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Housing, Heating and Health Study: Heater Analysis

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1 Summary

This report is primarily to inform the researchers leading the **Housing, Heating and Health** (HHH) Study about which residential heaters meet a set of performance criteria described below, and the relative performance of those heaters.

The report will also be made available to households (and landlords, in the case of rental housing) in the Study so that they can have full background information when making their choices between heater types (i.e. heat pumps, pellet burners or flued gas heaters). However, the **researchers** will tender for a preferred model for each type of heater, and only this model will be available through the Study. For owner-occupied housing, households will be able to choose their preferred heater type. In the case of rental housing, it is the landlord who will make the choice, in consultation with the tenant. The **capital** cost of the heater will not be borne by the households in the Study; however, the heater's ongoing **operating** costs will be.

The different heater types perform against the chosen criteria in this Study as follows.

- **Heat output**: available pellet fires release the most heat and are generally more suitable for larger houses in colder climates. Flued natural gas heaters are usually in the middle of the output range, and suited for most houses (although, due to the absence of piped natural gas in the South Island, gas heaters will not be installed there). Heat pumps range in output but again are suitable for most houses.

- **Indoor air emissions:** all heater types meet the criterion of zero or very low levels of indoor air emissions (assuming the flues, in the case of pellet fires or gas heaters, are correctly installed).

- **Outdoor air emissions:** all heat pumps meet standards and are the cleanest in terms of outdoor emissions. Flued gas heaters are next cleanest and pellet burners emit the most particulates; however, emissions are all below (i.e. more than meet) Environment Canterbury standards.

- **Carbon dioxide** emissions per unit of heat output: pellet burners are the most environmentally friendly, heat pumps are intermediate, and flued gas heaters the least sustainable.

- **Capital costs (equipment, flue kits and installation)** per unit of heat output: pellet burners are the lowest cost per kilowatt; heat pumps and flued gas heaters are very similar, and about one-third more costly per kW than pellet burners.

- **Operating costs** per unit of heat: heat pumps are probably the cheapest to run, closely followed by pellet burners, and with flued natural gas heaters being significantly more costly. Relative costs depend on whether pellet burners are run at full capacity or not (below capacity, costs per unit of heat rise). Pellet burner operating costs are comparable with those of a heat pump if the pellet fire is run at

full capacity. Also, heat pumps are costlier to run on cold nights when ambient temperatures are very low.

- **Lifetime costs (capital plus operating costs) over a 20 year life:** pellet burners' and heat pumps' overall lifetime costs are almost identical. Gas heaters are the most expensive. A sensitivity analysis shows that if electricity prices were to rise significantly (e.g. by 10%) heat pumps would become more costly than pellet fires. This appears more likely than a rise in pellet prices (or gas prices).

- **Usability and maintenance**: all heater types require yearly servicing by an authorised service technician, and usability and maintenance are comparable. For the homeowner, it may be easiest to maintain a pellet fire; a heat pump has the greatest number of parts to clean.

- **Safety**: heat pumps are the safest, as they have no hot parts that could burn a person; however, they have the most risk of electrical shock, although this is a low risk when used properly. Both pellet fires and flued natural gas heaters require shields or screens to minimise burn risks.

- In **summary**, taking into account the range of performance characteristics reviewed here, heat pumps and pellet fires score similarly overall and generally better than flued gas heaters. Pellet fires have the least carbon dioxide emissions (per kWh), and have the cheapest equipment cost on a per-kW basis. However, heat pumps have the lowest operating cost, and the best efficiency, with pellet fires next best. In terms of lifetime costs, pellet fires and heat pumps are comparable. Natural gas heaters seem to score less well on various dimensions (efficiency, equipment cost, operating cost and carbon dioxide emissions). From a community viewpoint, taking into account both lifetime costs and environmental sustainability, pellet fires appear marginally the most attractive option. However, from the individual household's point of view, especially if they are most concerned with operating costs, heat pumps may be the most attractive option.

- **Caveat**: It should be remembered that this assessment is not an exhaustive and comprehensive analysis but is based on a limited selection of heater models, and best pricing and performance data available at the time of analysis. Conclusions are sensitive to future electricity and fuel prices, and may also be influenced by constraints on carbon emissions and other considerations.

2 Introduction

The Housing, Heating and Health (HHH) Study involves replacing up to 600 households' unflued gas heaters and electric heaters with:

- Wood pellet burners, or
- Heat pumps, or
- Flued mains gas heaters.

This report analyses the comparative costs and performance, availability and possible suppliers, of the three main heating options for the HHH Study.

This report is primarily to inform the researchers in the HHH study about the range of heaters which meet the desired criteria set out below. The report will also be made available to households in the Study so that they can have full background information when making their choices between heater types (i.e. heat pumps, pellet burners or flued gas heaters). However, the researchers will tender for a preferred model for each type of heater, and only this model will be available to households as part of their involvement in the Study. Owner-occupiers will be able to choose their preferred heater type but in the case of rental housing, it is the landlord who will make the choice, in consultation with the tenant.

3 Performance requirements

Performance requirements to be met by the heaters are set out under the following headings:

- heat output;
- indoor air emissions;
- outdoor air emissions;
- carbon dioxide emissions;
- fuel availability;
- cost;
- usability and maintenance; and
- safety.

4 Heat output

Heaters to be used in the study must adequately heat the living room and immediately adjacent rooms[3] to at least 18 degrees Celsius in winter conditions in all study cities. Winter conditions are defined as including the conditions for the coldest month (long-term average) of the year.

[3] assuming intervening doors are left open and the house design does not make this impractical

Historical data for the mean minimum air temperatures for each city is given in **Table 1** (source NIWA). Data in Table 1 shows the mean minimum air temperature (over a month time period) and the month and year that it occurred.

Table 1: Historical mean minimum air temperatures

Location	Minimum temp. (°C)	Date of minimum temperature
Porirua	7.6	June 1969
Lower Hutt	6.7	June 1972 and July 1965
Upper Hutt	5.4	July 1943
Christchurch	4.3	July 1958
Dunedin	4.3	July 1995

NIWA data for July minimum average daily temperatures (averaged over 1971-2000) show a similar pattern: 6.3°C for the Wellington region, 1.9°C for Christchurch and 3.2°C for Dunedin. Heater outputs should be in a range to adequately heat a minimally insulated house (i.e. the standard EECA package of ceiling and under-floor insulation but no wall insulation) to 18°C in the living room and adjacent rooms.

It is also necessary to determine how many days a heat pump would struggle to operate due to very low outdoor temperatures, in order to ensure that heat pumps can safely be installed into houses in Christchurch and Dunedin. Most heat pumps are guaranteed to heat to a certain minimum outdoor temperature. **Table 2** shows the minimum outdoor temperatures that some heat pump brands require for operation.

Table 2: Minimum outdoor temperatures for heat pumps

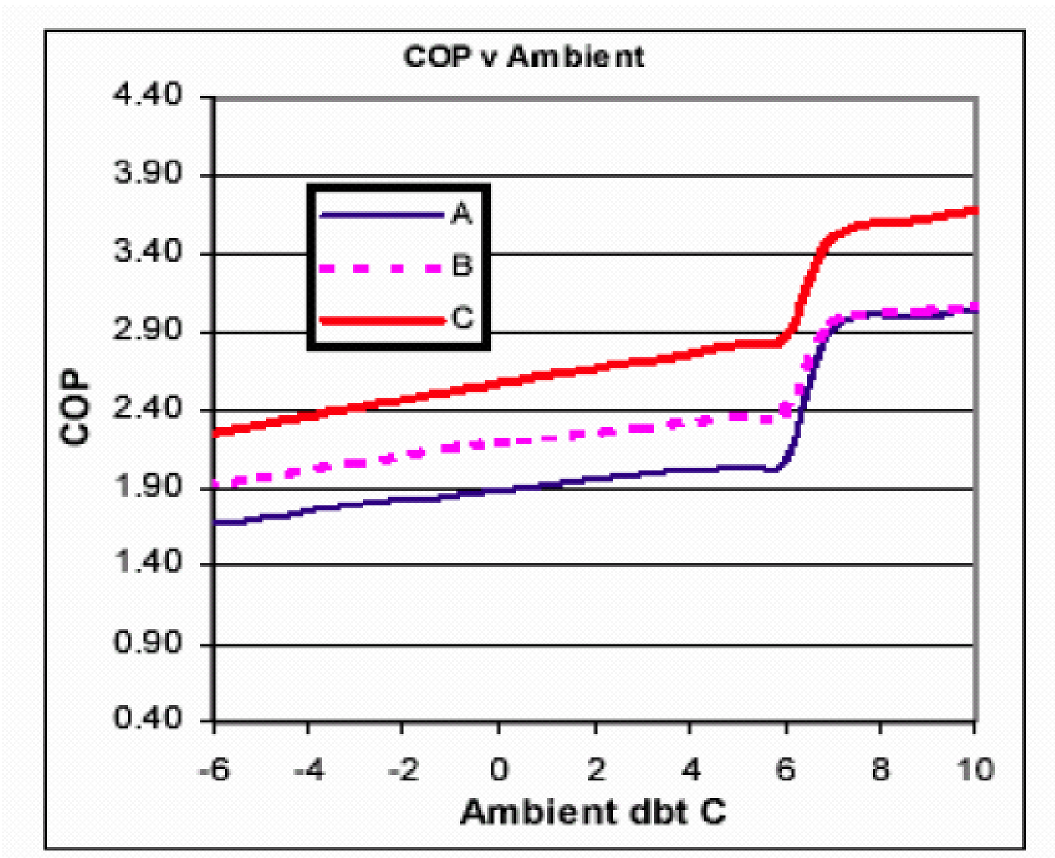
Brand	Minimum outdoor temperature (°C)
Mitsubishi	-9.5
Fujitsu	-15 or -10
Panasonic	-10
Daikin	-15 or -10

Anecdotal information supplied by Environment Canterbury suggests heat pumps struggle at around -8°C; however, this is said not have been a problem for heat pump performance in Christchurch as the temperature seldom gets that low.

When the evaporator temperature reaches 0°C and there is moisture in the air, the evaporator will eventually ice up, and the heat pump will shut down and go through a de-icing routine. Extra energy will be used when this happens and no heating to the room is produced. This is a normal part of the operation of a heat pump, though, and heat is produced again after a short period.

Low temperatures affect the heat pump's Coefficient of Performance (COP)[4]. **Table 3** shows the effect that low outdoor temperatures have on the COP. When outdoor temperatures are low, the power input remains reasonably consistent, which means that heating capacity decreases as the COP decreases. For instance, heat pump C in **Table 3** at 8°C has a COP of roughly 3.6. For a 6kW rated heat pump, the power input is 1.7kW. If the ambient temperature outside goes down to -2°C (so the COP falls to around 2.4) and the power input remains reasonably consistent, the heating output is only 4.2kW.

Table 3: Heat Pump coefficient of performance (COP) and outside temperature



Source: Adrian Hall, Presentation to MEPS Steering Committee 18 September , 2003

[4] The COP is defined as the heating capacity divided by the input power, in Watts/watt.

Information from NIWA shows that:

- the historical lowest air temperatures recorded in each city between 1971 and 2000 were: -2°C, -7°C and -8°C for Wellington, Christchurch and Dunedin, respectively.
- The number of days that receive frosts in each city are 10, 70 and 58 days, respectively.
- As noted above, the lowest **mean** daily minimum air temperature for each city (from data between 1971 and 2000) occurred in July for each city with the following mean temperature: 6°C, 2°C and 3°C respectively.

Because the historical lowest air temperatures all fall above the minimum temperature at which most brands of heat pumps are guaranteed to heat to, it should be assumed that the brands of heat pumps mentioned above will be able to heat adequately in all study cities, for all but a very few days per year. Because the power input remains relatively consistent with heat pumps when ambient temperatures fall, the heating capacity also **decreases** so there may be occasions when the heat pump cannot meet a 6 kW output load. This depends on the COP of the heat pump and its heating capacity but should not occur too often if the heat pump is properly sized for the house.

Using a heater selection matrix developed by DeLonghi to determine minimum heater output[5] suggests that the minimum heater output for all four cities should be no less than 3.7 kW. Similar but marginally higher heat output requirements are suggested by Associate Professor Bob Lloyd of Otago University. However, to leave a margin of safety, and deal with cold days and cold periods during cold days, heater output should be **no less than 6.0 kW**.[6]

It is not necessary to specify a maximum heater size for this study, given that cost and other factors will influence heater choices available within the study. Pellet fires are to be included in the study; the fires currently available in New Zealand are from Nature's Flame, and have 10.0, 11.0 and 11.7 kW of heat output. Taking into account heat outputs and the need for some degree of comparability of heater performance across cities in the study, and given the cost of larger heaters, a **range of 6-10 kW** is likely to be the most appropriate range for heaters in this study. Actual heater size can be determined on a house-by-house basis, taking into account cost-effectiveness, preferences and other factors. Slightly larger capacity heaters may be more suitable in Dunedin and Christchurch.

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[5] Assumptions made are that there are two external walls to the living room, which is 32 m^2 average size and 2.4 m stud height. Adjoining rooms are to be heated.

[6] A heat pump retailer states that the average sized heat pump that is installed into living rooms in Christchurch is 6 kW. Another heat pump retailer suggests that a 9 kW heat pump can heat a space of 68m^2, which is larger than the living rooms (plus adjacent areas) that are expected to be found in this study.

5 Indoor air emissions

The study requires that indoor air emissions from heaters, specifically NO_2, CO, HCOH (formaldehyde) and particulates, are as low as possible.

For both pellet fires and gas heaters, the products of combustion can contain the above substances. However, manufacturers of both pellet fires and flued natural gas heaters state that these heaters don't emit NO_2, CO, formaldehyde and particulates into the indoor air, as any products of combustion are vented through the flue system to the outside.

Heat pumps do not have products of combustion at the point of heat delivery and therefore do not emit the above substances directly into the indoor air.

Therefore, it can be concluded that all heaters to be used in this study will not have any direct indoor air emissions.

6 Outdoor air emissions

The HHH study requires that all heaters to be used will meet the 2004 Environment Canterbury (ECan) outdoor emissions standard of:

- less than 1 gram of particulate per kilogram of fuel burnt;
- less than 40 mg particulates per megajoule (MJ) usable heat output; and
- at least 65% heating efficiency.

The standard of less than 1 gram of particulate per kilogram of fuel burnt applies to solid fuel burners of a type **not** included in this study. The 40 mg particulates per MJ usable heat output and the 65% minimum heating efficiency requirement are used to assess pellet fires and flued gas heaters. All **heat pumps** meet the particulate criteria due to the nature of their operation, and all meet the minimum 65% heating efficiency standard.

Environment Canterbury states that all categories of **flued gas heaters** tested by the New Zealand Gas Suppliers Association meet their air emissions requirements The flued gas heaters shown below were tested by the Gas Suppliers Association and thus meet the air emissions requirements of ECan.

Table 4 shows emissions and efficiencies of heaters (flued gas heaters and pellet fires) sold throughout New Zealand. This information was obtained from the ECan website.[8] Note that one heater does not meet ECan's outdoor emissions standard and should not be used in the study (gray shaded).

[8] www.ecan.govt.nz.

Table 4: Heater outdoor emissions and efficiencies

Heater (brand)	Heater (model)	Output (kW)	Efficiency (%)	Outdoor emissions (mg particulate per MJ output)	Meets criteria?
PELLET FIRES:					
Nature's Flame	Bayview (EF3) Freestanding Dry	11.0	75.8	32.20	Yes
	Evolution (EF5)	11.0	92.1	15.70	Yes
	Bayview (EF3) Inbuilt Wetback	11.7	72	31.60	Yes
	Bayview (EF3) Insert Dry	11.7	72	31.60	Yes
	Bayview (EF3) Freestanding Wetback	10.0	82	32.00	Yes
FLUED NATURAL GAS HEATERS:					
Kent	Archer[9]	7.6	92	0	Yes
Masport	Baltimore	7.08	75	0	Yes
	Boston		80	0	Yes
	Calais	7.2	82	0	Yes
	Classic	7.3	80	0	Yes
	Grenada	7.2	82	0	Yes
	GZ30		68	0	Yes
	Madrid	7.4	76	0	Yes
	Monaco ACC	7.08	75	0	Yes
	Monaco ECS	7.1	75	0	Yes
	Naples	7.2	74	0	Yes
	Newport	7.0	60	0	No
	Piccolo	7.13	73	0	Yes
	Seville	7.2	74	0	Yes
	Sofia	7.13	73	0	Yes
	Ultimate DV Rear Exit	9.4	81	0	Yes
	Ultimate DV Top Exit	7.1	84	0	Yes
	Ultimate F37	8.6	81	0	Yes
	Ultimate F38	8.6	74	0	Yes
	Ultimate F39	8.6	84	0	Yes
	Ultimate I43	8.6	81	0	Yes
	Ultimate Standard	8.6	86	0	Yes
Rinnai	Energy Saver RHF1004	8.2	81	0	Yes
	Timberflame FS35ETR	6.5	72.3	0	Yes
	Timberflame FS35ETRS	6.5	77	0	Yes
	Timberflame FS35B	7.5	77	0	Yes
	Timberflame FS35S	7.5	77	0	Yes
	Timberflame IB30	6.0	71	0	Yes
	Timberflame IB35RB	6.8	74	0	Yes
	Timberflame IB35RS	6.8	74	0	Yes
	Timberflame IBF30	6.0	72	0	Yes
Yunca	E1B	6.4	82	0	Yes
	Eros	7.8	79	0	Yes
	Eros Delux	7.8	80	0	Yes
	Jervois	6.4	81	0	Yes
	Leedz FS	6.4	81	0	Yes
	Leedz Inbuilt	6.4	82	0	Yes
	Leedz Inbuilt Delux	6.4	82	0	Yes

[9] Information obtained on BBQ Factory website (www.bbqfactory.co.nz), not ECan website.

7 Carbon dioxide emissions

The operation of all three types of heaters contributes to carbon dioxide emissions, as each requires some electricity, and it can be assumed that some of the electricity required to operate the heater comes from a fossil fuel generating source. However, emissions of carbon dioxide vary considerably.

The conversion factor to be used to calculate carbon dioxide emissions is 625 tonnes carbon dioxide per gigawatt hour (GWh) electricity generated; this factor reflects a careful assessment (commissioned by the Climate Change Office) of the carbon intensity of generation "at the margin"[10]. Note that heaters to be installed in the project will be at the margin, i.e. new installations.

Electricity is consumed from the following heater activities:

- Pellet fires: ignition and running a fan;
- Flued natural gas heaters: ignition, running fan, electronic controls; and
- Heat pumps: operating the heat pump.

For **pellet fires**, ignoring the difference in start-up electricity usage, the following carbon dioxide emissions result from operation[11]:

- 4.3 g CO_2/MJ, or 15.6 g CO_2/kW per hour for a 10 kW model run at the 10 kW setting;
- 3.9 g CO_2/MJ, or 14.2 g CO_2/kW per hr for an 11 kW model; and
- 3.7 g CO_2/MJ, or 13.4 g CO_2/kW per hr for an 11.7 kW model .

No (net) carbon dioxide is produced from pellet fuel combustion, as wood fuel is approximately carbon neutral, i.e. it absorbs as much carbon dioxide in its growth as it releases when it is burnt. The manufacturing process for pellets involves compressing wood wastes into pellets, and it is understood that while this process emits carbon dioxide, the quantity is relatively small and can be disregarded in calculations. Therefore it is concluded that pellet fires only generate significant carbon dioxide through their electricity consumption.

For flued natural **gas heaters**, electricity is consumed at ignition, when the fans are running and for electronic controls. Masport report that their fans use a maximum of 120W. Electronic controls use a very small amount of electricity. BRANZ states that electronic controls use a few percent of the overall energy consumption of the heater; anywhere in the range of 0 to 10 W is typical. Assuming negligible electricity usage for controls and ignition, and that all flued natural gas heaters used a 120W fan continuously, the CO_2 emitted by fans equates to 75 g CO_2 per hour of operation.

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[10] From www.climatechange.govt.nz/resources/reports/electricity-emission-factor-reports/index.html entitled "Projects to Reduce Emissions programme- electricity emission factors" by the New Zealand Climate Change Office.

[11] Nature's Flame reports that 400W of electricity is used at ignition for the first 2 minutes and then 250W thereafter to run the fan. This equates to a difference of 150 W per minute, or 0.1 g less CO_2/MJ per hour emitted for a 10 kW fire. Therefore start-up electricity usage will be assumed to be negligible.

Carbon dioxide is generated as a product of natural gas **combustion --** 190 g CO_2 per kWh natural gas combusted[12].

Table 5, for flued **gas heaters**, shows for various heaters the amount of CO_2 emitted per hour of operation at the rated size of the heater, arising from electricity consumption as well as natural gas combustion.

Table 5: gCO_2 per hour of heat output, for various flued gas heaters

Heater size (kW output)	g CO_2 per hr at rated heat output (ex electricity consumed)	g CO_2 per hr at rated heat output (ex gas combustion)	**Total g CO_2 per hr at rated heat output**	Examples of heater brands
6.0	12.5	1140	**1153**	Masport Santa Fe FLS
6.4	11.7	1216	**1228**	Yunca Leedz and Jervois
6.5	11.5	1235	**1247**	Yunca FUZiON
7.1	10.6	1349	**1360**	Masport Cardrona ACC and Piccolo
7.5	10.0	1425	**1435**	Masport Monaco ECS (7.4 kW), Masport Madrid ECS (7.4 kW), Masport Sofia (7.5 kW), and Kent Archer (7.6 kW)

For **heat pumps**, it can be assumed that the heat pump runs at the nominal heating capacity continuously. CO_2 emissions will vary depending on the power output (or heating capacity) yielded for the given power input, or the coefficient of performance (COP). As outdoor air temperatures fall, the COP decreases, meaning less heat is delivered for the same power input. This means that more CO_2 will be generated at lower temperatures, as it will take more power input to deliver a constant internal temperature. As an example, **Table 6** shows the difference in CO_2 emissions using a 6.8kW Mitsubishi heat pump, assuming that the indoor air temperature is heated to 21°C.

Table 6: CO_2 emissions for a heat pump at different outdoor temperatures

Outdoor temperature (°C)	**gCO_2/MJ per hr heat output[13]**	**gCO_2/kW per hr heat output**
-10	61	220
-5	60	217
0	57	204
5	53	192
10	49	178

Table 6 shows that carbon dioxide emissions can increase by as much as 24% when the outdoor temperature falls by 20°C. CO_2 emissions might increase by as much as 42 g CO_2/kW per hr of heat output if outdoor temperatures went as low as -10°C.

[12] Source is the UK National Energy Foundation, http://www.nef.org.uk/energyadvice/co2calculator.htm
[13] Again, this is calculated as per hour of operation of the rated heating capacity of the heater, i.e. 6.8kW.

The rest of this report uses manufacturers' data to calculate CO_2 emissions, and assumes a 7°C outdoor temperature unless otherwise stated.

Examples of CO_2 emissions for different size heat pumps are shown in Table 7, with a 7.2kW heater highlighted (for reference in the comparison below). They are calculated per hr of operation at the rated heater output.

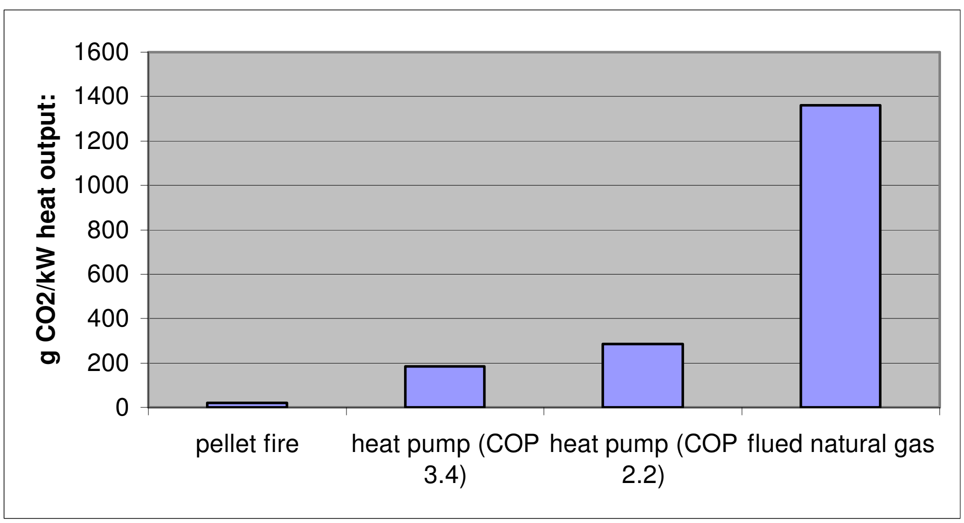
Table 7: gCO_2/kW per hr at rated heat output, for various heat pumps

kW output	kW input	g CO_2/kW per hour at rated output
6.0	1.95	203.1
6.5	1.84	176.9
6.8	2.05	188.4
7.2	2.12	184.0
8.1	2.65	204.5
8.5	2.58	189.7
9.0	3.25	225.7
9.5	3.32	218.4

Comparison of carbon dioxide emissions

Figure 1 compares CO_2 emissions from a pellet fire, a heat pump with a COP of 3.4 at 7°C, a heat pump operating at lower ambient temperatures (COP of 2.2) and a flued natural gas heater.

Figure 1: CO_2 emissions from various 7.2 kW heaters



This shows that heat pumps emit much more CO_2 than pellet heaters, given their electricity consumption. However, flued natural gas heaters emit the most CO_2 because of emissions from gas combustion. In terms of CO_2 emissions per unit of heat output, pellet burners are the most environmentally friendly, heat pumps are intermediate, and gas heaters the least sustainable.

8 Fuel availability

Reticulated natural gas is only available in the North Island, and Porirua and Hutt Valley have natural gas available. However, not all streets have reticulated natural gas, so availability should be checked with a gasfitter before a flued natural gas heater is selected for houses in these areas, or significant costs may be incurred.

Pellets for pellet fires are available in all study areas. Only one pellet fire company, Nature's Flame, is currently selling fires in New Zealand and their pellets must be used in their pellet fires. Pellets can be bought from the factory by the tonne, or through outlets in the study areas. If bought from the factory, pellets cost $421 per tonne, including freight, to Wellington. If bought by the bag, pellets cost $8.50 per 20 kg bag in Wellington (available at the BBQ Factory), $7.50 per bag in Christchurch (available at Mitre 10 and Placemakers) and $8.50 per bag in Dunedin (available at Mitre 10).

Electricity is available to all houses in all study areas.

9 Costs

Capital costs

The following **Table 8** summarises the capital (upfront) costs of heaters included in this report.[14] The cost is also reported in $/kW of useful heating output. Prices include GST and exclude installation costs, flue kits and any other accessories unless specified.

[14] Heat pump equipment costs were sought in Wellington; however, no company was able to give price quotes in time for this report. It should be assumed that prices will be similar to Christchurch and Dunedin prices because pellet fires are similar in price throughout the country.

Table 8: Heater prices (lowest price by city and heater type shown shaded)

Model:	Wellington area			Christchurch			Dunedin		
	Price	Price per kW	Source	Price	Price per kW	Source	Price	Price per kW	Source
PELLET FIRES									
Nature's Flame Classic freestanding 10.5 kW	$2500; $2499-2799	$238	BBQ Factory, Petone; Nature's Flame	a) $2799; b) $2799; c) $2499-2799	$238	a) Mitre 10 Mega; b) Mitre 10 Smiths c) Nature's Flame	$2500; $2499-2799	$238	Jacks Mitre 10; Nature's Flame
Nature's Flame Bayview (EF3) 11.7 kW	$2999-3449	$256	Nature's Flame	$2999-3449	$256	Nature's Flame	$2999-3449	$256	Nature's Flame
Nature's Flame Bayview (EF3) freestanding 11.7kW	$3200	$274	BBQ Factory, Petone	$2999	$256	Mitre 10 Mega	$3099	$265	Jacks Mitre 10
Nature's Flame Bayview (EF3) insert 11.7 kW	$3300	$282	BBQ Factory, Petone	$3099; $3199	$265	Mitre 10 Mega; Mitre 10 Smiths			
Nature's Flame Evolution (EF5) freestanding 11 kW	$3200; $2999-3149	$273	BBQ Factory, Petone; Nature's Flame	$2999; $2999; $2999-3149	$273	Mitre 10 Mega; Mitre 10 Smiths; Nature's Flame	$3000; $2999-3149	$273	Jacks Mitre 10; Nature's Flame
FLUED GAS HEATERS: (Wellington area only)									
Freestanding:									
Masport Monaco ECS 7.4 kW	$3199	$432	Masport website						
Masport Cardrona ACC 7.1 kW	$2549	$359	Masport website						
Masport Santa Fe FLS 6.0 kW	$2299	$383	Masport website						
Kent Archer 7.6 kW	$3,500 (incl. flue)	$461	BBQ Factory, Petone						
Yunca Jervois 6.4 kW	$1790; $1790	$280	BBQ Factory, Petone; Heating Centre						
Yunca FUZiON 6.5 kW	$2325	$358	Yunca factory prices (Dunedin)						
Yunca Leedz (6.4 kW)	$1995	$312	The Heating Centre						

	Wellington area			Christchurch			Dunedin		
Inserts:									
Masport Piccolo 7.1 kW	$1999	$282	Masport website						
Masport Sofia 7.5 kW	$2399	$320	Masport website						
Masport Madrid ECS 7.4 kW	$2999	$405	Masport website						
Kent Archer 7.6 kW	$3500 (incl. flue)	$461	BBQ Factory, Petone						
HEAT PUMPS									
Panasonic 6 kW				$2799	$467	Smiths City Colombo St	$2999 (6.6 kW)	$454	The Heating Company
Fujitsu 6.2 kW				$3500 (installed)	$565	Beattie	$2499 (unit) or $3199 (installed)	$403	The Heating Company
Mitsubishi 6.8 kW							$3249	$478	The Heating Coy.
Daikin 7.0 kW				$4400 (installed)	$629	Beattie	$4120 (7.2 kW) (installed), $3599 (unit) or $4299 (installed)	$514	G W Davies; The Heating Company
Panasonic 7.1 kW				$3299	$465	Smiths City Colombo St	$3549 (7.2 kW)	$493	The Heating Company
Mitsubishi 8.1 kW	$3799.95	$469	Black Diamond Technology	$3799.95	$469	Black Diamond Technology	$3649; $3799.95	$450	The Heating Company; Black Diamond Technology
Panasonic 8.1 kW				$3699	$457	Smiths City Colombo St	$3849 (8.6 kW)	$448	The Heating Company
Daikin 8.5 kW				$4700 (installed)	$553	Beattie	$4029 (unit) or $4729 (installed)	$474	The Heating Company
Fujitsu 8.5 kW				$4200 (installed)	$494	Beattie	$3149 (unit) or $3849 (installed)	$370	The Heating Company
Mitsubishi 9.0 kW	$4649.95	$517	Black Diamond Technology	$4649.95	$517	Black Diamond Technology	$4399; $4649.95	$489	The Heating Company; Black Diamond Technology

Table 9 shows typical installation costs in each of the study cities. It also shows installation cost on a per-kW basis, assuming that the lowest installation cost is used with the lowest and highest output heater to give costs for the smallest and largest heater. It should be noted that many factors contribute to the actual installation cost incurred in practice, including whether heaters can be attached to outside walls, length of pipe runs, etc.

Table 9: Typical heater installation costs

	Wellington area		**Christchurch**		**Dunedin**	
Heater Type	Installation cost:	Cost per kW	Installation cost:	Cost per kW	Installatio n cost:	Cost per kW
Pellet fire	$435: Nature's Flame; Up to $1000 for installation and flue (BBQ Factory, Petone)	$85-95 (assuming $1000 for flue kit and installation)	$435: Nature's Flame;	$85-95 (assuming $1000 for flue kit and installation)	$435: Nature's Flame	$85-95 (assuming $1000 for flue kit and installation)
Flued natural gas heater	$1200 (Southern Plumbing and Gasfitting)	$158-188	n/a		n/a	
Heat pump	$1000:Abode Air Conditioning	$111-167	$750 – 800: Gavin Lowe Air Conditioning; $800 – 850: Beattie	$83-125	$700: The Heating Company	$78-117

In addition to these costs, pellet fires and flued natural gas heaters usually have **flue kits** that are sold separately. Costs for these range from **$330** for a Yunca gas fire flue kit to **$535** for the pellet fire flue kit.

Table 10 shows **total** heater equipment costs, i.e. including flue kit costs and installation costs for each heater. It is assumed that the lowest price for each item is used when there is a difference in prices.

Table 10: Costs of heater equipment plus flue kit plus installation

	Wellington area:		Christchurch:		Dunedin	
Model:	Price:	Price per kW	Price:	Price per kW	Price:	Price per kW
PELLET FIRES:						
Nature's Flame Classic freestanding 10.5 kW	$4034	$384	$4034	$384	$4034	$384
Nature's Flame Bayview (EF3) 11.7 kW	$4534	$388	$4534	$388	$4534	$388
Nature's Flame Bayview (EF3) freestanding 11.7kW	$4735	$405	$4534	$388	$4634	$396
Nature's Flame Bayview (EF3) insert 11.7 kW	$4835	$413	$4634	$396		
Nature's Flame Evolution (EF5) freestanding 11 kW	$4534	$412	$4534	$412	$4534	$412
FLUED GAS HEATERS: (Wellington area only)						
Freestanding						
Masport Monaco ECS 7.4 kW	$4729	$639				
Masport Cardrona ACC 7.1 kW	$4079	$575				
Masport Santa Fe FLS 6.0 kW	$3829	$638				
Kent Archer 7.6 kW	$5030	$662				
Yunca Jervois 6.4 kW	$3320	$519				
Yunca FUZiON 6.5 kW	$3855	$593				
Yunca Leedz (6.4 kW)	$3525	$551				
Inserts						
Masport Piccolo 7.1 kW	$3529	$497				
Masport Sofia 7.5 kW	$3929	$524				
Masport Madrid ECS 7.4 kW	$4529	$612				
Kent Archer 7.6 kW	$5030	$662				
HEAT PUMPS:						
Panasonic 6 kW			$3549	$592	$3699	$617
Fujitsu 6.2 kW			$4250	$685	$3199	$516
Mitsubishi 6.8 kW					$3949	$581
Daikin 7.0 kW			$5150	$736	$4299	$614
Panasonic 7.1 kW			$4049	$570	$4249	$598
Mitsubishi 8.1 kW	$4800	$593	$4550	$562	$4349	$537
Panasonic 8.1 kW			$4449	$549	$4549	$582
Daikin 8.5 kW			$5450	$641	$4729	$556
Fujitsu 8.5 kW			$4950	$582	$3849	$453
Mitsubishi 9.0 kW	$5650	$628	$5400	$600	$5099	$567

Operating costs

However, 'capital' costs are not the only cost consideration. **Operating** or running costs for heaters are shown below in **Table 11**. These are shown as c/kWh of heat output, which takes into account the efficiency of the heater. It is assumed that the average efficiency for a flued gas heater is 78% and a heat pump operates at a COP of 3 (see Table 3 above).[15] Pellet fire operating costs come from manufacturers' data regarding kW output and length of time a 20 kg bag of pellets lasts.

[15] i.e. the ratio of useful heat output to heat input = 3.00. (This may be interpreted as 300% efficiency.)

Table 11: Heater operating costs (lowest cost for heat pumps in each city shaded)

	Wellington area		Christchurch:		Dunedin	
Energy Retailer:	Charge	Cost per unit of heat output	Charge	Cost per unit of heat output	Charge	Cost per unit of heat output
PELLETS (pellet fires)[16]						
Nature's Flame	$8.50/20kg bag (Mitre 10; BBQ Factory); $421/tonne including freight for 50 20kg bags	7.27 c/kWh	$7.50/bag (Mitre 10 and Placemakers)	6.41 c/kWh	$8.50 to $9.00/bag (Mitre 10)	7.69 c/kWh
FLUED GAS HEATERS (Wellington area only)						
Contact Energy:	Daily fixed charge: 103.16c; variable charge: 8.39 c/kWh	Variable cost of 10.76 c/kWh				
Genesis Energy	Daily fixed charge:73.72c; variable charge of 8.64 c/kWh	Variable cost of 11.08 c/kWh	N/A	N/A	N/A	N/A
ELECTRICITY (heat pumps)						
Contact Energy	N/A	N/A	All Day Econ'y Plan: Daily 63.24c; variable 16.37 c/kWh	Variable cost of 5.46c/kWh	All Day Econ'y Plan: Daily 77.19c; Variable 14.96 c/kWh	Variable cost of 4.99c/kWh
Empower	All Day Economy (Std User): Daily 62.87c; Var: 16.75 c/kWh	Variable cost of 5.58 c/kWh	All Day Econ'y; Daily 63.24c; Var: 16.37 c/kWh	Variable cost of 5.46c/kWh	N/A	N/A
Genesis	Household Composite Plan; Daily 91.25c; Var: 15.60c/kWh	Variable cost of 5.20c/kWh	N/A	N/A	N/A	N/A
Meridian	MeridianPlus Economy 24 Plan: Daily 104.04c; Variable 15.33 c/kWh	Variable cost of 5.11c/kWh	MeridianPlus Economy 24 Plan: Daily 63.88c; Variable 16.54 c/kWh	Variable cost of 5.51c/kWh	MeridianPlus Econ'y 24 Plan: 89.53c/day; Variable: 12.59c/kWh in summer; 15.96c/kWh in winter	Variable cost of 5.32c/kWh
Trust Power	N/A	N/A	N/A		Friends Plan: Daily 62.81c; Var: 19.00c/kWh	Variable cost of 6.33c/kWh

[16] This assumes a 11.7 kW EF3 model is used on **high** continually. The manufacturers say that if the heater is run at 1.9 kW, a 20 kg bag of pellets lasts up to 28 hrs; if the heater is on 11.7 kW, the same fuel lasts 10 hours. The cost per unit heat output will be **higher** if the heater is run on **low**, e.g. if run at 1.9 kW (the low setting), it will cost **16.04c/kWh** in Wellington (i.e. where a 20kg bag costs $8.50).

Prices include GST but do not take into account a standard 10% prompt payment discount that all gas and electricity supply companies offer.

Figure 2 below shows costs per kW delivered for a given level of heat output (7.2 kW is chosen, as it is around the middle of the range of capacities) for various heaters (using Wellington prices), using assumptions as for Table 12.

Figure 2: Operating cost per kWh delivered for various heaters at 7.2 kW

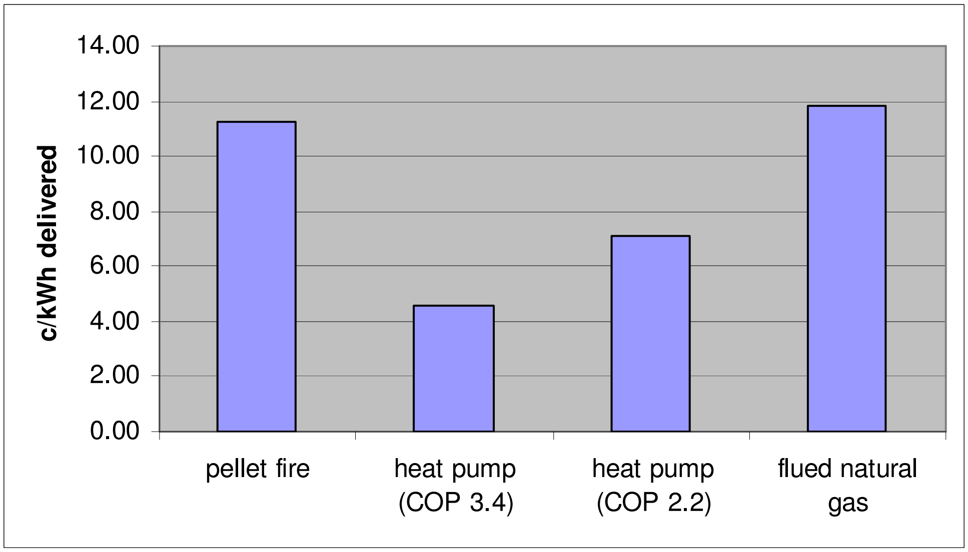
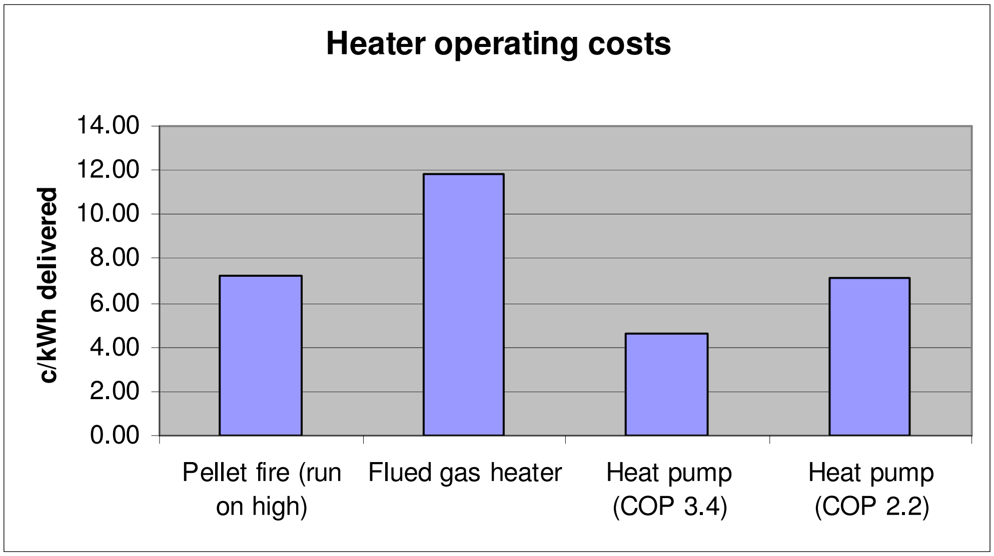


Figure 2 above suggests that, under these assumptions, **heat pumps are cheapest to run,** followed by pellet burners, with flued natural gas heaters being most costly.

However, there are important caveats to note. Prices used in the calculation above are for Wellington, and will differ for other cities; in Christchurch, for instance, pellet burner operation is currently around 12% cheaper than in Wellington, because pellets are cheaper (note also that electricity is around 5% cheaper). Moreover, the estimate above is for an 11.7 kW burner run at about two-thirds capacity (7.2kW), and this reduces its efficiency. Pellet burner operating costs (c/kWh) fall to 7.3c/kWh, i.e. **closer to those for a heat pump**, if the pellet fire is run **at full capacity** (shown in **Figure 3** below). This may require the pellet fire to be turned on and off more often (entailing minor inconvenience).

Heat pumps are also more expensive to run with a lower COP, which may occur on cold nights when ambient temperatures are very low. This is shown by the higher cost ‘bar’ for a heat pump operating at a COP of 2.2, in both Figure 2 above and Figure 3 below.

Figure 3: Operating cost per kWh delivered for various heaters (assuming heaters are run at full capacity)



One minor consideration is that times to reach steady-state operation vary. Anecdotal evidence from heating manufacturers shows that times to reach steady-state operation for each appliance are as follows:

- pellet fires- 2 minutes
- flued natural gas heaters- none
- heat pumps- 5 to 10 minutes

Start-up adjustment will raise running costs slightly, as more electricity and gas are used by the heater. Slightly higher running costs will occur each time the heater is turned on. However, the overall significance of start-up adjustment is negligible.

Table 12 below sets out running costs for a "**day**" across types and models of heaters, based on the following assumptions:

- each heater runs 6 hours per day **at rated capacity**;
- the cheapest energy plan is used in each city;
- daily fixed charges are excluded from running costs;
- no prompt payment discount is included;
- each heater model's efficiency is taken into account; and
- electricity for fans is not included for gas and pellet fires.

Note that Table 12 should **not** be used to compare heating costs across models, since total heat output over a day differs between models.

Table 12: Daily operating costs for heaters

	Wellington area	**Christchurch**	**Dunedin**
Model	Cost per day ($):	Cost per day ($):	Cost per day ($):
Pellet fires			
Nature's Flame Bayview (EF3) 11.7 kW	$5.10	$4.50	$5.40
Nature's Flame Bayview (EF3) freestanding 11.7kW	$5.10	$4.50	$5.40
Nature's Flame Bayview (EF3) insert 11.7 kW	$5.10	$4.50	$5.40
Flued gas heaters (Wgtn area only)			
Freestanding:			
Masport Monaco ECS 7.4 kW	$5.85		
Masport Cardrona ACC 7.1 kW	$5.78		
Masport Santa Fe FLS 6.0 kW	$4.19		
Yunca Jervois 6.4 kW	$4.83		
Yunca FUZiON 6.5 kW	$4.95		
Yunca Leedz 6.4 kW	$4.83		
Inserts:			
Masport Piccolo 7.1 kW	$5.78		
Masport Sofia 7.5 kW	$6.06		
Masport Madrid ECS 7.4 kW	$5.78		
Kent Archer 7.6 kW	$5.02		
Heat pumps			
Panasonic 6 kW	$2.59	$2.39	$2.38
Fujitsu 6.2 kW	$2.52	$2.32	$2.31
Mitsubishi 6.8 kW	$2.83	$2.65	$2.61
Daikin 7.0 kW	$2.87	$2.69	$2.65
Panasonic 7.1 kW	$2.88	$2.69	$2.66
Mitsubishi 8.1 kW	$3.39	$3.24	$3.15
Panasonic 8.1 kW	$3.31	$3.15	$3.07
Daikin 8.5 kW	$3.33	$3.17	$3.09
Fujitsu 8.5 kW	$3.55	$3.40	$3.30
Mitsubishi 9.0 kW	$3.95	$3.82	$3.69

Lifetime costs

Lifetime costs (capital plus operating costs) for various heaters can be estimated, adding capital costs and operating costs. These are shown in **Table 13** below. This table **can** be used to compare heater types.

In calculating lifetime costs, a number of assumptions are made:

- each heater produces the **same total heat output per day** (43.2 kWh, the equivalent of 6 hours per day at 7.2kW);
- daily fixed charges are excluded from running costs;
- no prompt payment discount is included;
- the cheapest energy plan is used in each city;

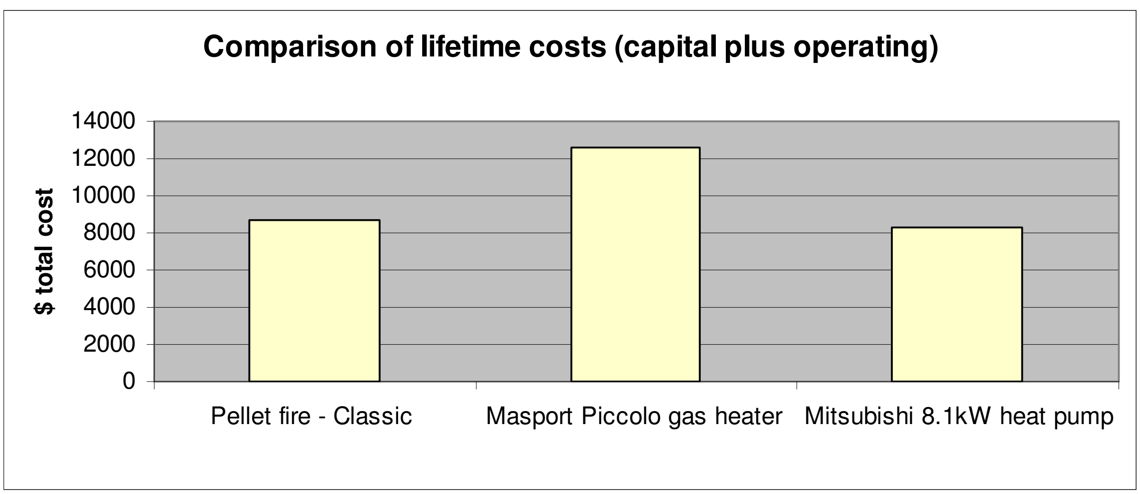
- each heater model's efficiency is taken into account; and
- electricity for fans is not included for gas and pellet fires.

Table 13: Lifetime costs (capital plus operating) for heaters

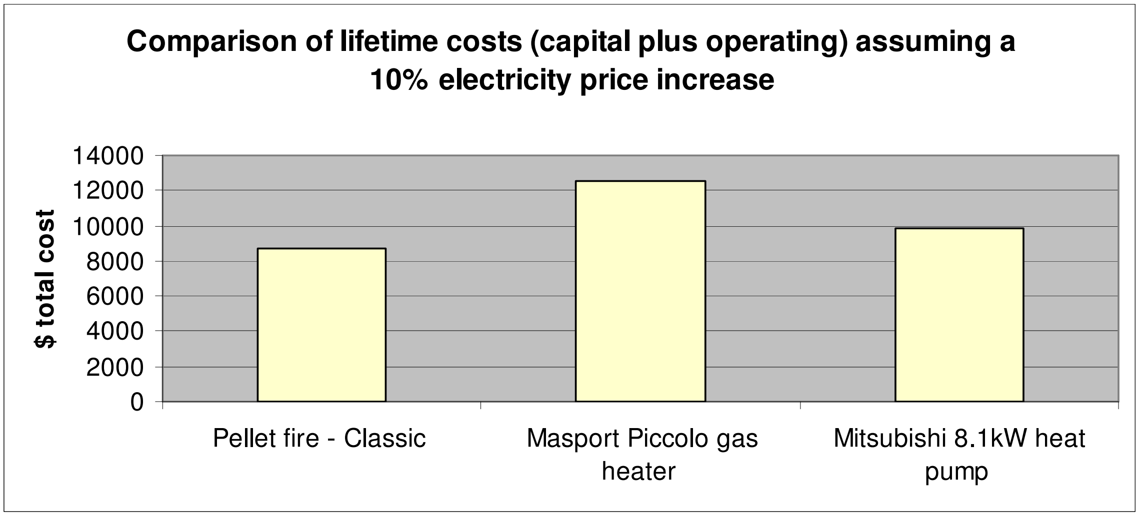
Model	**Capital cost**	**Present value of operating costs over 20 yrs***	**Total lifetime cost**
Pellet fire			
Nature's Flame EF3 11.7 kW	$4034	$4694	$8,727
Flued gas heater			
Masport Piccolo 7.1 kW	$4729	$7827	$12,556
Heat pump			
Mitsubishi 8.1 kW	$4800	$3515	$8,315

- Present value of future operating costs are discounted to the present using a discount rate of 5% real
- A carbon tax of $15/tCO2 is assumed to be introduced in year 2.

This analysis suggests that a pellet fire is **about the same** in terms of total lifetime costs, taken over a 20-year lifetime, as a heat pump. Again, gas heating costs more than the other two options.



A sensitivity analysis which increased the discount rate did not substantially alter this conclusion. However, a sensitivity analysis which assumed that there was an increase in the price of electricity of 10% (in year 2) suggests that a pellet fire's lifetime costs would in that event be somewhat lower than those for a heat pump.



10 Usability and maintenance

The following is information gathered about maintenance schedules for the various types of heaters.

Pellet fires require servicing by a service provider every 12 months.

- As regular maintenance by the owner, the inside of the glass should be cleaned daily with a wet rag, and the ash tray vacuumed out weekly.

Flued natural gas heaters must be checked and serviced every 12 months by an authorized technician. They should test for continued safe operation and spark strength.

- As regular maintenance by the owner, excessive lint from carpeting, bedding material, etc should be cleaned from the control compartments, burners and circulating air passageways.
- The flue system should be inspected annually for blockage and any signs of deterioration.

Heat pumps should be checked and serviced every 12 months by an authorized technician, which would take less than an hour. A competent service contractor should be hired annually to do more difficult maintenance such as checking the refrigerant level, making electrical or mechanical adjustments, lubricating the fan motor and checking the fan speeds. Incorrect settings can contribute to poor performance.

- As regular maintenance by the owner, the air filter should be cleaned every three to four months depending on usage.
- The front panel should be wiped with a soft dry cloth or washed with water.

- The heat exchanger in the indoor unit should be swept with a special-made brush on a vacuum cleaner.
- The air outlet and fan of the indoor unit should be cleaned with water or with a vacuum cleaner.
- Filter and coil maintenance has a dramatic impact on system performance and service life. Dirty filters, coils and fans reduce airflow through the system. This reduces system performance, and can lead to compressor damage if it continues for extended periods of time. Filters should be inspected monthly and cleaned or replaced as required by the manufacturer's instructions. The coils should be vacuumed or brushed clean at regular intervals as indicated in the manufacturer's instruction booklet. The outdoor coil may be cleaned using a garden hose.

Other miscellaneous considerations include the following:

- **Pellet fires** require that the pellet bags be stored in a dry place: damp pellets do not burn properly.

- **Heat pumps** can create a draught which some people find irritating. The outside unit can also create some noise in operation and should not be mounted on a wall where it will cause noise disturbance to neighbours.

11 Safety

The following is information gathered about safety issues related to the various types of heaters.

Pellet fires

- A fire guard should be used to protect children from the hot glass.

Flued natural gas heaters

- A fixed screen surround should be used to protect children from hot parts.
- A flue mounted shield can also be bought to prevent children from touching the hot flue.

Heat pumps

- There is no risk of fire, no electric elements or hot outer panels to harm a person.
- However, there is a danger of electric shock inside the front panel of the inside unit, the outside enclosure of the outside unit and if switches are operated with wet hands.
- Nothing should be inserted into the fan in the outside unit.

- The room should be well ventilated if the occupants are using the heat pump with a stove or other large appliance, as there is a small risk that an oxygen shortage may occur.
- The unit should not be cleaned with water, as it may enter the unit and degrade the insulation or cause electric shock.

12 Conclusions

The following summarises the performance criteria for the three types of heaters chosen for this study:

a **Heat output**: pellet fires release the most heat (typically 10 to 12 kW) and are arguably more suitable for larger houses in colder climates. Flued natural gas heaters are usually in the 7.0 kW range, which is suited for most houses (although, due to the absence of piped natural gas in the South Island, gas heaters will not be installed there). Heat pumps range from 6 to 9 kW, again suitable for most houses.

b **Indoor air emissions**: all heaters are comparable for indoor air emissions, as none release a measurable amount of NO_2, CO, HCOH (formaldehyde) and particulates (assuming the flues, in the case of pellet fires or gas heaters, are correctly installed).

c **Outdoor air emissions**: pellet fires are the only heaters that emit outdoor air particulates in a measurable amount; however they are still within ECan air emissions guidelines. While pellet fires and flued natural gas heaters generally have the same efficiencies (pellet fires average 79% efficiency while flued natural gas heaters average 78% efficiency), heat pumps have the best efficiencies (generally 300% unless operating in very cold conditions).

d **Carbon dioxide** emissions: pellet fires emit the lowest carbon dioxide, around 15 g per kWh, given that they are essentially carbon neutral, (i.e. as much CO_2 is absorbed from the atmosphere in growing the wood as they emit during burning). Heat pumps are second best, emitting between 180 to 230 g CO_2/kWh. Flued natural gas heaters emit the most CO_2, generally 1150 to 1440 g CO_2/kWh, mainly due to the high CO_2 from gas combustion.

e **Fuel availability**: all types of fuel are readily available in every city with the exception of mains natural gas being only available in the Wellington area and not in the South Island.

f **Capital cost**: heater equipment costs, including flues and installation, vary from model to model. The cheapest flued gas heater cannot be compared with the most expensive heat pump. Most pellet fires and flued natural gas heaters are in a similar cost range (~$4000 – $5000 including flue kits *and* installation). However, natural gas heaters cost more per unit of capacity, i.e. when considering $/kW of heat output. Heat pumps are generally $3000-$5000 but are the most expensive in terms of $/kW heat output. Installation costs are roughly the same for all heaters, around $1000 per heater, with heat pumps sometimes slightly less.

g **Operating cost**: heat pumps are the cheapest heaters to operate, with a cost per kWh of useful heat output of between 4.6 to 7c (with the higher cost applicable when heat pump performance falls at low temperatures). Pellet fires are more expensive than heat pumps and flued natural gas heaters are the most expensive to operate (around 7c and around 12c respectively).

h **Lifetime costs**: when both capital costs plus operating costs are considered, pellet fires and heat pumps have very similar total costs (taken over 20 years and using a 5% discount rate). Flued gas heaters are the most costly type of heater considered. If electricity were to increase significantly in relation to pellet prices, heat pumps would become more costly over their lifetime than pellet burners.

i **Usability and maintenance**: all heater types require yearly servicing by an authorised service technician. For the homeowner, it may be easiest to maintain a pellet fire; a heat pump has the greatest number of parts to clean. However, it does not appear that there is much of a difference in usability and maintenance across the types of heaters.

j **Safety**: heat pumps are the safest, as they have no hot parts that could burn a person; however, they have the most risk of electrical shock, although this is a low risk when used properly. Both pellet fires and flued natural gas heaters require shields or screens for burn risks.

In **summary**, heat pumps and pellet fires score the best in different categories. Pellet fires have the least carbon dioxide emissions (per kWh), and have the cheapest equipment cost, especially on a per-kW basis. However, heat pumps have the lowest operating cost, and the best efficiency, with pellet fires next best. In terms of lifetime costs, pellet fires and heat pumps are comparable. Natural gas heaters score relatively poorly on various dimensions (efficiency, equipment cost, operating cost and carbon dioxide emissions).

It should be remembered that this assessment is **not** an exhaustive and comprehensive analysis but is based on a limited selection of heater models, and best pricing and performance data available at the time of analysis. Conclusions are sensitive to future electricity and fuel prices, and may also be influenced by constraints on carbon emissions and other considerations.