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Warm Homes Technical Report: Detailed Study of Heating Options in New Zealand

Phase 1 Report

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Other publications in this series include:
Warm Homes Technical Report: Detailed study of heating options in New Zealand:
Phase 2 Report

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1 Introduction

The Ministry for the Environment has set up the Warm Homes project to examine ways to encourage New Zealand households to move to cleaner heating sources and increase household energy efficiency, with the overall aim of encouraging warmer, healthier homes.

EnergyConsult Pty Ltd and Strategic Energy Ltd have been contracted to provide information on different home heating options and their costs and benefits through:

- a review of current literature on home heating
- development of an Excel model to be used as the framework for evaluating different heating sources
- a rating of home-heating types, by specified criteria
- case studies based on different areas of New Zealand, different household types and a range of heating patterns.

This phase 1 report includes the results of the review of current literature on home heating. The focus is on the technical and financial aspects; social studies of heating choice and incentives for behaviour change are to be incorporated in a separately commissioned report on social drivers.

In this report, fuel poverty[1] is considered in the context of the relative operating costs of the various heating and fuel options that are evaluated. A heater with a high operating cost per unit of heat delivered into the room will contribute more to fuel poverty than a more economical heating option.

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[1] A household is in fuel poverty if, in order to maintain a satisfactory heating regime it would be required to spend more than 10% of its income on all household fuel use (DEFRA, 2001).

2 Process and Methodology

To carry out this task most effectively a template was established, comprising a list of 23 criteria to consider when evaluating heating options, such as issues relating to fuel supply, capital and operating costs and emissions. This template was then applied to each of the 20 heating options considered in this analysis.

Contact was made with a number of individuals and organisations known to have expertise in the area of home heating (see Appendix 1). From these contacts and from our own knowledge of relevant documentation on heating, a list of documents on heating was identified. These documents are included in the Bibliography and References.

Using these documents, and questions directed to various heating experts, the template was completed as far as practicable for each of the heating options. The results are included in section 4.

Section 5 includes a discussion of various relevant factors in relation to the selection and use of preferred heating options. Any gaps identified in the currently available information are also noted.

Appendix 2 contains more detailed data on the costs, emissions and efficiencies of all the heating options considered in this study, as well as graphs showing the relative operating costs of the various options.

While the focus of this phase of the work was on the review of existing literature, future phases of the project were kept in mind in terms of information that could be useful for modelling and case studies.

All costs given in Section 4 and Appendix 2 of this report are GST inclusive, and all capital costs are on the basis of installed costs.

3 Interpreting the Results

The results of this project are presented in template form to allow easy comparison of the various heating options. Most of the criteria used in the templates are self-explanatory, but there are a number of abbreviations and technical terms used that may not be familiar to all readers. The most significant of these are explained below.

Measurements of energy:

KWh: kilowatt hour

L/KWh: litre per kilowatt hour

W/m^2: watt per metre squared

mg/MJ: milligrams per megajoules

g/kg: grams per kilogram

Particulate emissions:

PM_{10}: particles measuring less than 10 microns in diametre

$PM_{2.5}$: particles measuring less than 2.5 microns in diametre

Greenhouse gas emissions:

CO_2: carbon dioxide

NOx: oxides of nitrogen

SOx: oxides of sulphur

Other emissions:

CO: carbon monoxide

Embodied energy: energy used during the production and use of the good

Efficiency of conversion of energy to heat: how much energy in fuel is converted to heat

Heating capacity: the amount of heat produced by the appliance measured in kilowatts

Heat-transfer system: ventilation system which extracts air from a warm room and channels it to a cold room. For this system to be feasible the space heater in the warm room must have sufficient heating capacity.

4 Results of the Literature Review

Heating Option 1: Open fire, burning wood	
Nature of fuel/energy source	Wood
Availability of fuel/energy source	Wood is widely available from commercial suppliers but can also be collected free from a variety of sources (eg, untreated off-cuts from timber yards, manufacturers, building contractors, forestry, demolition timber).
Fuel/energy consumption	0.4–0.6 m^3/100 kWh delivered; 125–200 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	5–15%: accepted range though may even be negative at times. The low efficiency of open fires is the result of heat lost by convection through the chimney. Most room heating occurs through heat radiation, but the effectiveness of this may be reduced by the effect of draughts caused by the movement of air towards the fireplace. The maximum efficiency of open fires is generally assumed to be 15%. Operating costs presented in this work are based on efficiencies of 10 and 15%.
Typical operating costs	These will vary according to the source of wood and the efficiency of the fire. Ministry for the Environment: 26–36 cents/kWh Christchurch City Council: 30–40 cents/kWh Own calculations: 27–53 c/kWh delivered: • Figures are based on retail prices in December 2004. • The upper range of the calculated cost reflects the very low efficiencies at which open fires can operate.
Typical capital costs	It has not been possible to obtain a precise cost for installing an open fire within an existing building because this appears to be an unusual occurrence. It is likely that the installation of an open fire in a new property would add a cost in the order of $6,000. However, this is not an option in the increasing number of areas where local councils have prohibited the installation of open fires because of their high emissions and low efficiency.
Heating capacity	Typically around 2 kW of effective heat output into living areas.
Nature of the heat (radiant, convection, etc)	Heating is mainly radiant, with limited convection into the room (most convection heat is lost up the chimney). However, if the fireplace includes a wetback then some of the convection heat will be captured by this to provide water heating.
Fuel/energy handling issues	Operating a wood fire is labour intensive and involves cutting wood to size and stacking it in a dry location. Fuel may be required to comply with local regulations (eg, Environment Canterbury regulation for water content of wood to be less than 25% by weight). A large, dry fuel store is required and a steady supply of fuel must be kept handy during use. Fuel must be placed directly into the burning fire.
Convenience of use	An open fire requires regular refuelling and frequent attention during use.
Ease of heat control	Heat output is not constant and is difficult to control accurately.
Effectiveness of heat transfer	Heat transfer is poor, with only very local heating. Considerable heat (approximately 85%) is lost via the chimney and by the creation of draughts.
Heat-up rate	Slow
Ability to heat whole house vs single room	The form of heat output, mainly radiant rather than convection, combined with the limited heat output and the lack of means to circulate or distribute this heat make this form of heating unsuitable for heating a whole house. Some older homes have multiple fireplaces, which allow heating of multiple rooms, but will still suffer from the very low efficiencies inherent in open fires.
Particulate emissions	PM_{10}: 9 g/kg; 490 mg/MJ

Heating Option 1: Open fire, burning wood	
Greenhouse gas emissions	SO_x: 0.2 g/kg; 11 mg/MJ NO_x: 1.4 g/kg; 77 mg/MJ CO_2: 1700 g/kg (94,000 mg/MJ) but considered neutral. Wood fires may be considered to be CO_2 neutral because this gas has been in atmospheric form before being incorporated into the wood as part of the growing process of the tree. CO_2 resulting from the burning of fossil fuel may be considered to be a net addition because this gas has not been in atmospheric form before combustion.
Other emissions	CO: 68 g/kg; 3700 mg/MJ $PM_{2.5}$: 8 g/kg: 440 mg/MJ Emissions will depend on the wood being used – treated wood may contain hazardous chemicals. Hazardous emissions can result from incomplete combustion. Ash residue from burning must be disposed of.
Health and safety issues in the home (eg, indoor emissions and moisture)	Objects can come into contact with naked flames or sparks if the fire is not screened adequately. Radiant heat can also damage or ignite fabrics or objects close to the fire. Smoke released into the room increases local concentration of hazardous pollutants. No detailed information is available to quantify this risk.
Embodied energy	Firebricks; concrete; hearth grate. Wood harvesting; transport of fuel.
Special features	Open fires are considered to be aesthetically pleasing by some. They could be used for basic cooking in the event of a disruption to the electricity supply.
Risks associated with this option	See Health and safety issues (above). Open fires can be used to burn materials other than firewood or coal, which will contribute to emissions. Open fires can be highly polluting when allowed to smoulder. Chimneys must be swept regularly to prevent the risk of fire.
General comments	Energy and labour intensive; messy to operate and maintain. Not an option in new houses in some areas due to local council restrictions on allowable emissions.
Suitability for use with heat-transfer system	No

Heating Option 2: Open fire, burning coal	
Nature of fuel/energy source	Coal
Availability of fuel/energy source	Kyoto Protocol obligations may influence coal's future cost and availability. Solid Energy, the main supplier of coal to the domestic market in New Zealand, has indicated that it will begin phasing out the supply of coal for domestic heating. This will be done approximately in accordance with various local government bans on the use of open fires. Note that other retailers of coal have not made any similar commitment to withdraw from this market, but will be obliged to act in accordance with any legislation on the burning of coal and/or use of open fires. Coal miners and others in mining areas may receive a free or cheap coal allowance. However, the number of coal-fire users who receive these benefits is not considered to be significant nationally.
Fuel/energy consumption	104–157 kg/100 kWh delivered. The wide range of values results from the factor of three between the worst- and best-case efficiencies (10–15%) estimated for open fires. The low efficiency of open fires is the result of heat lost by convection up the chimney. Most room heating is from radiation, but the effect of this will be diminished by the effect of draughts produced by the movement of air towards the fireplace. The maximum efficiency of open fires is generally assumed to be 15%. Operating costs presented in this work are based on efficiencies of 10 and 15%.
Efficiency of conversion of energy to heat	5–15%: accepted range, though may even be negative at times. The low efficiency of open fires is the result of heat lost by convection through the chimney. Most room heating is the result of radiation, but the effectiveness of this may be reduced by the effect of draughts produced by the movement of air towards the fireplace. The maximum efficiency of open fires is generally assumed to be 15%. Operating costs presented in this work are based on efficiencies of 10 and 15%.
Typical operating costs	Ministry for the Environment: 23–32 cents/kWh Christchurch City Council: 30–35 cents/kWh Own calculations: 37–55 cents/kWh The upper range of the calculated costs reflects the very low efficiencies at which open fires may operate.
Typical capital costs	It has not been possible to obtain a precise cost for installing an open fire within an existing building because this appears to be an unusual occurrence. It is likely that the installation of an open fire in a new property would add a cost in the order of $6,000. However, this is not an option in the increasing number of areas where local councils have prohibited the installation of open fires because of their high emissions and low efficiency.
Heating capacity	Typically around 2.5 kW of effective heat output into living areas.
Nature of the heat (radiant, convection, etc)	Heating is mainly radiant, with limited convection into the room (most convection heat is lost up the chimney). However, if the fireplace includes a wetback then some of the convection heat will be captured by this to provide water heating.
Fuel/energy handling issues	Operating a coal fire is labour intensive and potentially messy. Coal produces dust during handling and storage. A dry fuel store is required. Operation of the fire requires a steady supply of fuel to be kept handy during use. Fuel must be placed directly into the burning fire.
Convenience of use	Coal fires require regular attention to burn efficiently. A small fire must be lit using another fuel source before coal can be burnt.
Ease of heat control	A coal fire produces an unsteady heat and is difficult to regulate accurately.
Effectiveness of heat transfer	Heat transfer is poor, with only very local heating. Considerable heat is lost via the chimney and by the creation of draughts.
Heat-up rate	Slow

Heating Option 2: Open fire, burning coal	
Ability to heat whole house vs single room	The form of heat output, mainly radiant rather than convection, combined with the limited heat output and the lack of means to circulate or distribute this heat, make this form of heating unsuitable for heating a whole house. Some older homes have multiple fireplaces, which allow heating of multiple rooms, but will still suffer from the very low efficiencies inherent in open fires.
Particulate emissions	PM_{10}: 21 g/kg; 910 mg/MJ
Greenhouse gas emissions	CO_2: 2721 g/kg; 118,000 mg/MJ SO_x: 5.1 g/kg; 220 mg/MJ NO_x: 4.1 g/kg; 180 mg/J
Other emissions	CO: 70 g/kg; 3000 mg/MJ $PM_{2.5}$: 20 g/kg; 870 mg/MJ Elements in coal, including mercury, are released to the atmosphere during burning. Emissions produced by incomplete combustion may also be hazardous. Ash residue from burning must be disposed of.
Health and safety issues in the home (eg, indoor emissions and moisture)	Objects can come into contact with naked flames or sparks if the fire is not screened adequately. Radiant heat can also damage or ignite fabrics or objects close to the fire. Smoke released into the room increases the local concentration of hazardous pollutants. No detailed information is available to quantify this risk.
Embodied energy	Firebricks; concrete; hearth grate. Mining; transport of fuel.
Special features	Open fires are considered to be aesthetically pleasing by some. They could be used for basic cooking in the event of a disruption to electricity supply.
Risks associated with this option	See Health and safety issues (above). Open fires can be used to burn materials other than firewood or coal, which will contribute to emissions. Open fires can be highly polluting when allowed to smoulder. Chimneys must be swept regularly to prevent the risk of fire.
General comments	Coal fires are energy and labour intensive, and are also messy. These fires are not an option in new houses in some areas due to local council restrictions on allowable emissions.
Suitability for use with heat-transfer system	No

Heating Option 3: Multi-fuel burner	
Nature of fuel/energy source	Coal or wood
Availability of fuel/energy source	Wood is widely available from commercial suppliers but can also be collected free from a variety of sources (eg, untreated off-cuts from timber yards, manufacturers, building contractors, forestry, demolition timber). Kyoto obligations may influence the future cost and availability of coal. Solid Energy, the main supplier of coal to the domestic market in New Zealand, has indicated that it will begin phasing out the supply of coal for domestic heating. This will be done approximately in accordance with various local and national government bans on the use of open fires. Note that other retailers of coal have not made any similar commitment to withdraw from this market, but will also be obliged to act in accordance with any legislation on the use of coal for domestic heating.
Fuel/energy consumption	Coal: 20–28 kg/100 kWh of heat delivered. Wood: 0.07–0.09 m^3/100 kWh of heat delivered, 26–36 kg/100 kWh of heat delivered.
Efficiency of conversion of energy to heat	55–75% This will vary with the type of fuel being burned and the design of the fire. While these burners have the flexibility to burn a range of fuels, the optimum design of a coal burner is quite different to that for a wood burner. This results in the design of a multi-fuel burner being a compromise, with efficiency reduced as a consequence.
Typical operating costs	Ministry for the Environment: 4–12 cents/kWh Own calculations: 7–10 cents/kWh
Typical capital costs	Approximately $3,000 installed.
Heating capacity	15–19 kW
Nature of the heat (radiant, convection, etc)	Convection; some radiant.
Fuel/energy handling issues	**Wood:** Labour intensive, involving cutting wood to size and stacking to dry. A large, dry fuel store is required. Fuel may be required to comply with local regulations (eg, Environment Canterbury regulation for water content of wood to be less than 25% by weight). **Coal:** Coal dust; mess from handling coal. A large, dry fuel store is required. The operation of a coal/wood fire requires a steady supply of fuel to be kept handy during use. Fuel must be placed directly into the burning fire.
Convenience of use	A multi-fuel fire requires regular refuelling and frequent attention during use.
Ease of heat control	There is only limited ability to regulate the operation of the heater accurately and the output will not be steady.
Effectiveness of heat transfer	This depends on whether the heater is inbuilt (in fireplace) or freestanding within the room. Since inbuilt models have less surface area from which to radiate heat, they transfer less heat to the room. As a result, an inbuilt heater will typically be less efficient than the equivalent freestanding device.
Heat-up rate	Slow
Ability to heat whole house vs single room	Can achieve moderate heating of whole house if heat can be distributed. Good air/heat circulation is required to prevent overheating in the vicinity of the heater.
Particulate emissions	PM_{10}: 12–19 g/kg (660–830 mg/MJ) reported by Environment Canterbury. However, the latest models from Harris Flame Technology are claimed to be in the range of 3.4–5.2 g/kg (187–230 mg/MJ).

Heating Option 3: Multi-fuel burner	
Greenhouse gas emissions	Greenhouse emissions will vary with the fuel burnt, as follows. **Coal:** CO_2: 2170 g/kg; 94,350 mg/MJ SO_x: 1.1 g/kg; 48 mg/MJ NO_x: 1.6 g/kg; 70 mg/MJ **Wood:** CO_2: 1730 g/kg; 94,800 mg/MJ SO_x: 0.2 g/kg; 11 mg/MJ NO_x: 1 g/kg; 55 mg/MJ
Other emissions	**Coal:** CO: 110 g/kg; 4800 mg/MJ $PM_{2.5}$: 17 g/kg; 740 mg/MJ **Wood:** CO: 98 g/kg; 5400 mg/MJ $PM_{2.5}$: 11 g/kg; 600 mg/MJ This will depend on the wood being used – treated wood may contain hazardous chemicals. Ash residue from burning must be disposed of. Mercury and other elements in coal are released to the atmosphere during burning. There may be products of incomplete combustion. Note that there is not a linear relationship between g/kg and mg/MJ for emissions. This is because MJ/kg values differ for wood and coal.
Health and safety issues in the home (eg, indoor emissions and moisture)	Smoke released into the room increases the local concentration of hazardous pollutants. No research into this appears to be available. The appliance will be hot and thus may pose a risk of burning for children. There is a risk that objects placed close to the fire may overheat and burn, or that sparks might escape if the door is opened for re-fuelling. Fuel must be placed on burning fire.
Embodied energy	Steel; glass; ceramics; transport; flue; installation.
Special features	May be considered aesthetically pleasing if flames are visible. Some models can heat water in a wetback but the energy used to heat the water reduces the reported efficiency of space heating. Some freestanding models could be used for basic cooking in the event of a disruption to the electricity supply.
Risks associated with this option	Poor operation and inappropriate quality or type of wood or coal can result in emissions and/or the release of hazardous substances. These heaters can be used to burn materials other than firewood or coal, which will contribute to emissions.
General comments	Versatility may result in compromised efficiency.
Suitability for use with heat-transfer system	Yes

Heating Option 4: Enclosed wood burner	
Nature of fuel/energy source	Wood
Availability of fuel/energy source	Wood is widely available from commercial suppliers but can also be collected free from a variety of sources (eg, untreated off-cuts from timber yards, manufacturers, building contractors, forestry, demolition timber).
Fuel/energy consumption	0.07– 0.1 m^3/100 kWh; 25–36 kg/100kWh.
Efficiency of conversion of energy to heat	55–75%. This depends on whether the heater is freestanding, inbuilt, or with a wetback. The results of wood burner efficiency tests carried out for Environment Canterbury indicate that inbuilt appliances are typically 3–5% less efficient than the equivalent freestanding model. The efficiency of operation of wood burners may be affected if they are not operated in accordance with manufacturers' intentions. Removal of the firebricks by users, or operating the burner with the door open to enable large pieces of wood to be burnt, will reduce efficiency. This effect has been observed in a number of installations checked by Environment Canterbury as part of their Clean Heat Project.
Typical operating costs	These will vary according to the source of wood and the efficiency of the fire. Ministry for the Environment: 4–8 cents/kWh Christchurch City Council: 6–8 cents/kWh Own calculations: 5–10 cents/kWh delivered. Figures are based on retail prices of wood in December 2004.
Typical capital costs	Range: $1,500–$6,000. Most mainstream models can be supplied and installed for around $2,300–$2,600.
Heating capacity	5 kW–24 kW Most mainstream models put out between 11 kW and 20 kW. Appliances can be run at reduced output (eg, 11 kW can be run at 4 kW).
Nature of the heat (radiant, convection, etc)	Mainly convection, but also some radiant component.
Fuel/energy handling issues	Wood must be gathered in volume, stored correctly, dried, cut to size, kept handy and replenished during use. Fuel may be required to comply with local regulations (eg, Environment Canterbury regulation for water content of wood to be less than 25% by weight).
Convenience of use	Requires regular, frequent attention. Can be filled up to burn for several hours. Burner and chimney must be maintained to ensure efficient and safe operation.
Ease of heat control	The heat output of these heaters can be regulated by use of a damper, but this is not a very accurate means of control. In some areas the introduction of low emissions standards has resulted in burner designs with a reduced ability to control the amount of air intake, which reduces the ability to control the amount of heat output.
Effectiveness of heat transfer	This depends on whether the heater is inbuilt (in fireplace) or freestanding within the room. Because inbuilt models have less surface area from which to radiate heat, they transfer less heat to the room. As a result, an inbuilt heater will typically be less efficient than the equivalent freestanding device.
Heat-up rate	Slow
Ability to heat whole house vs single room	Can achieve moderate heating of whole house if heat can be distributed. Good air/heat circulation is required to prevent overheating in the vicinity of the heater.

Heading Option 4: Enclosed wood burner	
Particulate emissions	PM_{10}: 0.5–12 g/kg; 27–660 mg/MJ Depends on the age of the heater and its operation. Appliances must be operated correctly to achieve low levels of emissions. Older wood burners can be operated with a restricted air supply. This may cause partial combustion and result in the appliance operating at lower efficiency and with higher levels of emissions than open fires. Newer burners are designed to prevent this effect. Some newer models designed for markets where Clean Air regulations have been implemented produce PM_{10} at the rate of 1 g or less per kg of fuel burnt. Note that there can be a significant difference between particulate emissions from laboratory testing compared with those from real-life operation. A factor of 3:1 has been used in the past by Environment Canterbury in their modelling, and they are currently carrying out research into reviewing that ratio.
Greenhouse gas emissions	SO_x: 0.2 g/kg; 11 mg/MJ NO_x: 0.5–1 g/kg; 27–55 mg/MJ CO_2: 1730–1860 g/kg (94,800–102,000 mg/MJ) but considered to be neutral.
Other emissions	CO: 34–98 g/kg; 1870–5390 mg/MJ $PM_{2.5}$ 3–11 g/kg; 165–605 mg/MJ Depends on source of wood (eg, treated wood may contain hazardous chemicals). Ash residue must be disposed of.
Health and safety issues in the home (eg, indoor emissions and moisture)	Smoke released into the room increases local concentration of hazardous pollutants. The appliance will be hot and thus may pose a risk of burning for children. There is a risk that objects placed close to the fire may overheat and burn, or that sparks might escape if the door is opened for re-fuelling. Fuel must be placed on burning fire.
Embodied energy	Steel; ceramics and firebricks; transport – domestic freight.
Special features	Log burners can be used to heat wetbacks, but this reduces their efficiency and may also overheat the water. Some freestanding models could be used for basic cooking in the event of a disruption to the electricity supply.
Risks associated with this option	Improper operation can lead to pollution problems.
General comments	There has been an improvement in open wood-burning fires, but they need care to operate at low emission levels. Inbuilt models radiate less heat into a room, which places them at a disadvantage when calculating efficiency. This means that inbuilt models can often struggle to meet new target figures of 65% efficiency, even when the freestanding version of the same heater model can achieve the efficiency standard. Some models are available with a wetback option to use heat to boost hot-water heating. This option reduces the measurement of the efficiency of the heater, as well as resulting in a cooler combustion temperature, which can mean slightly higher levels of emissions. The National Environmental Standards design standard for wood burners is 1.5 g/kg of emissions and a thermal efficiency of 65% .
Suitability for use with heat-transfer system	Yes

Heating Option 5: Pellet burner	
Nature of fuel/energy source	Pelletised wood
Availability of fuel/energy source	The fuel for pellet fires is designed specifically for these appliances, using pellets of a particular composition and shape. Pellet fires cannot burn normal firewood so their operation is dependent on the availability of manufactured fuel. This fuel is currently only available from a limited number of sources. However, as pellet fires become more common, there appears to be an increase in the number of pellet manufacturing facilities in New Zealand. Users of pellet fires could potentially also source pellets from other overseas outlets.
Fuel/energy consumption	21–26 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	75–92%
Typical operating costs	Ministry for the Environment: 4–8 cents/kWh Christchurch City Council: 8–10 cents/kWh Nature's Flame: 7 cents/kWh Own calculations: 7–9 cents/kWh delivered.
Typical capital costs	$2,700–$5,000 Pellet fires were until recently priced around the $4,500 level. However, Nature's Flame can now supply a lower-cost model for around $2,700 installed. This has the same firebox as the more expensive models but has fewer features (eg, no automatic lighter).
Heating capacity	10 kW–11 kW
Nature of the heat (radiant, convection, etc)	Mainly radiant; some convection.
Fuel/energy handling issues	Pellets must be loaded into a hopper. Large hoppers are available to reduce the frequency of loading.
Convenience of use	Easy to operate.
Ease of heat control	Good – output can be reduced to approximately 2 kW.
Effectiveness of heat transfer	This depends on whether the heater is inbuilt (in fireplace) or freestanding within the room. Because inbuilt models have less surface area from which to radiate heat, they transfer less heat to the room. As a result, an inbuilt heater will typically be less efficient than the equivalent freestanding device.
Heat-up rate	Slow
Ability to heat whole house vs single room	Can achieve moderate heating of whole house if heat can be distributed. Good air/heat circulation is required to prevent overheating in the vicinity of the heater.
Particulate emissions	PM_{10}: 0.5–0.6 g/kg; 27–33 mg/MJ
Greenhouse gas emissions	SO_x: 0.2 g/kg; 11 mg/MJ NO_x: 5.2 g/kg; 280 mg/MJ. Note that this is a relatively high level, but it is based on the only available data (Scott, 2004). Scott uses data derived from work carried out in 1998, which may well overstate the level of NO_x emissions from a current model pellet fire. It would be useful to test a current model for NO_x emissions. 2006 update: D Gong (2005) has found NO_x emissions from pellet burners to be in the order of 1g/kg of fuel. This is less than the originally stated figure of 5.2g/kg. CO_2: 1480 g/kg (80,200 mg/MJ) but considered neutral.
Other emissions	CO: 15 g/kg; 815 mg/MJ $PM_{2.5}$: 1.5 g/kg; 82 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	The appliance will be hot and thus may pose a risk of burning for children.

Heating Option 5: Pellet burner	
Embodied energy	Fire: steel; ceramics / fire bricks. Energy required to make fuel pellets.
Special features	Self-feeding from hopper.
Risks associated with this option	Requires electricity to power fuel feed auger, although some heaters have a battery backup in case of power failure.
General comments	Note that most models have two or three electric motors to drive fans, fuel feeders, etc, which means a dependence on electricity for them to work as well as some continual background noise. A battery backup option is available for some models. Pellets are produced from waste material from a renewable resource. This is more sustainable than using fossil fuels directly, or indirectly in gas or peak-hour electric heating. Only pellets can be burnt in a pellet fire. Because pellets are manufactured to a specification, there is a much greater degree of control over the fuel used in these fires, with a corresponding degree of control over the emissions. Possible risk of high fuel prices as fuel is supplied from a limited number of firms.
Suitability for use with heat-transfer system	Yes

Heating Option 6: Flued gas heater – convection	
Nature of fuel/energy source	Gas – bottled or reticulated.
Availability of fuel/energy source	Reportedly plentiful despite concerns over commercial gas supplies from New Zealand fields. Recent price increases have been attributed to constraints on availability. There is a limited number of gas suppliers in any location. Reticulated natural gas is only available in the North Island; reticulated LPG is currently only available to a very limited extent in some parts of the South Island, mainly in new subdivisions. Delivery of gas cylinders to some locations may be difficult/expensive.
Fuel/energy consumption	8–10 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	75–85%
Typical operating costs	Ministry for the Environment: 7.0 cents/kWh Christchurch City Council: 18–21 cents/kWh Own calculations: • Bottled gas 14–21 cents/kWh delivered and 25 cents/day for cylinder hire. • Reticulated natural gas: ranges from 7 cents/kWh with 92 cents/day connection charge, to 17 cents/kWh with 56 cents/day connection charge, depending on tariff.
Typical capital costs	\$1,000–\$3,000
Heating capacity	1.4 kW–6 kW
Nature of the heat (radiant, convection, etc.)	Convection
Fuel/energy handling issues	Gas bottle storage and supply; none apparent for reticulated gas.
Convenience of use	Very easy to use – timer options are available with some heater models. No operator intervention in fuel supply.
Ease of heat control	Good – many have thermostat options.
Effectiveness of heat transfer	Good if fan assistance available.
Heat-up rate	Fast
Ability to heat whole house vs single room	Larger heaters may have the capacity to heat the whole house but this will depend on the ability to circulate warm air through the house. Potential for overheating room where heater is located.
Particulate emissions	PM_{10}: 0.05 g/kg; 1.4 mg/MJ
Greenhouse gas emissions	NO_x: 1.5 g/kg; 42 mg/MJ CO_2: 2500 g/kg; 55,300 mg/MJ
Other emissions	CO: 0.2 g/kg; 5.6 mg/MJ $PM_{2.5}$: 0.3 g/kg; 8.4 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	Risk of gas leaks, but no figures are available for the incidence of this. However, there is only a low incidence of any notifiable gas accidents (see Risks, below), so the risk of gas leaks will also be low.
Embodied energy	Steel; ceramics. Transport of bottled gas.
Special features	Programmable operation.

Heating Option 6: Flued gas heater – convection	
Risks associated with this option	Long term availability of gas supply. Although there is a risk of explosion in the case of fuel leaks, there are no reports of any instances of this. Data from the Energy Safety Service shows a relatively low incidence (15–18 per year) of notifiable accidents for all natural gas and LPG applications. This includes home heating as well as other gas applications.
General comments	–
Suitability for use with heat-transfer system	No

Heating Option 7: Flued gas heater – flame effect (enclosed)	
Nature of fuel/energy source	Gas – bottled or reticulated.
Availability of fuel/energy source	Reportedly plentiful despite concerns over commercial gas supplies from New Zealand fields. Recent price increases have been attributed to constraints on availability. There is a limited number of gas suppliers in any location. Reticulated natural gas is only available in the North Island; reticulated LPG is currently only available to a very limited extent in some parts of the South Island, mainly in new subdivisions. Delivery of gas cylinders to some locations may be difficult/expensive.
Fuel/energy consumption	9–13 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	60–85%
Typical operating costs	Ministry for the Environment: 7 cents/kWh Christchurch City Council: 18–21 cents/kWh Own calculations: • Bottled gas: 14–21 cents/kWh delivered and 25 cents/day for cylinder hire. • Reticulated natural gas: ranges from 7 cents/kWh with 92 cents/day connection charge, to 10.5 cents/kWh with 56 cents/day connection charge, depending on tariff.
Typical capital costs	$2,500–$3,500
Heating capacity	5.5 kW–10 kW
Nature of the heat (radiant, convection, etc)	Convection and radiant.
Fuel/energy handling issues	Gas bottle storage and supply; none apparent for reticulated gas.
Convenience of use	Very easy to use.
Ease of heat control	Good
Effectiveness of heat transfer	Good
Heat-up rate	Fast if fan assisted.
Ability to heat whole house vs single room	An appropriately sized heater can heat a whole house if it is possible to circulate air from the heater throughout the house. However, a heater capable of heating the whole house would have the potential for overheating room where it is located.
Particulate emissions	PM_{10}: 0.03–0.05 g/kg; 0.7–1.1 mg/MJ
Greenhouse gas emissions	NO_x: 1.5 g/kg; 32.5 mg/MJ CO_2: 2500 g/kg; 54,200 mg/MJ
Other emissions	CO: 0.2 g/kg; 4.3 mg/MJ $PM_{2.5}$: 0.3 g/kg; 6.5 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	Risk of gas leaks but no figures are available for incidence of this. However, there is only a low incidence of any notifiable gas accidents (see Risks below), so the risk of gas leaks will also be low.
Embodied energy	Steel; ceramics. Transport of bottled gas.
Special features	–

Heading Option 7: Flued gas heater – flame effect (enclosed)	
Risks associated with this option	Long term availability of gas supply. Although there is a risk of explosion in the case of fuel leaks, there are no reports of any instances of this. Data from the Energy Safety Service show a relatively low incidence (15–18 per year) of notifiable accidents for all natural gas and LPG applications. This includes home heating as well as other gas applications.
General comments	Some of these models are designed to partially fit into an open fireplace cavity and therefore reduce the impact on space in the living room.
Suitability for use with heat-transfer system	Possibly, for larger-output models.

Heating Option 8: Flued gas heater – radiant	
Nature of fuel/energy source	Gas – bottled or reticulated.
Availability of fuel/energy source	Reportedly plentiful despite concerns over commercial gas supplies from New Zealand fields. Recent price increases have been attributed to constraints on availability. There is a limited number of gas suppliers in any location. Reticulated natural gas is only available in the North Island; reticulated LPG is currently only available to a very limited extent in some parts of the South Island, mainly in new subdivisions. Delivery of gas cylinders to some locations may be difficult/expensive.
Fuel/energy consumption	9–12.5 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	60–80%
Typical operating costs	Ministry for the Environment: 7 cents/kWh Christchurch City Council: 18–21 cents/kWh Own calculations: • Bottled gas: 15–20 cents/kWh delivered and 25 cents/day for cylinder hire. • Reticulated natural gas: ranges from 11 cents/kWh with 92 cents/day connection charge, to 14 cents/kWh with 56 cents/day connection charge depending on tariff.
Typical capital costs	$800–$1,800
Heating capacity	3 kW–5 kW
Nature of the heat (radiant, convection, etc)	Mainly radiant, with some convection.
Fuel/energy handling issues	Gas bottle storage and supply; none apparent for reticulated gas.
Convenience of use	Very easy to use.
Ease of heat control	Good
Effectiveness of heat transfer	Good
Heat-up rate	Fast
Ability to heat whole house vs single room	The form of heat output, mainly radiant rather than convection, combined with the limited heat output and the lack of means to circulate or distribute this heat make this form of heating unsuitable for heating a whole house. A heater capable of heating the whole house would have the potential for overheating in the room where it is located.
Particulate emissions	PM_{10}: 0.03–0.05 g/kg; 0.8–1.4 mg/MJ
Greenhouse gas emissions	NO_x: 1.5 g/kg; 32.5 mg/MJ CO_2: 2500 g/kg; 54,200 mg/MJ
Other emissions	CO: 0.2 g/kg; 4.3 mg/MJ $PM_{2.5}$: 0.3 g/kg; 6.5 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	Risk of gas leaks, but no figures are available for the incidence of this. However, there is only a low incidence of any notifiable gas accidents (see Risks, below), so the risk of gas leaks will also be low.
Embodied energy	Steel; ceramics. Transport of bottled gas.
Special features	–

Heading Option 8: Flued gas heater – radiant	
Risks associated with this option	Long term availability of gas supply. Although there is a risk of explosion in the case of fuel leaks, there are no reports of any instances of this. Data from the Energy Safety Service show a relatively low incidence (15–18 per year) of notifiable accidents for all natural gas and LPG applications. This includes home heating as well as other gas applications.
General comments	Some of these models are designed to partially fit into an open fireplace cavity and therefore reduce the impact on space in the living room.
Suitability for use with heat-transfer system	No

Heating Option 9: Unflued gas heater – portable	
Nature of fuel/energy source	Gas – 9 kg bottles.
Availability of fuel/energy source	Reportedly plentiful despite concerns over commercial gas supplies from New Zealand fields. Recent price increases have been attributed to constraints on availability. 9 kg bottles are widely available from garage forecourts and bottled gas suppliers.
Fuel/energy consumption	9–10 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	80–90%
Typical operating costs	Ministry for the Environment: 12–15 cents/kWh Christchurch City Council: 18–21 cents/kWh Own calculations: 20–22 cents/kWh
Typical capital costs	$250–$350
Heating capacity	3 kW–4 kW
Nature of the heat (radiant, convection, etc)	Mainly radiant, but some convection.
Fuel/energy handling issues	Bottle installation; leaks between bottle and heater.
Convenience of use	Easy to use. No automation options.
Ease of heat control	Reasonable/good control.
Effectiveness of heat transfer	Good
Heat-up rate	Fast
Ability to heat whole house vs single room	Limited – typically small appliances. Appliance can be moved to heat a number of rooms in turn but must not be used in bedrooms.
Particulate emissions	PM_{10}: 0.03g/kg; 0.7 mg/MJ
Greenhouse gas emissions	NO_x: 1.5 g/kg; 42 mg/MJ CO_2: 2500 g/kg; 54230 mg/MJ
Other emissions	CO: 0.2 g/kg; 4.3 mg/MJ $PM_{2.5}$: 0.3 g/kg; 6.5 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	CO with high risk of suffocation from oxygen depletion if used in poorly ventilated areas. Creating ventilation typically results in heat loss. Potential adverse effects from breathing combustion products vented into room. Produce significant amounts of moisture – potentially 1 litre per hour of operation. Radiant heat may ignite materials close to heater. Not permitted for use in bedrooms. Risk of leaks when connecting gas bottle.
Embodied energy	Steel; ceramic. Transport of gas bottles; use of dehumidifier.
Special features	Portable
Risks associated with this option	Health – CO poisoning; dampness. Need regular maintenance to ensure safe operation. Although there is a risk of explosion in the case of fuel leaks, there are no reports of any instances of this. Data from the Energy Safety Service show a relatively low incidence (15–18 per year) of notifiable accidents for all natural gas and LPG applications. This includes home heating as well as other gas applications. Long term availability of gas supply.

Heading Option 9: Unflued gas heater – portable	
General comments	Cheap, accessible, easily introduced form of heating. However, the issues associated with moisture production and emissions of CO make this form of heating an undesirable and potentially unhealthy option. As a result of these negative health effects, these heaters are banned from use in some situations in Australia.
Suitability for use with heat-transfer system	No

Heating Option 10: Gas-fired central heating	
Nature of fuel/energy source	Gas – reticulated or 45 kg bottles.
Availability of fuel/energy source	Reportedly plentiful despite concerns over commercial gas supplies from New Zealand fields. Recent price increases have been attributed to constraints on availability. There is a limited number of gas suppliers in any location. Reticulated natural gas is only available in the North Island; reticulated LPG is currently only available to a very limited extent in some parts of the South Island, mainly in new subdivisions. Delivery of gas cylinders to some locations may be difficult/expensive.
Fuel/energy consumption	10–11.5 kg/100 kWh delivered.
Efficiency of conversion of energy to heat	90%
Typical operating costs	Ministry for the Environment: 12–14 cents/kWh Christchurch City Council: 17–21 cents/kWh Own calculations: • Bottled gas: 14 cents/kWh delivered and 25 cents/day for cylinder hire. • Reticulated natural gas: 10 cents/kWh with connection charge of between 56 and 92 cents/day.
Typical capital costs	$7,000–$15,000 depending on size of house and inclusion of water heating.
Heating capacity	18 kW–30 kW
Nature of the heat (radiant, convection, etc)	Convection
Fuel/energy handling issues	Gas bottle storage and supply; none apparent for reticulated gas.
Convenience of use	Easy
Ease of heat control	Normally timer and thermostatically controlled – can have individual thermostats in each room or on each radiator.
Effectiveness of heat transfer	Good – some losses depending on conduction type.
Heat-up rate	Fast
Ability to heat whole house vs single room	Good – central heating systems are designed specifically to heat the whole house.
Particulate emissions	PM_{10}: 0.03 g/kg; 0.7 mg/MJ
Greenhouse gas emissions	NO_x: 1.5 g/kg; 33.2 mg/MJ CO_2: 2500 g/kg; 55,300 mg/MJ
Other emissions	CO: 0.2 g/kg; 4.4 mg/MJ $PM_{2.5}$: 0.3 g/kg; 6.6 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	None
Embodied energy	Steel; ceramics. Potentially complex installation.

Heating Option 10: Gas-fired central heating	
Special features	High efficiency due to combustion efficiency and controllability. Can provide all the heating and hot water in the house with virtually no need for electricity or supplementary fuel. The heat distribution system lasts for decades. Only the boilers and pumps need replacing every 15–20 years. Easy to change fuels by just changing the boiler. Very quiet. No draughts. Very high heat output with even heat distribution. Can go to maximum heat output easily and conveniently Can add significant value to a home.
Risks associated with this option	Supply of gas. Although there is a risk of explosion in the case of fuel leaks, there are no reports of any instances of this. Data from the Energy Safety Service show a relatively low incidence (15–18 per year) of notifiable accidents for all natural gas and LPG applications. This includes home heating as well as other gas applications.
General comments	This is a very high-quality building service, which is standard throughout the world in countries where heating is required in the winter. Although this system has a high initial cost, the long term benefits and high quality of heating have made it a very popular heating system among those who can afford it. A condensing boiler can be an option to further enhance the efficiency of a central heating system. While these are currently rare in New Zealand, they can offer higher efficiency with a resultant lowering in fuel costs. A condensing boiler would add approximately $1,500 to the cost of a central heating system compared with a conventional boiler.
Suitability for use with heat-transfer system	N/A

Heating Option 11: Electric resistance heater – convector panels	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	100 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	100% at point of use but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Ministry for the Environment: 11–14.5 cents/kWh Christchurch City Council: 6–20 cents/kWh Own calculations: • Standard rate: 19.5 cents/kWh (Meridian Energy, Christchurch) • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • These costs are based on Meridian tariffs for Christchurch; the standard rate is based on the Anytime tariff. Note that a cheaper Economy tariff is also available but supply to some appliances can be interrupted under this agreement so it might not be suitable for all heating applications. The tariffs quoted here offer a 10% discount for prompt payment but this has not been applied to the operating costs presented here.
Typical capital costs	$300–$500
Heating capacity	1k W–3 kW
Nature of the heat (radiant, convection, etc)	Convection
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Easy – thermostatically controlled.
Effectiveness of heat transfer	Good but local – single room.
Heat-up rate	Medium/fast
Ability to heat whole house vs single room	Poor
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	None – low temperature.
Embodied energy	Steel; plastic.
Special features	–
Risks associated with this option	Rising electricity prices and seasonal constraints on electricity supplies. Potential electricity supply constraints at peak demand times of the day.
General comments	–
Suitability for use with heat-transfer system	No

Heating Option 12: Electric resistance heater – radiant	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	100 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	100% at point of use, but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Ministry for the Environment: 11–14.5 cents/kWh Christchurch City Council: 6–20 cents/kWh Own calculations: • Standard rate: 19.5 cents/kWh (Meridian Energy, Christchurch) • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • These costs are based on Meridian tariffs for Christchurch. The standard rate is based on the Anytime tariff. Note that a cheaper Economy tariff is also available but supply to some appliances can be interrupted under this agreement so it might not be suitable for all heating applications. The tariffs used for these calculations offer a 10% discount for prompt payment but this has not been applied to the operating costs presented here.
Typical capital costs	$50–$250
Heating capacity	1 kW–2.4 kW
Nature of the heat (radiant, convection, etc)	Radiant
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Limited – generally either on or off, although some models have a basic thermostat incorporated into the design.
Effectiveness of heat transfer	Intense local heat – suitable for small rooms or particular areas.
Heat-up rate	Fast
Ability to heat whole house vs single room	Poor
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	Radiant elements can ignite materials or cause burns.
Embodied energy	Steel; plastic.
Special features	–
Risks associated with this option	Rising electricity prices and seasonal constraints on electricity supplies. Potential electricity supply constraints at peak demand times of the day.
General comments	Very limited heating area.
Suitability for use with heat-transfer system	No

Heating Option 13: Night store	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	100 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	100% at point of use, but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Ministry for the Environment: 6.6–10cents/kWh Christchurch City Council: 6–10cents/kWh Own calculations: • Night rate: 8.4 cents/kWh. • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • These costs are based on Meridian tariffs for Christchurch. The tariff used for these calculations offers a 10% discount for prompt payment, but this has not been applied to the operating costs presented here.
Typical capital costs	$900–$1,500
Heating capacity	1.7 kW–6 kW
Nature of the heat (radiant, convection, etc.)	Convection
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Usually thermostatically controlled. However, the heat may be delivered when not required. These heaters are designed to store heat by warming firebricks inside the heater during the night. They then release this heat slowly during the following day, regardless of the ambient temperature. As a result, some heating may occur on warm days even if this is not required.
Effectiveness of heat transfer	Good
Heat-up rate	Slow
Ability to heat whole house vs single room	Poor
Particulate emissions	None at point of use but, electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	None
Embodied energy	Steel; ceramics; plastic.
Special features	–
Risks associated with this option	Rising electricity prices and seasonal constraints on electricity supplies. Vulnerable to any changes to the current regime of night-rate electricity pricing which is currently common throughout New Zealand.
General comments	Night-store heating is a more suitable option for occupants who are typically at home during the day to receive the benefit of the slow release of heat throughout the day.
Suitability for use with heat-transfer system	No

Heating Option 14: Electric underfloor	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	130–160 W/m^2 110–125 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	80–90% at point of use but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Christchurch City Council: 6–20cents/kWh Own calculations: Night rate: 9–10 cents/kWh. • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • This form of heating is generally connected to a night-rate electricity supply to take advantage of that cheaper form of energy, which can effectively be stored in the thermal mass of a floor. • These costs are based on Meridian tariffs for Christchurch. The tariff used for these calculations offers a 10% discount for prompt payment, but this has not been applied to the operating costs presented here.
Typical capital costs	\$80–\$120/m^2
Heating capacity	130–160 W/m^2
Nature of the heat (radiant, convection, etc)	Conduction, convection.
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Usually thermostatically controlled and/or controllable by individual rooms of a house.
Effectiveness of heat transfer	Good
Heat up rate	Fast
Ability to heat whole house vs single room	Could be installed throughout the entire house.
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg,. indoor emissions and moisture)	None
Embodied energy	Steel; plastic.
Special features	–
Risks associated with this option	Rising electricity prices. Seasonal constraints on electricity supplies. Vulnerable to any changes to the current regime of night-rate electricity pricing which is currently common throughout New Zealand.
General comments	This option needs to be installed at the time of house construction and is not practical to retrofit into existing homes.
Suitability for use with heat-transfer system	No

Heating Option 15: Heat pump	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	35–40 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	220–300% of delivered energy at point of use but full fuel-cycle efficiency will be lower when generation and transmission losses are considered. Inverter models show greater efficiency than non-inverter types. Efficiency is dependent on outside air temperature. Cooler outside air will lower the co-efficient of performance of a heat pump with the result that it is more efficient in warmer regions (such as Zones 1 and 2, as defined by the Energy Efficiency and Conservation Authority).
Typical operating costs	Ministry for the Environment: 3.7–7.3 cents/kWh Christchurch City Council: 5–10 cents/kWh Own calculations: • Standard rate: 6.5–9 cents/kWh (Meridian Energy, Christchurch) • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • These costs are based on Meridian tariffs for Christchurch; the standard rate is based on the Anytime tariff. Note that a cheaper Economy tariff is also available but supply to some appliances can be interrupted under this agreement so it might not be suitable for all heating applications. The tariffs used for these calculations offer a 10% discount for prompt payment, but this has not been applied to the operating costs presented here.
Typical capital costs	Approximately $2,000–$2,500 for small (< 3 kW) units. Approximately $2,500–$3,000 for medium (3–5 kW) units. Approximately $3,000–$3,500 for large (5–7 kW) units. The above costs are based on single-outlet heat pumps. Whole house split-ducted options typically range from $6,000 to $8,000.
Heating capacity	3 kW–12 kW (typically 3–6kW for a single-outlet heat pump, with larger models having two or more heat outlets).
Nature of the heat (radiant, convection, etc.)	Convection
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Usually thermostatically controlled. Heat pumps can also be programmed to automatically switch on at a preset time of day.
Effectiveness of heat transfer	Good
Heat-up rate	Moderate/fast.
Ability to heat whole house vs single room	Good if designed/sized appropriately.
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	None

Heating Option 15: Heat pump	
Embodied energy	Steel; plastic; copper.
Special features	Can achieve greater than 100% efficiency.
Risks associated with this option	Rising electricity prices. Seasonal constraints on electricity supplies.
General comments	They need to be installed correctly – determined by whether heating or cooling is the main use, as well as optimum siting of both the outdoor and indoor units. Inverter heat pumps are more efficient than non-inverter models due to the use of electronics to alter the quantity of heat output, rather than simply having the heating on or off, as is the case for a conventional split-cycle unit. It should be noted that heat pumps use a fan to circulate the air. This means there is some background noise when the appliance is operating.
Suitability for use with heat-transfer system	No

Heating Option 16: Ceiling heating – distributed	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at peak demand times.
Fuel/energy consumption	80–100 W/m^2 100 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	100% of delivered energy at point of use, but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Christchurch City Council: 6–20 cents/kWh Own calculations: • Standard rate: 19.5 cents/kWh (Meridian Energy, Christchurch). • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch) • These costs are based on Meridian tariffs for Christchurch; the standard rate is based on the Anytime tariff. Note that a cheaper Economy tariff is also available but supply to some appliances can be interrupted under this agreement so it might not be suitable for all heating applications. The tariffs used for these calculations offer a 10% discount for prompt payment but this has not been applied to the operating costs presented here.
Typical capital costs	\$50–\$80/m^2
Heating capacity	80–100 W/m^2
Nature of the heat (radiant, convection, etc.)	Radiant
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Timer and thermostatically controlled.
Effectiveness of heat transfer	Good
Heat up rate	Fast
Ability to heat whole house vs single room	Yes if designed/sized properly.
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	None
Embodied energy	Foil
Special features	–
Risks associated with option	Rising electricity prices.
General comments	Only suitable for new houses.
Suitability for use with heat-transfer system	No

Heating Option 17: Ceiling heating – radiant	
Nature of fuel/energy source	Electricity
Availability of fuel/energy source	Usually readily available but may be subject to shortages at times of peak demand.
Fuel/energy consumption	110 kWh/100 kWh delivered.
Efficiency of conversion of energy to heat	90% of delivered energy at point of use, but full fuel-cycle efficiency will be lower when generation and transmission losses are considered.
Typical operating costs	Christchurch City Council: 6–20 cents/kWh Own calculations: • Standard rate: 19.5 cents/kWh (Meridian Energy, Christchurch) • There will also be a fixed connection charge (eg, 63.9 cents/day Meridian Energy, Christchurch). • These costs are based on Meridian tariffs for Christchurch; the standard rate is based on the Anytime tariff. Note that a cheaper Economy tariff is also available, but supply to some appliances can be interrupted under this agreement so it might not be suitable for all heating applications. The tariffs used for these calculations offer a 10% discount for prompt payment but this has not been applied to the operating costs presented here.
Typical capital costs	$100–$250
Heating capacity	250 W
Nature of the heat (radiant, convection, etc.)	Radiant
Fuel/energy handling issues	None
Convenience of use	Easy
Ease of heat control	Instant control
Effectiveness of heat transfer	Good
Heat-up rate	Fast
Ability to heat whole house vs single room	No
Particulate emissions	None at point of use, but electricity generation will produce particulate emissions when electricity supplied from coal- and gas-powered generators.
Greenhouse gas emissions	
Other emissions	
Health and safety issues in the home (eg, indoor emissions and moisture)	Heat can be intense at source – heater must be located to minimise risk of burning/combustion.
Embodied energy	Glass; copper; filament materials.
Special features	–
Risks associated with this option	Rising electricity prices. Seasonal constraints on electricity supplies.
General comments	
Suitability for use with heat-transfer system	No

Heating Option 18: Diesel heater	
Nature of fuel/energy source	Diesel
Availability of fuel/energy source	Widely available, although additional charges may be made for home delivery in some regions.
Fuel/energy consumption	10 L/100 kWh
Efficiency of conversion of energy to heat	65–80%
Typical operating costs	Ministry for the Environment: 8.4– 9.8 cents/kWh Christchurch City Council: 8–10 cents/kWh Own calculations: 10–12.5 cents/kWh
Typical capital costs	\$3,500–\$4,500
Heating capacity	7 kW–12 kW
Nature of the heat (radiant, convection, etc.)	Mainly convection, but also some radiant component.
Fuel/energy handling issues	Requires fuel storage tank; fuel oil can be messy.
Convenience of use	Easy
Ease of heat control	Good
Effectiveness of heat transfer	Good
Heat-up rate	Slow
Ability to heat whole house vs single room	Can achieve moderate heating of whole house if heat can be distributed. Good air/heat circulation is required to prevent overheating in the vicinity of the heater.
Particulate emissions	PM_{10}: 0.3 g/kg; 6.5 mg/MJ
Greenhouse gas emissions	CO_2: 3200 g/kg; 80,200 mg/MJ SO_x: 4.0 g/kg; 87 mg/MJ NO_x: 2.0 g/kg; 43 mg/MJ
Other emissions	CO: 0.5g/kg; 10.8 mg/MJ $PM_{2.5}$: 0.2g/kg; 4.3 mg/MJ
Health and safety issues in the home (eg, indoor emissions and moisture)	None apparent.
Embodied energy	Steel; ceramics; transport of fuel.
Special features	Diesel heaters can be used to heat wetbacks, but this reduces the efficiency of heat transfer for space heating and may also overheat the water.
Risks associated with this option	Availability of fuel supply; rising oil prices.
General comments	–
Suitability for use with heat-transfer system	Yes

Heating Option 19: Oil-fired central heating	
Nature of fuel/energy source	Diesel
Availability of fuel/energy source	Widely available, although additional charges may be made for home delivery in some regions.
Fuel/energy consumption	7–9 L/100 kWh
Efficiency of conversion of energy to heat	90%
Typical operating costs	Own calculations: 9 cents/kWh.
Typical capital costs	\$7,000–\$15,000 depending on size of house and inclusion of water heating.
Heating capacity	15–35 kW.
Nature of the heat (radiant, convection, etc.)	Radiant and natural convection.
Fuel/energy handling issues	Diesel is usually stored in tanks of 500 L or larger. The fuel is piped to the boiler.
Convenience of use	Requires hardly any user input and runs entirely automatically. Maybe service once a year.
Ease of heat control	Controllability is part of the design. Systems can be programmed to come on to heat up before the household rises and go off immediately the room reaches a set temperature. Each room can be set to a different temperature.
Effectiveness of heat transfer	Good: use of water as the heat-transfer medium is the best form of heat transfer. A central heating system is designed so that the output of the radiators matches the heat loss of the room.
Heat-up rate	Fast: a large heat output enables very rapid heat-up rates. Can also be programmed to come on without manual input.
Ability to heat whole house vs single room	It is designed to be a whole-house system and is most cost-effective as a whole-house and hot-water system.
Particulate emissions	PM_{10}: 0.3 g/kg
Greenhouse gas emissions	CO_2: 3200 g/kg SO_x: 4.0 g/kg NO_x: 2.0 g/kg
Other emissions	CO: 0.5 g/kg $PM_{2.5}$: 0.2 g/kg
Health and safety issues in the home (eg, indoor emissions and moisture)	Generally most appliances have balanced flues, meaning no interchange of internal air and combustion air. Even distribution of heat means that damp and associated mould are eliminated from homes with central heating.
Embodied energy	–

Heating Option 19: Oil-fired central heating	
Special features	High efficiency due to combustion efficiency and controllability. Can provide all the heating and hot water in the house with virtually no need for electricity or supplementary fuel. The heat distribution system lasts for decades. Only the boilers and pumps need replacing every 15–20 years. Easy to change fuels by just changing the boiler. Very quiet. No drafts. Very high heat output with even heat distribution. Can go to maximum heat output easily and conveniently. Can add significant value to a home.
Risks associated with this option	Availability of fuel supply.
General comments	This is a very high quality building service, which is standard throughout the world in countries that need heating in the winter. Although it has a high initial cost, the long term benefits and high quality of heating have made it one of the world's most popular heating systems among those that can afford it.
Suitability for use with heat-transfer system	N/A

Heating Option 20: Wood pellet-fired central heating	
Nature of fuel/energy source	Wood pellets
Availability of fuel/energy source	Pellets – local supplies; limited to certain areas.
Fuel/energy consumption	24–26 kg/100kWh delivered.
Efficiency of conversion of energy to heat	90–92%
Typical operating costs	7.5 cents/kWh.
Typical capital costs	$15,000–$20,000 depending on size of house. Lower price is for heating to all rooms; the more expensive option also provides water heating.
Heating capacity	15–35 kW.
Nature of the heat (radiant, convection, etc.)	Radiant and natural convection.
Fuel/energy handling issues	Pellets are usually in a hopper, which needs refilling every few days – depending on the weather and heat load. Can get much larger hoppers for many months' supply.
Convenience of use	Pellets require topping up and ash requires occasional removal.
Ease of heat control	Controllability is part of design. Systems can be programmed to come on to heat up before the household rises and go off immediately the room reaches a set temperature. Each room can be set to a different temperature.
Effectiveness of heat transfer	Good: use of water as the heat-transfer medium is the best form of heat transfer. A central heating system is designed so that the output of the radiators matches the heat loss of the room.
Heat-up rate	Fast: large heat output enables very rapid heat-up rates. Can also be programmed to come on without manual input.
Ability to heat whole house vs single room	It is designed to be a whole-house system and is most cost-effective as a whole-house and hot-water system.
Particulate emissions	PM_{10}: 0.4 g/kg
Greenhouse gas emissions	SO_x: 0.2 g/kg NO_x: 5.2 g/kg. Note that this is a relatively high level, but it is based on the only available data (Scott 2004). Scott uses data derived from work carried out in 1998, which may well overstate the level of NO_x emissions from a current model pellet fire. It would be useful to test a current model for NO_x emissions. CO_2: 1480 g/kg, but considered neutral.
Other emissions	CO: 15 g/kg $PM_{2.5}$: 1.5 g/kg
Health and safety issues in the home (eg, indoor emissions and moisture)	Generally most appliances have balanced flues, meaning no interchange of internal air and combustion air. Even distribution of heat means that damp and associated mould are eliminated from homes with central heating.
Embodied energy	–

Heating Option 20: Wood pellet-fired central heating	
Special features	High efficiency due to combustion efficiency and controllability. Can provide all the heating and hot water in the house with virtually no need for electricity or supplementary fuel. The heat distribution system lasts for decades. Only the boilers and pumps need replacing every 15–20 years. Easy to change fuels by just changing the boiler. Very quiet. No drafts. Very high heat output with even heat distribution. Can go to maximum heat output easily and conveniently. Can add significant value to a home.
Risks associated with this option	Limited sources of fuel supply.
General comments	This is a very high quality building service, which is standard throughout the world in countries that need heating in the winter. Although it has a high initial cost, the long term benefits and high quality of heating have made it one of the world's most popular heating systems among those that can afford it. Pellet-fuelled central heating is established in other countries but has yet to become widespread in New Zealand.
Suitability for use with heat-transfer system	N/A

5 Discussion

This review covers printed and on-line material relating to the use and performance of domestic home heating appliances in use in New Zealand. It aims to include any material that classifies and objectively assesses appliances by type, within the following categories:

- appliance energy efficiency by type of appliance
- appliance costs – capital and operating
- extent of ownership of appliances
- typical use of appliance: hours per day, days per year
- adverse effects of use
- beneficial effects of use
- ease of operation
- availability of fuel supplies
- regulations pertaining to heating appliances.

This review does not include promotional material from manufacturers, although this is readily available for appliances currently on the market.

Note that:

- heating appliance emission figures are sourced from Scott (2004), Gas Appliance Suppliers Association Inc (2004) and Environment Canterbury (2004b)
- heating appliance capacity and capital cost figures are sourced from Ward (2004), MfE (2002) and the authors' own experience
- all own calculations are based on information from Baines (1993); gas and electricity prices were obtained from published tariffs accessed on 10 December 2004
- wood prices were obtained from retailers.

It is also assumed that:

- appliance classifications are consistent among reports
- figures provided by fuel suppliers are accurate and have been interpreted correctly by the authors.

At the end of Appendix 2 there are two graphs showing a presentation of the costs of operating various heating options. The first graph includes open fires amongst the appliances presented. The second graph excludes open fires which, with their relatively high operating costs, tend to make comparisons between the other options less clear.

Appliance energy efficiency, by type of appliance

A comparison of the efficiency of a number of types of heating is provided in MfE (2002). This information forms part of a technical report written to inform decision-making relating to reducing emissions from domestic home heating. Where appropriate, this work examines a range of types of heating appliance for each energy source (eg, electricity, gas and wood). This document references a number of related bodies of work offering further data. Efficiency figures are consistent with generally accepted values.

The work of Ward (2002) also examines a range of heating options for each fuel source. It provides the reader with sufficient information and guidance to enable potential suitable types of heating to be identified according to the proposed application.

The Environment Canterbury (2004b) web pages relating to oil and wood burner emissions include appliance efficiency information. This does not provide any information about other types of heater (such as electric), but does serve as a source of information to enable wood or oil burners to be compared.

It is worth noting that the efficiency figures quoted refer to the efficiency with which delivered energy is turned into heat by the heating appliance. These figures ignore energy losses associated with the generation or production of the energy/fuel concerned and the losses due to distributing and transporting the energy/fuel. These losses can be ignored at the household level when comparing the efficiency of the heating appliances, but they should be considered when considering the relative efficiencies of heating types and fuels in terms of their social/ environmental effects.

Appliance costs – capital and operating

MfE (2002) provides an indicative range of capital costs and also develops operating costs for each heating type presented. This work provides an indication of relative cost of operation, although fuel price increases since this document was published have made the absolute values inaccurate. The same is true for the capital costs presented.

Ward (2004) covers a more comprehensive range of appliances than the MfE (2002) report. In general the costs are in agreement, but Ward’s material reflects recent fuel price rises and the increasing diversity of appliances. No source material is referenced.

The operating cost figures produced by the Christchurch City Council (Itskovich, 2004) are very generic but are in general agreement with the work of Ward and with the results produced in the course of compiling the current report. Information from Baines (1993) has been used extensively in this report.

Note that the costs presented for all appliance types in section 4 are theoretical and do not take into account occupant behaviour or factors such as house construction and insulation. The work of MfE (2005) is based on measured heating energy consumption, and so provides a way to compare theoretical and actual values. The most recent Building Research Association of New Zealand (BRANZ) Home Energy End-use Project report (BRANZ, 2004) also includes measured fuel consumption figures. Walker J, pers. com. (2004) includes information about the effect of the use of heat pumps on users’ electricity bills, but this is largely anecdotal and does not contribute quantitative material.

Operating costs will also vary from region to region and over time. In this document the objective has been to use reasonable and current estimates of the various costs so that comparisons can be made between different heater types. Future phases of this project will include the development of a model that will allow comparisons to be made based on an unlimited number of inputs for capital and operating costs of various appliances.

Although some households using wood as a source of fuel do so by gathering their own wood for ‘free’, there is usually some cost associated with this fuel gathering; for example, vehicle running costs, trailer or chainsaw hire. For the purposes of this analysis it is assumed that wood used as a fuel is sourced from commercial operators at current market prices.

Extent of ownership of appliances

The BRANZ Home Energy End-use Project has documented the use of appliances for a number of years and has added to this with each new survey round. The most recent report (BRANZ, 2004) provides detailed information about relative numbers of heating appliance types but does not provide an analysis of heater type by region.

MfE (2005) investigates the extent to which different types of appliance are used throughout New Zealand. This research covers seven locations, six of which (Invercargill, Gore, Reefton, Westport, Upper Hutt and Te Kuiti) are not generally included in work of this type. The Environment Canterbury Christchurch Home Heating Survey (Lamb, 2002) investigated the relative numbers of appliance types in use within Christchurch. Finally, the 2001 Census includes information about heating appliances available in houses. While this information is now becoming outdated, it does provide an indication of relative numbers of appliances.

Typical use of appliances: hours per day, days per year

This information is available as part of the Home Energy End-use Project work carried out by BRANZ (2004) to measure residential energy use. This work is concerned with analysing overall household energy use, and it also provides a comparison of use by region. However, it does not provide detailed information about heating use, including seasonal and daily heating use by heating type. The draft work of MfE (2005) builds on this and provides more detailed information about actual use.

Work carried out on behalf of Environment Canterbury (Lamb, 2002) reports the extent of use of heating systems by type, but covers only Christchurch.

These pieces of work were limited in the number of participants they could include in their surveys. As a result, the small sample size has the potential to introduce significant errors if extrapolating to obtain indicative regional or national figures.

Adverse effects of use

The adverse effects of using a heating appliance vary according to the type of appliance, when it is used and how it is operated. The most significant adverse effect is arguably air pollution. Research published in Scott (2004) quantifies this for particulate emissions, trace gases and carbon monoxide for combustion heating appliances fired by coal, wood, pellets, oil and gas. It does not attempt to quantify emissions associated with the generation of electricity. The figures are presented as g/kg with no g/MJ equivalents; the latter format is preferable for some applications because it provides the basis for broader comparisons.

Ministry for the Environment (2002) discusses the benefits of a means of quantifying emissions reliably, but does not provide any information for appliances.

Beneficial effects of use

At any given time, when the use of home heating is required, a wide cross-section of heating types will be in operation. Some of these appliances may cause problems, but in some cases may help to overcome other problems. For example, on a very cold, still night, the emissions from wood burners and coal fires can cause bad air pollution, but can also help to remove load on the electricity transmission and distribution networks, preventing black-outs. There appears to be no published research into how to achieve balance between these conflicting demands.

Ease of operation

The main aim of using heating appliances is to bring a room or house to a desired temperature. It is important that the user of a heater should be able to control the appliance so that the aims can be achieved. Little material is available on this subject except from manufacturers.

The work of Ward (2004) is intended to enable users to identify the most appropriate type of appliance and to understand the operational implications of each. As with running costs, ease of operation varies from user to user. It would be helpful if potential users could be made aware of issues that other users had experienced when operating appliances over a period of time. Walker J, pers. com. (2004) discusses this, but the small sample size and anecdotal responses make this report interesting but not particularly useful.

Availability of fuel supplies

One aspect of the dependability of a heating appliance is the ready availability and affordability of its energy source. Most of the appliances currently on offer use energy sources that are generally in plentiful, but not unlimited, supply. The situation regarding any or all of these energy sources changes on a daily basis as a consequence of global events.

No single definitive publication covers this topic, although there is a wealth of background information on oil, gas and electricity supplies. The most relevant and topical information can be found in the daily press and in business or current affairs periodicals.

Regulations pertaining to heating appliances

The choice of heating appliance is becoming increasingly constrained by local and national emissions regulations. The regulations covering emissions to air in Canterbury are set out in Environment Canterbury, 2004a. MfE (2002) discusses other proposed or current regulations.

The Ministry for the Environment (2004) has set out draft national environmental standards, which will impose restrictions on emissions. There is no reference to other legislation in draft at present, but information of this nature would be beneficial to the current work.

Whole house vs single room heating

It is worth noting that some of the heating options detailed in this report are capable of heating an entire home (eg, central heating systems). Such heating systems are typically priced around, or in excess of, $10,000. Other options are capable of heating a single room only (e.g. smaller heat pumps and unflued gas heaters). These options are typically priced at less than, or around, $2,000. Most solid-fuel burners fit in between these two situations. They are capable of heating more than one room and, depending on the layout of the home and the ability for warm air to circulate, have the potential to heat a substantial percentage of a home. Most solid-fuel burners typically cost around $2,500 to $3,000.

While technically outside the scope of this report, one factor that can make a considerable difference to the required size of the heater (and therefore its capital cost) as well as the cost to operate the heater, is effective home insulation. With typically 40% of heat being lost through an uninsulated home’s ceiling and another 10% being lost through the floor, basic building envelope insulation measures can make a significant difference to heating costs as well as reducing emissions through the requirement for a smaller heater than may have otherwise been the case.

Ventilation and heat-transfer systems

Domestic ventilation systems and similar products are *ventilation systems* – not heaters. They operate by removing moist air from a room, and replacing it with warmer or drier air sourced from within a ceiling cavity or outside.

Despite not being heaters, they can offer two advantages in relation to heating. Firstly, drier air is easier to heat than moist air, so a domestic ventilation system can allow a heater to operate more effectively. Secondly, a domestic ventilation system will bring in air from outside the room, which then results in some movement of air from that room into other areas. In this way it creates a flow of air from one room to another, thereby assisting the movement of warmth around a home. Installed costs typically range from $1,200 to $1,800 sourced from Consumer online (www.consumer.org.nz).

Another option that can assist with the effectiveness of home heating is a heat-transfer system. These systems involve a heat outlet in a warm room usually situated close to a large heat source such as a wood burner. Ducting is then installed from this source to one or more other rooms within a house and an in-line fan is used to distribute this air to other parts of the house. Typical costs range from $600 to $1,200 depending on the extent of ducting/outlets. There are also options available such as a speed controller, which can be used to control the fan speed and thereby the heat-transfer rate. A thermostat can also be placed in the heat-source area so that heat will not be drawn until the temperature in that room has reached a pre-set level.

A heat-transfer system could be used effectively in conjunction with a large heat source to help in distributing heat more evenly throughout a house. Note that a heat-transfer system would offer little benefit if the main heat source was only of sufficient capacity to heat the area in which it is situated.

A comment is made at the bottom of each template in section 4 as to whether the particular heating option would be suitable for operating in conjunction with a heat-transfer system.

Direct vs indirect use of fuel

This report has focused on the micro level of the use of various heating appliances in an individual home. This means that, for example, electric heaters can be shown to have zero emissions at the point of use. However, at a macro level, many electric heating systems will have an impact on the requirements for future electricity generation, which may well involve the combustion of fuel, with the consequent release of particulate, greenhouse and other emissions in some other location. The requirements to upgrade electricity transmission infrastructure would also involve significant capital expenditure, of the order of several thousand dollars per household that converts to electricity.

Another issue in this regard is whether it is more efficient, from a macro viewpoint, to burn gas directly in a gas heater than it is to burn gas at a lesser efficiency in a thermal power station and then transmit the resulting energy possibly several hundred kilometres to its point of use. In this situation the inefficiencies created via generation losses and transmission losses will need to be quantified and the full fuel-cycle efficiency considered.

Gap analysis

Although there is a range of good quality data for the PM_{10} emissions from solid-fuel appliances, there is a general lack of data on liquid and gaseous fuel appliances. As part of the process of approving heating appliances for Environment Canterbury's Clean Heat Project, some work has been undertaken in association with Gas Appliance Suppliers Association (GASA) to determine the emissions from a number of LPG heaters. This information has been used to infer emissions from gas-fuelled appliances. Although this will introduce some errors, it should be considered in the context of gas emissions generally being very low in comparison with solid-fuel burners.

This testing for Environment Canterbury's Clean Heat Project approval has also been applied to liquid-fuelled heaters, so some data are available for these items, but they are specific to particular models and may not necessarily be applicable across other models.

This testing has focused mainly on PM_{10} emissions and the calculation of heater efficiency. Data on other emissions such as NO_x can be scarce, and, as noted, the primary source of this data used in this report (Scott, 2004) may not accurately reflect the emissions of current model heaters.

There is uncertainty between the relationship of emissions from an enclosed wood burner operating under real-life conditions and operating under laboratory conditions. Environment Canterbury – with funding from the Sustainable Management Fund – is currently finalising some research into this relationship, which will lead to the establishment of accepted ratios to apply to laboratory-tested emissions. Environment Waikato in conjunction with the MfE are also studying this issue in Tokoroa.

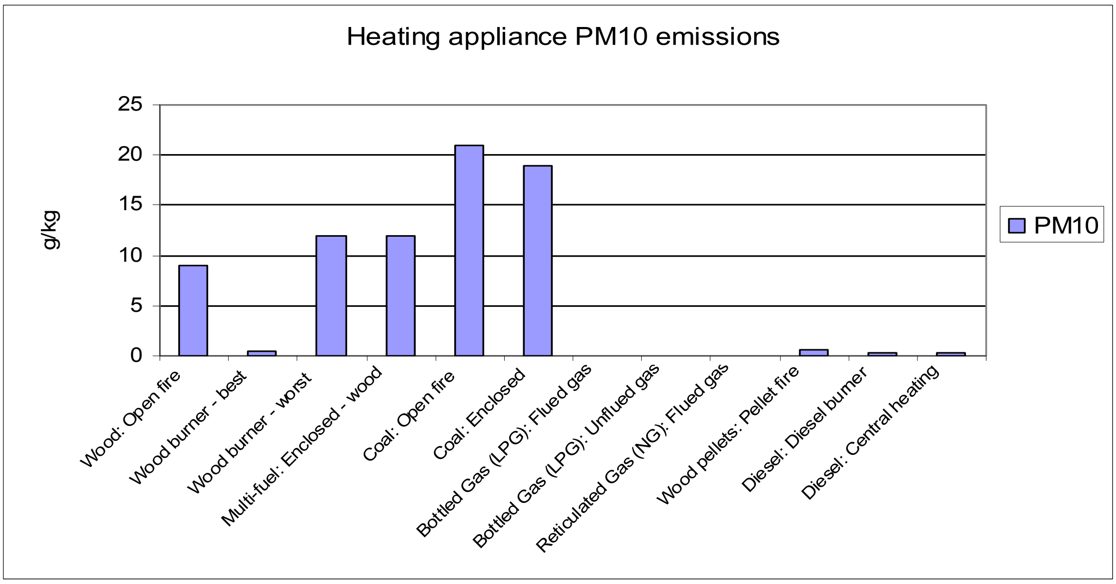
Finally, there appears to be a lack of data on the emissions, both PM_{10} and other, associated with electricity generation from coal and gas. Though such generation is usually undertaken at some distance from major population centres, it does effect air quality and potentially can have health impacts depending on prevailing air flows, population locations, etc.

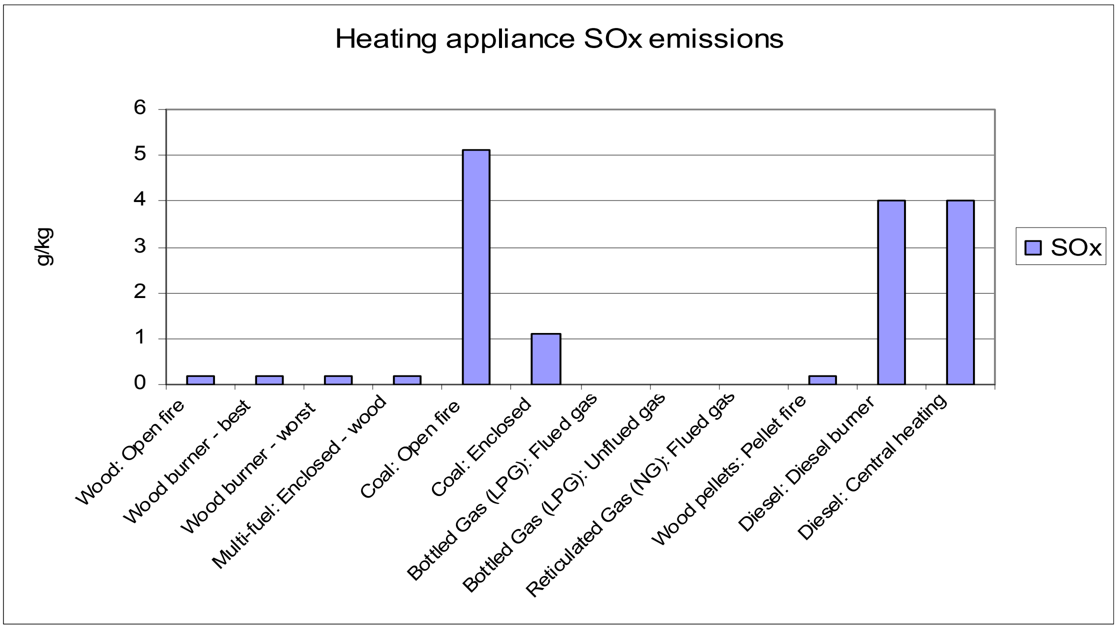
Appendix 1: Individual Contacts

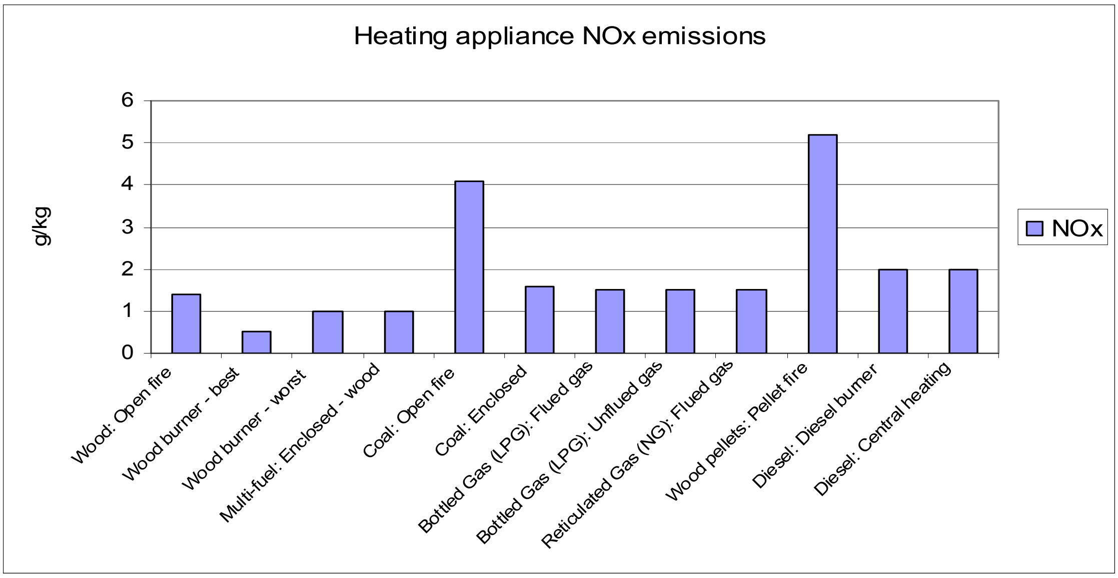
During the course of this research, contact was made with a number of individuals and organisations with an interest or expertise in the field of home heating in New Zealand. The authors would like to acknowledge the co-operation of the following individuals with this work:

Organisation	Contact
BRANZ	Lynda Amitrano
Christchurch City Council	Leonid Itskovich and Terry Moody
EECA	Stephen Ward, Allen Davison and Robert Tromop
Environment Canterbury	Mike Gaudin, Angie Scott and Ken Lawn John Walker
Ministry for the Environment	Matt Hickman and Rebecca Scannell
Natures Flame	Andy Matheson and Steve Cunningham

Appendix 2: Fuel Costs and Emissions Data

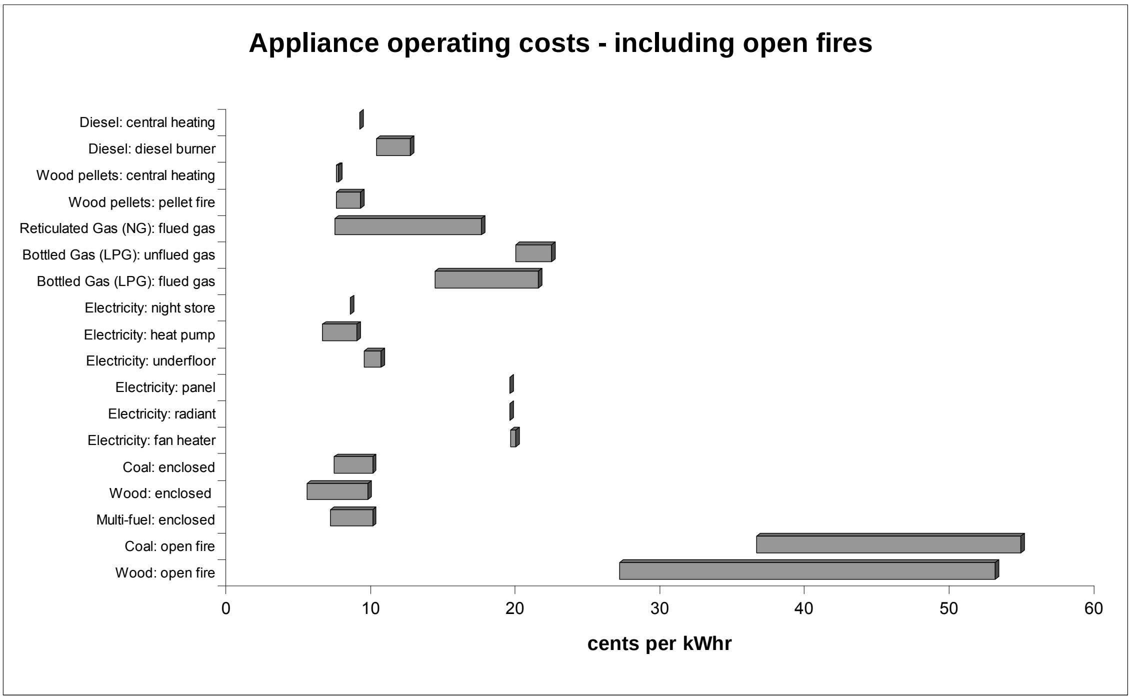


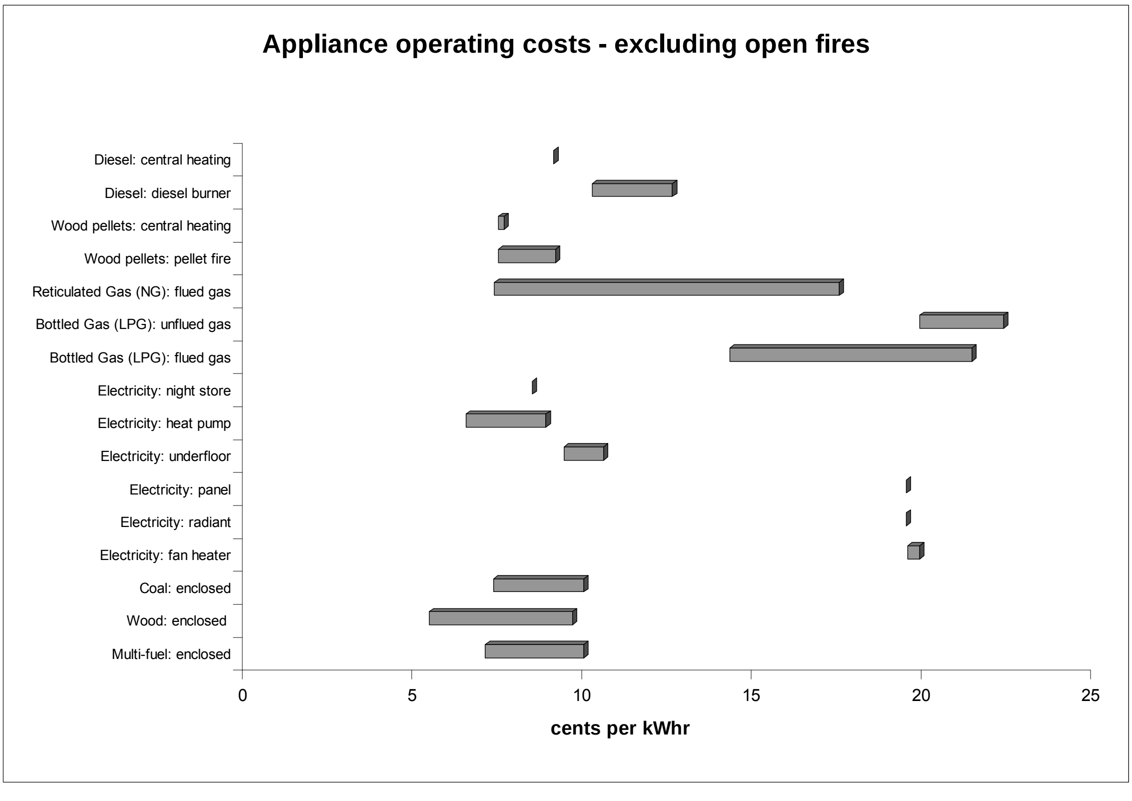




Wood prices

	$/cord	$/kg	$\$m^3$
Christchurch			
Pine	156	0.14	50
Gum	225	0.18	72
Hardwood	238	0.15	76
Auckland			
Pine	188	0.17	60
Gum	266	0.21	85
Hardwood	281	0.18	90
Wellington			
Pine	209	0.19	65
Gum	330	0.26	103
Hardwood	285	0.18	89


Appliance operating costs - including open fires
Diesel: central heating
Diesel: diesel burner
Wood pellets: central heating
Wood pellets: pellet fire
Reticulated Gas (NG): flued gas
Bottled Gas (LPG): unflued gas
Bottled Gas (LPG): flued gas
Electricity: night store
Electricity: heat pump
Electricity: underfloor
Electricity: panel
Electricity: radiant
Electricity: fan heater
Coal: enclosed
Wood: enclosed
Multi-fuel: enclosed
Coal: open fire
Wood: open fire
0
10
20
30
40
50
60
cents per kWhr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Electricity: heat pump
Electricity: underfloor
Electricity: panel
Electricity: radiant
Electricity: fan heater
Coal: enclosed
Wood: enclosed
Multi-fuel: enclosed
0
5
10
15
20
25
cents per kWhr

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