Data on cost and performance is readily available. Analysis of this technology will provide a useful yardstick to compare other options with.
Biomass	Conventional combustion plant		No	Requires a large heat plant for generation. Generally not economic below $1MW_e$.
	Gasification plant		No	Requires a large heat plant for generation. Generally not economic below $1MW_e$.
	Modular organic Rankine cycle	Generic	Yes	This technology uses woody biomass and feedstock to produce low-grade heat for the generation of electricity. Can also be adapted to use geothermal power. Potential is expected to be limited and difficult to accurately quantify.
Geothermal	Conventional steam generation		No	Not economic at microgeneration level.
	Modular organic Rankine cycle	Generic	No	Not economic at microgeneration level.

Comment: The work being carried out by Eco Innovation in Taranaki and some other small New Zealand companies in a number of areas of microgeneration should form a separate part of the study. The use of second-hand equipment for electricity generation has significant environmental implications.

Key

+++	High potential for New Zealand
++	Moderate potential for New Zealand
+	Some potential for New Zealand

Heat generation technologies

Source/category	Technology	Brand	Included in stage 2	Comments
Solar	Passive solar design	Generic	Yes	For new buildings, significant energy savings can be made for little or no extra cost. Proper orientation is a key element in the design.
	Solar water heaters	Generic	Yes	Domestic applications both for new houses and retrofit applications will be evaluated. Commercial applications will also be evaluated, including government facilities.
	Heat pumps (air-source)	Generic	Yes	Existing technology but designs are still improving and costs declining. It is expected that the potential will be difficult to accurately quantify.
Geothermal	Direct heating		Yes	Is a limited resource and the potential is difficult to accurately quantify. Potential for continued direct use needs to be addressed.
	Heat pumps (ground-source)	Generic	Yes	Little uptake in New Zealand at present. Would have to compete with air-source heat pumps. It is expected that the potential will be small.

Biofuels	Wood burners	Generic	Yes	Current technology.
	Open fires	Generic	No	Inefficient, high level of emissions. Use is steadily reducing and we have assumed that open fires will be phased out.
	Biogas (municipal waste)		No	Some landfills will have about $3MW_e$ generation.
	Biogas (anaerobic digestion)		Yes	Organic waste from food processing using digesters. Dairy effluent treatment using anaerobic digestion.
	Pellet burners (wood waste)	Nature's Flame	Yes	Currently only one supplier of pellets. We will include both domestic and commercial applications, including schools and replacement of coal over time.
Fossil fuels	Coal burners	Generic	Yes	Schools etc. Conventional technology.
	Gas heating	Generic	Yes	Long-term gas use likely to be in fuel cells? Direct space heating. See 'electricity'.
	LPG	Generic	Yes	Long-term gas use likely to be in fuel cells? Direct space heating. See 'electricity'.

Various (storage)	Ice banks		No	Current technology. New forms of storage are continually being developed. Diurnal (salt hydrates, water rocks) and long term (lakes, rocks).
Gas CHP	Stirling engine	WhisperGen	Yes	Considerable potential; expensive at present. It is expected that the potential will be difficult to accurately quantify. See 'electricity'.
	Fuel cells	Generic	Yes	Considerable potential; very expensive at present. It is expected that the potential will be difficult to accurately quantify. See 'electricity'.

Pumping technologies

Source/category	Technology	Brand	Included in stage 2	Comments
Solar	Solar pumping		No	Requires energy conversion to achieve pumping/niche market.
Wind	Wind pumping	Beaver Meadows	Yes	Existing and proven technology.
Hydro	Venturi pumping		No	Niche market (also see 'electricity'/'hydro'/'Venturi' for technology).
	Hydraulic-ram pump	Uniflow	Yes	Existing and proven technology.

Energy efficiency technologies

Source/category	Technology	Brand	Included in stage 2	Comments
Solar	Passive solar design improvements	Generic	Yes	Although some passive solar design improvements will be difficult to retrofit, the technical potential is expected to be significant. It is expected that the potential will be difficult to accurately quantify.
Electricity	Water-heating efficiency improvements	Generic	Yes	Potential is expected to be significant and able to be quantified with available data sources.
	Power factor correction/improvements	Generic	No	Potential is expected to be difficult to quantify and smaller than other energy efficiency measures.
	Motor efficiency improvements	Generic	No	Potential is expected to be difficult to quantify and smaller than other energy efficiency measures.
	Lighting	Generic	Yes	Potential is expected to be significant and able to be quantified with available data sources.
Electricity and gas	HVAC recommissioning	Generic	No	Potential is expected to be difficult to quantify.
All fuels	Insulation improvements	Pink Batts, Bradford Gold etc	Yes	Potential is expected to be significant and able to be quantified with available data sources.

	Double glazing	Smith & Smith	Yes	Although double glazing is difficult to retrofit, the technical potential is significant. The potential is expected to be difficult to accurately quantify.
	Fuel switching	Generic	No	An example of this is using gas instead of electricity for water/space heating. Potential is expected to be difficult to quantify and smaller than other energy efficiency measures.
	Appliance efficiency improvements	Generic	No	Potential is expected to be difficult to quantify and smaller than other energy efficiency measures.

Comment: While the importance of considering energy efficiency improvements in this study is recognised, it is important that that main focus remains on energy generation technologies.

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