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Consumer Energy Options in New Zealand – 2016 Update

Prepared for Gas Industry Company

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Executive summary

Introduction and purpose

This report examines the relative economics of different fuel and technology options for meeting three different consumer energy needs:

- mass-market (residential) space heating;
- mass-market (residential) water heating; and
- industrial process heat.

These segments have been chosen because they account for the majority of energy demand for residential and industrial customers.¹

The purpose of this report is twofold:

- to assist consumers to make the energy choices which will best meet their requirements (including through providing information that energy retailers and distributors can use to help them assist consumers in making good choices); and
- to provide information for policy makers on whether the price signals currently provided to consumers are likely to encourage decisions that are in the best interests of New Zealand.

This report builds on the analysis from the previous Consumer Energy Options report.² It updates the results to reflect the latest cost information, and includes considerable new analysis on the extent to which current gas and electricity network pricing arrangements may not be delivering the best long-term outcomes for New Zealand.

Mass-market space and water heating

Currently there are a range of different charging approaches by the different network companies for residential supply of electricity and gas. As is illustrated in Figure 1 and Figure 2 below, this is resulting in considerable variation around the country in the effective price that consumers pay for fuel for space and water heating.

¹ The other two main uses of gas in New Zealand are as a feedstock in the petrochemical industry (e.g. to manufacture methanol or urea), or as a fuel for power generation. Potentially, also, gas could be used as a transport fuel. However, consideration of all such uses of gas is out of scope for this study.

² The previous Consumer Energy Options report can be found here: <http://www.gasindustry.co.nz/dmsdocument/4152>.

Figure 1: Range of electricity network prices for space and water heating

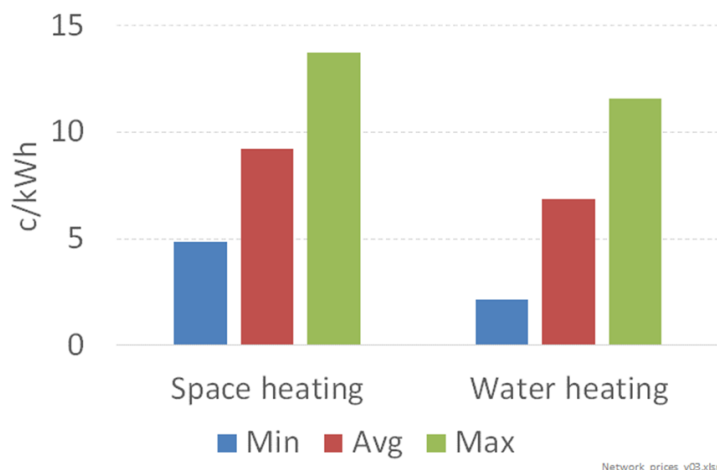
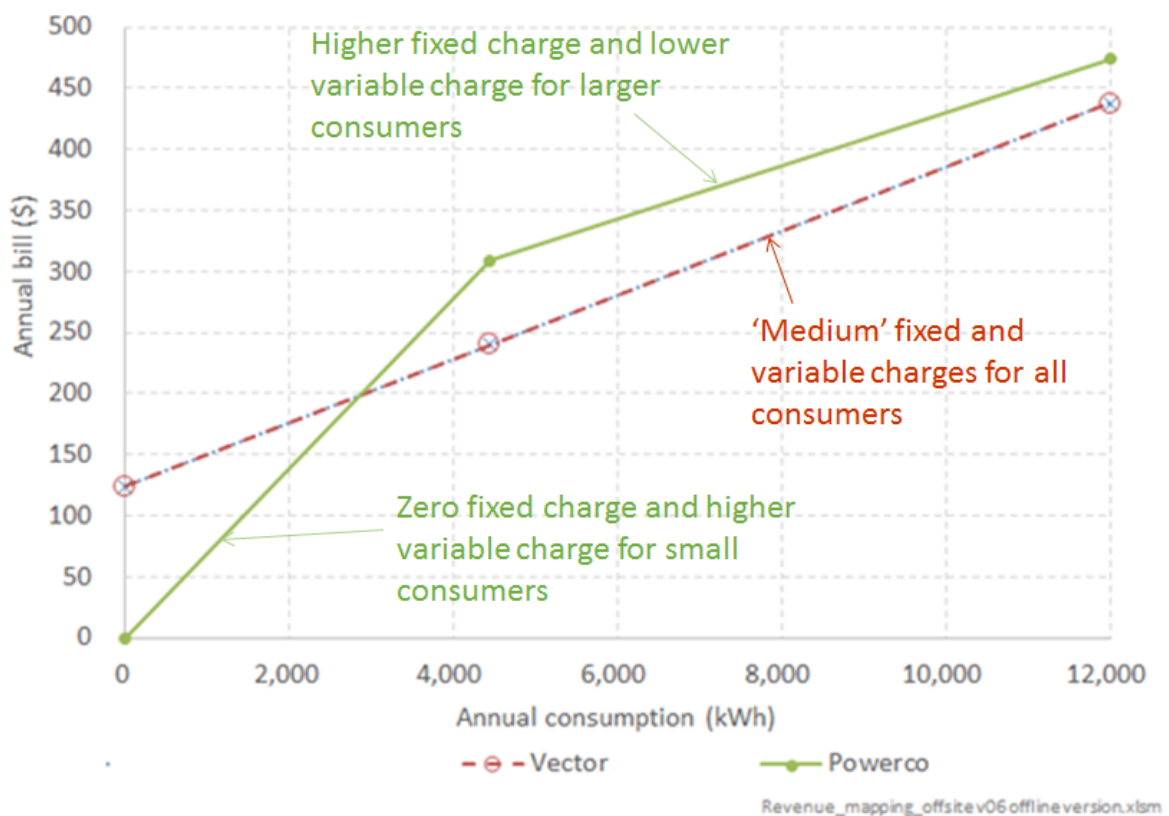


Figure 2: Different gas network charging approaches³



In the vast majority of cases, this variation does not appear to reflect differences in the incremental network costs associated with supplying additional electricity or gas for space or water heating demand. Rather, the difference in prices to consumer appear to reflect legacy decisions around issues such as: whether metering controlled electricity hot water should be achieved via a second controlled meter; different philosophies for recovering sunk assets via fixed or variable charges; and different approaches to apportioning costs between different customer groups (residential,

³ In addition to the variation in price structure, Powerco will generally fund most (if not all) of the initial one-off connection cost of a property to the gas network, whereas Vector will generally not.

commercial, etc.). More recently, this variation has been further exacerbated in electricity by the regulatory-mandated introduction of a low-user fixed charge variant.

This variation in charging approach is resulting in variation as to whether electricity, gas, or another fuel (e.g. wood) is the cheapest option for meeting consumers' space or water heating requirements depending on where in the country the consumer is located. As such, it can be hard to generalise as to which fuel option is likely to be lowest cost for a consumer.

This is further complicated by the fact that the different capital costs of the appliance options, coupled with the presence of fixed charges for fuel supply, means that the size of a consumer's heat requirements (i.e. do they consume a lot of, or little, heat) can have a bearing on which option is likely to be best. Thus, for meeting a small heating requirement it can be cheapest to choose an option which has low capital and/or fixed costs even if it has much higher variable costs, whereas the reverse may be true for meeting a large heating requirement.

Further, the presence of gas fixed charges complicates the evaluation of gas for space and water heating. Put simply, if a consumer has gas for one use (e.g. water heating), it considerably improves the economics of choosing gas for space heating as the fixed charges will not be an additional cost that needs to be considered.

That said, it is possible to draw some general conclusions:

- If a consumer has an existing functional heater (whether gas, electric, or solid fuel), they would in most cases be best to stick with that heater, even if its on-going running costs are materially higher than alternatives. This is because such alternatives would result in the consumer incurring significant up-front capital costs which will generally outweigh the benefit of lower running costs.
- The high capital costs of solar water heating and heat pump water heating almost always materially outweigh the benefits of very low variable costs on a whole-of-life basis.
- For small space heating requirements (e.g. a small bedroom) it is generally the case that a simple resistance electric heater is likely to be lowest cost, with the benefit of very low capital costs more than outweighing the high variable costs.
- Whole-of-house central heating (electricity or gas) is unlikely to be lower cost than fitting and sizing individual controllable heaters to meet each room's requirements. That said, whole-of-house heating does provide considerable 'quality' benefits that is of value to many consumers.⁴

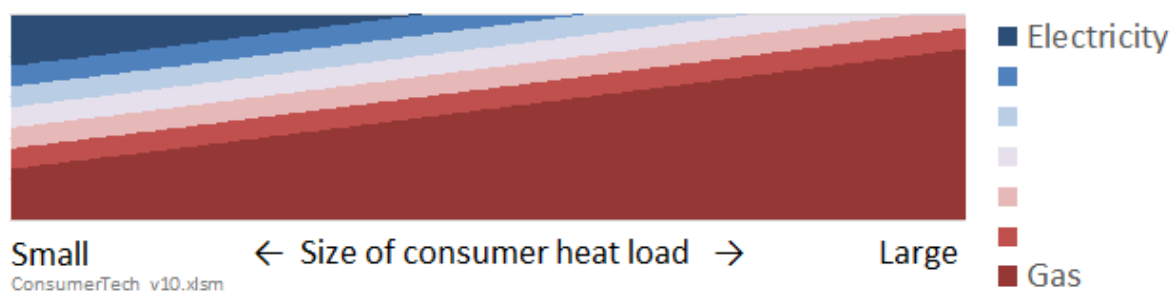
Further, it is possible to indicate some trends as to whether generally gas or electricity is the cheapest fuel option.⁵ Figure 3 shows this evaluation graphically for water heating, with the colour indicating whether gas or electricity is likely to be lowest cost.

⁴ This point also highlights that the different options can have considerable variation in non-price quality characteristics which many consumers value. For water heating, the key quality differentiator is never running-out of hot water with instant gas water heating, whereas this can happen for cylinder-based water heating options if several members of a household have baths / showers in quick succession.

There is considerable variation in the quality features for space heating such as: the ambience of a real flame being one positive differentiator for wood burners and some gas fires; the ability for heat pumps to act as air conditioners in the summer in warmer parts of the country; and the inconvenience of storing and carrying wood for woodburners.

Despite these quality characteristics being key factors for many consumers, their subjective nature means they are hard to value, and as such they are not considered in this report.

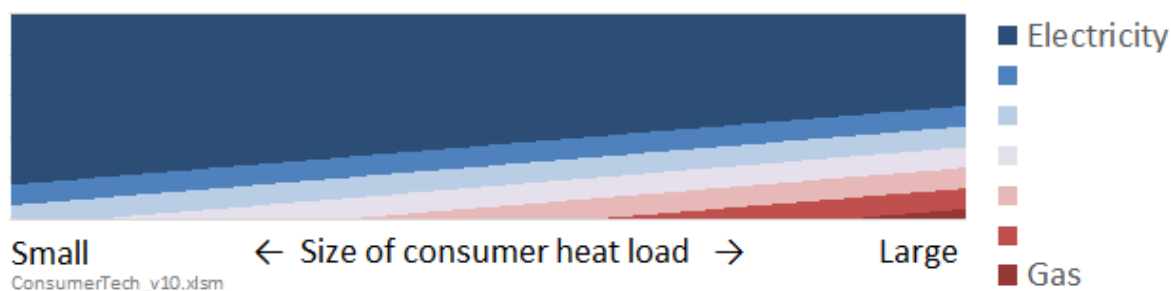
Figure 3: Illustration of whether instant gas or an electric cylinder is likely to be the lowest cost water heating option for consumers requiring a new water heater based on current network prices



Thus, gas is almost always lowest cost for medium to large water heating requirements. However, for small water heating loads, an electric cylinder can sometimes be lower cost than an instant gas water heater. This can be in situations where the electricity option has high fixed charges and low variable charges (noting that electricity fixed charges are not taken into consideration for the evaluation of heater economics) and/or the gas option has high fixed charges (which can be due to the charging approach of the gas network company and/or due to the consumer only using gas for water heating).

Figure 4 below illustrates that the reverse outcome occurs for space heating. In other words, for small heat loads electricity options are likely to be lowest cost (being electric resistance heaters), and even for large heat loads electricity (in the form of heat pumps) is generally the lowest cost option.

Figure 4: Illustration of whether electricity or gas is likely to be the lowest cost space heating option for consumers requiring a new space heater based on current network prices



The evaluations illustrated in Figure 3 and Figure 4 are based on the current prices that consumers see which. As previously mentioned, these exhibit significant variation around the country for largely legacy reasons, rather than reflecting variation in the fundamental economic costs of supplying gas or electricity to meet a heating load.

Analysis was undertaken as to what may be the ‘true’ economic cost of meeting additional space and water heating loads from either electricity or gas. The results of this analysis are shown in Figure 5 and Figure 6 below.

⁵ As indicated earlier, it is generally the case that solar water heating is not the cheapest on a whole-of-life basis. Wood log burners can in many cases be cheaper options for heating rooms with a large heat load – particularly if the consumer has access to cheap wood. However, the significant variation in wood fuel costs (particularly in cities) and the lack of controllability of wood burners makes it hard to compare them on a like-for-like basis. Accordingly, wood burners are not included in this general analysis.

Figure 5: Illustration of whether gas or electricity is likely to be lowest cost from a whole-of-NZ perspective for meeting new water heating loads

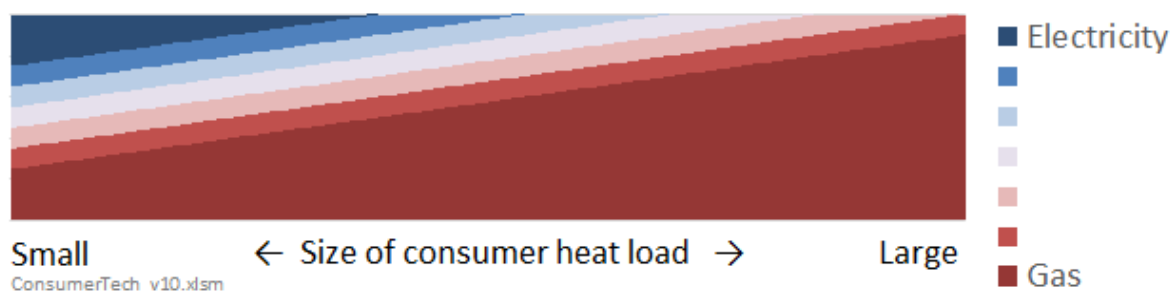
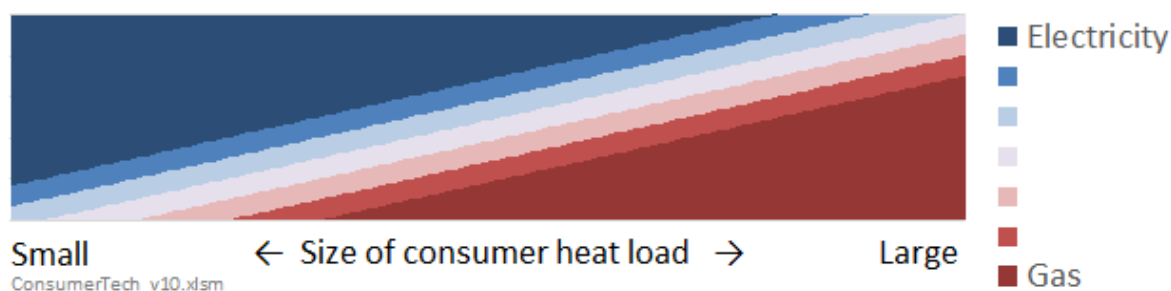


Figure 6: Illustration of whether gas or electricity is likely to be lowest cost from a whole-of-NZ perspective for meeting new space heating loads



When comparing Figure 5 with Figure 3, it can be seen that the relative economics of water heating from a whole-of-NZ perspective is not substantially different to the price signals consumers are currently seeing.

However, comparing Figure 6 with Figure 4 illustrates that there is a material difference between the whole-of-NZ and current consumer perspectives for space heating. In particular, gas becomes a lower cost option in most cases for meeting larger space heating loads when considered from a whole-of-NZ perspective. This is principally due to the significant increase in electricity network prices for space heating due to the peak-dominated nature of space heating demand, and the largely sunk aspect of gas network costs.

For small space heating loads electricity continues to be the lowest cost option due to the very low capital cost of resistance electric heaters.

These results indicate that the non-cost-reflective nature of electricity prices in particular is likely to be having an adverse effect on the economic efficiency of consumer choices. Thus consumers may be choosing a heat pump to meet their space heating requirements rather than a gas heater, despite a gas heater being a lower cost option from a whole-of-NZ perspective. This is likely to be having knock-on effects on water heating choices in some cases, as the gas fixed charge will only apply to water heating rather than space and water heating.

It is beyond the scope of this study to consider what regulatory changes may be required to result in electricity and gas network companies changing the structure of their network tariffs in such a way as to facilitate the most cost-efficient heating choices by consumers. However, it appears likely that changes will need to be made to the economic regulation of networks under Part 4 of the Commerce Act – in particular the form of control in terms of whether a revenue or price cap should apply.

It is also likely that there will need to be greater regulatory involvement in terms of helping network companies develop their network pricing methodologies. However, it is not clear whether such involvement should be limited to guidance or complete prescription of pricing methodologies, or whether the extent of regulatory involvement should vary between electricity and gas networks and between transmission and distribution networks.

There are two final points which are worth highlighting:

Firstly, this analysis and the conclusions as to the relative economics of gas versus electricity are considered robust against a wide range of CO₂ costs. This is because:

- The carbon-intensity of electricity heating options is very similar to that of gas heating options. This is because the type of generation that will meet an increase in residential heating demand is relatively fossil-heavy compared with the average type of generator to meet demand in general.
- Carbon costs represent a very small fraction of the overall lifetime costs of the different heating options.⁶

Secondly, the analysis reveals that the extent of retail competition could have a bearing on consumers' long-term energy choices. This is due to the effect that fixed charges to recover retail service costs have on the relative competitiveness of gas versus electricity options. Thus, fostering retail competition to try and help bring retail service costs back down is not only going to be good for customers in general, but it will help gas's competitiveness and could facilitate more efficient fuel choices for New Zealand as a whole.

Industrial process heat

The analysis reveals that for medium- and small-sized industrial process heat requirements gas is very strongly competitive because:

- The significantly greater capital cost for solid-fuelled boilers (i.e. coal & biomass), coupled with significant economies of scale for boilers, means that solid-fuelled boilers are not really cost-effective for smaller-scale applications.
- Liquid-fuelled options have a very high wholesale fuel cost – even at current low world oil prices.

The extent of this competitive position is such that it would even make sense for consumers with an existing non-gas fired boiler (with a sunk capital cost) to switch over to gas, and incur the cost of a new gas boiler. This conclusion is expected to be robust against a very wide range of feasible fuel and CO₂ prices.

For large-scale industrial process heat applications, the economies of scale in boilers means that the capital cost penalty faced by solid-fuelled boiler options is significantly less. Accordingly, fuel, CO₂, and transport costs start to become the dominant factors.

Liquid and biomass-fuelled options are generally uncompetitive due to:

- the high oil-linked costs of liquid options – even at current low world oil prices; and
- the relatively high wholesale and transport cost of biomass fuels.

That said, the cost of biomass is very location-specific within New Zealand. Biomass can be least-cost for heat loads located on, or very close to forestry processing plant.

Therefore, the main inter-fuel competition for these large-scale industrial process heat requirements is between coal and gas.

For new-build situations, gas is competitive against coal due to the lower CO₂ and boiler capital costs of gas outweighing the high wholesale and transport costs. This relative competitive position will be strongly reinforced if CO₂ prices rise from their current low levels.

That said, the economics of coal can also be quite location-specific in New Zealand, with industrial facilities located close to the mine mouth potentially enjoying significantly lower fuel costs.

⁶ For example, CO₂ costs represent only about 2.5% of the whole-of-life costs of an electric cylinder water heater if CO₂ is valued at \$25/tCO₂.

Coal is currently competitive against gas for *existing* coal-fired boilers. This is because of the currently low CO₂ and coal prices – particularly for those industrial coal-using facilities located close to coal mines.

Over time, gas is expected to increase its share of industrial process heat demand because:

- CO₂ prices are likely to move up, which favours gas due to its lower carbon intensity;
- lower cost coal from existing mines located close to industrial plant is expected to decline over time;
- as existing coal-fired boilers reach the end of their economic life and need replacing (although it should be noted that boilers can easily last for 40 to 50 years), the lower capital cost of gas-fired boilers comes into the total cost assessment; and
- users are likely to be wary of major re-investment in coal-fired boilers because of the risk of significant future rises in CO₂ prices.

As with mass-market space & water heating, there can also be non-price benefits of the different industrial process heat fuel options which can be of additional value to some industrial consumers.

In this, the main issue appears to be how clean-burning the different options are for industrial users with sensitive processes. A good example of this is food processing, where ash and other particulates from solid fuel options can be a concern, whereas gas is regarded as the cleanest-burning of options.

In some situations, the superior controllability of gas and liquid-fuelled options can also be a benefit relative to solid-fuelled options.

However, in general, non-price quality benefits do not appear to be anywhere near as significant a factor for industrial process heat as for mass-market space & water heating.

Unlike mass-market space & water heating, there do not appear to be the same divergences between the cost-benefit of different options from a public or private perspective.

The only material externality could be considered to be CO₂ pricing, to the extent that the current low CO₂ price in New Zealand doesn't reflect the likely cost to New Zealand society from global warming resulting from CO₂ emissions.

If CO₂ prices were to rise to \$25/tCO₂ or higher, the economics of gas would become even more compelling against coal or liquid-fuelled options.

However, biomass is unlikely to be competitive against gas except in future scenarios of extremely high CO₂ and/or gas prices.

In summary, the economics of gas for provision of intermediate-temperature process heat look robust compared to alternative fuels in the majority of cases, and can withstand material increases in gas wholesale or network prices.

1 Introduction

Purpose

This report examines the relative economics of different fuel and technology options for meeting three different consumer energy needs:

- mass-market (residential) space heating;
- mass-market (residential) water heating; and
- industrial process heat.

These consumer energy uses have been chosen because, as Appendix E sets out, they account for the majority of energy demand for residential and industrial customers.⁷

The purpose of this report is twofold:

- to assist consumers to make the energy choices which will best meet their requirements; and
- to provide information on whether price signals currently provided to consumers are likely to encourage decisions that are in the best overall interests of New Zealand.

This report builds on the analysis from the previous Consumer Energy Options report.⁸ It updates the results to reflect the latest cost information, and includes considerable new analysis on the extent to which gas and electricity network charging arrangements may affect outcomes for consumers and for New Zealand.

Approach

Determining which fuel + technology option is likely to best to meet a consumer's requirements is complex. This is because the economics of the different options can be very situation specific, driven by:

- ***Different consumer situations:***
 - the quantity of heat desired;
 - the geographic location of the consumer (as the availability and price of fuels can vary materially by location); and
 - the presence and type of any existing heating appliances.
- ***Different characteristics of the fuel + technology options:***
 - capital intensity;
 - fuel efficiency;
 - fuel costs, including:
 - the absolute level of costs; and

⁷ The other two main uses of gas in New Zealand are as a feedstock in the petrochemical industry (e.g. to manufacture methanol or urea), or as a fuel for power generation. Potentially, also, gas could be used as a transport fuel. However, consideration of all such uses of gas is out of scope for this study.

⁸ The previous Consumer Energy Options report can be found here:

<http://www.gasindustry.co.nz/dmsdocument/4152>.

- the structure of such costs, including variance over different times of the day and year, and the split between variable and fixed costs;
- fuel emissions intensities; and
- non-price ‘quality’ characteristics of the different fuel + technology options.

Such differences mean that the best option for one consumer situation may be different to that for another consumer situation.

Accordingly, the analysis has been developed in a way that attempts to consider all of these different situations in an internally consistent fashion.

In addition, the analysis has sought to determine whether the apparent best option for a consumer based on the charges they face for the various fuels and appliances, may differ to the best option for New Zealand as a whole based on the underlying resource cost implications of the different options. Examples of the type of issues examined that can give rise to divergences between the ‘private’ and ‘public’ benefit of different options include:

- the extent to which electricity and gas costs vary according to the time-of-day and time-of-year, yet consumer prices may be flat across the year;
- the extent to which some electricity and gas network costs charged to consumers on a variable basis may be unavoidable from a whole of New Zealand perspective because they are sunk; and
- the extent to which CO₂ costs faced by New Zealand are not reflected in domestic fuel prices.

Report structure

- Section 2 presents the analysis relating to mass-market space and water heating.
- Section 3 presents the analysis relating to industrial process heat.
- Appendix A presents analysis examining the current structure of electricity and gas charges and whether these provide appropriate signals to consumers as regards the underlying resource cost implications of their consumption decisions. It also considers the extent to which economic regulation arrangements may be influencing the behaviour of network companies in terms of how they structure their prices to consumers.
- The remaining appendices provide additional detail on the assumptions behind the analyses.

Acknowledgements

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- Christian Hoerning from EECA;
- George Block from Consumer NZ; and
- Kirk Archibald from EECA.

2 Mass-market space and water heating

2.1 Approach to analysis

Consumers have many options for meeting their space and water heating requirements. Comparing these options is challenging because of the significant differences in heater characteristics (costs and efficiencies) and fuel costs (both fixed and variable).

Accordingly, in order to enable ‘apples with apples’ comparisons, this analysis seeks to determine for each of these options the **lifetime cost per useful kWh of heat provided**, or $\$/\text{kWh}_u$, where the ‘u’ subscript denotes ‘useful’ heat.

Put simply, this means summing all the different costs that will be incurred over the life of the heater (including initial capital costs, as well as ongoing running costs), and dividing by the actual space heat or hot water provided during that lifetime.

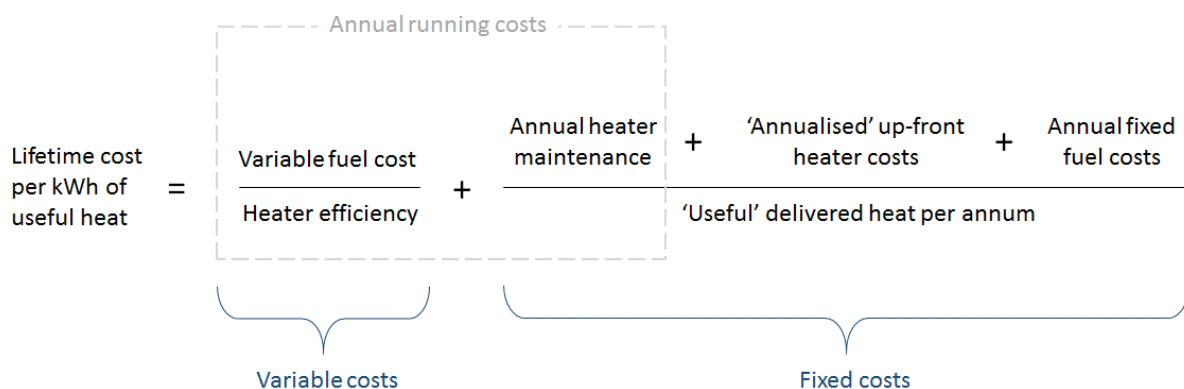
Further, many of the costs are fixed, meaning the impact on the economics of a particular heater will depend on how much the heater is used. Accordingly, three different sample consumer heating requirements (‘small’, ‘medium’, and ‘large’) are examined to determine whether the heating choice will change based on the consumer’s heating requirement. Appendix B details the derivation of the different sample space and water heating loads.

This sub-section shows how this lifetime cost per useful kWh of heat provided is progressively built-up from three main cost categories:

- annual running costs;
- up-front heater costs; and
- fixed fuel costs.

Figure 7 below shows how these ‘moving parts’ fit together to deliver an overall lifetime cost per useful kWh of heat provided.

Figure 7: Key ‘moving parts’ in calculating lifetime cost of a heating option



The results for water heating for a customer with a medium-sized heating requirement are used to illustrate this approach.

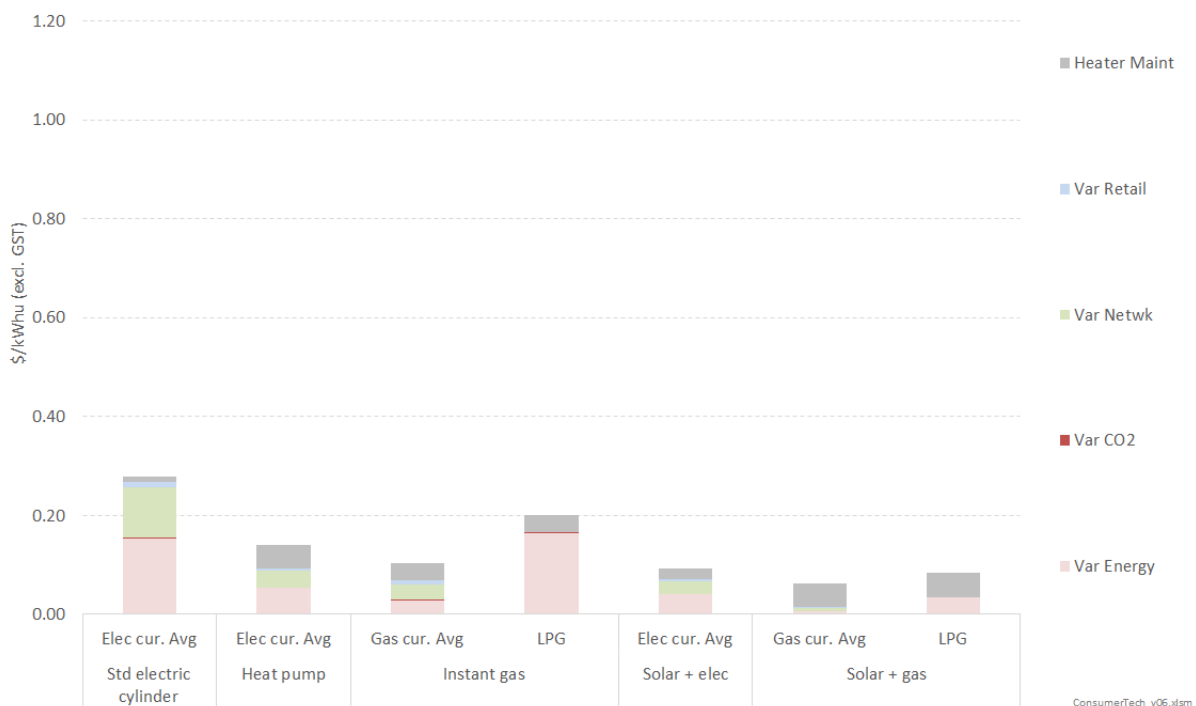
Annual running costs – water heating as an example

The $\$/kWh_u$ annual running costs comprise two main components:

1. The variable cost of the fuel (i.e. any $\$/kWh$ fuel charges) factored by the appliance efficiency. For example, a $\$0.06/kWh$ gas cost becomes a $\$0.07/kWh_u$ cost if the fuel passes through an 85% efficient gas water heater.
2. Any annual heater maintenance costs which are ‘variabilised’ by dividing by the amount of useful heat provided. For example, a $\$75$ annual fee for maintaining an instant gas water heater becomes a $\$0.04/kWh_u$ cost when divided by a 1,800 kWh_u annual water heating requirement.

Figure 8 below illustrates the variation in current typical annual running costs for different types of water heater.

Figure 8: Typical current annual running costs for a medium-sized water-heating requirement expressed in $\$/kWh_u$



As can be seen, when only the running costs of the different options are considered, the solar water heating options are the cheapest – with solar with gas back-up being the absolute lowest cost. The fuel costs of this option (i.e. the gas used to heat the water on the days the sun isn’t shining) are close to zero, with the most significant annual running cost being the cost of getting the heater maintained.

This graph also shows the impact of appliance efficiency on the cost per useful kWh provided. Thus, although the first two options face the same *delivered* cost of electricity (approximately $\$0.18/kWh$ in this example) the effective useful cost of electricity is significantly different between the two: $\approx \$0.27/kWh_u$ for the standard electric cylinder and $\approx \$0.09/kWh_u$ for a heat pump electric cylinder.

This is because the efficiency of the electric cylinder is only 69%, whereas for the heat pump cylinder it is 200%.⁹

The analysis distinguishes between the different cost components for the variable cost of the fuel. Thus, although most consumers will typically see a variable \$/kWh price for their electricity or gas on their bill, this analysis breaks that down into its main underlying components¹⁰:

- energy (representing the electricity generation or gas upstream market price – often referred to as the ‘wholesale’ cost);
- CO₂ (representing the cost of the NZ emissions trading scheme factored by the emissions intensity of each fuel) ;
- network (representing for electricity and gas, the cost of transmission plus distribution); and
- retail (representing retailers’ cost-to-serve and cost-to-acquire plus any retail margin).

The purpose of breaking these costs down into these component parts is that it enables consideration of the extent to which the prices charged to consumers may not represent the ‘true’ underlying resource cost for New Zealand as a whole. Appendix A details the derivation of all the values used for these different elements.

The last point to appreciate is that for gas heater options the analysis presents the results for appliances fuelled by reticulated natural gas (‘gas’), and also liquefied petroleum gas (‘LPG’) which is generally delivered via bottles to consumers’ properties.

Up-front heater costs – water heating as an example

The next step in working out the lifetime cost of the different options, is taking account of the up-front costs of purchasing and installing the heater.

These costs are ‘annualised’ to give a \$/yr value¹¹, and then ‘variabilised’ by dividing by the annual quantity of useful kWh delivered to give a \$/kWh_u value.

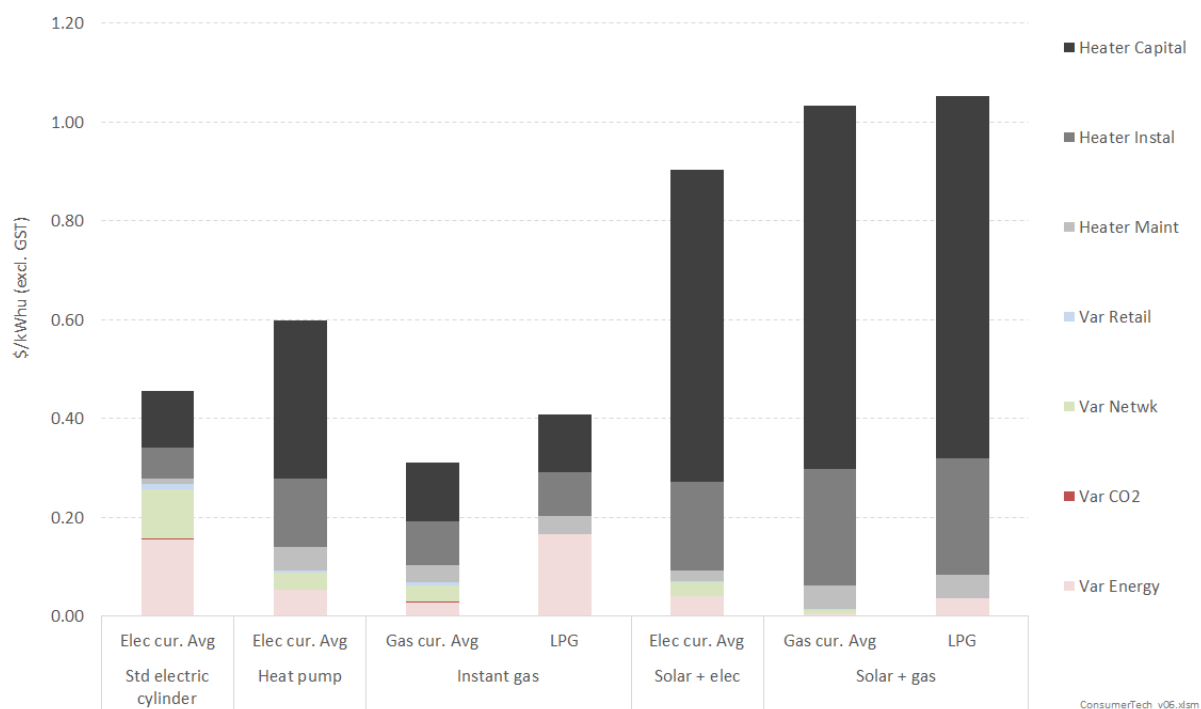
Figure 9 below continues the medium-sized water heating example, and adds the variabilised up-front heater costs of each option to the annual running costs shown previously in Figure 8.

⁹ As detailed in Appendix B, the efficiency of cylinder-based water heating options is not just a function of the efficiency with which the heater heats the water, but also how much heat is wasted through heat radiating away from the cylinder as ‘standing losses’. Thus, although a standard resistance electric water heater is 100% efficient at heating the water, the fact that a lot of the heat is wasted by standing losses brings the effective efficiency of the heater down to a lower level. Often this effective efficiency value is referred to as the ‘coefficient of performance’.

¹⁰ For the analysis from the perspective of the consumer, the value for each component is that which a retailer is likely to use given the price signals which it faces, including the constraints of any metering technology. For the analysis from the perspective of ‘New Zealand Inc’, the value for each component represents the underlying economic cost to New Zealand.

¹¹ Annualising is essentially ‘spreading’ the up-front cost over the life of the appliance, taking into account the cost of borrowing money (a.k.a. the ‘discount rate’) to fund the initial purchase. For example, the annualised cost of a \$1,000 heater with a 15-year life and using a 6% discount rate, is \$103/year.

Figure 9: Typical annual running costs + variablised heater costs for a medium-sized water-heating requirement expressed in \$/kWh_u



As can be seen, when up-front capital costs are taken into account, the solar options go from being the cheapest options to the most expensive. Similarly, the high capital cost of heat-pump water heaters significantly affects their competitiveness.

Fixed fuel costs – water heating as an example

The last set of costs to take into account are any fixed costs that are associated with the fuel. For example, \$/day fixed charges or, in the case of supplying gas to a property which isn't currently connected to the gas network, the initial cost of this gas connection (which is annualised in the same way as for up-front heater costs).

As with annual heater maintenance costs, and annualised up-front heater costs, these fixed costs are 'variablised' by dividing by the amount of useful heat provided.

However, unlike heater-related costs, these fuel-related fixed costs are incurred by the *property* as a whole. Therefore, simply variablising by the amount of useful heat provided by the heater will give a very high effective \$/kWh_u figure.

Accordingly, as well as showing the effect of these variablised fixed fuel costs when just spread across the heater's heat load, the analysis also shows how much lower these costs would be if spread across the likely heat load from all the space and water heating appliances for that property's situation.

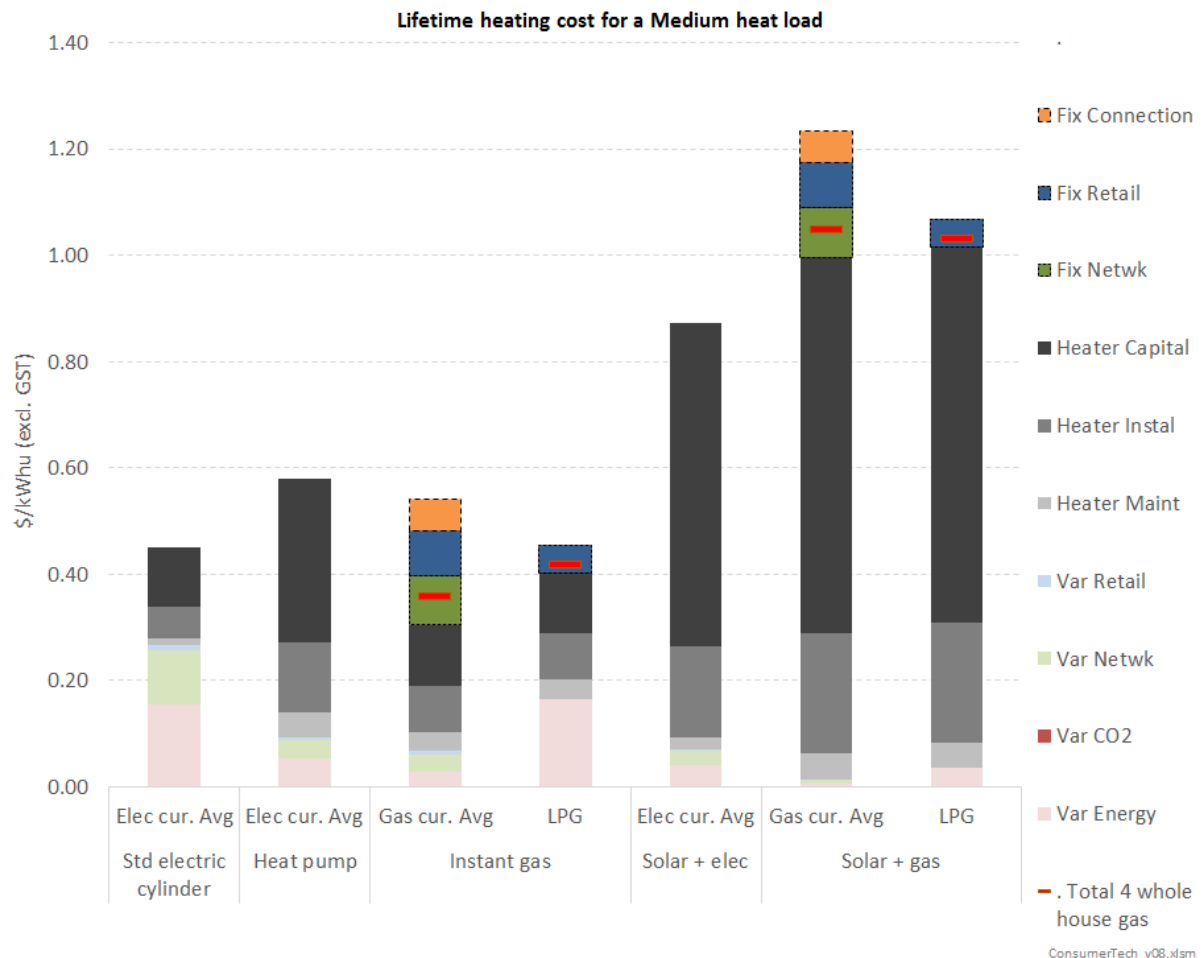
The last point to appreciate is that the fixed costs of electricity supply are not included as a cost for electric heating options. This is because electricity is not considered to be a discretionary fuel, and thus fixed costs are not avoidable whether a consumer chooses an electric heating option or not.¹²

¹² The prospect for consumers completely disconnecting from the electricity grid through becoming self-sufficient via photovoltaics (PV), batteries, diesel back-up and non-electric heating options is not considered in

This applies to consideration of the situation from a consumer’s perspective, as well as from a whole-of-New-Zealand perspective.

Figure 10 below continues the medium-sized water heating example, and shows the impact of adding these fixed fuel costs to the annual running costs and up-front heater costs set out in Figure 8 and Figure 9 previously.

Figure 10: Typical total lifetime costs for a medium-sized water-heating requirement expressed in \$/kWh_u



As can be seen, gas fixed charges can materially affect the relative economics of gas-fired heating options versus electric alternatives.

In this example, if a consumer were only considering gas for water heating, then the fixed costs associated with gas supply make the economics of water heating marginal when compared with a standard electric cylinder – and more expensive if the house needed to be connected to the gas network in the first place and the consumer were to face that cost.

However, if a consumer were considering gas for water heating and space heating, then instant gas water heating remains the most cost-effective option – as indicated by the red dash for ‘Total 4

this study. This is because indicative analysis indicates that such options are likely to be uneconomic based on current costs for most situations.

whole house gas' which shows the effective cost of gas if a consumer were to use gas for space and water heating.¹³

Heating options considered

This report only considers the main heating options for consumers. Thus a number of technologies have not been evaluated as follows:

- Pellet burners and electric night storage heaters have not been evaluated because neither of them is being widely offered for sale in New Zealand.¹⁴
- Un-flued gas heaters (including LPG cabinet heaters) are not evaluated because their use is not recommended for health reasons.
- Central heating options are not evaluated because their costs are too situation specific to estimate reliably. Further, the benefit of such options generally relates more to non-price quality aspects (i.e. whole house heating, and controllability) rather than being the least-cost means of heating a property.

2.2 Results

Figure 11 and Figure 12 show the estimated lifetime heating costs for water and space heating, respectively, for different-sized heating loads based on *average* current prices to consumers. The 'average' is italicised because, as is discussed later, there is considerable variation in the costs faced by consumers in different situations.

A brief comment on wood burners and heater installation costs

The costs shown for space heating wood burners in this analysis are based on the average reported firewood price from research undertaken by Consumer NZ.¹⁵ However, as this Consumer research points out there is a significant range in firewood prices around New Zealand, with the cheapest prices being half this amount, and the most expensive being 75% greater than this amount. Plus, many rural New Zealanders may have access to 'free' wood from being able to collect it themselves.

Further, unlike most electric and gas space heating options driven by thermostats, wood burners are relatively hard to control to deliver a constant desired room temperature. This can materially affect their effective efficiency at heating a room to a desired temperature.

Therefore, although a central figure is presented in this analysis, it is less able to be compared on an 'apples with apples' basis with the other heating options.

For many New Zealanders wood burners can be one of the least-cost (and most enjoyable!) means of heating their homes – particularly if they have a requirement to heat large living spaces. However, there is relatively little discussion on wood burners in this analysis given this inability to compare on a like-for-like basis with other heating options.

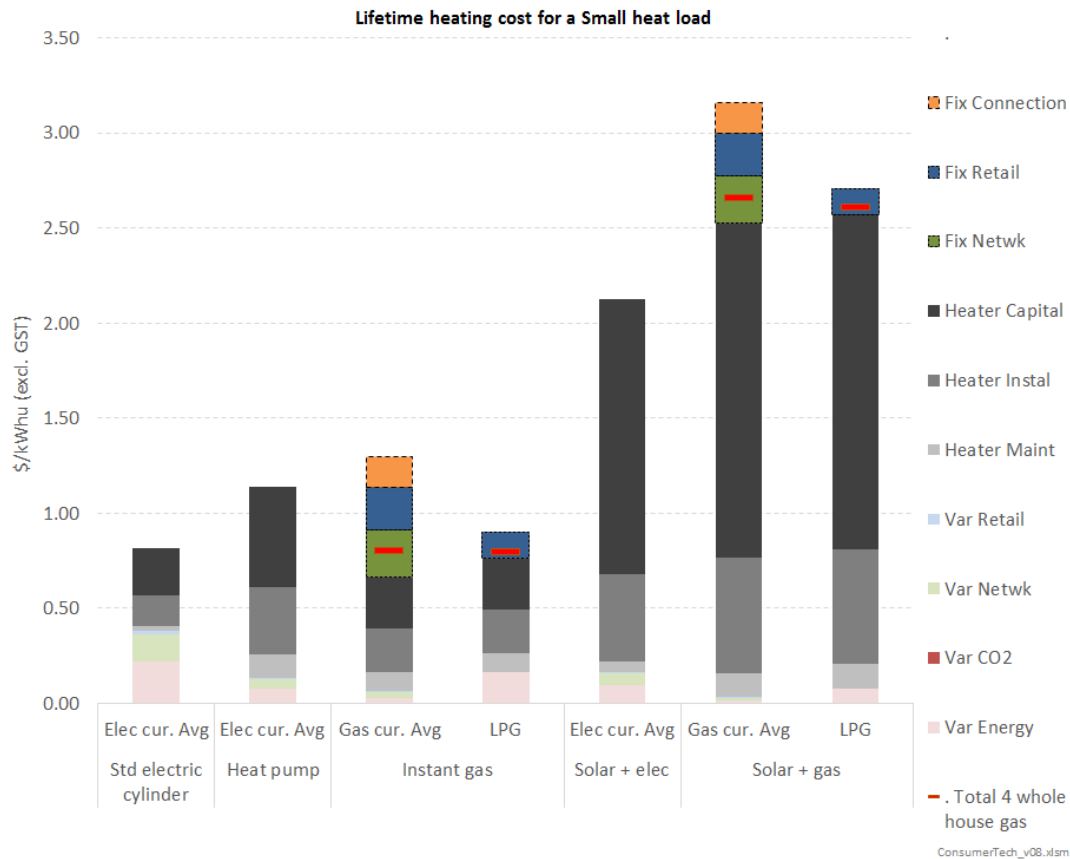
¹³ The red dash is in the lower half of the fixed cost portion of these bars because the model assumes that there will be multiple space heaters in a property. If there were only one space heater and one water heater in a property, each of which used exactly the same amount of gas, then the red dash would be in the middle of the fixed cost portion of these bars.

¹⁴ Night storage heaters used to be promoted in some parts of New Zealand, but this is no longer the case. In addition, EECA's technical advisers suggest that the heating benefits of night storage heaters for the evening (which is one of the main times when heating is required) are minimal due to the heat being lost during the day.

¹⁵ <https://www.consumer.org.nz/articles/firewood#price-survey-pine>

A similar issue arises with regards to heater installation costs, particularly for heat pumps, flued gas heaters, and wood burners. A central estimate has been used based on market research. However, there can be very large variation based on the specifics on individual properties, with some properties incurring significantly greater installation costs than others. Generally a 'difficult' property for a heat pump will similarly be difficult for a flued gas heater so the relativities between these two may not change too much. However, installation costs can change the relativities between other fuel options.

Figure 11: Estimated lifetime water heating costs for different-sized heating loads based on average current prices to consumers



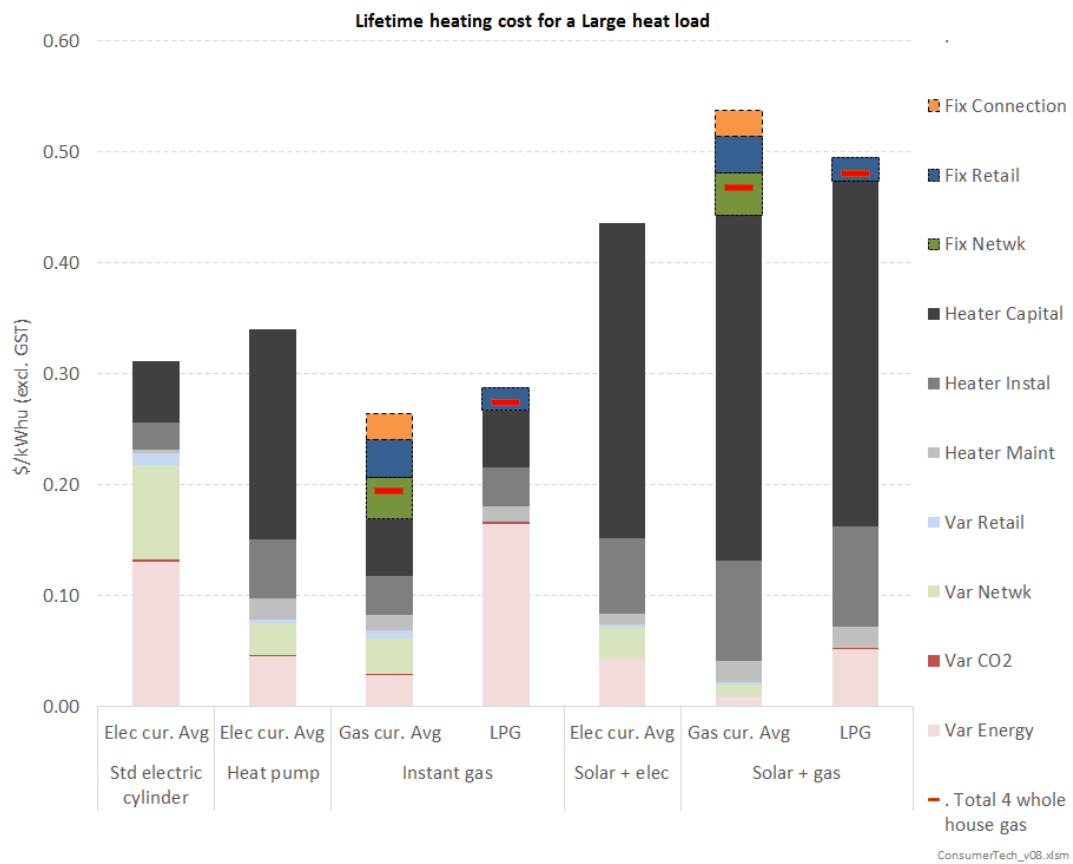
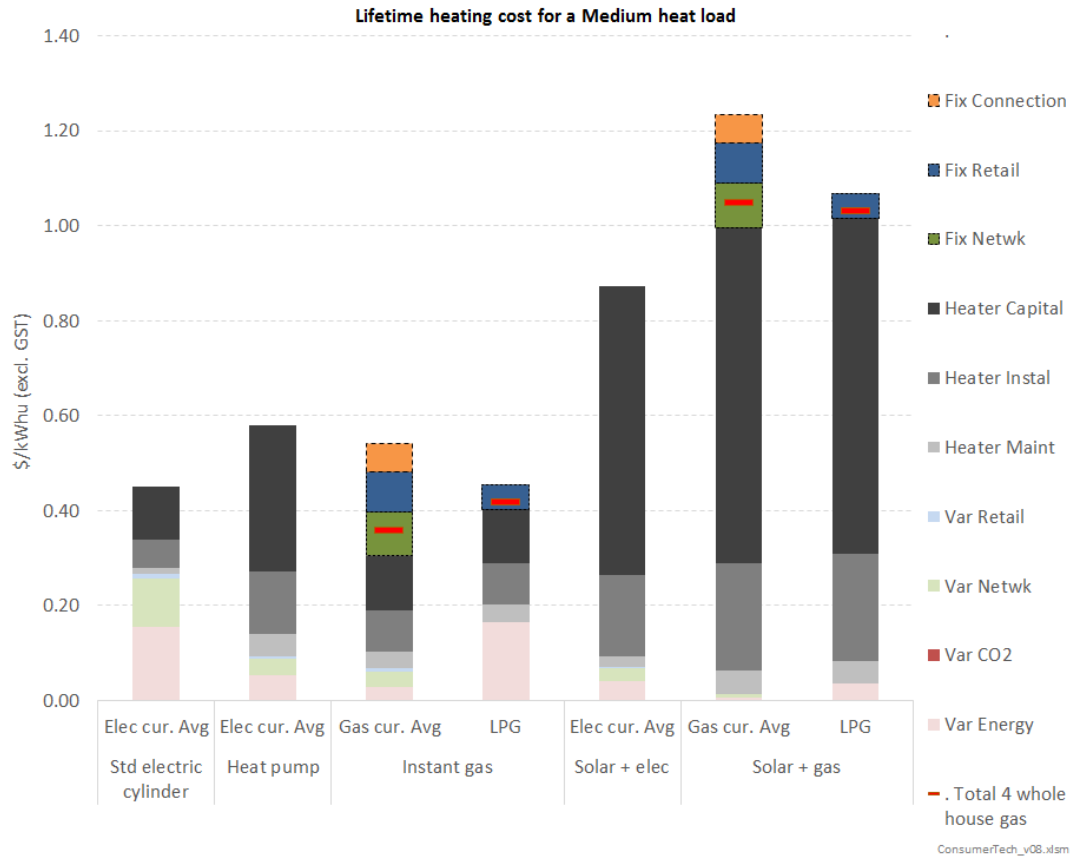
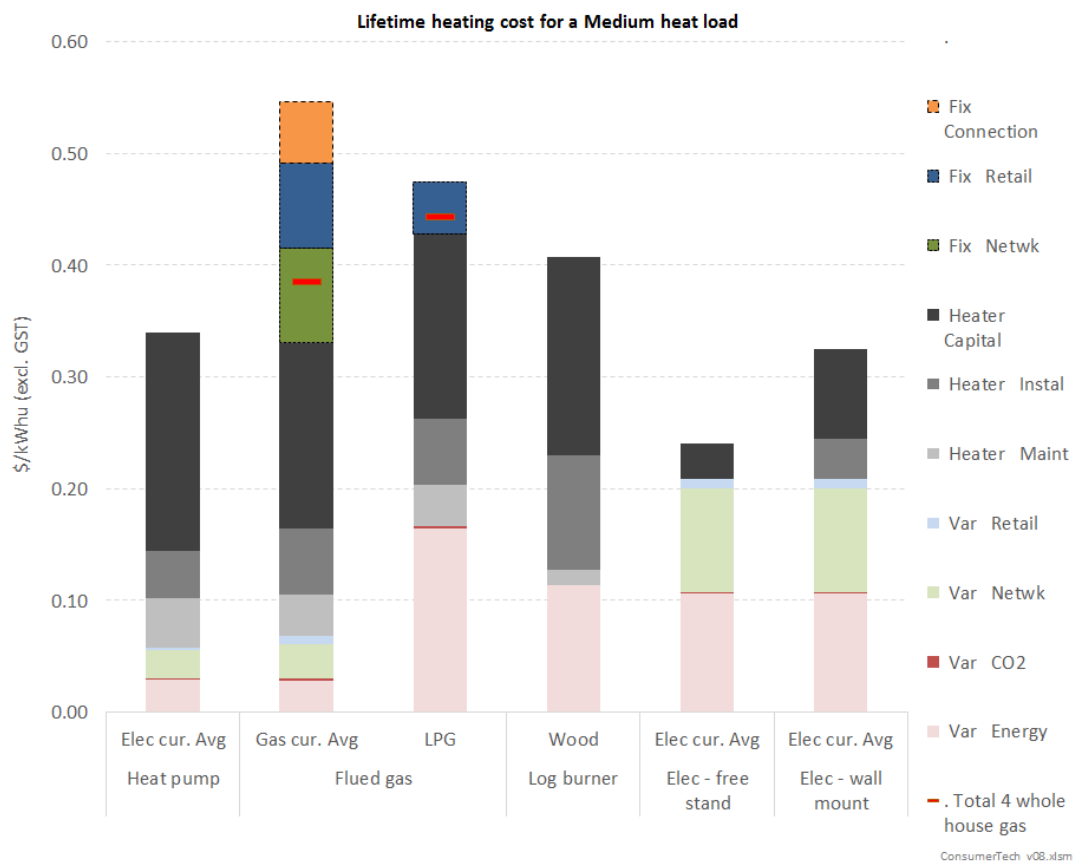
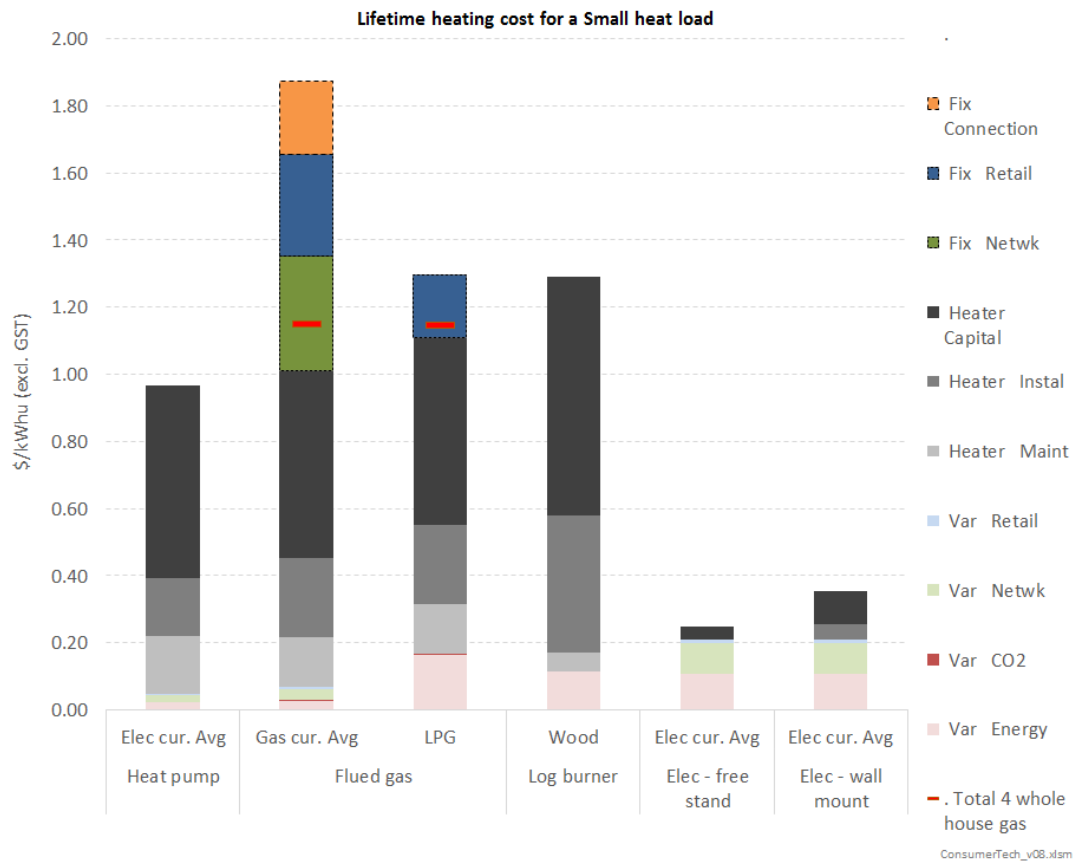
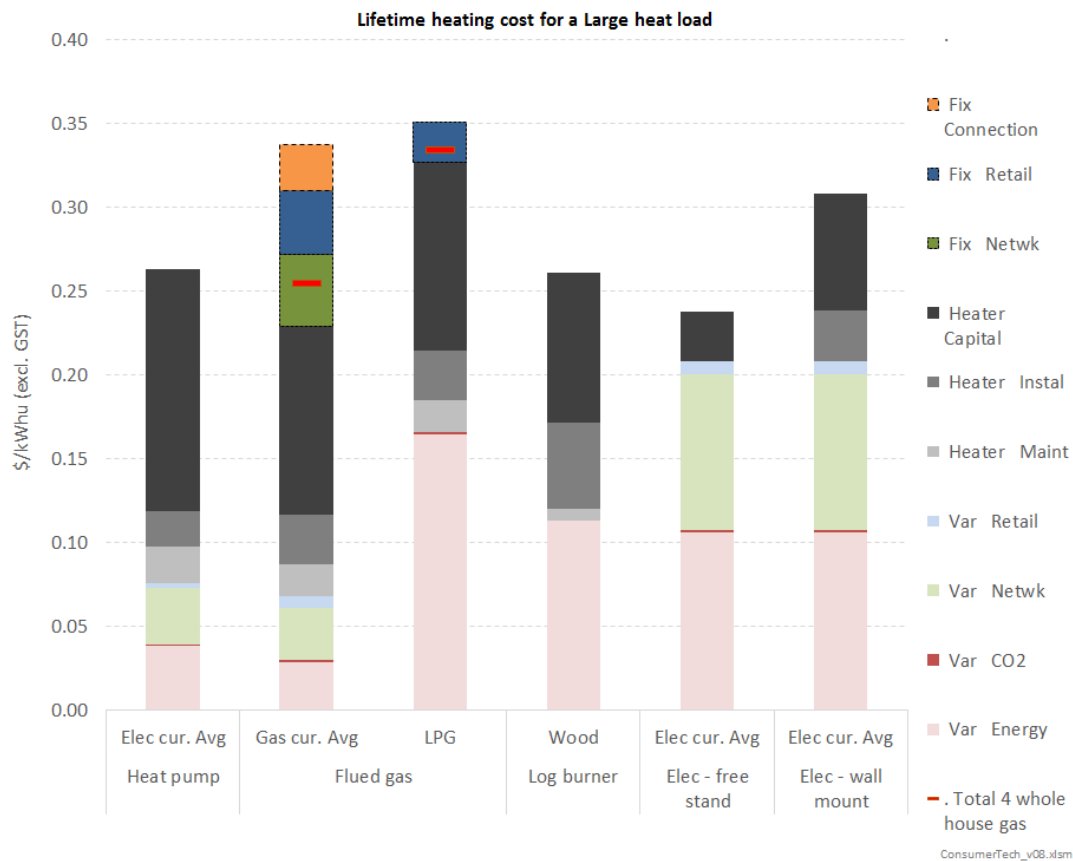


Figure 12: Estimated lifetime space heating costs for different-sized heating loads based on average current prices to consumers





There are a number of initial key take-aways from the above results.

- 1) The capital intensity of most heating options means that the right option can vary with a consumer's situation. General conclusions which can be drawn are:
 - a) For small space heating loads, it is almost invariably going to be the case that a simple resistance electric heater will be cheapest. In such situations, the benefit of not spending high up-front capital costs more than out-weighs the much higher variable costs of operation.
 - i) Part of the benefit of simple resistance electric heaters in these small heat-load situations is that it is possible to buy very small heaters (e.g. 1 kW), whereas most other heaters only go down to 3 to 3.5 kW in size (or 8.5 kW in the case of wood burners!).
 - ii) Conversely, simple resistance electric heaters only go up to about 2.5 kW in size. This means that for the medium and large space heating loads, they become increasingly less practicable as multiple heaters will be required in a living area with a medium to large heating requirement. This compares with heat pumps, flued gas heaters or log burners where a single heater can meet both the medium and large heat load requirements.
 - b) The high capital costs of solar water heating means that these options are invariably the most expensive from a lifetime perspective.
 - c) If a consumer has an existing appliance (for which the up-front capital costs are sunk), it is generally most cost-effective to stick with that option even if it has higher running costs. This is because the heater installation and capital costs should not be considered for the existing heater, but would be incurred from switching to another option.
- 2) Fixed fuel charges can have a very large impact on the economics of gas-fired appliances. Thus, from a whole home heating requirement, gas can often be cheapest. However, evaluating water

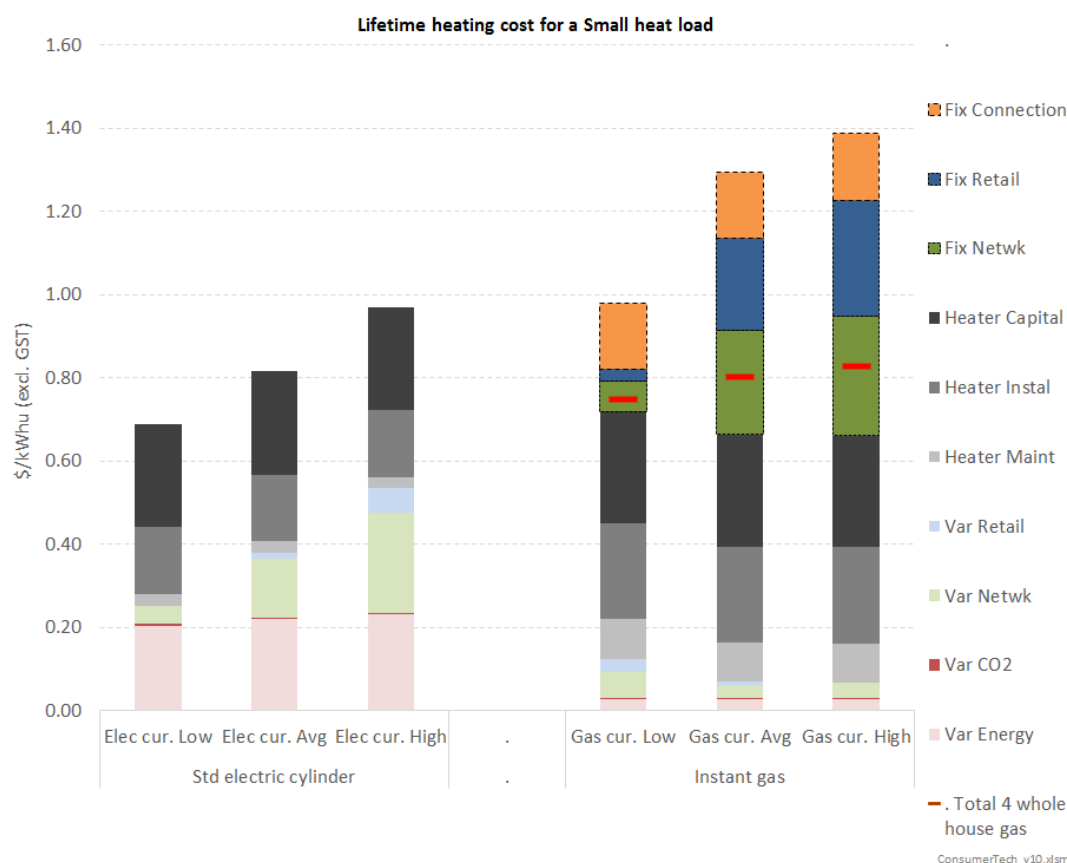
or space heaters on their own, and apportioning the fixed fuel charges entirely to that heater can result in the gas-fired heater appearing to be more expensive.

This last point is a significant issue because, as set out in more detail in Appendix A, there is currently a large variation in the relative mix of fixed and variable charges that consumers around the country face for both electricity and gas. As set out in Appendix A, this variation is due to:

- the extent to which networks recover their costs from fixed versus variable charges;
- the extent to which gas networks require customers to cover the costs of connecting to the gas network; and
- the extent to which retailers recover their retail costs from fixed versus variable charges.

To illustrate the impact of these variations, Figure 13 and Figure 14 below show how the economics of the fuel choice options vary with this variation in the ‘structure’ of electricity and gas prices.¹⁶

Figure 13: Impact of range of current electricity and gas pricing approaches on water heating economics¹⁷



¹⁶ For the purposes of this illustration heat-pump and solar water heating options are always excluded because they are generally uneconomic on a whole-of-life basis due to their very high capital costs outweighing the benefit of very low variable costs.

¹⁷ “Elec cur. Low” shows results using the lowest current observed variable price for electricity applying to water heating. “Elec cur. Avg” shows results using the average current observed variable price for electricity applying to water heating, and so on for “Elec cur. High”
 “Gas cur. Low” uses the mix of observed current gas network variable and fixed charges and retail variable and fixed charges applying to water heating which gives the lowest overall cost of operation. And so on for “Gas cur. High” and “Gas cur. Avg”.

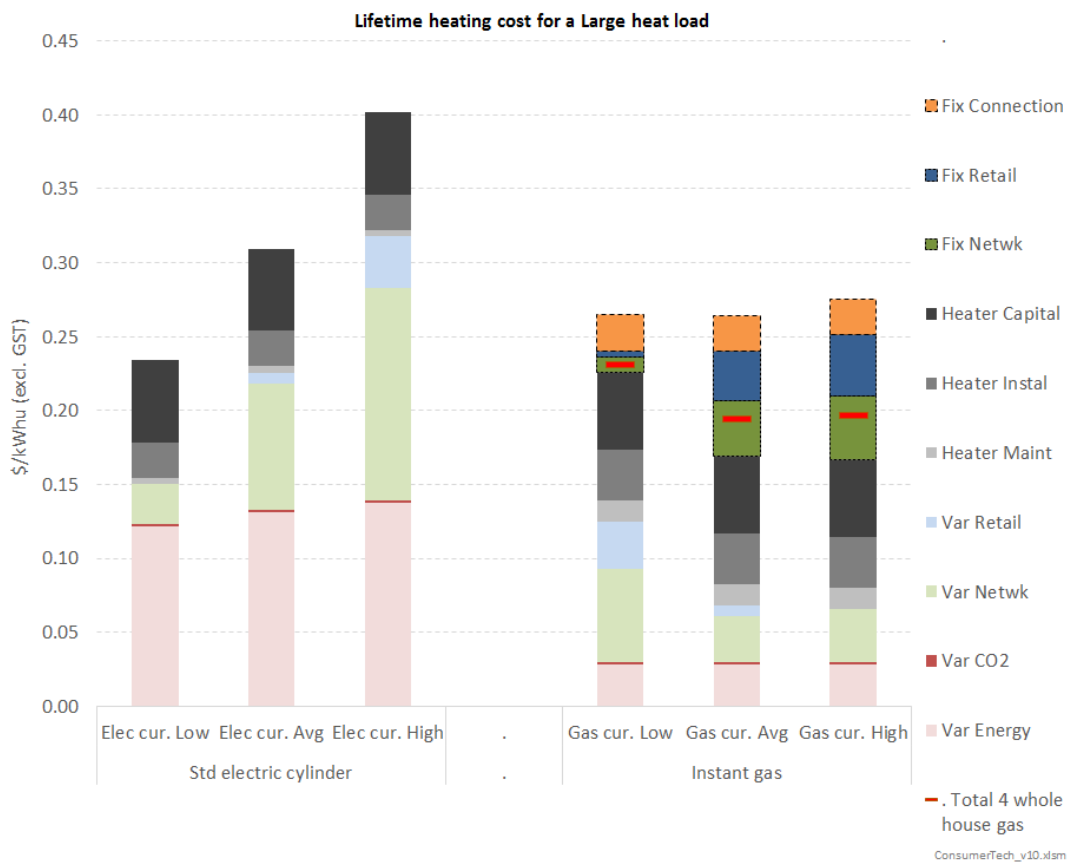
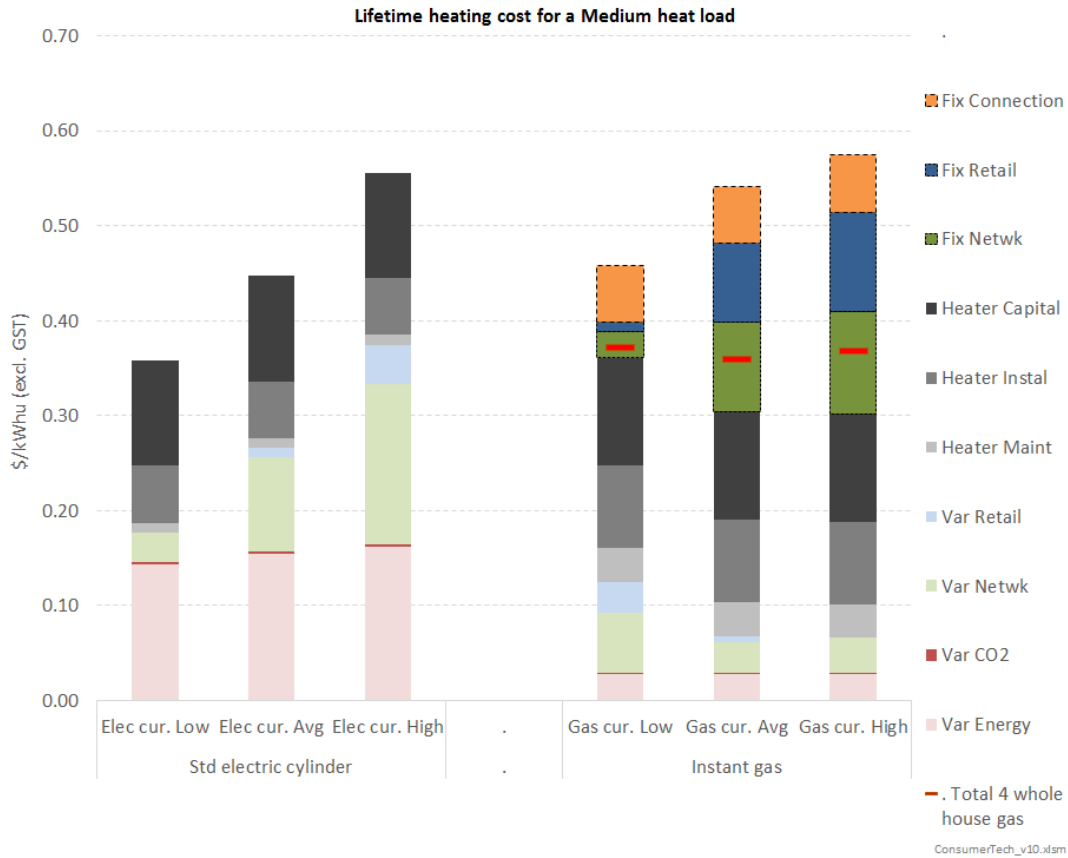
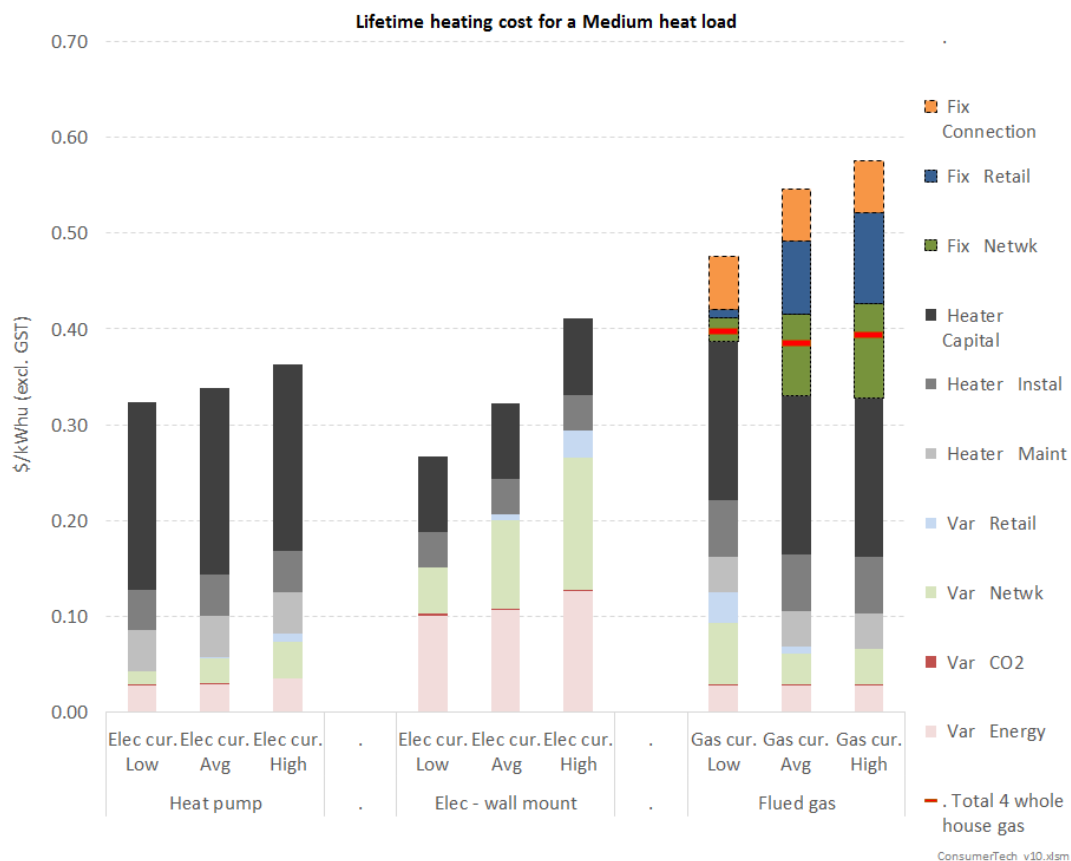
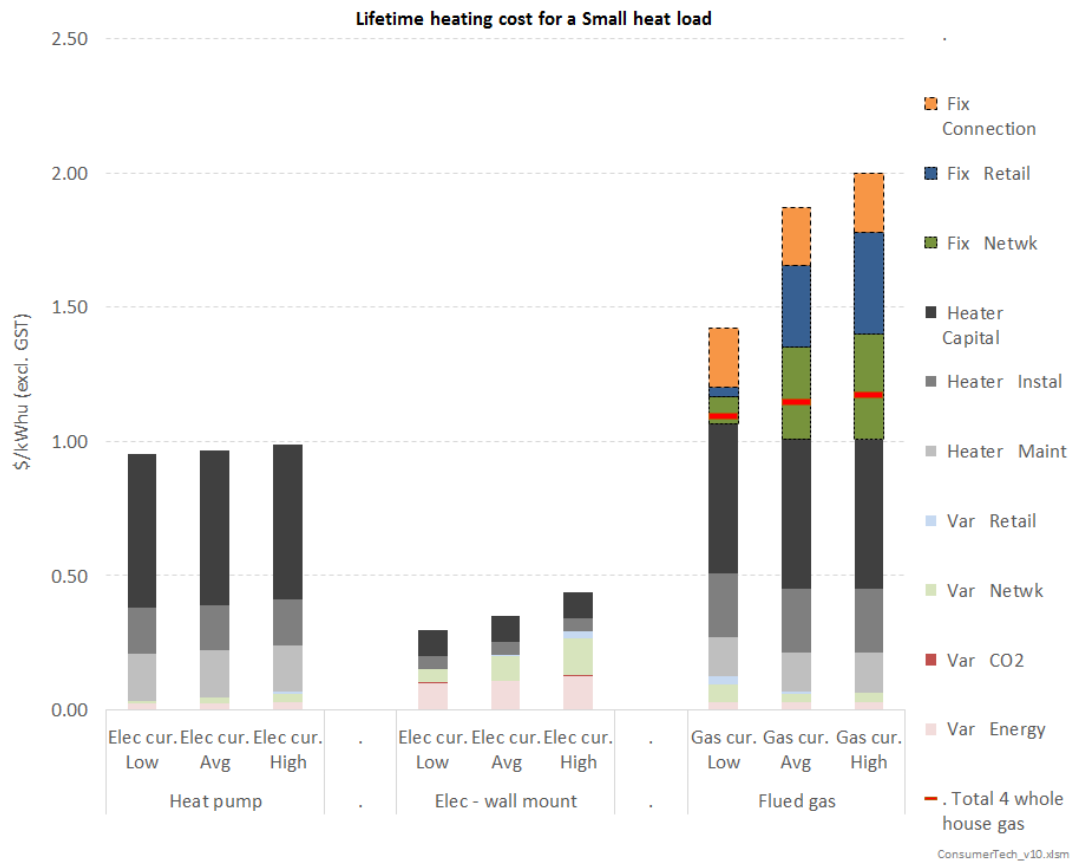
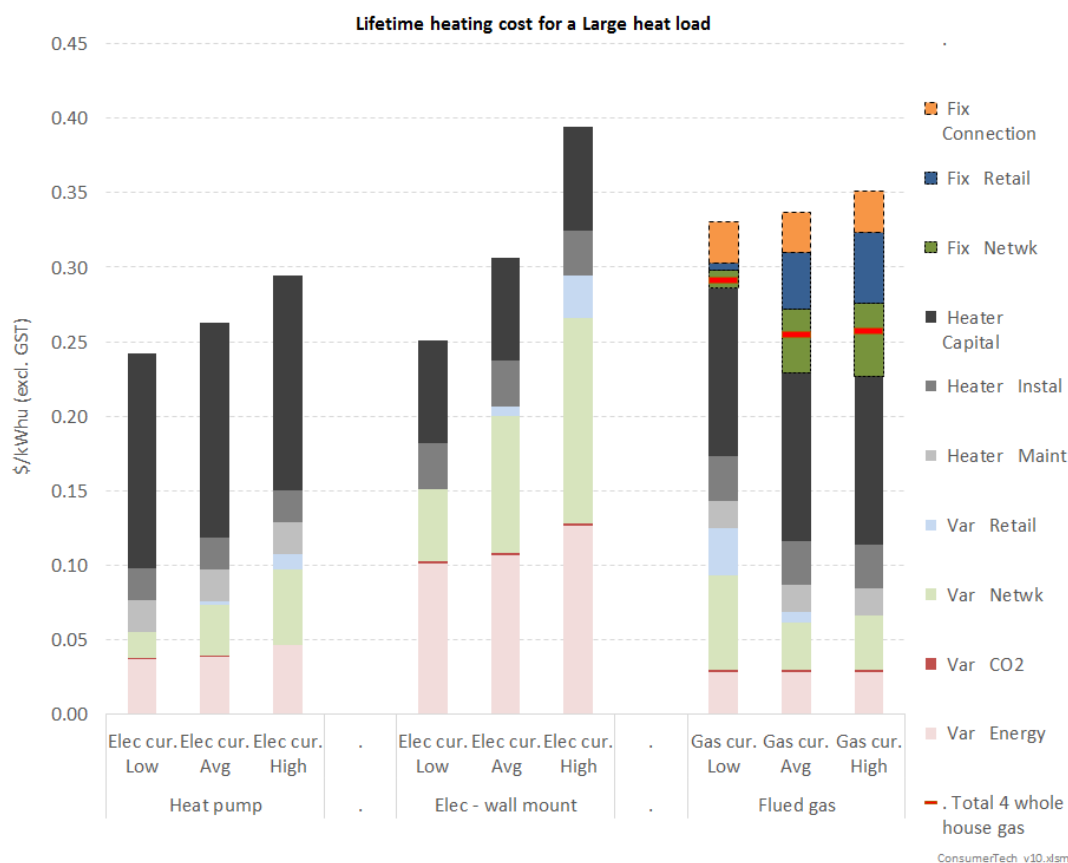


Figure 14: Impact of range of current electricity and gas pricing approaches on space heating economics





As can be seen, the variation can have a significant impact on which option is cheapest for the consumer. In particular, differences in charges across networks may alter the cost ranking of gas versus electricity heating in some situations.

However, as further set out in Appendix A, most of this variation is not due to a fundamental difference in the costs incurred by the different networks or retailers in serving consumers. Rather it is due to:

- differences in approach by networks as to how to recover their allowable revenues;
- differences in retailers' approaches for recovering their retail cost-to-serve and margin;
- the requirements for electricity networks and retailers to offer low-fixed charge versions of tariffs; and
- possible incentives on networks arising from the current form of the Commerce Commission price control.

Where different charging approaches alter consumer choices but don't reflect differences in underlying costs, they could result in inefficient consumer choices. i.e. a consumer choosing an option which may appear cheaper from their perspective, but is not cheapest from a whole-of-New Zealand perspective.

This then begs the question of what is likely to be the lowest cost heating option from a whole-of-New Zealand perspective?

Appendix A sets out some analysis which addresses each of the cost components associated with electricity and gas supply (i.e. energy, CO₂, network, and retail) and considers what is likely to be a better estimate of the 'true' cost to New Zealand for each of these components. In doing so, it considers whether these costs are likely to be affected by the 'shape' of demand (i.e. the within-day

and within-year profile of consumption), and thus whether there could be material differences in meeting a space heating demand profile versus a water heating demand profile.

The key points of this analysis are as follows:

- For the wholesale component, the analysis addresses the issue that currently consumers generally face a 'flat' price which doesn't vary throughout the year, even though the wholesale cost of electricity and gas can vary significantly on a seasonal and (in the case of electricity) within-day basis.

Being charged this flat price means that loads which are very peaky (e.g. space heating) will typically face a lower price than they 'should' based on their demand profile.

The analysis estimates what a more cost-reflective price for space heating and water heating demand profiles should be.

- This flat versus time-of-use issue is also addressed for the CO₂ component of electricity prices in an analysis which considers what type of electricity generation will increase output in the long-run in response to demand growing at different times of the day and year.

In addition, the analysis considers the impact of future CO₂ prices applying to all fuels potentially being higher than the relatively low prices that have been experienced over recent years.

- For the network component of charges, the analysis considers the extent to which demand growth for heating purposes at times of system peak will result in increased network costs in the long-run.¹⁸

– For electricity the analysis concludes that:

- Demand growth for heating purposes (especially space heating) will likely give rise to increased network investment requirements, but there is likely to be considerable variation in the extent of this due to:
 - variation in the extent of surplus capacity across different networks; and
 - uncertainty in the extent to which there will be significant uptake in electric vehicles and whether this will give rise to pressure on peak demand.
- There is considerable uncertainty as to what may be the \$/kW/yr long-run marginal cost (LRMC) of network investment. Some of this is likely to be inherent variation between different network situations, but a considerable amount of this uncertainty appears to be due to different approaches in how to calculate such costs. Two different approaches are considered:
 - that done by Orion as part of deriving its consumer charges; and
 - the regulatory-prescribed method undertaken by Australian network companies as part of deriving their consumer charges.
- The network cost implications of electric space heating are much greater than for water heating. This is due to the fact that:
 - the timing of water heating demand across each day can be controlled, whereas space heating demand is less controllable; and

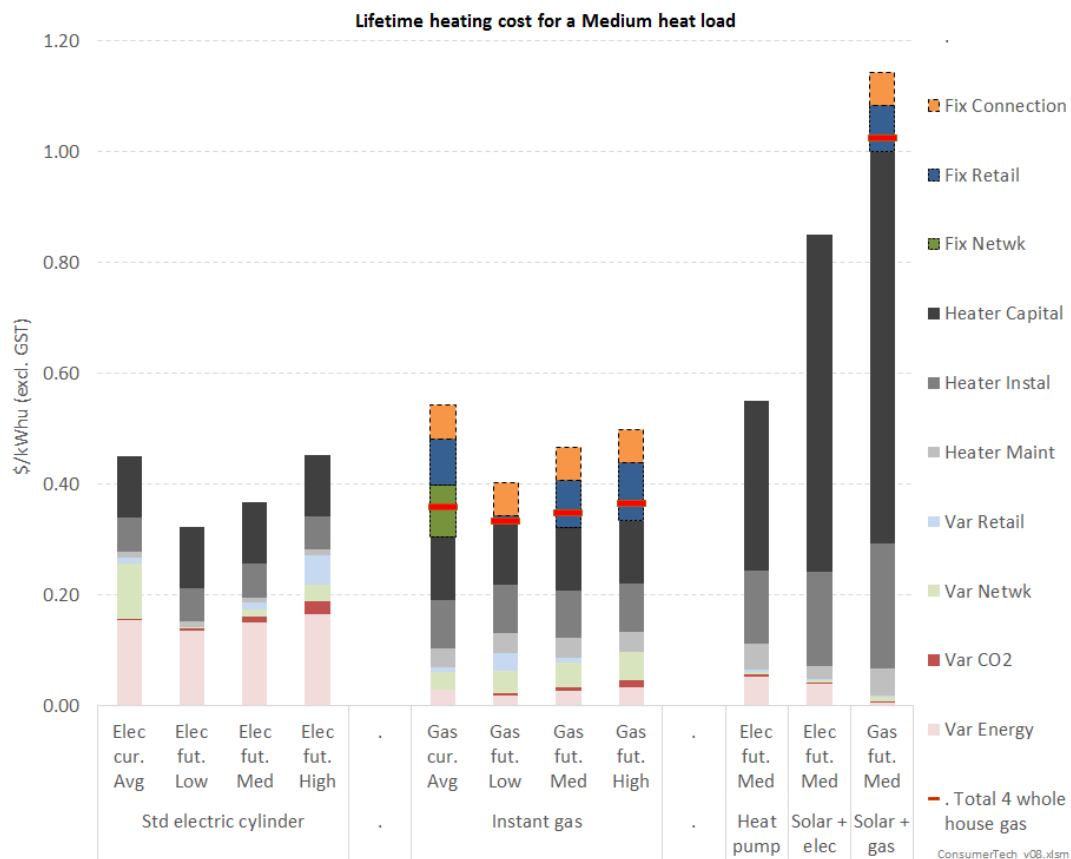
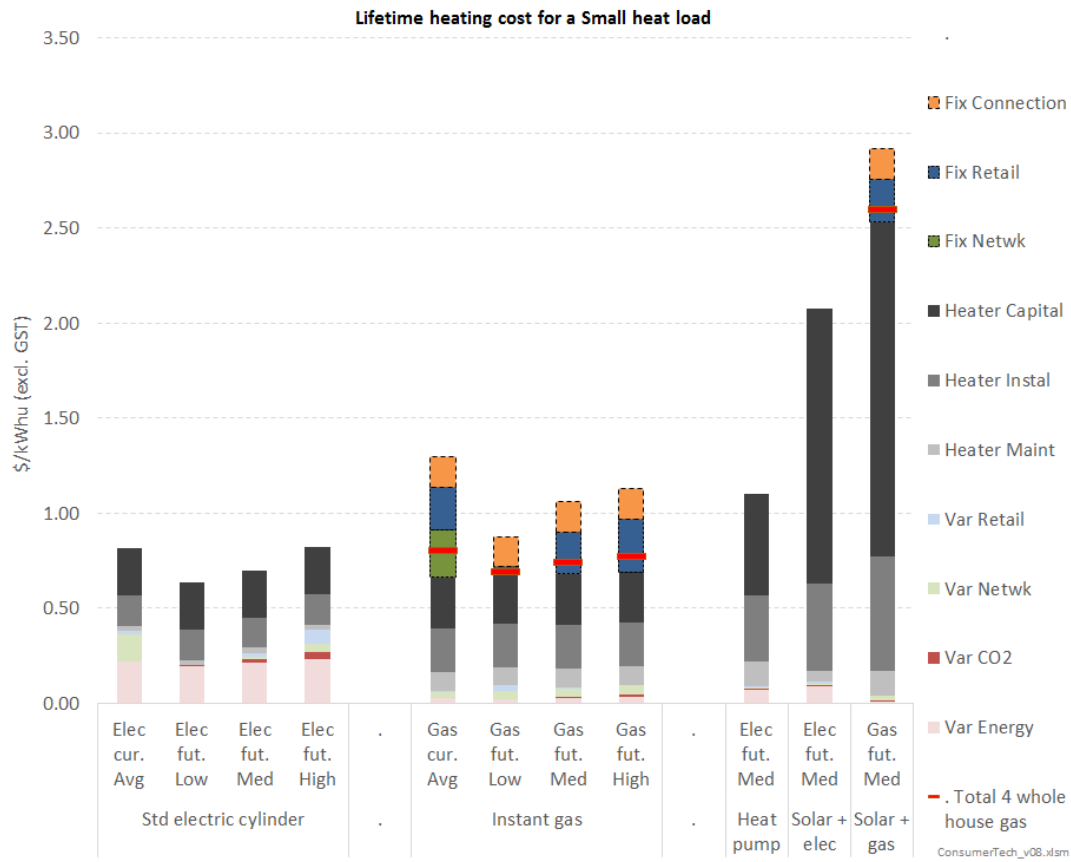
¹⁸ This is based on a framework which considers that the key driver of network costs in the long-run is not the volume of kWh transported, but the peak kW quantity needed to be transported, and thus the capacity of the network required to be built to accommodate such peak demand.

- the demand profile of space heating is much more heavily weighted towards peak periods than for water heating.
- For gas the analysis concludes that:
 - Increased space or water heating demand is unlikely to give rise to a material need for investment. This is because of the significant surplus capacity on the gas networks and no prospect of an equivalent ‘game changing’ technology such as electric vehicles to change this.
 - In the absence of a need to signal the network investment implications of increased gas demand in consumer prices, gas networks have some discretion about the structure of their charges (noting that the total revenue amount is subject to a capping mechanism under the Commerce Act). Some gas networks have chosen to rely mainly on fixed charges, rather than throughput-related charges. Their annual revenues are less affected by short-term demand changes such as weather-induced effects, but the presence of higher fixed charges may hinder retention and growth of gas customers. Conversely, some other gas networks have chosen to offer tariffs with lower fixed charges and higher throughput related charges, in part to strengthen longer term demand. The choice of charging approaches may be influenced in part by the short-term incentives network companies face from current form of the economic regulation under Part 4 of the Commerce Act.
- For the retail component of charges the analysis finds:
 - There has been a significant increase in the retail cost-to-serve and cost-to-acquire over the past five to ten years.
 - Retail costs do not vary with the kWh consumed by a customer, and therefore probably most appropriately recovered via a fixed charge.
 - Both the above facts mean that retail costs are likely to have a detrimental impact on the relative economics of gas versus electricity heating options (given that for electricity, fixed costs are not included in such an evaluation). Partially offsetting this, significant dual-fuel efficiencies can be achieved from a retailer supplying both electricity and gas to a property.

Figure 15 and Figure 16 below show the results of the analysis in terms of comparing the current average electricity and gas price faced by consumers, with a High to Low range of possible future cost-reflective / least-distortionary prices for water and space heating, respectively.

This comparison is done for the same appliances and heat loads as for Figure 13 and Figure 14 previously, plus also includes the main other heating options (but only for the Medium projection of possible future prices).

Figure 15: Lifetime water heating costs when assessed against a likely range of cost-reflective electricity and gas prices



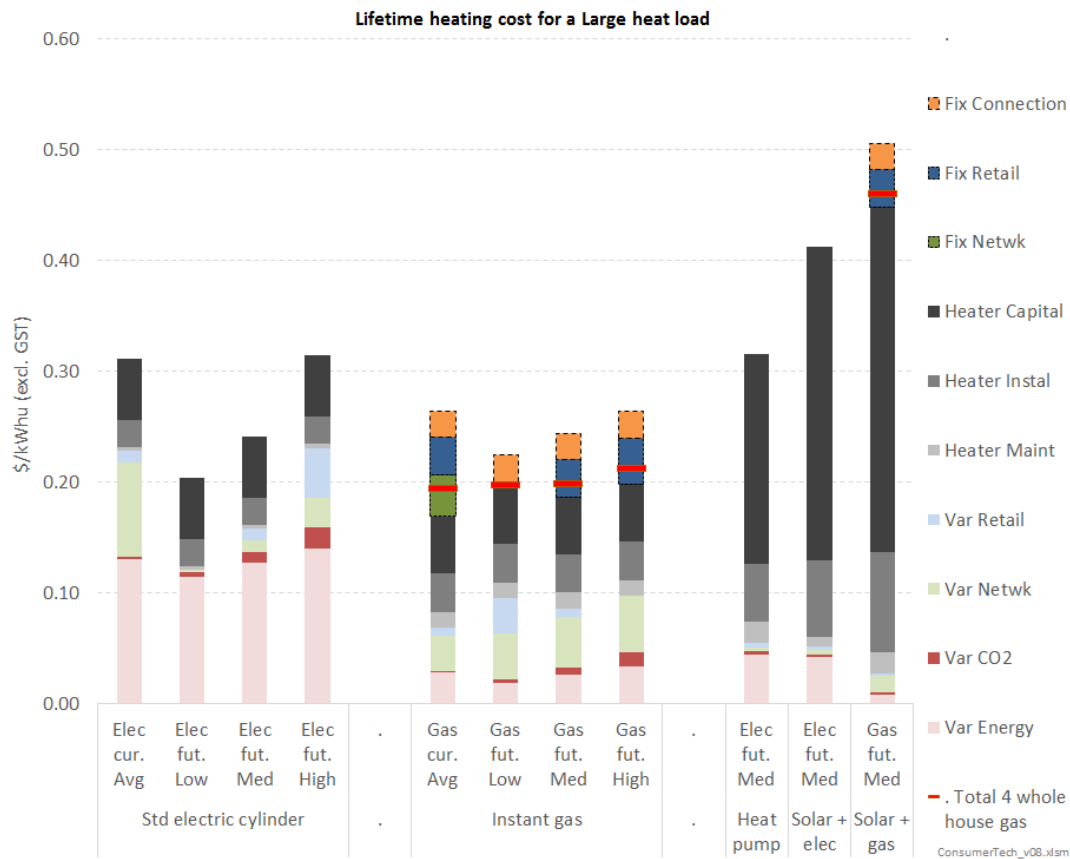
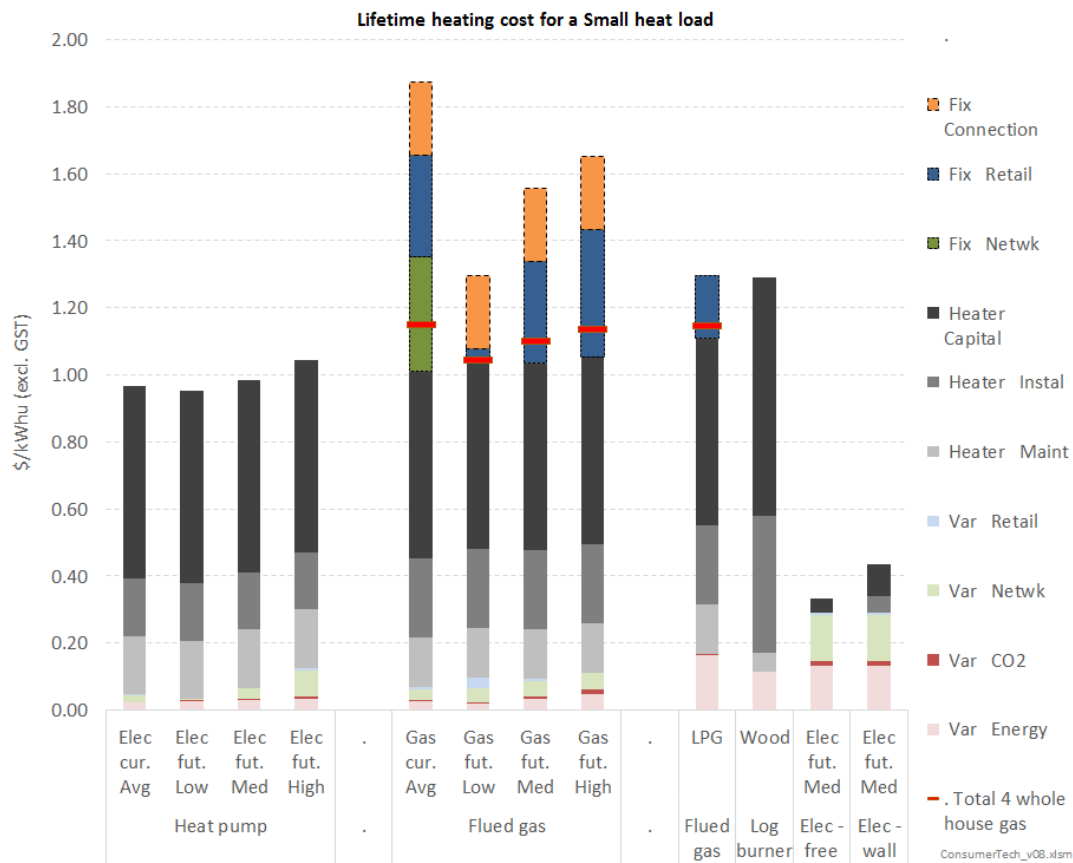
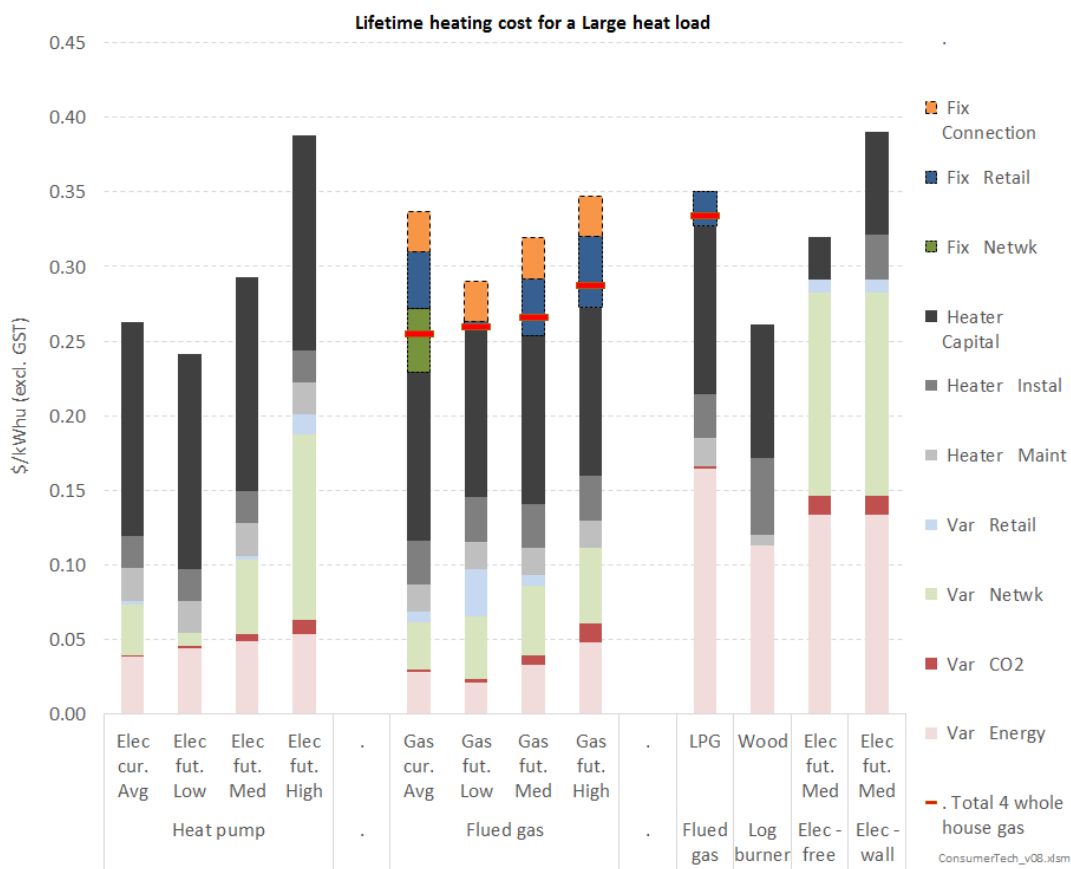
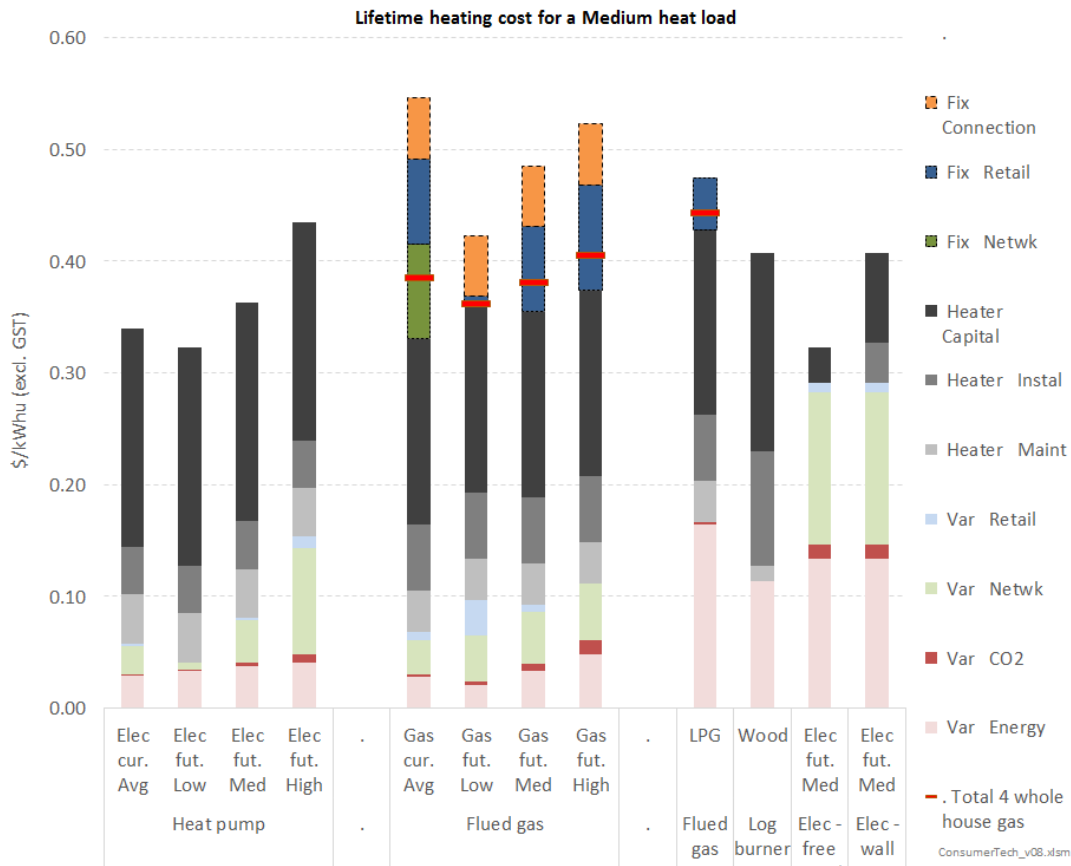


Figure 16: Lifetime space heating costs when assessed against a likely range of cost-reflective electricity and gas prices





The key conclusions from the above graphs, and the analysis in Appendix A, are:

- For water heating, it appears that a move to more cost-reflective pricing will, on average, likely improve the economics of electric options more than gas options. However, gas water heating is likely to still be cost-competitive for a consumer. (Plus, as set out in Appendix C below, instant gas water heating has significant non-price benefits (e.g. never running out) compared to cylinder-based options).

Further, from an economic whole-of-New-Zealand perspective, the sunk nature of gas network costs means that gas-fired water heating options are likely to be least-cost in most situations. This is because the network costs (the light and dark green bars in the graphs) relating to gas options should not be included.

However, as detailed in Appendix A, this creates a challenge for gas network companies as to how best to structure their gas prices to residential and commercial and industrial customers in a way which maximises the relative competitiveness of gas across all these customer segments. As also detailed in Appendix A, this also presents a challenge to ensure that the price control regulations appropriately incentivise these companies to achieve such outcomes.

- For space heating, on average it appears that electric space heating will face an increase in consumer costs from a move to more cost-reflective pricing – particularly if peak electricity network costs are genuinely at the ‘High’ end of the range (reflecting costs and LRMC-calculating approaches undertaken in Australia). Conversely, gas-fired space heating consumers are expected to face a decrease in prices from a move to more cost-reflective tariffs. This will improve the economics of gas-fired options for consumers, making them cheaper than electricity options in many cases – although for small heat loads resistance electric heaters are still likely to be least cost.

As with water heating, from a whole-of-New Zealand perspective the economics of gas-fired space heating look even more compelling due to the sunk nature of gas network costs. The exception to this is the situation of small heating loads where even after discounting gas network costs, simple resistance electric heaters appear to be the cheapest option.

- The extent of retail fixed costs will have a material bearing on gas economics for both space and water heating. Should retail fixed costs continue to rise they will have a negative impact on gas in the long-run, and vice versa if they were to fall back again.

This appears to suggest that the extent of retail competition in both the gas and electricity markets could have an impact in the long run on the fuel choices made by consumers. If competition drives retailer innovation and reduces the ability of high cost-to-serve retailers to pass such costs onto consumers, this should benefit gas in the long run.

2.3 Summary

The analysis reveals that the right heating choice for a mass-market energy consumer can vary significantly according to their situation. In particular:

- The right choice for customers with relatively small heating requirements are likely to be different to those with larger heating requirements due to the significant up-front capital costs associated with some heating options; and
- Consumers with an existing functional heater (whether gas, electric or solid fuel) would in most cases be best to stick with that heater, even if its on-going running costs are materially higher than alternatives. This is because such alternatives would result in the consumer incurring significant up-front capital costs which will generally outweigh the benefit of lower running costs.

In general, these drivers of the right choice for a consumer also reflect the underlying economic cost to New Zealand of the different options – there is a just as much a cost to New Zealand in replacing existing capital with new capital, even if the on-going operating costs are lower.

However, in some cases the least-cost choice for a consumer *doesn't* reflect the least cost choice to New Zealand. In particular, differences in the way that electricity and gas fixed costs are recovered can result in consumers being encouraged to choose options which don't represent the least-cost outcome for New Zealand.

For example, in one location, the structure of charges may encourage consumers to choose gas-fired space and/or water heating, whereas a different charging structure adopted at another location may encourage uptake of electricity options – even though the underlying resource costs to New Zealand from additional electricity or gas heating may be identical at the two locations.

The current large variation in prices charged to consumers for supplying electricity and gas to meet space or water heating loads don't appear to directly reflect variations in the underlying economic cost to New Zealand of such supply. Rather such variation is due to factors such as:

- Historical constraints imposed by old 'dumb' metering technology and configurations, and limited billing IT capabilities;
- The way that policy requirements such as the low-fixed charge regulations, and rural-urban pricing constraints have been implemented;
- Variations in the approaches taken by network companies for apportioning allowable regulated revenues between different classes of customer;
- Variations between networks with regards to more 'fundamental' factors such as the proportion of residential customers, or the underlying cost of the network (e.g. due to rural / urban factors);
- Possible incentives on network companies arising from economic regulation under the Part 4 regime which may result in network companies favouring particular pricing approaches; and
- Variations in approach between retailers as to recovery of retail service costs.

None of these drivers of pricing approaches will inherently result in prices to consumers reflecting the underlying costs to New Zealand for meeting additional space or water heating demand from electricity or gas.

In this respect, this study has sought to establish what is the likely 'true' cost to New Zealand from additional electricity or gas demand to meet space or water heating growth, and what prices to consumers may be if they were re-structured in order to reflect these underlying costs. The key conclusions from this analysis are:

- For water heating, it appears that a move to more cost-reflective pricing will, on average, likely improve the economics of electric options more than gas options. However, instant gas water heating is likely to still be cost-competitive for a consumer with a need to install a new water heater. Plus instant gas water heating has material 'quality' benefits (e.g. never running out) compared to cylinder-based options, which are likely to continue to be of significant value to many consumers;

Further, from an economic whole-of-New-Zealand perspective, the sunk nature of gas network costs means that gas-fired water heating options are likely to be least-cost in most situations. Thus, the prices which consumers will see for recovery of existing gas network assets should not be included when evaluating the costs of gas demand from a whole-of-New-Zealand perspective.

However, this creates a challenge for gas network companies as to how best to structure their gas prices to residential and commercial and industrial customers in a way which maximises the

relative competitiveness of gas across all these customer segments. This also presents a challenge to ensure that the price control regulations appropriately incentivise these companies to achieve such outcomes, as it is potentially the case that current settings are not achieving this.

- For space heating, on average it appears that electric space heating will face an increase in consumer costs from a move to more cost-reflective pricing.

Conversely, gas-fired space heating consumers are expected to face a decrease in prices from a move to more cost-reflective tariffs. This will improve the economics of gas-fired options for consumers, making them cheaper than electricity options in many cases – although for small heat loads, resistance electric heaters are still likely to be least cost.

As with water heating, from a whole-of-New Zealand perspective the economics of gas-fired space heating look even more compelling due to the sunk nature of gas network costs. The exception to this is the situation of small residential heating loads where, even after adjusting incremental gas network costs to the true value, simple resistance electric heaters appear to be the cheapest option.

- The extent of annual fixed costs for retail service will have a material bearing on gas economics for both space and water heating. Should these costs continue to rise they will have a negative impact on gas in the long-run, and vice versa if they were to fall back again.

This appears to suggest that the extent of retail competition in both the gas and electricity markets could have an impact in the long run on the fuel choices made by consumers. If competition drives retailer innovation and reduces the ability of high cost-to-serve retailers to pass such costs onto consumers, this should benefit gas in the long run.

In summary, for consumers needing to install a new heating appliance¹⁹, gas is likely to continue to be the least-cost option *for New Zealand* for mass-market water heating and also, in many cases, for space heating.

However, in some cases, the distortions caused by current electricity and gas pricing arrangements mean that the price signal that consumers face will result in them choosing a different option to that which results in the lowest cost option for New Zealand.

The challenge is making the necessary changes to electricity and gas pricing arrangements such that consumers see a price signal that will better ensure that they make choices which are least-cost for them *and New Zealand*.

To move to more cost-reflective pricing, there may need to be changes to aspects of the current economic regulation of network companies. This is because the incentives which network companies face under the current price control regime may be resulting in pricing approaches which result in outcomes which are less efficient for New Zealand in the long-term.

Given the relatively long lifetime of heating assets, it is likely to be important to move to these more cost-reflective pricing structures sooner, rather than later.

Lastly, the analysis reveals that the extent of retail competition could have a bearing on consumers' long-term energy choices. This is due to the effect that fixed charges to recover retail service costs have on the relative competitiveness of gas versus electricity options. Thus, fostering retail competition to try and help bring retail service costs back down is not only going to be good for customers in general, but it will help gas's competitiveness and could facilitate more efficient fuel choices for New Zealand as a whole.

¹⁹ Generally, for space and water heating, if a consumer has an existing workable heater, it is likely to be least-cost to continue with that heater, even if it has higher running costs.

3 Industrial process heat

Appendix E sets out analysis which establishes that the principal industrial process heat requirement that consumes significant quantities of fuel and has real fuel choice options, is intermediate-temperature process heat raised by boilers. The analysis in Appendix E finds that:

- low-temperature process heat accounts for relatively little fuel consumption; and
- the economics of high-temperature process heat are generally dominated by process-specific considerations, meaning fuel choices are limited.

Appendix E also establishes that electricity is not a practicable option for producing steam at such relatively high temperatures (i.e. 100°C to 300°C).

Accordingly, the main alternatives to gas for intermediate-temperature combustion boilers are:

- solid fuel options (coal or biomass); and
- liquid fuel options (diesel, LPG, or fuel oil)²⁰.

The framework for considering the relative economics of the different options is fundamentally the same as for considering the options for mass-market space & water heating. i.e. the analysis seeks to establish the lifetime cost per useful kWh of heat provided, taking into account the capital and non-fuel operating costs of the boilers, as well as the fuel and CO₂ costs of the different fuels.

As with space & water heating, the size of the heat load can have a significant impact on the relative economics of the different options. This is not just because of the different capital costs of the options, but also because the \$/kWh costs of the fuel can vary significantly with different levels of consumption. This is particularly the case for gas, where the \$/kWh network charges for a very large transmission-connected boiler can be orders of magnitude less than for a small distribution-connected boiler.

Accordingly, the analysis considers the relative economics of the different fuel options for the following four types of industrial user (whose estimated share of total New Zealand process heat load is indicated in the square brackets)²¹:

- very-large gas transmission-connected industrial users [45%];
- large gas distribution-connected industrial users [38%];
- medium gas distribution-connected industrial users [12%]; and
- small gas distribution-connected industrial users [5%].

Appendix D sets out some of the detailed assumptions behind the analysis with the final results presented in Figure 17 to Figure 20 below.

For each industrial user situation, two sets of graphs are presented:

- 1) based on current fuel and CO₂ prices; and
- 2) based on expected central projections of fuel and CO₂ prices.

For each graph, the costs are shown for an industrial user with an “Existing” workable boiler of a particular type, and also the costs that would be incurred if a user were to install a “New” boiler of a particular type.

²⁰ Black liquor is also a liquid fuel, but as it is a by-product of wood processing, it is only available for such users, and thus not considered further in this discussion of the general economics of such options.

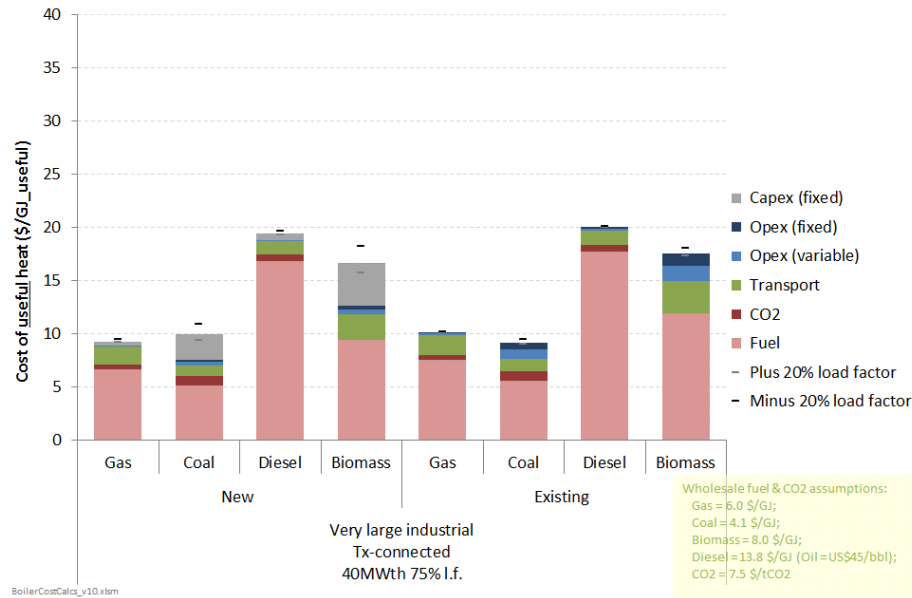
²¹ Source: Concept analysis using EECA’s ‘Heat plant database’

As can be seen, in situations where a user has an existing boiler there is no recovery of boiler capital costs ('capex') because this is a sunk cost, whereas such costs would be incurred from installing a new boiler. Conversely, an existing boiler is assumed to have higher non-fuel operating costs ('opex') and worse fuel efficiencies (leading to higher fuel & CO₂ costs).

The only liquid-fuelled option shown is diesel. This is because the cost of the other two liquid options (LPG and fuel oil) are broadly similar – at least in the context of comparison with the other main fuel options – with the prices of all three liquid fuels fundamentally driven over the long term by the international price of oil.

Figure 17: Intermediate process heat boiler economics for very large gas transmission-connected industrial users

Current prices



Central future prices

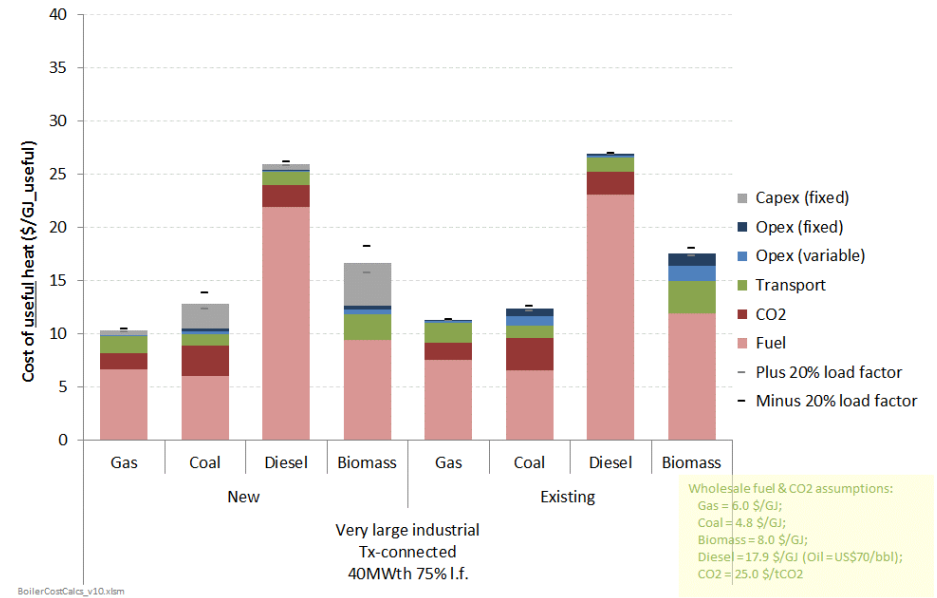
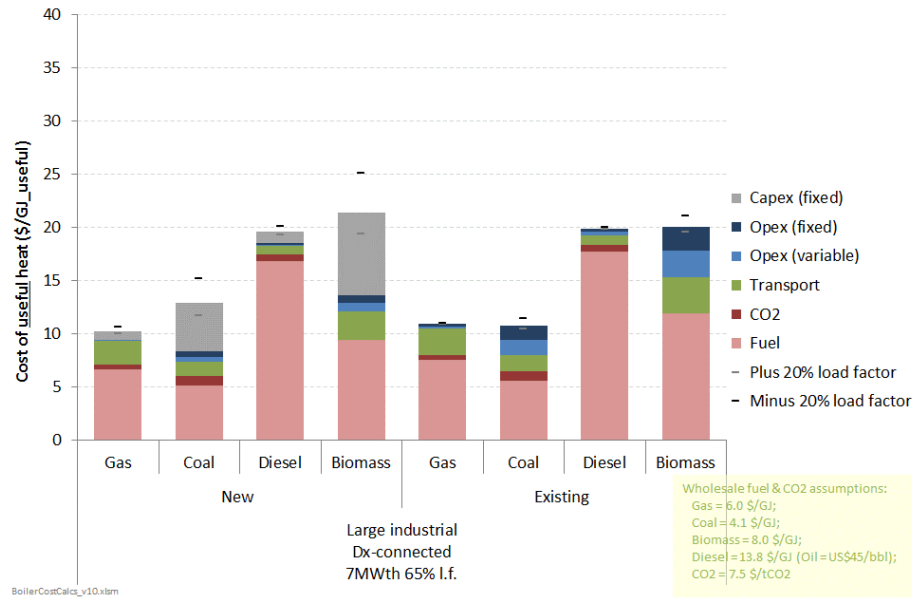


Figure 18: Intermediate process heat boiler economics for large gas distribution-connected industrial users

Current prices



Central future prices

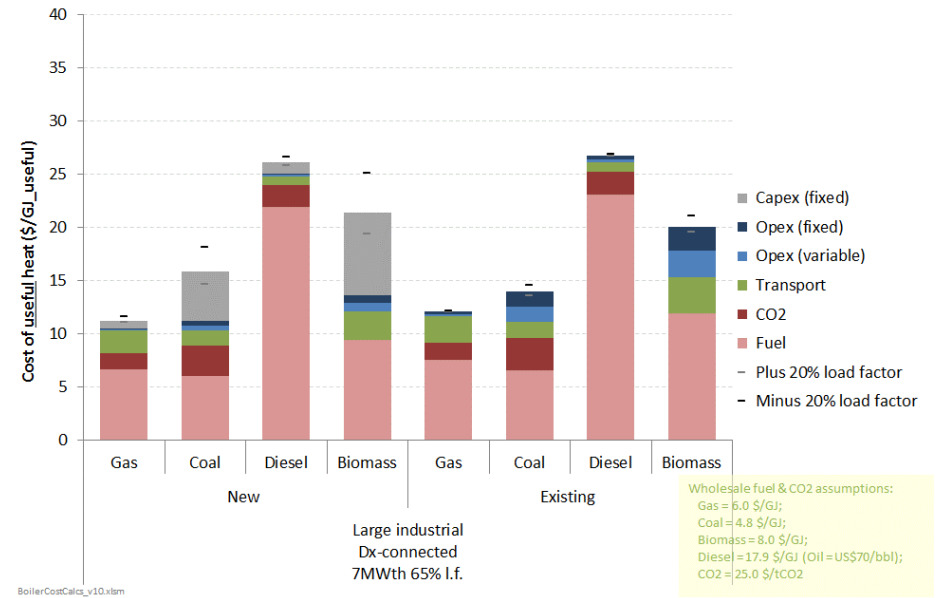
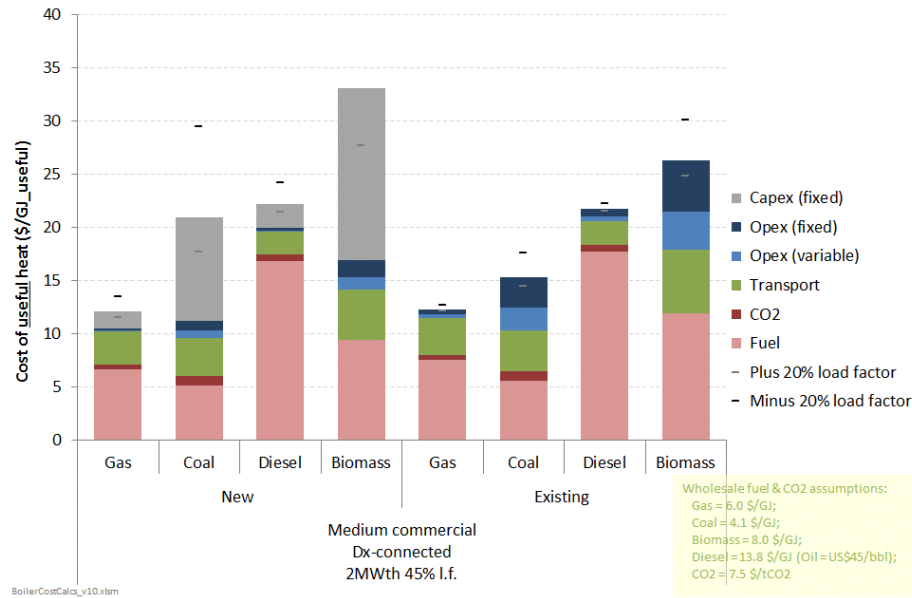


Figure 19: Intermediate process heat boiler economics for medium gas distribution-connected industrial users

Current prices



Central future prices

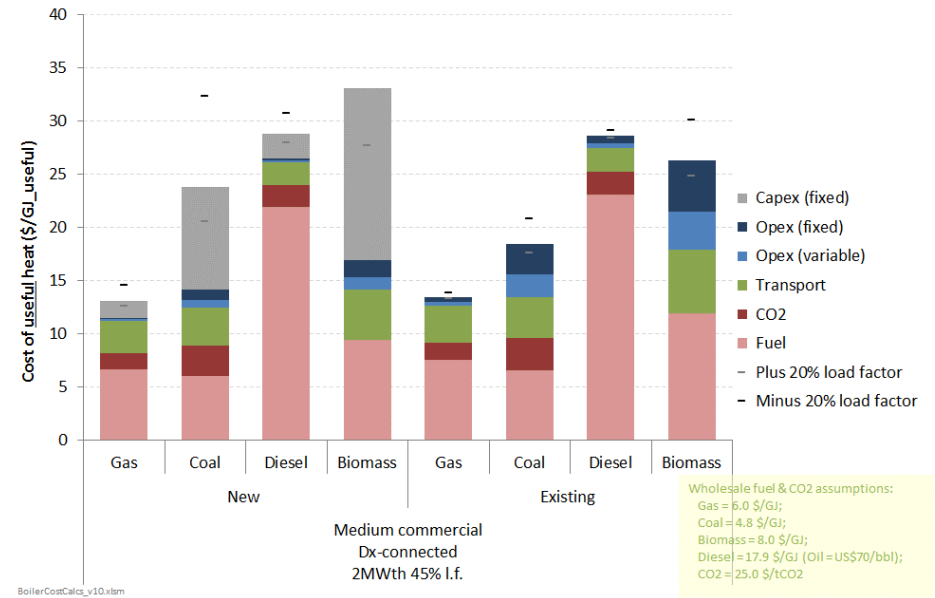
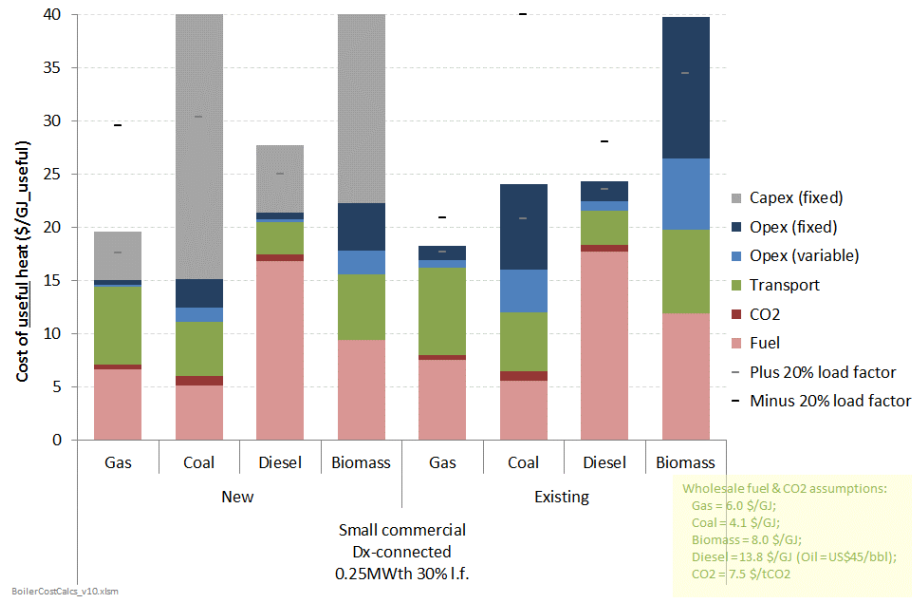
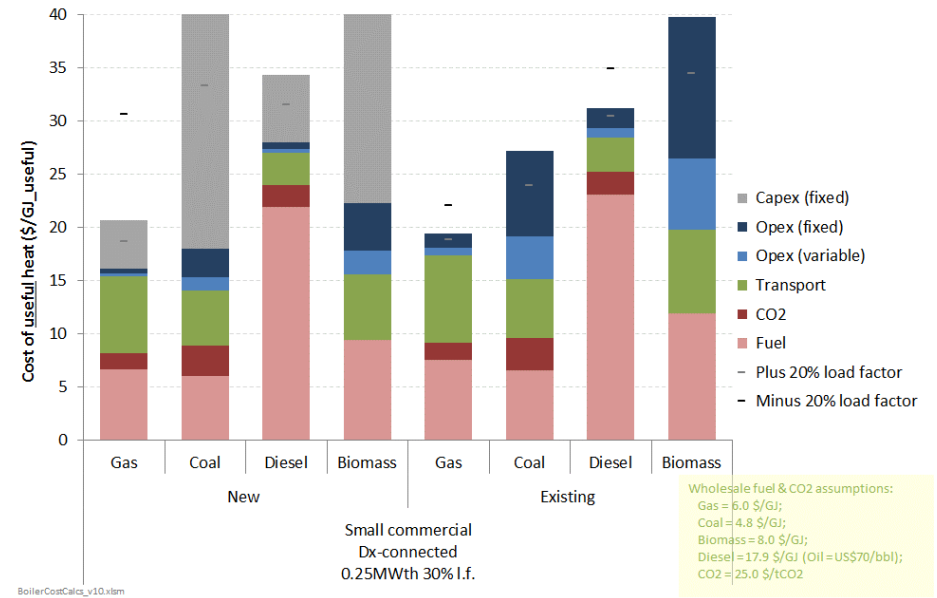


Figure 20: Intermediate process heat boiler economics for small gas distribution-connected industrial users

Current prices



Central future prices



For medium- and small-sized industrial process heat requirements gas is very strongly competitive because:

- The significantly greater capital-cost for solid-fuelled boilers (i.e. coal & biomass), coupled with significant economies of scale for boilers, means that solid-fuelled boilers are not really cost-effective for smaller-scale applications.
- Liquid-fuelled options have a very high wholesale fuel cost – even at current low world oil prices.

The extent of this competitive position is such that it would even make sense for consumers with an existing non-gas fired boiler (with a sunk capital cost) to switch over to gas, and incur the cost of a new gas boiler. This conclusion is expected to be robust against a very wide range of feasible fuel and CO₂ prices.

For large-scale industrial process heat applications, the economies of scale in boilers means that the capital cost penalty faced by solid-fuelled boiler options is significantly less. Accordingly, fuel, CO₂, and transport costs start to become the dominant factors.

Liquid and biomass-fuelled options are generally uncompetitive due to:

- the high oil-linked costs of liquid options – even at current low world oil prices; and
- the relatively high wholesale and transport cost of biomass fuels.

That said, the cost of biomass is very location-specific within New Zealand. The most extreme example relates to industrial process heat for forestry processing or pulp/paper manufacturing requirements where there is a lot of on-site biomass residue available to be used as a fuel. In these situations, the fuel cost of biomass is effectively free (or may even have a *negative* cost due to the opportunity cost of residue disposal). Similarly, industrial facilities located very close to forestry processing plant may face significantly lower biomass costs than those shown above. However, generally, the delivered cost of biomass is materially higher than coal and gas.

Therefore, the main inter-fuel competition for these large-scale industrial process heat requirements is between coal and gas.

For new-build situations, gas is competitive against coal due to the lower CO₂ and boiler capital costs of gas outweighing the high wholesale and transport costs. This relative competitive position will be strongly reinforced if CO₂ prices rise from their current low levels.

That said, the economics of coal can also be quite location-specific in New Zealand, with industrial facilities located close to the mine mouth potentially enjoying significantly lower fuel costs.

Coal is currently competitive against gas for *existing* coal-fired boilers. This is because of the currently low CO₂ and coal prices – particularly for those industrial coal-using facilities located close to coal mines.

Over time, gas is expected to increase its share of industrial process heat demand because:

- CO₂ prices are likely to move up, which favours gas due to its lower carbon intensity;
- lower cost coal from existing mines located close to industrial plant is expected to decline over time;
- as existing coal-fired boilers reach the end of their economic life and need replacing (although it should be noted that boilers can easily last for 40 to 50 years), the lower capital cost of gas-fired boilers comes into the total cost assessment; and
- users are likely to be wary of major re-investment in coal-fired boilers because of the risk of significant future rises in CO₂ prices.

As with mass-market space & water heating, there can also be non-price benefits of the different industrial process heat fuel options which can be of additional value to some industrial consumers.

In this, the main issue appears to be how clean-burning the different options are for industrial users with sensitive processes. A good example of this is food processing, where ash and other particulates from solid fuel options can be a concern, whereas gas is regarded as the cleanest-burning of options.

In some situations, the superior controllability of gas and liquid-fuelled options can also be a benefit relative to solid-fuelled options.

However, in general, non-price quality benefits do not appear to be anywhere near as significant a factor for industrial process heat as for mass-market space & water heating.

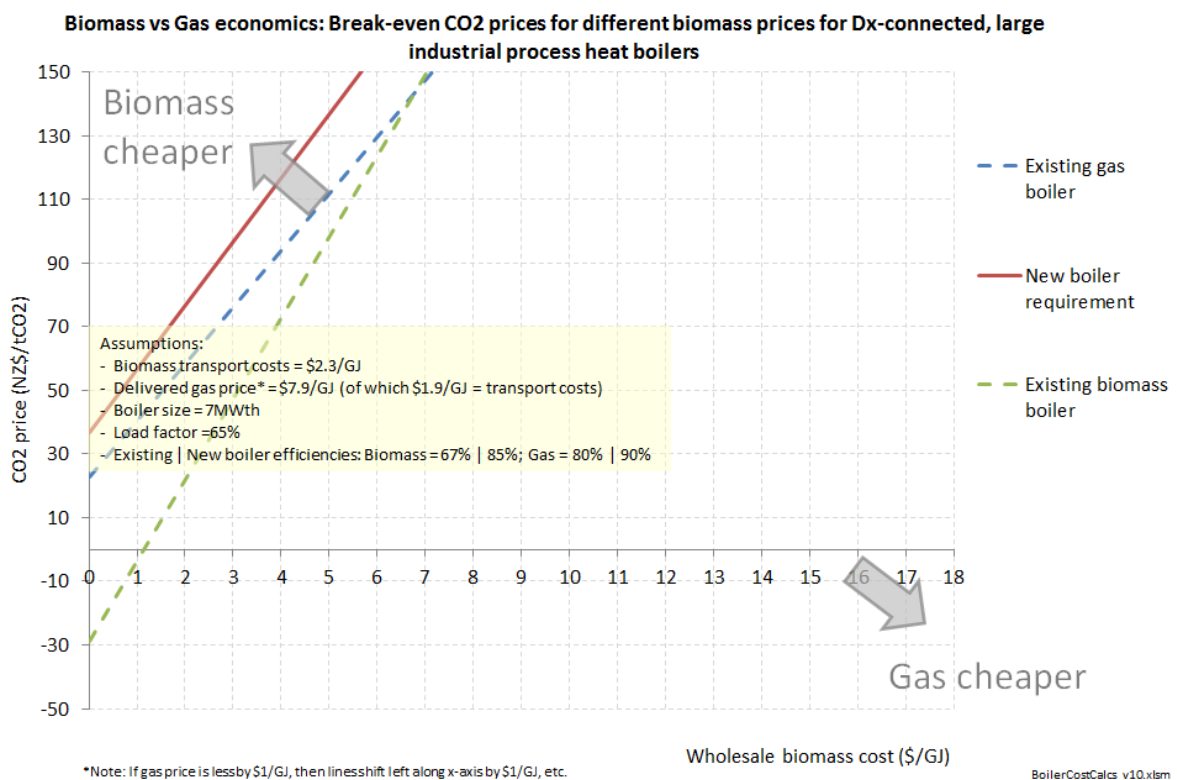
Unlike mass-market space & water heating, there do not appear to be the same divergences between the cost-benefit of different options from a public or private perspective.

The only material externality could be considered to be CO₂ pricing, to the extent that the current low CO₂ price in New Zealand doesn't reflect the likely cost to New Zealand society from global warming resulting from CO₂ emissions.

If CO₂ prices were to rise to \$25/tCO₂ or higher, the economics of gas would become even more compelling against coal or liquid-fuelled options.

However, as illustrated in Figure 21 below, biomass is unlikely to be competitive against gas except in future scenarios of extremely high CO₂ and/or gas prices.

Figure 21: Break-even CO₂ prices for biomass to be cheaper than gas for large gas distribution-connected industrial process heat boilers



In summary, the economics of gas for provision of intermediate-temperature process heat look robust compared to alternative fuels in the majority of cases, and can withstand material increases in gas wholesale or network prices.

Appendix A. Analysis of cost components of electricity and gas

This appendix sets out analysis on the main cost components of electricity and gas. This information is used as an input to estimate underlying resource costs of different energy options from the perspective of New Zealand as a whole, and how those costs may differ to the prices currently seen in consumer tariffs.

Price signals to consumers and underlying resource costs for New Zealand

For most fuel options, consumers simply see an overall price expressed in \$/kWh (or some other metric which reflects the energy being sold – e.g. \$/m³ of wood, or \$/kg of LPG).

In some cases, e.g. firewood, this ‘all-up’ figure is an appropriate basis on which to evaluate the underlying resource cost of the fuel.

However, in other cases – particularly electricity and gas – it is important to consider the underlying components of this ‘all-up’ cost. This is because there can be divergences between the cost signals provided to the consumer, and the underlying resource cost to New Zealand as a whole.

This section details the costs for each fuel, distinguishing between four underlying cost components:

- wholesale energy costs;
- CO₂ costs;
- network costs; and
- retail cost-to-serve.

In doing so, it specifically considers whether the underlying costs are likely to be affected by the ‘shape’ of demand (i.e. the within-day and within-year profile of consumption). This is relevant because space heating demand has a distinct winter- and evening-peak profile, whereas water heating demand is more even across the year, and is potentially controllable within the day for options where there is a storage cylinder.

Wholesale energy costs

Electricity

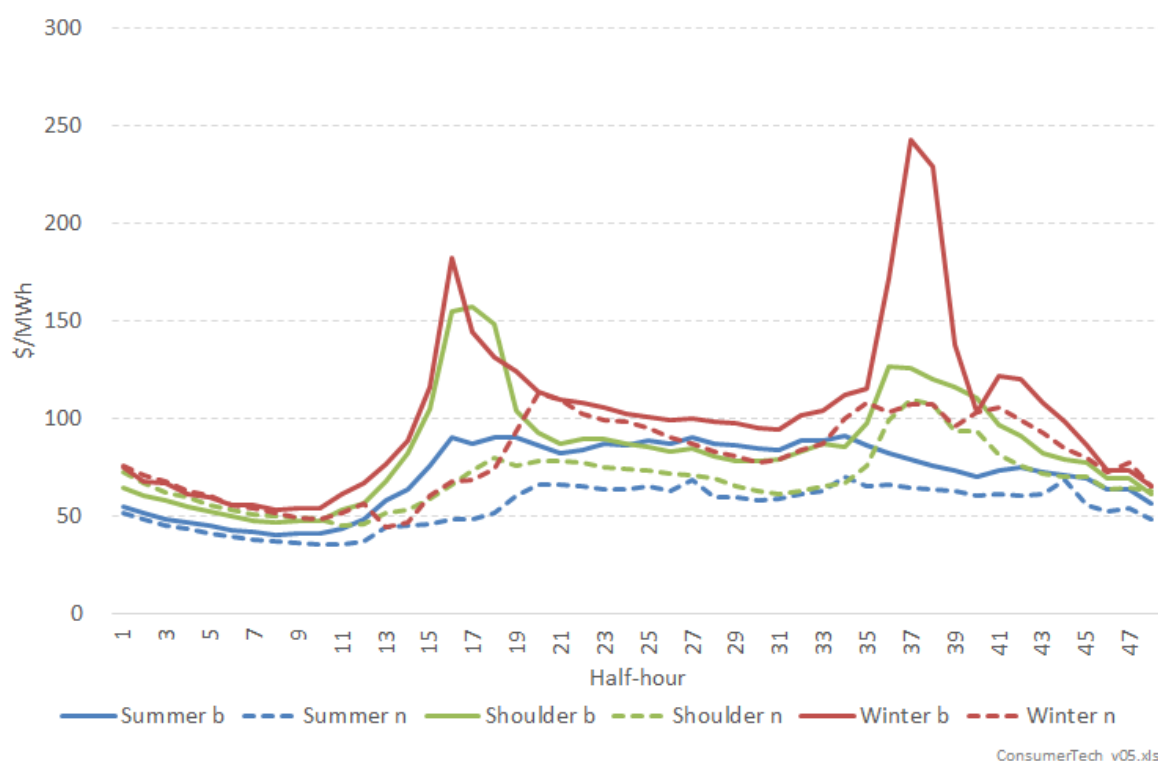
For electricity, the wholesale energy component represents the cost of generation, factored by transmission & distribution lines losses in transporting the electricity to end consumers.

A reasonable estimate of this wholesale cost can be derived from the forward curve for electricity hedges (e.g. the ASX hedge products). A value of \$80/MWh was chosen as a central estimate of this cost of wholesale electricity.

However, when considering the costs of electricity for heating purposes, it is important to consider the ‘shape’ of prices over the day and year. This is because there is significant variation on a seasonal and diurnal basis between prices, with winter prices typically being significantly higher than summer prices, and morning and evening peak-time prices being significantly higher than night-time prices.

This is illustrated in Figure 22 below, which is based on an analysis of historical prices, and shows the variation between seasons, different times of the day, and between business days (‘b’) and non-business days (‘n’).

Figure 22: Typical shape of wholesale electricity prices²²



Combining the above price shapes with the demand shapes set out in section Appendix B, the demand-weighted average wholesale electricity prices were calculated for typical space and water heating profiles, as well as the typical overall residential consumption profile – with this latter shape being the basis on which the ‘flat’ electricity price to consumers is currently calculated.

This analysis reveals that the wholesale cost of supplying electricity to meet a space heating-only consumption profile is likely to be 20-25% higher than a flat price based on the average residential electricity consumption profile.

In comparison, the wholesale cost of meeting a water heating-only profile is likely to be 2-3% less than this average residential cost.

Accordingly, it appears that charging a flat price electricity price to consumers means that electricity space heating will appear cheaper than its ‘true’ cost, whereas the wholesale price signal for electricity water heating appears broadly appropriate.

These ‘true’ demand-weighted average wholesale prices for space and water heating are used to evaluate the economics of such technologies from a whole-of-New Zealand perspective.

Over time, as smart metering becomes ubiquitous, it is possible that electricity retailers may move to more sophisticated tariffs such as time-of-use tariffs or maximum-demand tariffs. If the time-blocks for such tariffs are suitably granular then this distortion should significantly reduce, and the wholesale component of the prices consumers see will be a closer reflection of the ‘true’ underlying cost.²³

²² ‘Summer’ = Dec to March inclusive, ‘Winter’ = June to September inclusive, and ‘Shoulder’ = April, May, October, and November.

²³ Past Concept analysis indicates that a nine-block time-of-use tariff should be largely sufficient to provide the level of granularity required, with the nine blocks being a combination of three seasons (summer, shoulder, and winter) and three diurnal periods (day, night, and peak).

Gas

The wholesale cost of gas represents the upstream cost of exploration and production. A central value of \$6/GJ has been used, based on analysis undertaken for GIC as part of the Supply / Demand study.

Like electricity, this too has 'shape' to reflect the different opportunity costs of gas at the different times of the year driven by its close association with oil production.²⁴ Thus, in summer when gas demand is low, the opportunity cost of gas production is low given that it will generally enable additional oil sales to occur. Conversely, at times of winter peak, the cost of gas production can be relatively high, as the upstream sector may be approaching the limits of its production deliverability.

The central estimate for the extent to which this 'shape' factor will affect the underlying cost of meeting a space or water heating consumption profile is that the cost of supplying a space heating profile will be 35% higher than the cost of supplying a typical residential profile, whereas a water heating only profile will cost about 20% less than the cost of a typical residential profile.²⁵

Thus, if retailers charge for gas via an 'anytime' tariff which doesn't change throughout the year, gas space heating will appear cheaper than its true cost, whereas gas water heating will appear more expensive.

Again, if gas retailers apply sufficiently granular seasonal pricing (e.g. summer, shoulder, winter) this price distortion should largely disappear.

CO₂ costs

While the CO₂ emissions associated with most fuels are straightforward to estimate, this is not the case for electricity.

The CO₂ implications of electricity demand will depend on the type of electricity generation which meets that demand. This will vary according to when during the year the demand occurs, and won't just apply to changed operation to the existing generation fleet, but will also impact on what new generation is built (or existing generation is retired).

Previous studies²⁶ for GIC have demonstrated that over the longer term, incremental heating demand which occurs predominantly in the winter and/or during diurnal peaks will mostly be met by increased fossil generation. Conversely, increased demand which is more baseload in shape will generally be met in New Zealand by increased renewable generation (predominantly wind & geothermal).

Detailed modelling of such factors is outside the scope of this current study. However, a framework was developed which allowed high-level estimation of these factors, and the extent to which the demand-weighted average CO₂ price for meeting a typical residential electricity consumption profile may be different to the demand-weighted average for a space heating or water heating consumption profile.

This framework suggests that the demand-weighted average price relating to CO₂ emissions could be about 55% higher for a space heating profile than for an average residential profile, and about 5% less for a water heating profile. These demand-weighting factors are used to evaluate the CO₂ component of costs for electricity space and water heating.

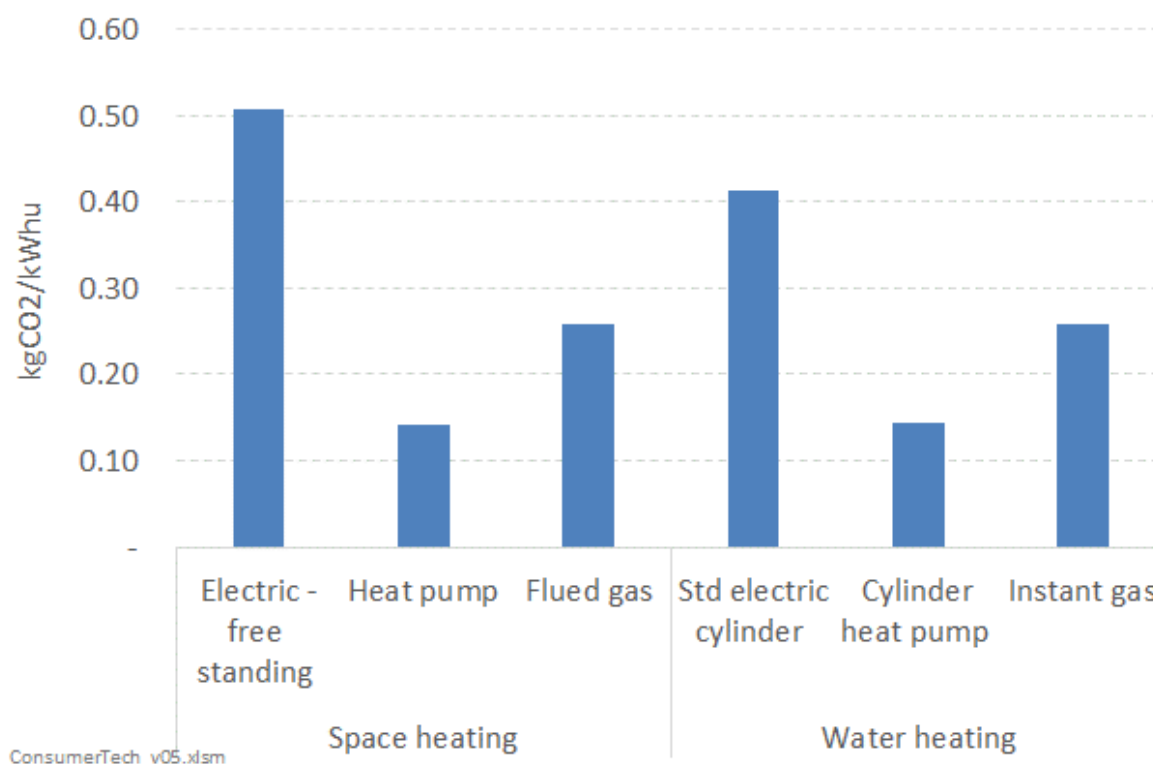
²⁴ The 'shape' to gas prices is fundamentally seasonal rather than diurnal, as gas is primarily traded on a daily basis, whereas electricity is primarily traded on a half-hourly basis.

²⁵ These factors are estimates based on the observed uplift of the wholesale component of gas prices to the typical retail tariff, and estimates of the proportion of a typical residential customers' load to meet space versus water heating.

²⁶ See previous versions of the Consumer Energy Options study and Gas Supply / Demand studies.

When factored through the various heater efficiencies, the difference in emissions between electricity and gas heating options is illustrated in Figure 23 below.

Figure 23: Estimated effective CO₂ intensities of different space and water heating technologies



As can be seen, resistance electric heating options are the most emissions intensive, particularly for space heating given its winter-dominated heating profile.

The higher efficiencies of heat pumps mean their emissions are less than that of gas heating whose emissions are roughly mid-way between the two electric heating options.

The other issue in relation to CO₂ prices in general (i.e. not just specific to consideration of electricity-related emissions), is whether future CO₂ prices applying to all fuels will be higher than the relatively low prices that have been experienced over recent years.

The central estimate of future CO₂ prices used to evaluate the likely future cost of the different technologies is NZ\$25/tCO₂. This compares with prices of ≈ NZ\$5/tCO₂ which have been experienced in recent years.

Network costs

Electricity

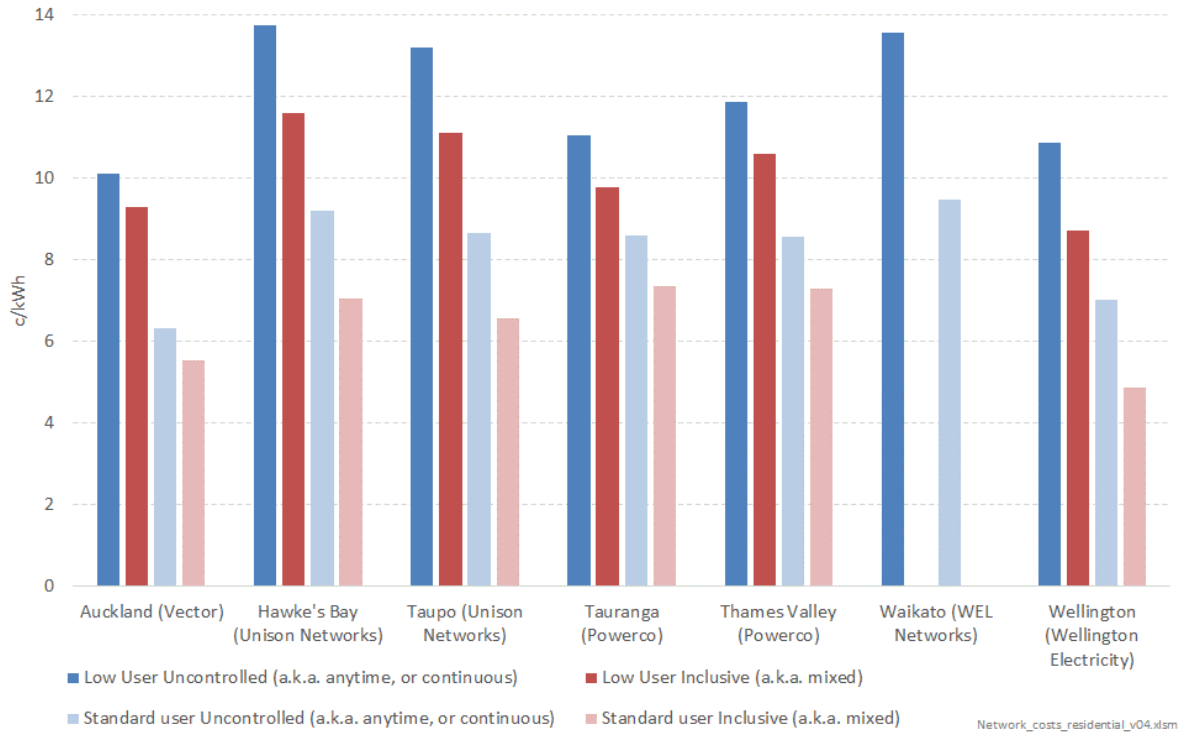
The network component of residential electricity prices is generally comprised of a \$/day fixed charge plus a \$/kWh variable charge.

However, for the purposes of evaluating the economics of electric heating, only the variable component of costs are considered. This is because electricity is not considered to be a discretionary fuel, and thus fixed costs are not avoidable whether a consumer chooses an electric

heating option or not.²⁷ This applies to consideration of the situation from a consumer’s perspective, as well as from a whole-of-New-Zealand perspective.

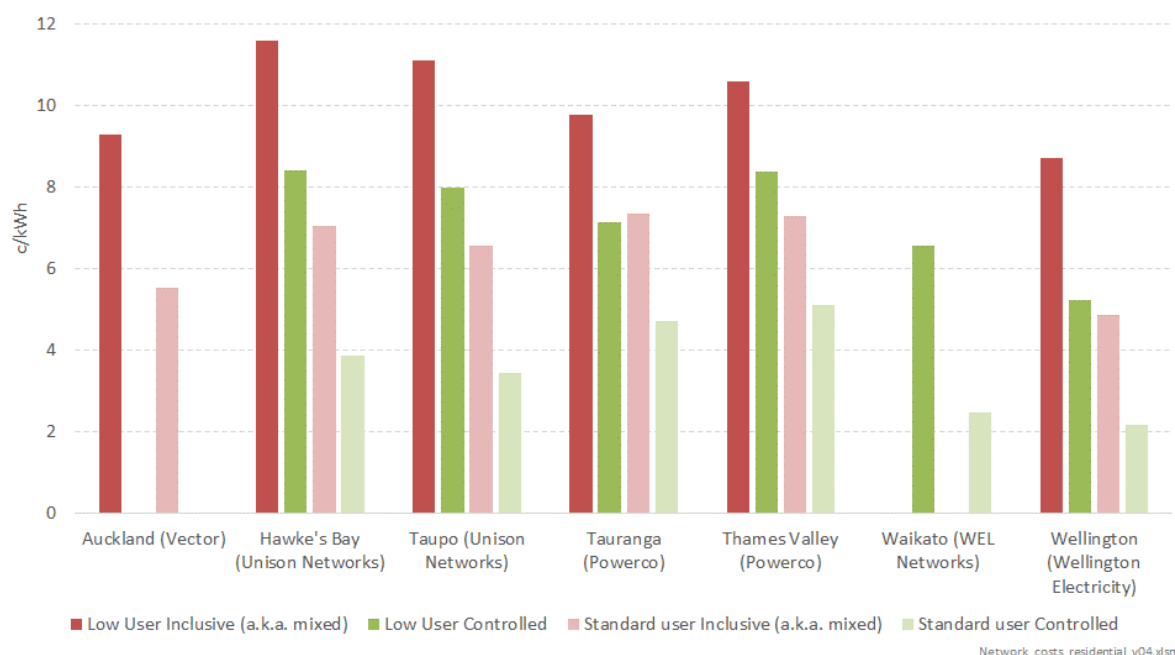
Despite the relatively simple underlying structure of current electricity network tariffs, there is considerable variation as to the price that consumers currently face for space and water heating. This is illustrated in Figure 24 and Figure 25 below.

Figure 24: Electricity network tariffs applying to space heating in a sample of different network areas



²⁷ The prospect for consumers completely disconnecting from the electricity grid through becoming self-sufficient via PV, batteries, diesel back-up and non-electric heating options is not considered in this study. This is because indicative analysis indicates such options are likely to be uneconomic based on current costs for most situations.

Figure 25: Electricity network tariffs applying to water heating in a sample of different network areas



The factors driving such variation in electricity network tariffs are:

- Different approaches for rewarding controlled water heating, in particular whether controlled water heating is metered via:
 - a separate controlled meter with an associated ‘controlled’ network tariff; or
 - a single meter covering the whole property with the network discount applied for control applied to an ‘inclusive’ tariff which applies to the whole property.
- The proportion of overall residential electricity network charges which the network company recovers via fixed charges.
- Whether the property qualifies for a low-user network tariff, or not.
- Significant differences in the share of common overall costs charged by electricity network companies to residential customers in aggregate. In turn this can reflect differences in:
 - the proportion of residential customers on a network;
 - differences in approach taken by network companies as to how they apportion common costs among different customer classes; and
 - underlying differences in the common costs of the different networks (e.g. reflecting rural / urban differences).

In some cases, the variations may reflect underlying differences in the economic cost of providing electricity network services (e.g. due to differences in the customer density on networks). In other cases, they do not reflect any specific difference in costs, but instead arise from differing approaches to *recovering* overall costs.

Furthermore, the scale of the variation in network charging approach is such that it can have a significant impact on the relative economics of electricity space and water heating versus alternative fuel options. Thus, two consumers whose heating requirements and other characteristics are largely identical could face significantly different price signals purely as a function of the charging approach

their network company has adopted – even if the underlying resource cost implications of choosing electric heating are identical.

It is outside the scope of this exercise to model each and every variation in electricity network charging approach. Further, it is possible that there will be significantly more variation in network charges in the future. This is because of the potential significant restructuring of electricity network tariffs in coming years as distribution companies take advantage of smart metering and billing technology in order to send more cost-reflective price signals to their consumers.

Thus, it is possible we will see new electricity mass-market distribution tariff structures including: time-of-use structures (e.g. some combination of summer/winter and day/night/peak charging), capacity charges, and maximum demand charges.²⁸

Rather than try and model all these existing and potential new network charges, the analysis has instead sought to estimate the likely ‘true’ economic cost of increased demand from electric heating.

In this, it is considered that the key long-term demand-related driver of electricity network costs is not the volume of kWh flowing across the network, but is instead the level peak kW demand (which is sometimes expressed as the peak kVA demand)²⁹ as this dictates the size of a significant proportion of network assets needing to be built.

Accordingly, the network cost of increased demand growth is likely best expressed on a \$/kW/yr basis, where the kW relates to the kW demand at the time of the *network’s* peak, and the \$ relates to the annualised cost of investment in the network to increase capacity by a notional extra kW.

Network costs are typically ‘large and lumpy’ making estimation of the \$/kW/yr impact of demand on such costs challenging. For example, a significant investment may be required in a particular part of the network in a few years’ time which, once made, may not require further investment for another 30 to 40 years. Prior to the investment being made the cost of increased peak demand is likely to be extremely high, whereas just after the investment is made, the cost of increased peak demand will be very low.

Accordingly, in order to derive likely order-of-magnitude estimates, the approach which has been taken is to use published estimates of the long-run marginal cost (LRMC) of network investment to meet demand growth on average across a wide range of network situations, and over a long period of time.

²⁸ Capacity charges are charged on a \$/kVA/yr basis, with the kVA element being based on the size of the connection to the consumer’s property. At the moment this is typically 15kVA for mass-market consumers, but it is possible that AMI technology that is being rolled out will enable consumers to elect to have a smaller capacity connection – with their supply being interrupted if their instantaneous consumption goes above this level.

Maximum demand charges are charged on a \$/kW/yr basis, with the kW element being the consumer’s measured contribution to the *network’s* peak demand in a particular period.

²⁹ In some situations peak demand is expressed on a kW basis, and in other situations it is expressed on a kVA basis. The difference between the two relates to the power factor of the demand. For the purposes of this analysis, the two can be considered to be broadly equivalent.

There doesn't appear to be much published analysis of these costs in New Zealand, with only one significant example having been found: Orion's derivation of a 'Long Run Average Incremental Cost' (LRAIC) as part of its development of its network prices.

Accordingly, this Orion example has been supplemented with another estimate using data from the NEM in Australia. There, distribution companies are required to develop estimates of the LRMC of meeting demand growth as part of developing their network prices.

For mass-market customers, Orion has estimated a distribution network LRAIC of \$101/kVA/yr. It has also passed-on the transmission charge in such a way that this equates to a cost of \$51/kVA/yr. This gives a rough estimate of peak-demand-driven network LRMC of approximately \$150/kVA/yr.³⁰

For comparison, the average of the Australian network companies' distribution LRMC estimates is A\$235/kW/yr³¹ (\approx NZ\$260/kW/yr). No specific estimate of the Australian transmission LRMC has been found in these pricing documents.

As can be seen, there is significant difference between the Orion and Australian estimates, with the Australian estimates of the distribution LRMC being two-and-a-half times that of Orion's estimate. Part of this may reflect different network circumstances, but it is suspected that a significant driver of the differences relates to the different approaches in deriving such estimates:

- Orion's approach is to take the estimated replacement cost of the entire existing network, and divide those network costs which are assessed to be driven by peak demand by the quantity of current peak demand.
- The Australian networks' approach is to project forward different levels of peak demand growth over a long period of time, and estimate the different levels of costs that will be incurred to meet such demand growth.

It is outside the scope of this study to comment on which approach is likely to give the best estimate of the 'true' network cost implications of peak demand growth. Accordingly, a range of different cost estimates are used, reflecting this range between the Orion and Australian numbers.

Further, the above estimates implicitly assume that future peak demand growth from electric heating will give rise to the need to make additional network investment to meet such growth. However, in many New Zealand networks this is currently not the case, either due to significant headroom capacity or due to such networks facing *declining* underlying demand.

Accordingly, a 'Low' LRMC estimate has also been developed which assumes that any rise in heating-related peak demand will not give rise to any network investment requirements for many years.

In considering whether increased electric heating demand at peak will likely give rise to the need for network investment, a key assumption relates to the uptake of electric vehicles (EVs). If large-scale EV uptake were to occur³² and the cost of charging vehicles at peak were not signalled, it is likely that EV demand would rapidly use up any spare network capacity. Accordingly, in such a future,

³⁰ As mentioned previously, \$/kVA/yr and \$/kW/yr can be considered to be broadly equivalent for the purposes of this analysis.

³¹ "Efficiency of Tariffs for Current and Emerging Technologies. A report for the Australian Energy Market Commission", NERA, 21 July 2014

³² In this, it is considered that EV uptake of a scale where 'just' 5% to 10% of household were to have EVs would have a material impact on electricity demand.

increased demand growth at peak from other sources of demand such as heating would definitely give rise to the need for increased peak investment.³³

In order to estimate the economic cost of space and water heating on a \$/kWh basis, these estimates of the \$/kW/yr LRMC of peak-demand driven network expansion are factored by estimates of:

- the within-year and within-day shape of demand, and thus what proportion of demand occurs during periods where peak demand is likely to occur (i.e. morning and evening peak periods in the winter); and
- what proportion of this demand which occurs at peak is capable of being controlled.

This second factor means that even if an appliance generally consumes power during periods where peak demand is most likely to occur (e.g. winter evenings), if it is capable of being controlled during the few periods of actual peak demand (e.g. the few coldest July/August evenings in the year) then its peak demand implications will be a lot less than would be suggested by its general pattern of consumption.

For this, 80% of electric water heating demand is assumed capable of being reliably controlled at peak. This means that electric water heating demand has relatively little network peak demand growth implications.

Conversely, only 5% of electric space heating demand is assumed to be capable of being reliably controlled at peak. This reflects the fact that:

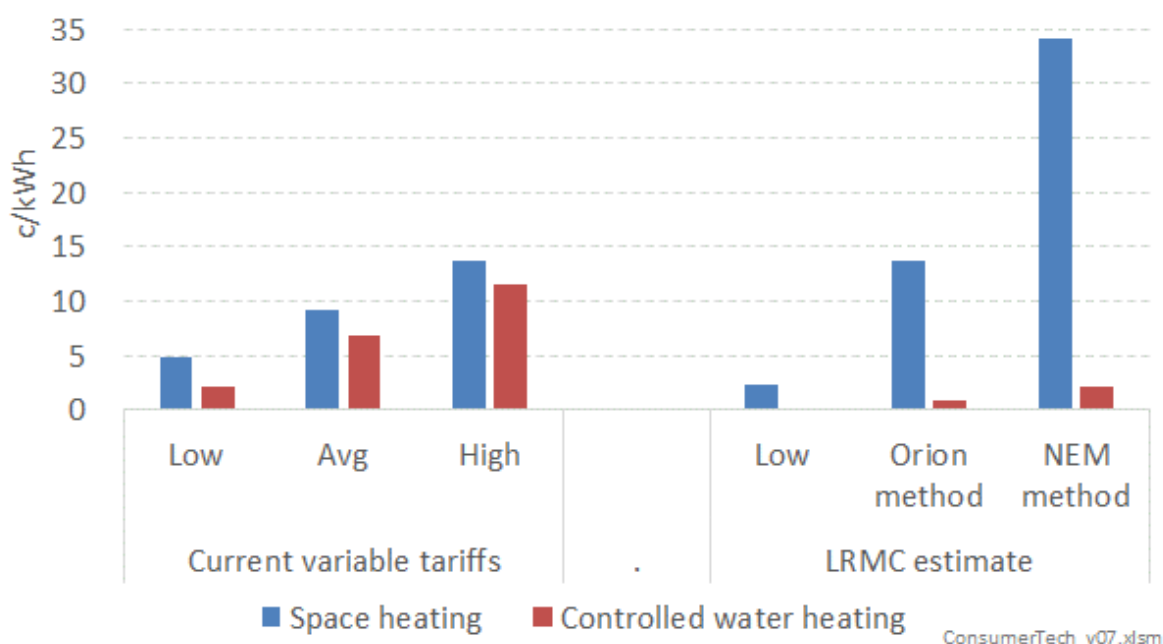
- a) little or no space heating is currently connected to circuits which can be controlled by a network company; and
- b) space heating is generally far less suitable for being controlled for the periods of time necessary to reliably manage peak demand.³⁴

Figure 26 below shows the overall estimated network cost implications of space and water heating demand using the above framework and assumptions, and also compares them with the current range of observed prices as illustrated in Figure 24 and Figure 25 above.

³³ It is potentially the case that if the network costs of charging their EVs at peak are signalled to consumers, network investment could be substantially delayed due to encouraging consumers to not charge their EVs at such times, but instead at night. However, such an outcome would not mean that electric heating should not be considered to have no peak demand cost. This is because if signalling peak prices to consumers is necessary to prevent the need for peak investment, then all demand at peak (whether it be EV, heating, lighting, etc.) should be considered to impose such peak costs on the system.

³⁴ Conversations with some network companies indicate that whereas hot water can be controlled for 4-5 hours in the coldest winter evenings without much customer disruption (due to the large amount of stored heat in an electric hot water cylinder), the same is not true of space heating given that the heat from a large proportion of New Zealand houses will escape relatively quickly due to a lack of insulation. Further, the human welfare consequences of a cold house in the coldest winter evenings are significantly more severe than the human welfare consequences of running out of hot water if a household happens to consume a lot of hot water during these periods.

Figure 26: Demand-weighted average electricity network costs of heating demand³⁵



The above analysis appears to indicate that, in general:

- Consumers with electricity space heating appliances may currently be facing electricity network prices which are materially lower than the ‘true’ underlying network cost implications.
- Conversely, consumers with controlled water heating are currently facing electricity network prices which are materially higher than the ‘true’ network cost implications of such demand.

Over time, if networks move to the more sophisticated tariffs made capable by advanced metering (e.g. time-of-use tariffs or maximum-demand tariffs) there is the potential for these distortions to progressively be removed, and the network component of the prices consumers see will be a closer reflection of the ‘true’ underlying cost.

Gas network costs

The economics of gas networks are similar to those of electricity networks, in that a significant proportion of the costs of both networks are driven by the need to have sufficient capacity to meet peak demand.

Therefore, in principle, the nature of the network cost implications from gas heating should be very similar to that from electric heating.

However, in practice, it seems likely that the gas network cost implications of increased peak demand will be lower than for electricity networks. This is because it appears that in the current New Zealand context, there is more surplus capacity on the gas transmission and distribution networks than on the electricity networks.

This evaluation is based on inspection of the proportion of planned expenditure under the Commerce Commission regime relating to “System Growth” for gas networks as compared to electricity networks, as well as anecdotal comments from some network companies.

³⁵ As set out on page 21 of the main report, “Low” shows results using the lowest current observed variable price for electricity applying to space or water heating. “Avg” shows results using the average current observed variable price for electricity applying to space or water heating, and so on for “High”.

An additional factor is that electricity networks must cope with instantaneous peaks, whereas gas networks can meet short-term and localised peaks using linepack.³⁶

Further, unlike electricity which has the potential for significant demand growth relating to EVs, there is no such game-changing technology on the horizon for gas.

Lastly, the proportion of demand composed of residential load is materially lower for gas networks than for electricity networks.

On balance, therefore, it would appear that increased residential demand for gas for space or water heating would be unlikely to have a material impact in terms of the need for gas network investment, whereas electricity demand increases would be likely to have such an impact.

From an economic perspective, it therefore appears likely that the network cost implications of increased space and water heating demand for gas would be low or close to zero in many instances.

This could suggest that recovering gas network costs predominantly (or entirely) from fixed daily charges would be preferred for efficiency, because it would not discourage utilisation of the available spare capacity in gas networks at times of peak demand.

However, reliance on fixed charges may not promote efficient usage decisions. This is because gas is a *discretionary* fuel for most customers – particularly residential consumers where they have competitive heating alternatives from other fuels such as electricity and wood.

Thus, whereas an electricity fixed charge is not an avoidable cost for most consumers and therefore is less likely to influence electricity consumption decisions³⁷, a gas fixed charge is an avoidable cost.

Accordingly, recovering gas network costs via a fixed charge could influence consumers' decisions as to whether to use gas appliances at all for meeting their space and water heating requirements. Indeed, for consumers with below-average consumption this will almost certainly be the case, with gas being more likely to appear uncompetitive with electricity or wood alternatives.

Over time, therefore, it is likely that recovery of gas network charges via fixed charges for residential consumers will result in the proportion of smaller-sized consumers using gas becoming progressively less, than if gas network charges were recovered via variable charges.

Conversely, for consumers above a certain level of consumption, recovering some proportion of gas network costs via a fixed charge may maximise the competitiveness of gas versus other fuel options.

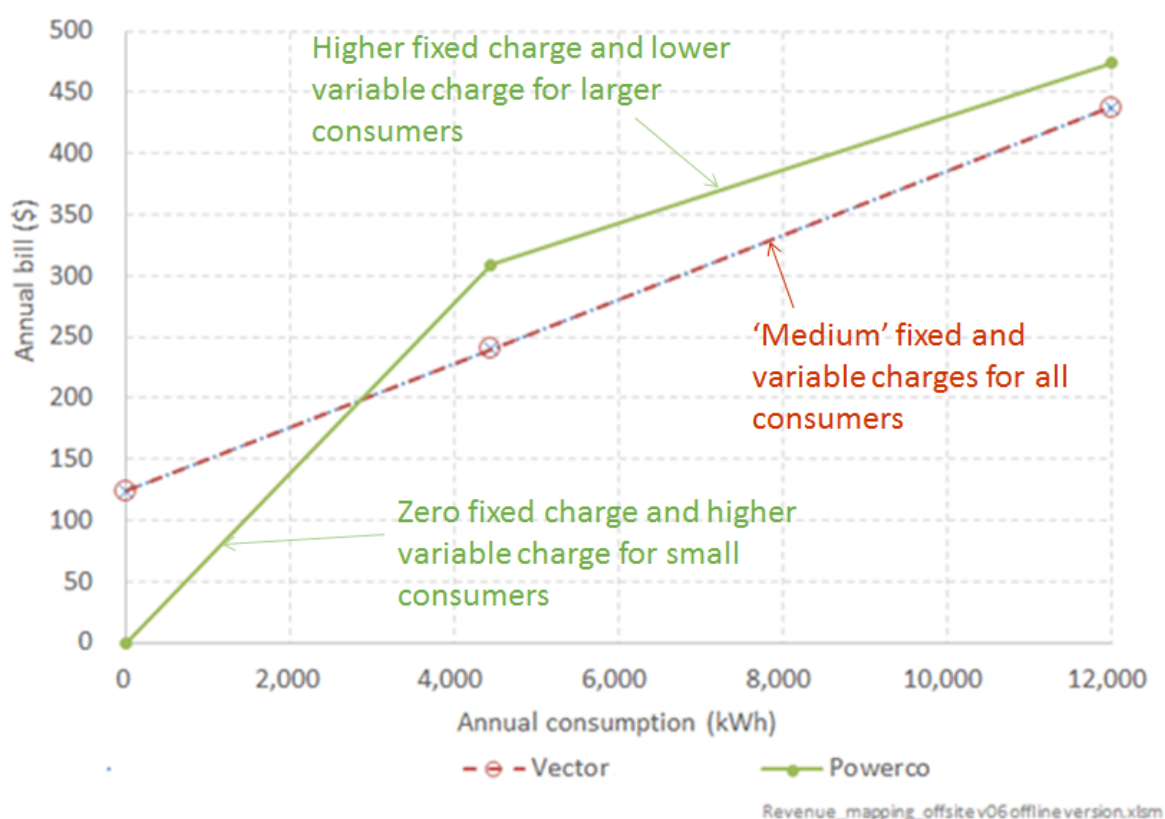
More generally, the most efficient tariff for residential customers could be some form of hybrid structure whereby the proportion of costs recovered from fixed charges varies with the amount of gas consumed.

As illustrated in Figure 27 below, an example of this type of approach is that adopted by Powerco. Under its pricing, consumers can elect to either be on a structure with zero fixed charge and higher variable, or higher fixed and lower variable, with the cross-over point of indifference being approximately 4,200 kWh/yr.

³⁶ Linepack refers to the range of allowable pressures in a gas pipeline. Thus, if demand were particularly high for a period of time (e.g. 12 hours) it would be possible to meet this demand by drawing more gas out of the pipeline than was being injected into it during this 12 hours, with the 'extra' gas being provided by the resultant drop in pressure associated with gas supply being less than gas demand.

³⁷ This analysis does not consider the income effects of different charging structures for those consumers suffering from fuel poverty. Consideration of such issues is outside the scope of this analysis.

Figure 27: Variation in residential network bills with annual consumption



The other choice that network companies face in deciding their pricing approach is how to allocate costs between the various consumer groups. For the purposes of gas network cost recovery, the three main customer groups are residential, commercial, and industrial.

If gas networks were facing capacity constraints then it would appear most appropriate to allocate costs to these customers in proportion to their use of this scarce capacity – and to ensure that the structure of prices were such as to signal this \$/kW/yr capacity cost for consumption at times of peak.

However, if capacity is not scarce, and efficient network pricing is more about recovering network costs in the least distortionary manner, other factors come into consideration. In particular, if network demand from one group of consumers is much more price-sensitive, it could be appropriate to recover proportionately less of the network costs from this more price-sensitive group, than from other groups of customers for whom gas is strongly competitive.

Taking the relative price sensitivity of consumers into account when determining how to allocate network costs to consumers is known as 'Ramsey pricing', and has been shown to result in efficient outcomes.

In the context of gas, it appears that, in general, residential consumers are likely to be more price-sensitive than industrial consumers who use gas for process heat. This is based on the analysis set out in sections 2 and 3 analysing the economics of different fuel options for residential and industrial consumers, respectively.

Therefore, it could be more efficient to allocate a greater proportion of gas network costs to industrial consumers than would be suggested by the relative extent to which industrial and residential consumers use network capacity at peak.

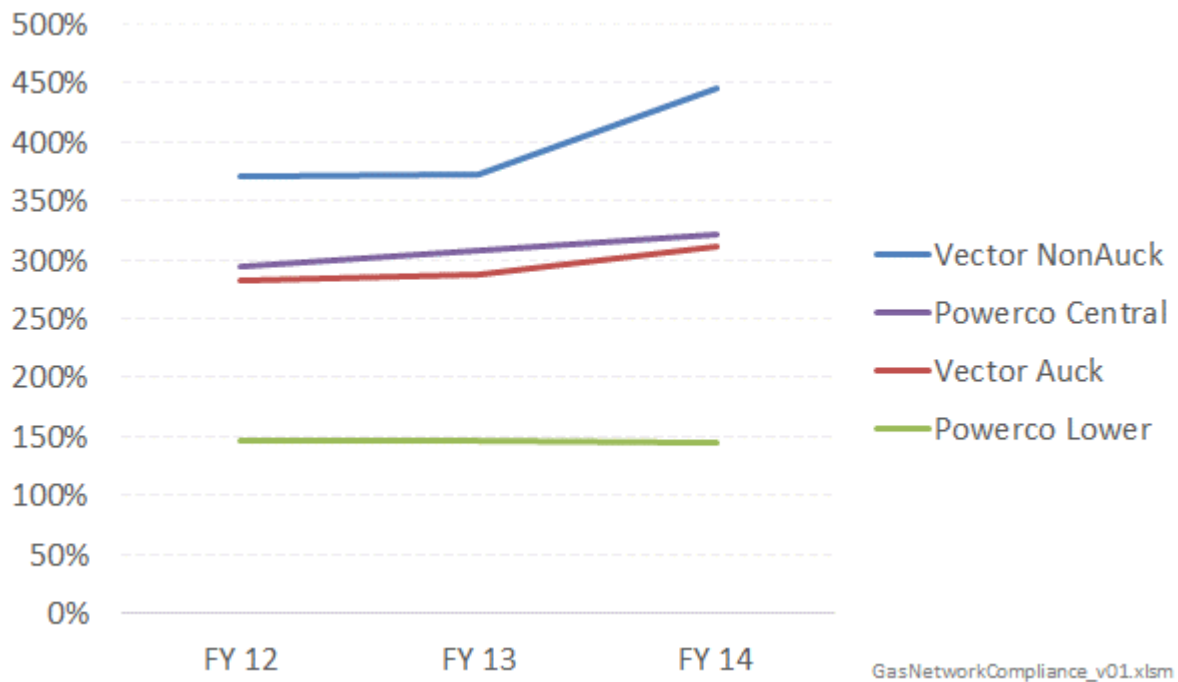
It is beyond the scope of this study to analyse in detail the extent to which such allocation is already occurring, or could occur to a greater extent. However, it is notable that gas networks in general

appear to have re-balanced their charges over recent years in the *reverse* direction. i.e. a progressively greater proportion of network charges being allocated to residential customers.

This is illustrated by Figure 28 below which shows how the ratio of the proportion of revenue recovered from residential customers divided by the proportion of total gas distribution network demand from residential customers has moved over time. Such a measure ‘corrects’ – albeit in a very simplistic fashion – for changes in the overall quantity of demand from different consumer groups over time, and also for changes over time relating to the overall quantity of revenue network companies are allowed to recover under the Commerce Commission price control regime.

As can be seen, only the ‘Powerco Lower’ region has not seen an increase in the proportion of revenue recovered from residential consumers.

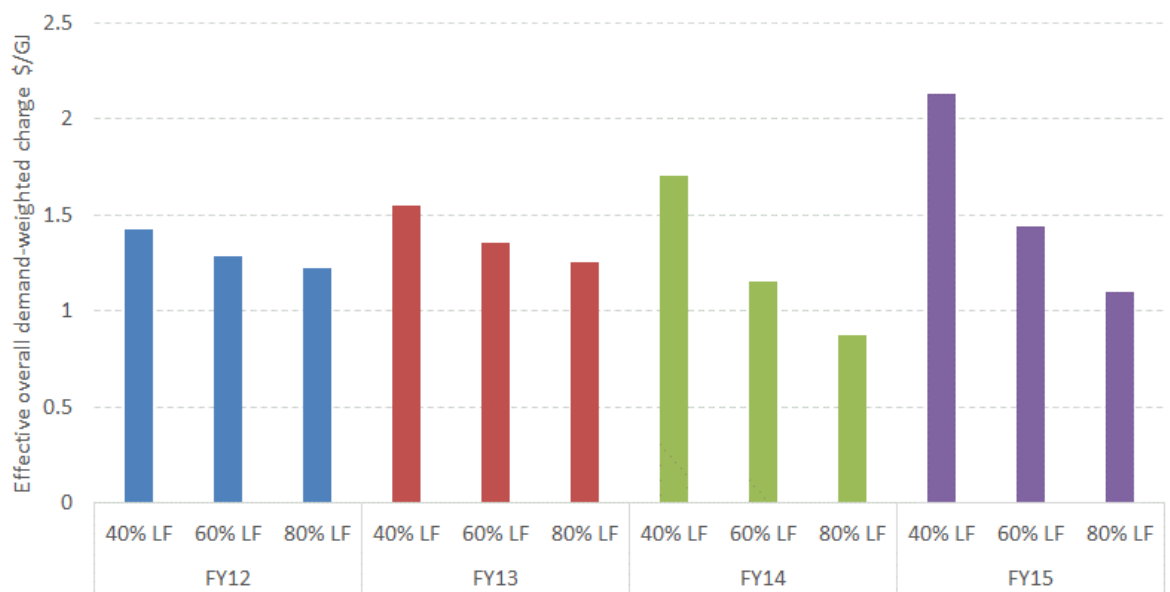
Figure 28: Ratio of residential gas network charges to residential gas network demand



Source: Concept analysis of Commerce Commission disclosures

As illustrated in Figure 29 below, similar outcomes appear to have occurred on the Vector transmission network, with a progressive re-balancing of charges away from throughput-based recovery to capacity-based recovery. This is resulting in a higher proportion of costs being recovered from residential consumers relative to industrial consumers, because residential consumers typically have a much lower load factor (i.e. are ‘peakier’) than industrial consumers.

Figure 29: Historical movement in the effective \$/GJ transmission charge for consumer groups with different load factors (LFs) at the Pukekohe delivery point³⁸



Revenue_mapping_offsitev06offlineversion.xlsm

The analysis in sections 2 and 3 on the economics of different fuel options suggests that this re-balancing may have a negative effect on gas demand in the long term. i.e. reductions in demand from residential consumers switching away from gas may not be compensated for by increases in demand from industrial gas consumers.

No specific analysis has been undertaken as to why gas network companies may have adopted the pricing approaches they have. However, anecdotally, it appears that the incentives on gas network companies from the Part 4 price control regime may have had some influence. In particular, throughput-based pricing significantly increases year-on-year revenue volatility for network companies under the current form of the price controls for both the transmission and distribution companies. In particular, if demand is lower/higher than projected by the regulator when setting the price control (e.g. due to unusually warm/cold weather, or the regulator under-/over-forecasting underlying demand) the network company will earn lower/higher revenues, without any potential wash-up to correct in future years.

It is potentially the case that different forms of price control may alter gas network companies' incentives for how they structure prices, and result in network companies being more comfortable with pricing structures which result in more efficient outcomes – in terms of utilisation of the existing gas network – over the longer-term.

For the purposes of evaluating the relative economics of gas space and water heating compared with other alternatives in section 2, an approach has been taken whereby a 'less-distortionary' gas pricing approach was estimated. This involved:

- 'unwinding' the recent inter-consumer-group re-balancing between residential, commercial and industrial consumer groups illustrated in Figure 28 and Figure 29 above; and
- recovering the residual revenue needed from residential consumers via a variable \$/GJ throughput charge.

³⁸ Pukekohe has been chosen as a representative transmission point for the Auckland area.

This approach was adopted for the purposes of analysis given the information available. It provides a more robust analysis than use of raw tariff data, but the results should not be treated as definitive. It is likely that an even less-distortionary gas network pricing approach could be achieved through different approaches to allocation of gas network costs between consumer groups, and/or different approaches to determining the proportion of revenue recovered via fixed charges (e.g. similar to the pricing approach adopted by Powerco and illustrated in Figure 27). However, estimation of such an approach is outside the scope of this exercise.

Gas connection costs

Roughly 260,000 North Island households are connected to the gas network. However, it is estimated that a similar number of households are not connected but are 'gas-fronted'. i.e. a gas pipe runs along their street.

These gas-fronted properties represent a significant potential additional source of gas consumers. However, connecting these properties to the gas network involves some up-front costs in terms of laying a pipe from the gas main to the consumer's property.

It is estimated this cost is approximately \$1500 per property. This is a relatively substantial additional cost for a household considering whether to switch to gas and, anecdotally, is understood to be a contributing barrier to many households making such a switch – with the cost of changing-over the appliances being another (and actually greater) barrier.

In some cases this barrier may be due to households facing capital constraints. In others, households may be concerned about potentially moving house before they can get the full value of the gas connection, and they won't be 'compensated' through the cost of the connection being reflected in an increase in the value of their house. More generally, recent insights from behavioural economics have shown that people are generally not good at evaluating options which have high up-front costs with the benefit being spread over a longer period of time.

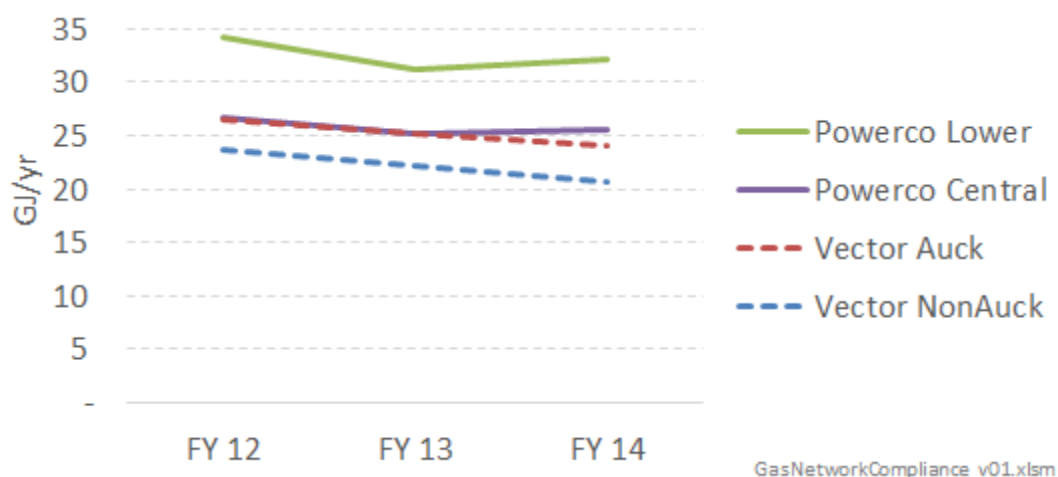
All the above factors can result in consumers not electing to switch to gas, even if it could be the lowest cost option over the life of the asset.

Powerco has sought to overcome this barrier through funding some or all of the upfront cost of the gas connection, and recovering the capital costs through inclusion in their regulatory asset base.

Anecdotally, such measures appear to be having some success in improving gas uptake, and may explain some of the arrest in the decline in gas demand per residential ICP on the Powerco networks as illustrated in Figure 30 below.³⁹

³⁹ Some of the outcomes illustrated in Figure 30 may also be due to the type of network pricing practices by Powerco illustrated in Figure 27, and also due to some other promotional initiatives undertaken by Powerco such as its 'GasHub'.

Figure 30: Average gas consumption per residential ICP on different gas distribution networks



Source: Concept analysis of Commerce Commission disclosures

It is not clear whether regulatory and/or other factors (e.g. coincidence of overlap between electricity and gas networks owned by a network company) may explain the different approaches adopted by gas network companies to pricing and customer connections.

Retailer costs

For consideration of electricity and gas costs, ‘retailer costs’ cover the costs associated with metering, billing, marketing, and other aspects of customer service. Evaluation of such costs also includes the margin retailers earn.

In considering the impact on the economics of different heating appliances, the following are the key considerations:

Retailer costs do not vary with the quantity of kWh consumed by a customer

Accordingly, the least-distortionary means of recovering such costs could be considered to be a \$/day fixed charge.

This will improve the competitiveness of electricity heating appliances versus gas alternatives given that electricity (unlike gas) is not a discretionary fuel, and therefore such fixed costs should not be included in the evaluation of their relative economics.

Currently there is significant apparent variation in the extent to which retailers recover their retail cost-to-serve via fixed charges versus variable charges.

A simple analysis of tariffs⁴⁰ published on Powerswitch from a variety of different retailers for a variety of different areas suggests that some retailers are recovering most, if not all, of their retail costs and margin via the fixed charge, whereas others appear to be recovering most from their variable charges.

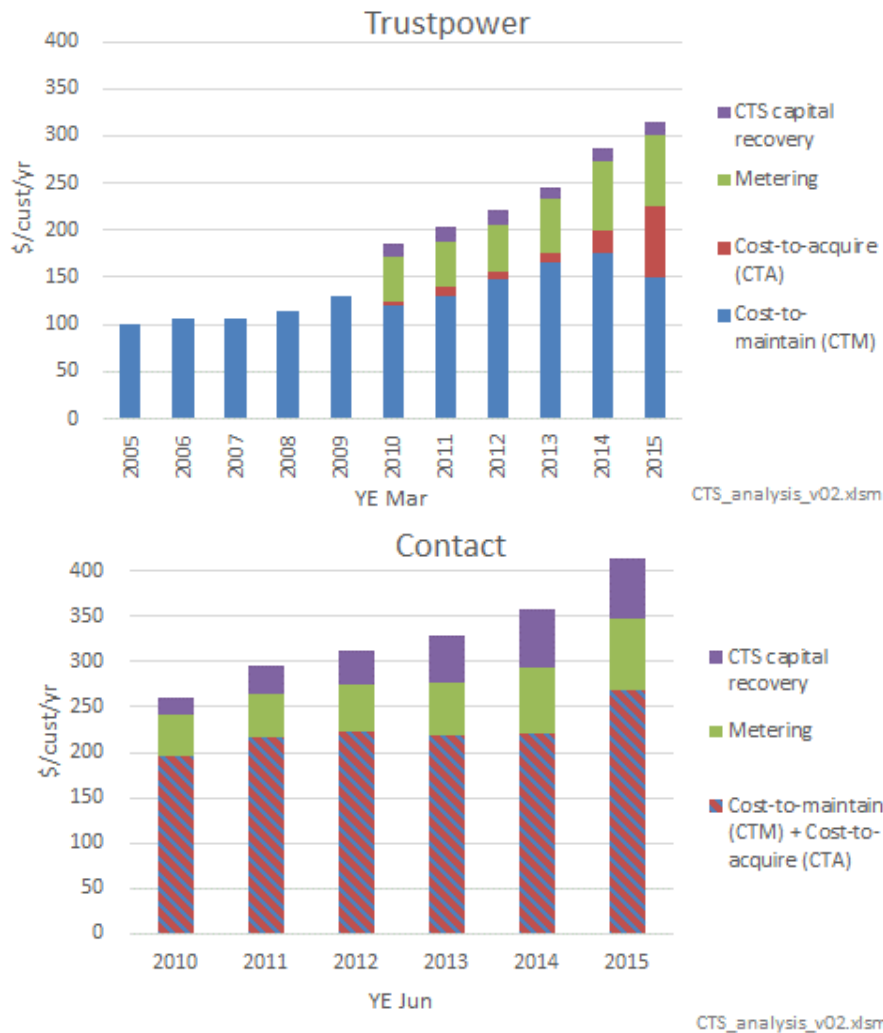
This variation in approach appears to apply as much to gas charges as to electricity charges.

⁴⁰ The analysis took published fixed and variable charges then subtracted published network charges and an estimate of the wholesale component of energy. The residual was considered to be for the recovery of retail costs and margin.

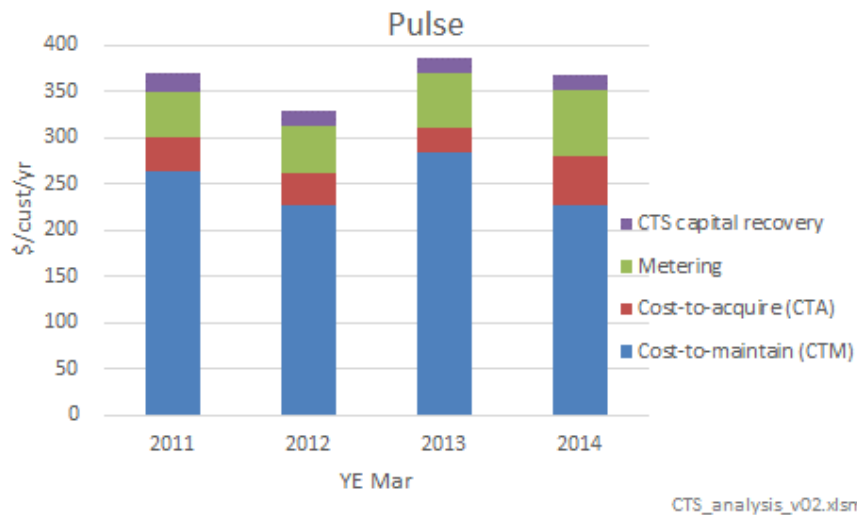
Retailer costs have risen significantly over recent years

As set out in Figure 31 below, retailer costs-to-serve (a.k.a. cost-to-maintain) and costs-to-acquire (a.k.a. marketing costs) appear to have risen significantly over the past 5 to 10 years.

Figure 31: Historical change in composition of CTS for three retailers⁴¹



⁴¹ The three retailers shown are the only ones whose accounts present information in a sufficiently disaggregated way to enable such estimation.



Source: Concept analysis of company reports and investor presentations

Given that the recovery of such costs via fixed charges will materially impact on the relative economics of gas versus electricity appliances, these cost increases are significant.

There are 'dual-fuel' economies from retailers supplying both electricity and gas

Most retailers who supply gas can also supply electricity. If a retailer supplies both services to a property there are opportunities to make material efficiencies in both the cost-to-serve (e.g. through 'single bill' service) and cost-to-acquire.

It is not clear what the scale of savings may be, but examination of dual-fuel discounts offered by retailers suggests that the incremental costs from acquiring a gas account as a dual fuel customer could be 2/3 of the costs of serving as a single-fuel customer.

This 2/3 value has been used to estimate the cost-reflective cost of servicing a retail gas customer.

Appendix B. Assumptions relating to mass-market space & water heating

Size and 'shape' of heat load

Size of heat load

A significant proportion of the lifetime costs of space and water heating can come in the form of up-front-capital costs for the appliance, or ongoing fixed costs relating to appliance maintenance or fuel-supply fixed charges.

Given that there is significant variation between the different fuel options as to the size of these fixed costs, the size of heat load can have a material effect as to which fuel option is best. Thus, it is generally less economic to choose an option with higher fixed costs if such costs are only going to be spread over a small quantity of kWh, even if the option has low variable costs.

To take account of this, the analysis considers the relative economics of the different fuel options for three different consumer heating requirements: a 'small', 'medium' or 'large' heating load.

This heating load is expressed as *useful* heat. i.e. how much actual hot water, or space heating is required. This is expressed in kWh_u, where the 'u' subscript denotes 'useful'.

For water heating, the heat loads are the same as was used for the earlier Consumer Energy Options study. These were based on analysis derived from the HEEP study. The values are shown in Figure 40 in the following sub-section.

However, for space heating, a different approach and associated heat loads have been developed.

The earlier Consumer Energy Options study estimated the likely range of different *overall* space heating requirements for different-sized properties in different locations and with different heating requirements (driven by factors such as level of insulation, desired indoor temperature, how much the home is occupied during the day, etc.). These different space heating requirements were then translated into an estimate of the number of heaters required for the entire house for each technology option, and the associated capital costs were calculated.

However, this approach ignored the fact that there can be very different heating requirements within a property. Thus, the amount of heat required for bedrooms is typically significantly less than for living areas. Similarly, a small room within a house will require much less heating than a large room.

Accordingly, for this study the economics of space heaters are considered in relation to individual space heaters being able to meet particular-sized heating loads within a property. The three representative small, medium and large heating loads are 500, 2,000, and 4,000 kWh_u, respectively.

This approach will give a more appropriate determination of the best approach for different requirements within the home. As set out in more detail in section 2.1, this approach doesn't mean that options which incur fixed fuel costs which apply to the property as a whole (e.g. gas fixed charges) will appear more expensive. This is because the analysis of a particular space heater situation also shows the effect of spreading these property-related costs across the likely heat load from all the space and water heating appliances for that property's situation.

'Shape' of heat load

As well as considering the overall quantity of heat consumed, it is also important to assess *when* such heat will be consumed during the day and year.

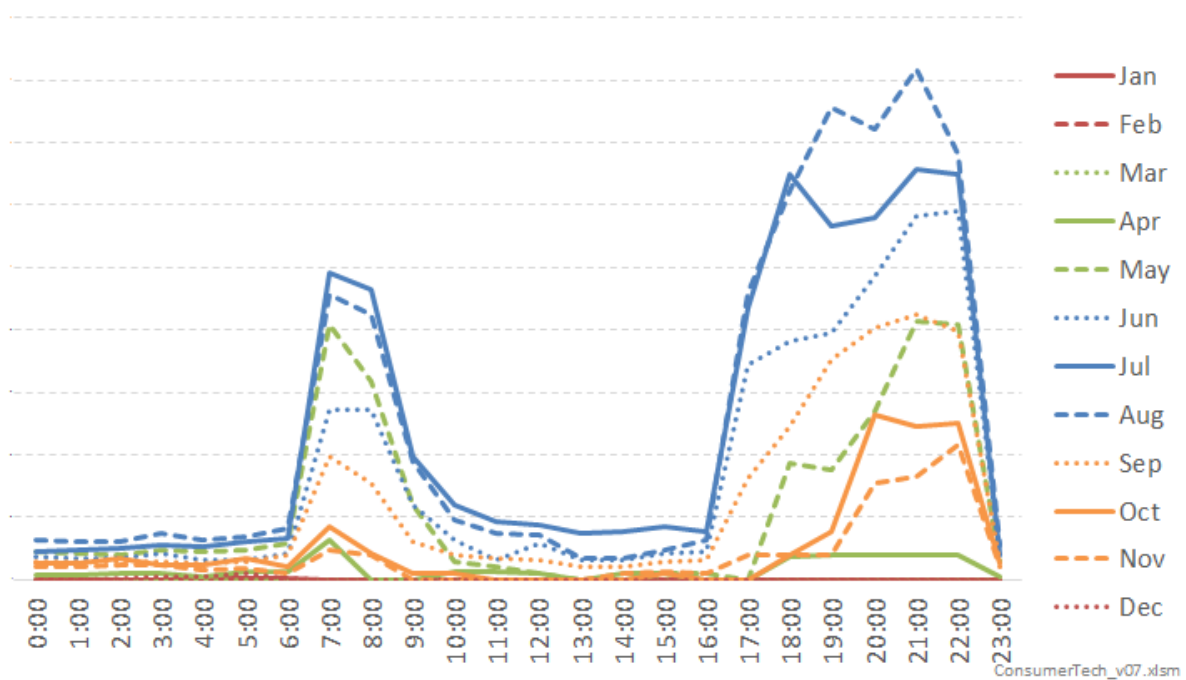
This is because for some fuels, particularly electricity and gas, there can be considerable variation in the underlying costs of supply depending on time-of-day and/or season. In particular, a large proportion of the costs of such fuels is associated with having sufficient capacity (both gas/electricity network, and gas upstream or electricity generation) to meet periods of peak demand. In general, demand is generally higher in mid-morning and early evening on weekdays, and also higher in winter than summer.

Thus a heating demand profile which is heavily concentrated towards these peak periods, will have significantly higher costs than a heating demand profile which is spread more evenly throughout the day and year.

Accordingly, in calculating the costs of the different options, the consumption profiles of space and water-heating loads are considered

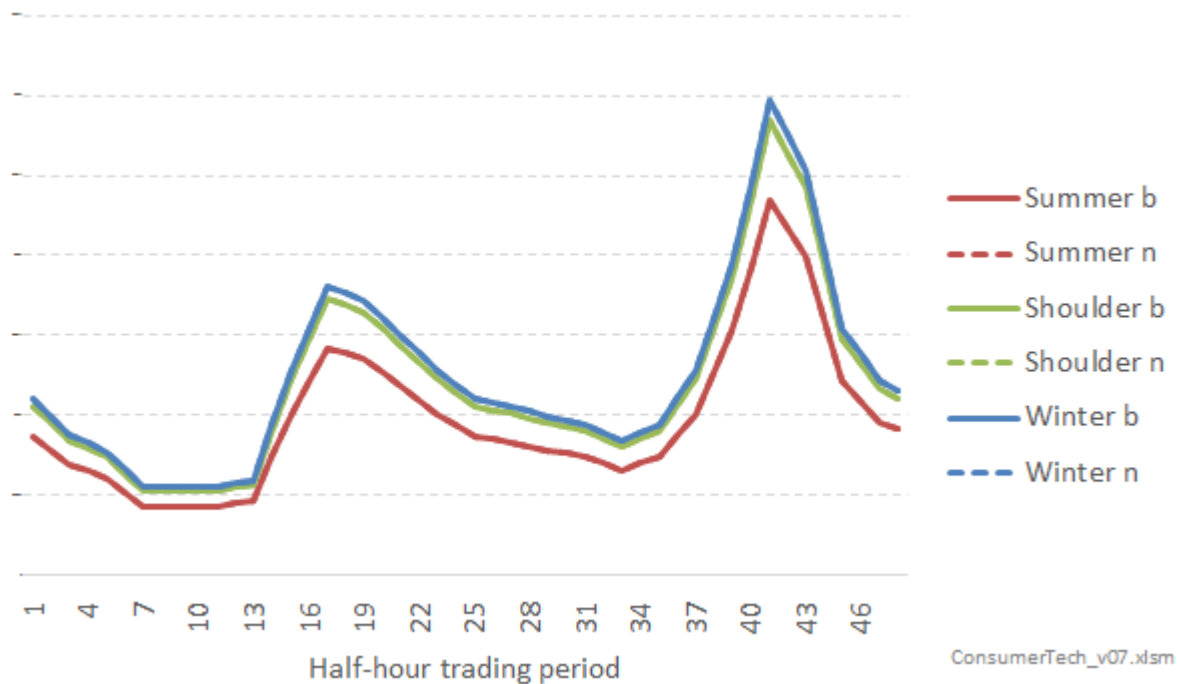
The profiles used are set out below.

Figure 32: Average residential space heating profile



Source: Concept modelling using Niwa temperature data

Figure 33: Average residential water heating profile⁴²



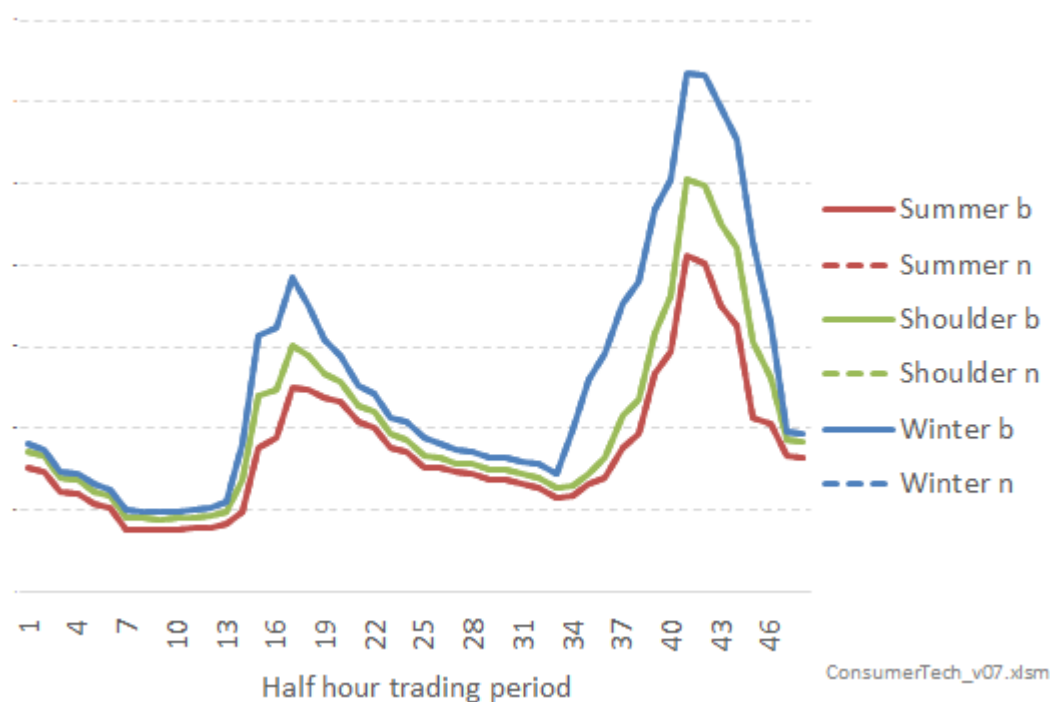
Source: Concept modelling using electricity grid demand data and HEEP seasonal data

As can be seen, space heating has a considerable seasonal shape as well as a strong diurnal shape, whereas water heating has much less of a seasonal shape, but still has a strong diurnal shape.

In addition to these space- and water-heating-specific heating profiles, the *overall* consumption profile of an average residential customer is used in this analysis. This is to enable calculation of the typical 'flat' cost which will currently be charged to consumers (based on the average residential profile), whereas the specific space and water-heating profiles enables determination of the 'true' costs for meeting such heating profiles. The average demand profile used is set out in the following figure.

⁴² The 'b' and 'n' refer to business and non-business days which, for this situation, are assumed to be identical for residential consumers.

Figure 34: Average residential demand profile



Source: Concept modelling

Heater appliance costs and efficiencies

The following graphs set out the assumptions used for the capital and installation costs, and the appliance efficiencies (a.k.a. coefficients of performance). These have been derived by Concept from a mix of research on appliance sales websites, and discussions with individuals in EECA and Consumer NZ.⁴³

It should be appreciated that these are the central estimates of such values. There have been observed to be significant ranges for most of the appliances for these various values, with installation costs additionally having significant property-specific ranges in costs.

With respect to appliance efficiencies, a key point to note is that some appliances vary in their efficiencies according to:

- the size of heat load; and
- the geographic location of the property.

With respect to variation in efficiency with the size of the heaters:

- For heat pump space heaters, the coefficient of performance of the heaters has been observed to get worse for progressively larger heaters. This is shown in Figure 38 below.

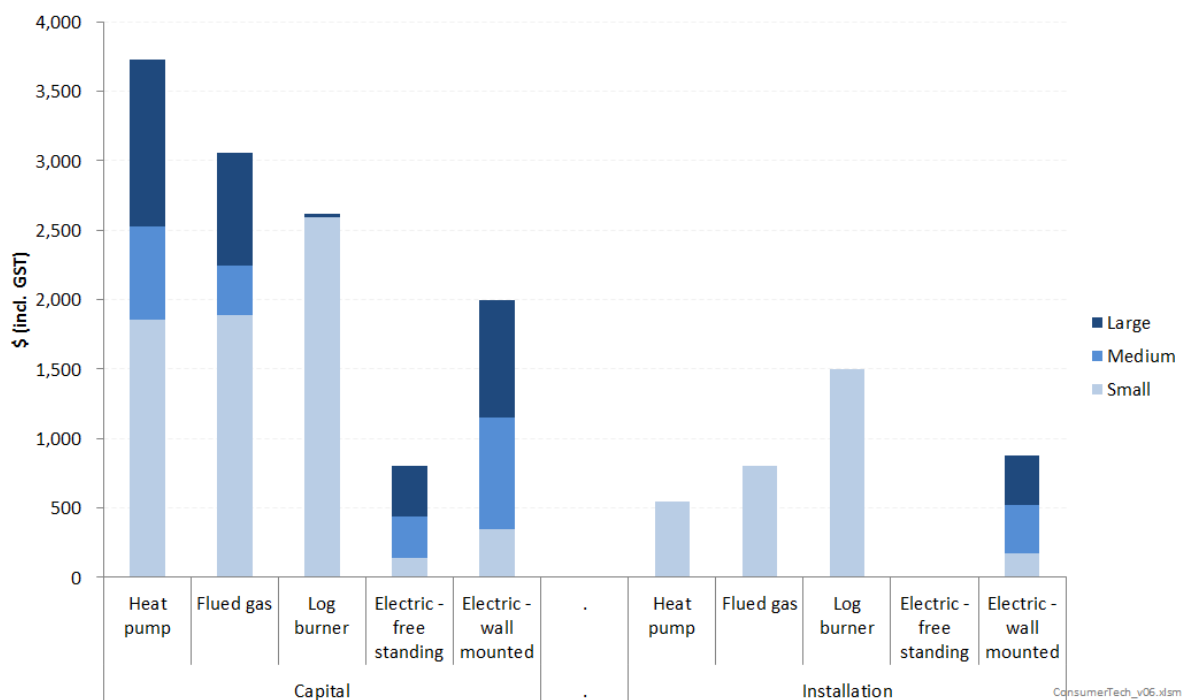
⁴³ It should be noted that, despite the helpful input of individuals from a number of organisations, these assumptions are entirely Concept's, and are not formally endorsed by any other organisation.

- For water heaters, the key factor is that cylinder standing losses account for a proportionately greater amount of useful heat for smaller heat loads. The values for the standing losses are based on published BRANZ analysis and are shown in Figure 40 below.

The geographic driver of heater efficiency relates to heat pump heaters (space & water) and solar water heaters:

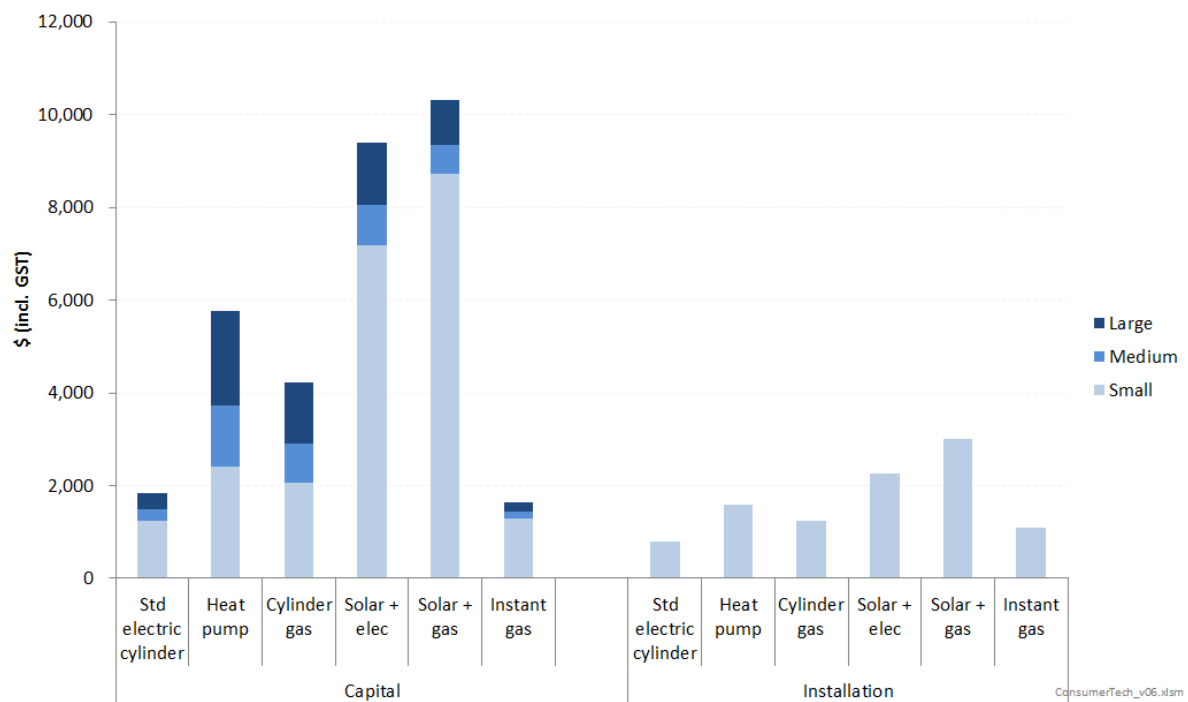
- For heat pumps, the coefficient of performance of the heater depends on the outside ambient temperature. Performance is worse for colder outside temperatures. This means heat pumps are materially more efficient in warmer climates than colder climates.
- For solar water heaters, the variation in performance relates to the amount of sunshine occurring in different parts of the country. Put simply, it means that solar water heaters are more efficient in relatively sunny Auckland than in less sunny Dunedin.

Figure 35: Space heater capital and installation costs



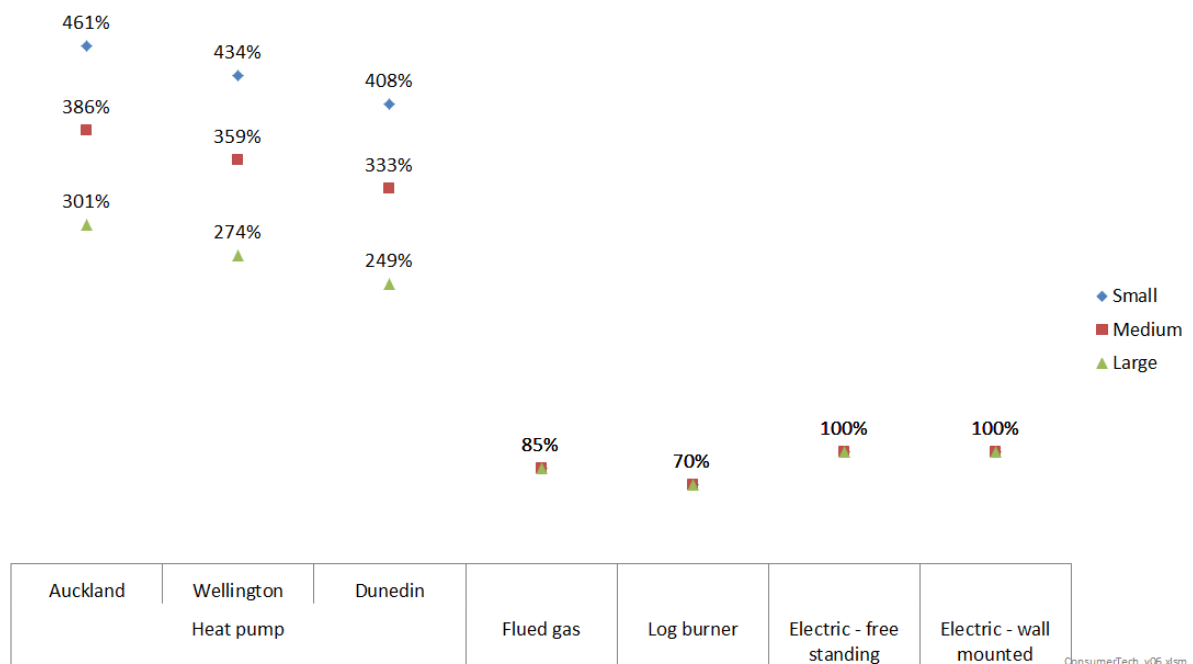
Source: Concept research from a variety of sources

Figure 36: Water heater capital and installation costs



Source: Concept research from a variety of sources

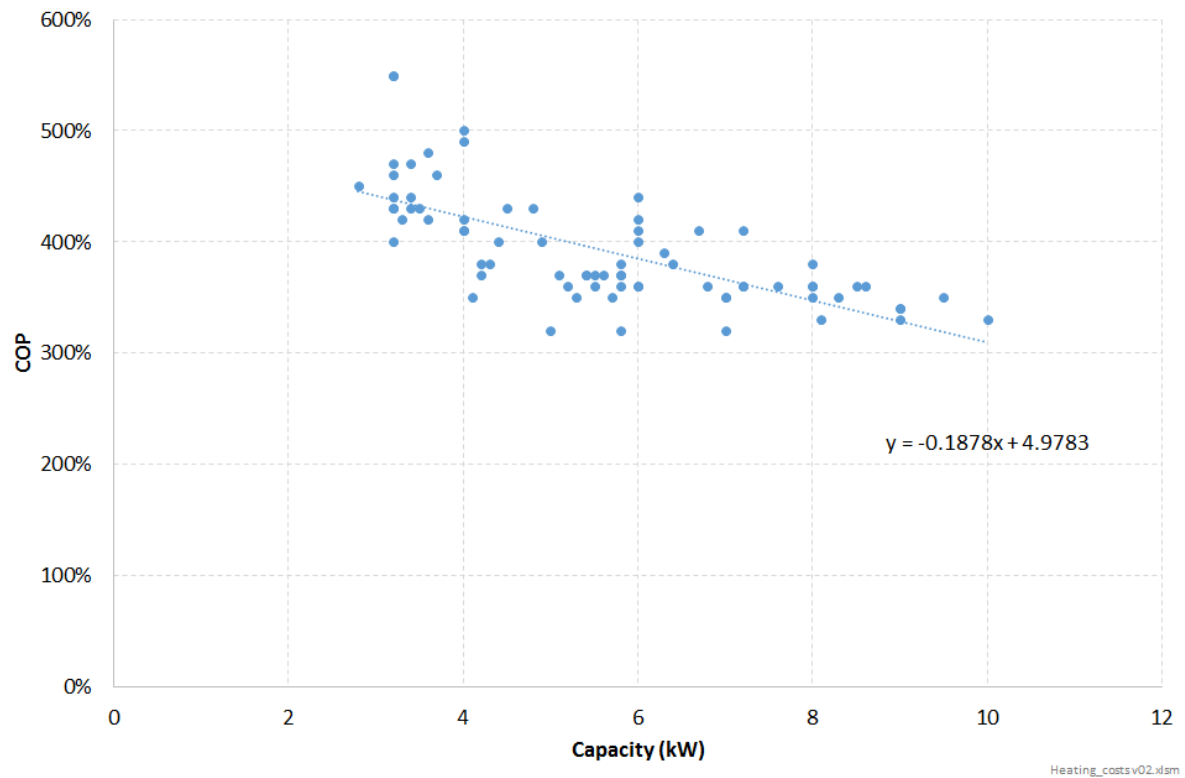
Figure 37: Space heating appliance efficiencies⁴⁴



Source: Concept research and modelling

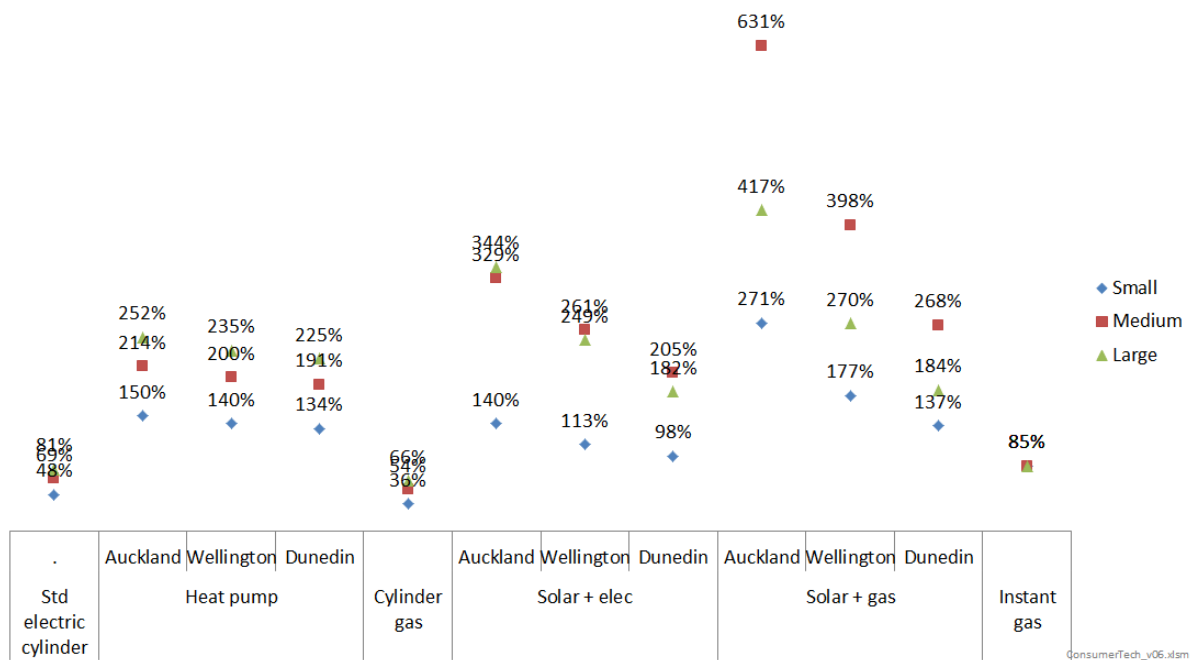
⁴⁴ Heat pump COPs have been derived from Concept modelling of effective COPs using NIWA data for hourly temperatures and known variation of heat pump COPs with ambient temperature. The variation between small, medium, and large is based on the observed variation in heat pump COP with size of heater as shown in Figure 38.

Figure 38: Variation in published heat pump coefficients of performance with heater capacity



Source: Concept research and modelling

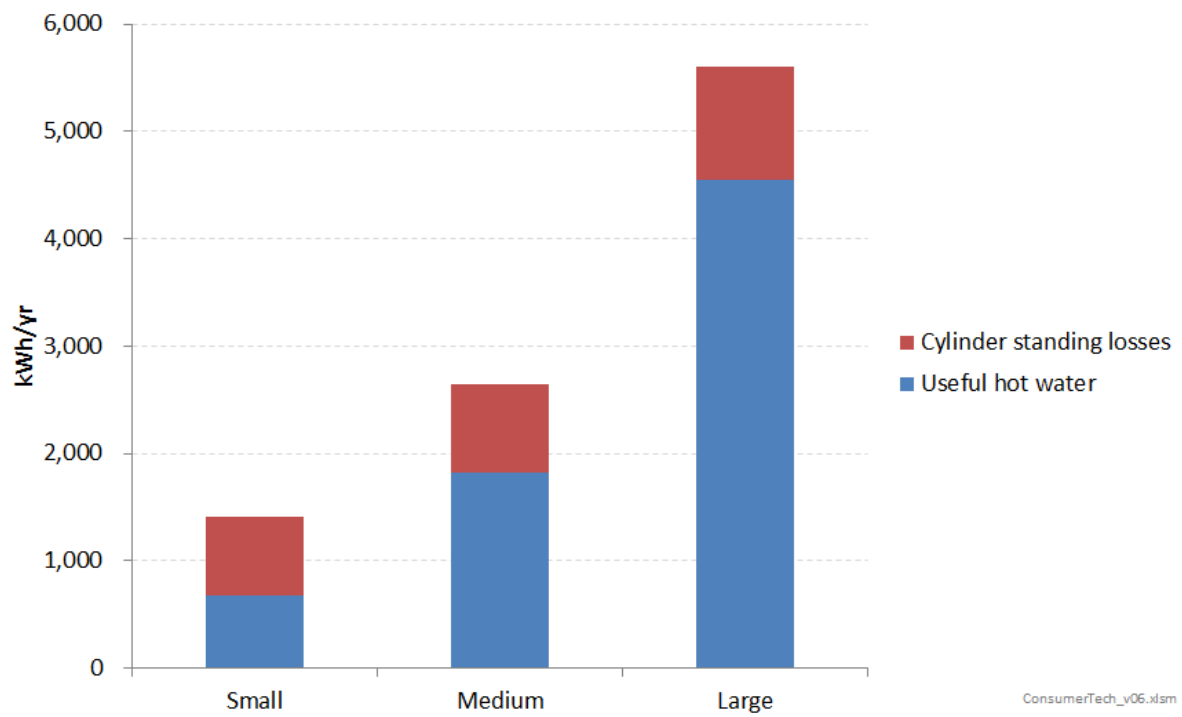
Figure 39: Water heating appliance efficiencies⁴⁵



Source: Concept research and modelling

⁴⁵ The variation in efficiency between cylinder-based systems of different sizes relates to the proportion of standing losses for different sized heat loads as illustrated in Figure 40 below. The regional variation for heat pumps and solar systems relates to the differences in incoming water temperature and (for solar) differences in the amount of sunshine. The superior efficiency for solar + gas versus solar + electric is the ability for solar + gas to keep the water in the cylinder at a lower temperature and use the gas to boost the water to the correct temperature. This reduces the standing losses for such systems.

Figure 40: Average cylinder-based standing losses and useful hot water loads



Source: Concept analysis using HEEP data

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Appendix C. Non-price quality aspects of the different mass-market heating options

Although the above analysis is based purely on the lifetime cost of delivering hot water or space heating, there are other non-price aspects of the different heating options which can be of value to many consumers.

Water heating

For water heating, the principle non-price differentiator is between cylinder-based options and instant gas heating, and whether such options have a risk of running out of hot water.

For cylinder-based options, within a window of a few hours, consumers are limited to the amount of hot water stored in the cylinder and can run out of hot water if they use it intensively. (Something that a family with teenagers hogging the shower have been known to experience...). This may be exacerbated in winter if the hot water electricity is being controlled, and/or if the cylinder is too small for the particular family situation.

Conversely, instant gas water heating will never run out.

Another non-price quality aspect that some people enjoy about instant gas water heating is that it doesn't result in interior house space being taken up by a large hot water cylinder. Conversely, some people like the warmth from a hot water cylinder and store their clothes in an 'airing cupboard' located next to the cylinder.

Table 1 below highlights some of the main non-price quality aspects of different water heating options.

Table 1: Quality aspects of different water heating appliances

Quality aspect	Appliances affected
Never running out of hot water	Good for instant gas, and solar + instant gas boost. Bad for cylinder-based options – particularly those with a long recovery time (e.g. some heat pumps).
Not taking up interior house space	Bad for cylinder options. Good for instant gas.
Health risk from scalding water	Worse for cylinder options as they have been observed to have increased likelihood of incorrectly set, or faulty, thermostats or tempering values.
Noise from operation	Sometimes an issue with heat pump systems. ⁴⁶

In general, instant gas water heating scores highly on these non-price quality attributes.

⁴⁶ To address this, some units have a timer functionality which prevents operation during particularly noise-sensitive times and if they are located in a particularly noise-sensitive position (e.g. outside a bedroom window). However, this will have a detrimental effect on the availability of hot water at certain times.

Space heating

There is far greater variation in the different types of non-price quality aspects relating to space heating. Table 2 below sets out the different quality aspects associated with space heating and which appliances fare better or worse against each measure.

Table 2: Quality aspects of different space heating appliances

Quality aspect	Appliances affected
Evenly heating the whole home	Good for central heating. Worse for heating approaches relying on one or two large interior heaters, particularly log or pellet burners but also, heat pumps, or large flued gas heaters.
Delivering space cooling	Good for heat pumps.
Speed of heating	Good for gas heating.
Controllability of heating / delivering heat when wanted	Not good for log burners, night storage heaters, and some stand-alone electric heaters. All other options are capable of control via the use of thermostats and timers (of varying degrees of sophistication).
Aesthetics of a 'real fire'	Very good for open fires. Good for log-burners and flame gas fires.
Visual aesthetics for house exterior	Worse for heat pump options requiring multiple exterior units (i.e. for larger houses).
Noise	A problem for some heat pumps.
Ease of use	Not so good for log-burners (requires fuel storage, and carrying sometimes heavy fuel). Similar for pellet burners.
Respiratory health and dampness issues	Bad for <u>un-flued</u> gas or LPG options (including cabinet heaters).

Appendix D. Assumptions relating to industrial process heaters

The following charts illustrate the key assumptions driving the industrial boiler analysis.

Figure 41: Central wholesale fuel and transport costs assumptions

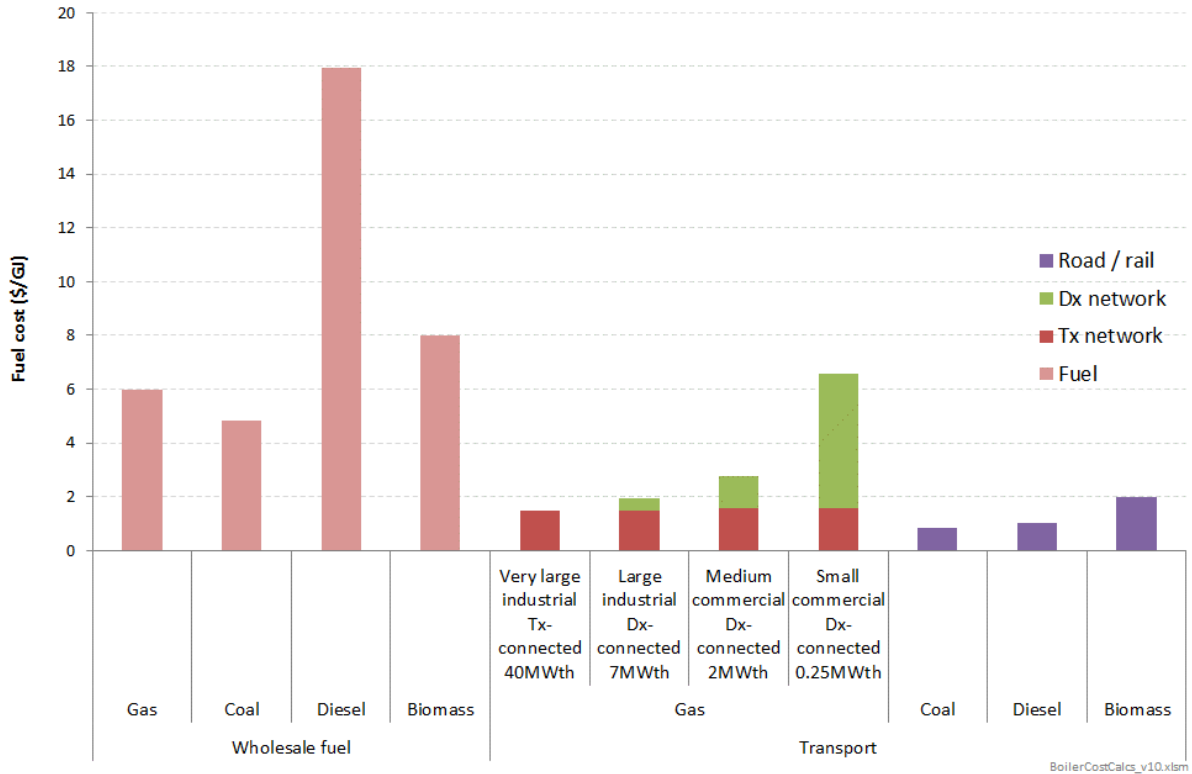


Figure 42: Intermediate process heat boiler efficiency assumptions for different fuels

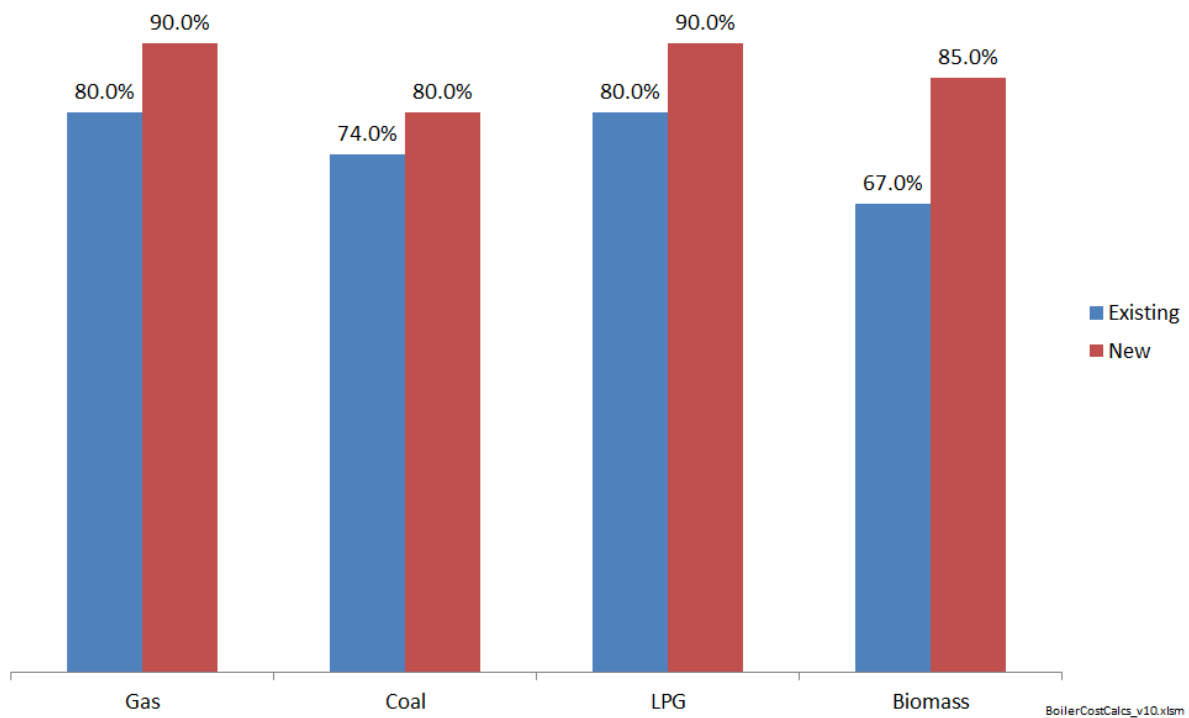
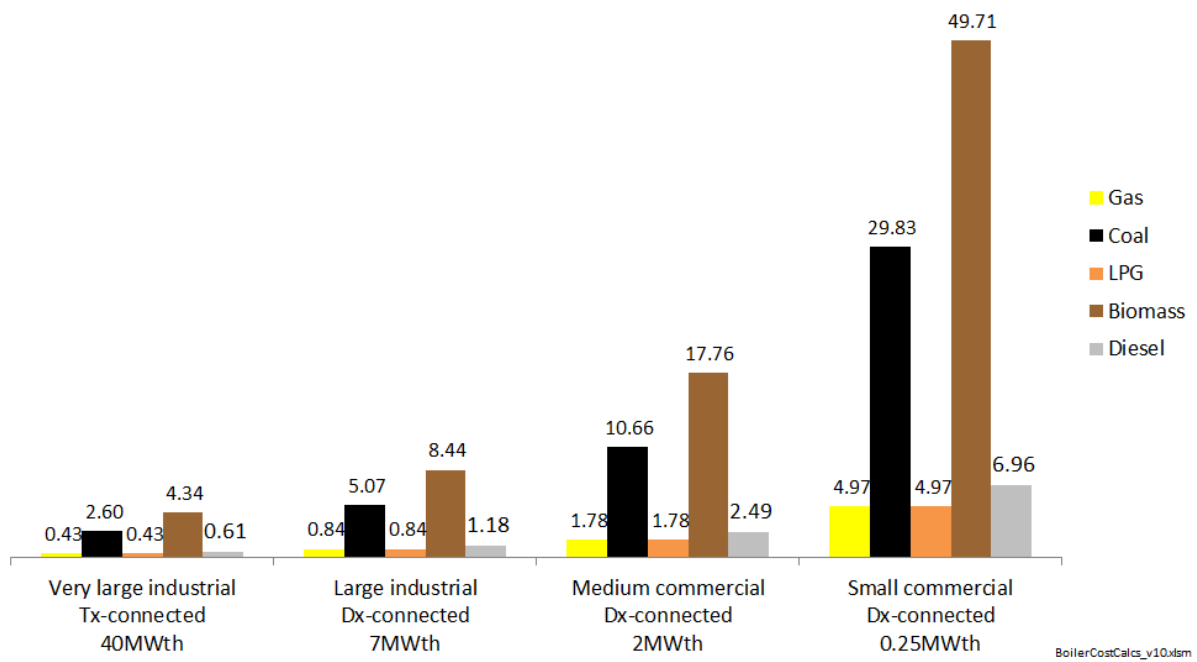


Figure 43: Amortised boiler capex + fixed boiler opex (\$/GJ)



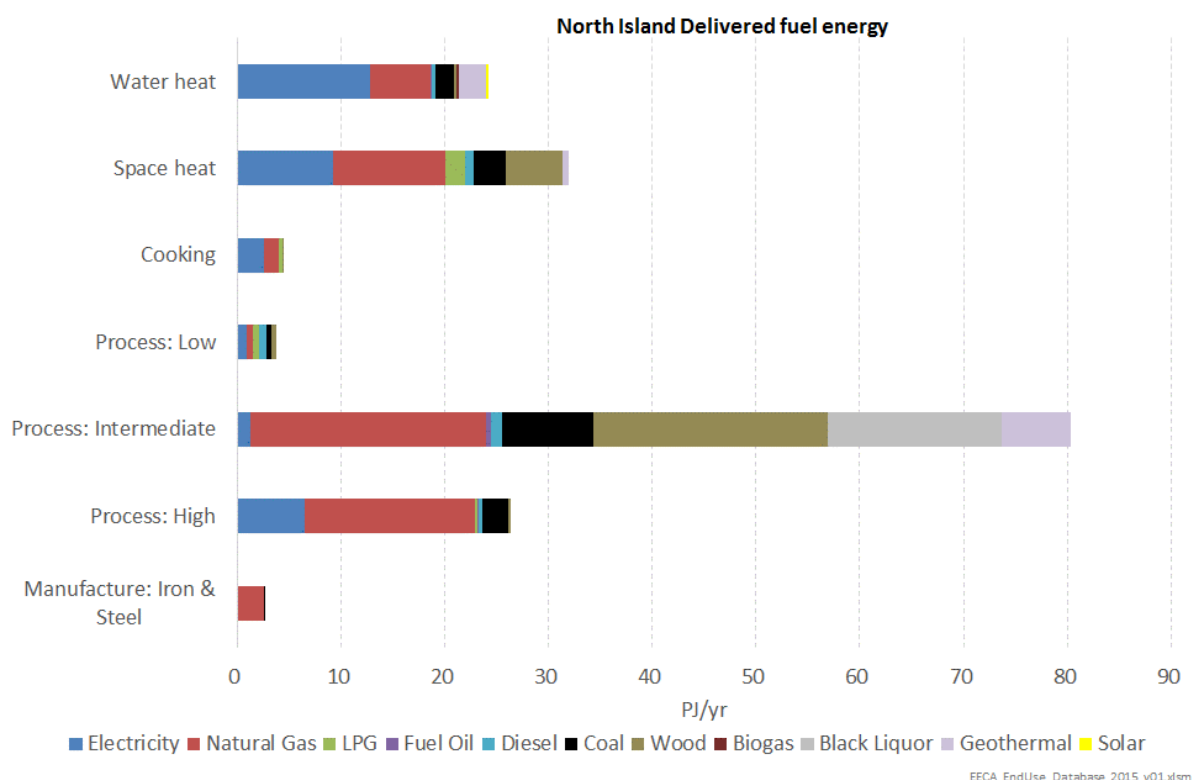
Appendix E. Determination of energy end-uses to examine

The purpose of this study is to analyse the relative economics of different fuel options for energy end-use applications⁴⁷ for which:

- the quantity of energy used is significant; and
- gas is a feasible alternative.

Figure 44 shows the North Island⁴⁸ fuel shares for all end-use energy applications for which gas is a feasible option.

Figure 44: Fuel shares for the delivery of end-use energy among different energy applications



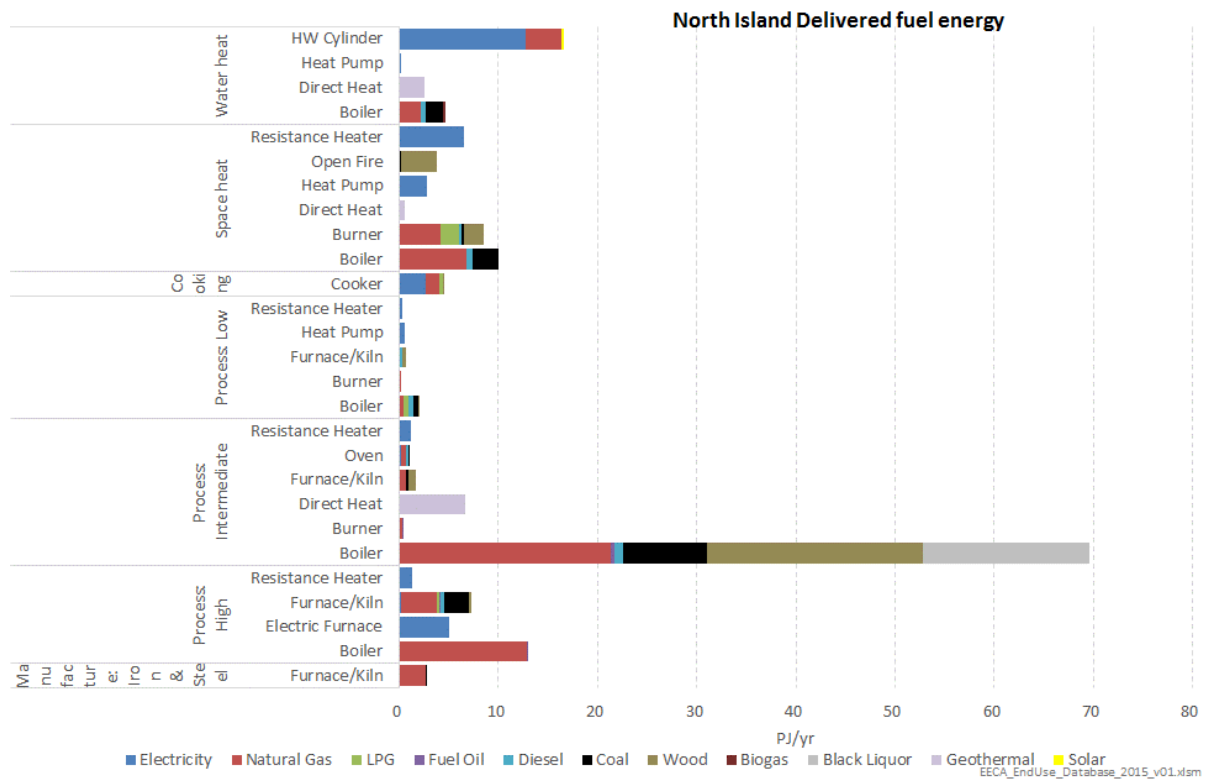
Source: Concept analysis using EECA energy end-use database data

This is broken down further by end-use technology in Figure 45 below, and by broad economic sector in Figure 46 below.

⁴⁷ The other two main uses of gas in New Zealand are as a feedstock in the petrochemical industry (e.g. to manufacture methanol or urea), or as a fuel for power generation. Potentially, also, gas could be used as a transport fuel. However, consideration of all such uses of gas is out of scope for this study.

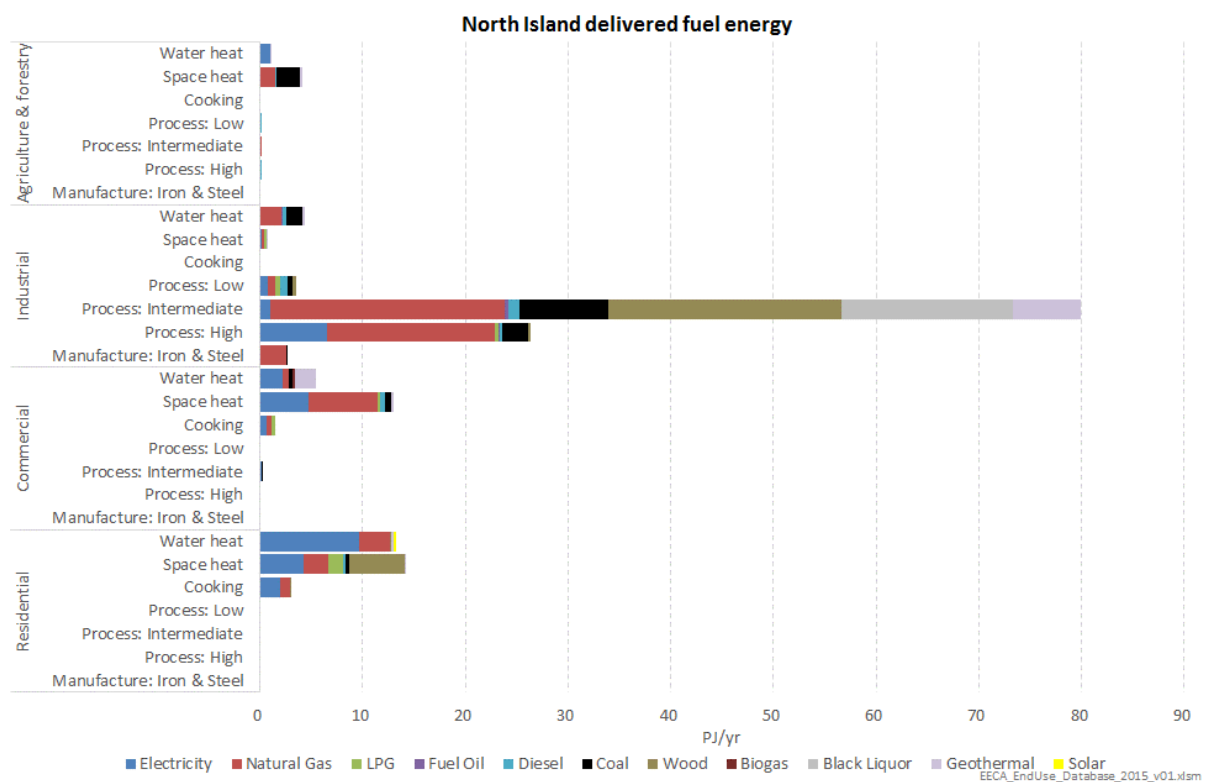
⁴⁸ Because gas is only available in the North Island, the analysis in this appendix only focusses on energy shares in the North Island.

Figure 45: Fuel shares for the delivery of end-use energy among different energy applications and technologies



Source: Concept analysis using EECA energy end-use database data

Figure 46: Sectoral split of fuel use among energy requirements



Source: Concept analysis using EECA energy end-use database data

The key take-aways from the above analysis are that it is useful to think of the economics of gas versus alternative fuel options for three main segments:

- residential & commercial water heating;
- residential & commercial space heating; and
- industrial process heat.

These are all material end-uses of gas for which there are significant alternative fuel options.

Cooking is not considered because it comprises a very small share of total energy consumption, plus non-price quality considerations often dominate consumer’s choice of cooking appliance.

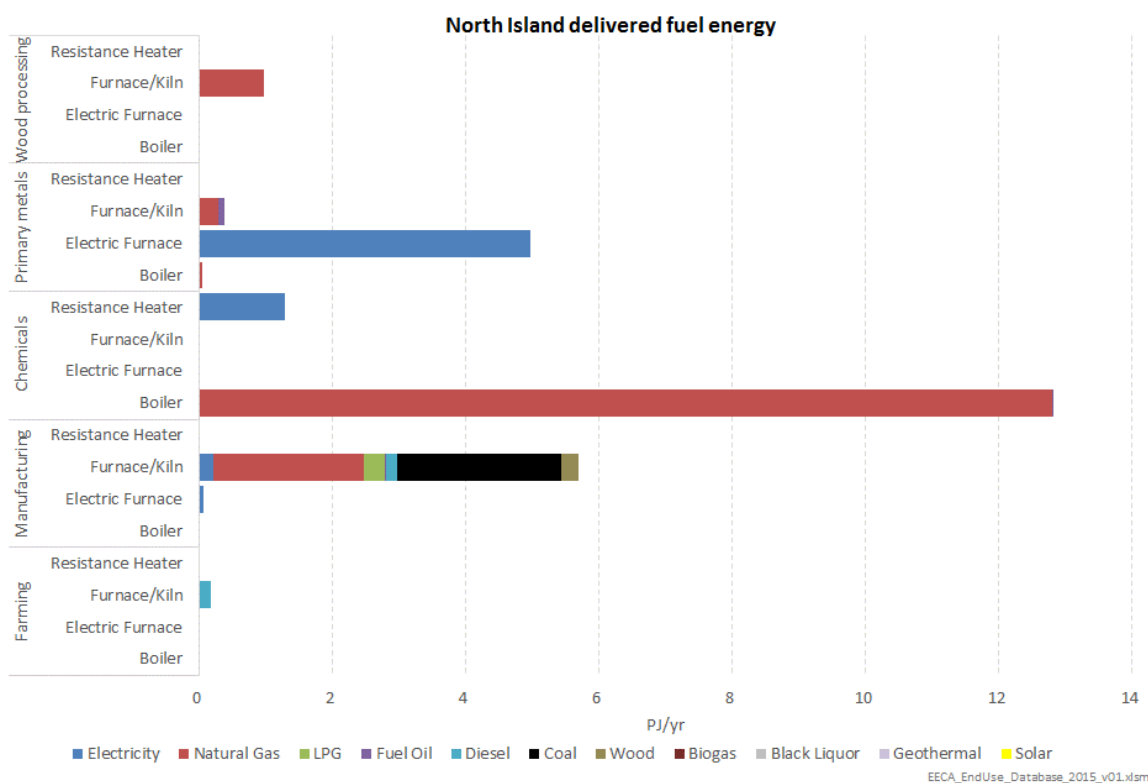
Energy used in the manufacture of iron & steel is also not considered because process-specific considerations dominate fuel and technology decisions.

With respect to industrial process heat, Figure 45 previously indicates that it is useful to consider process heat as split between high-, intermediate-, and low-temperature process heat.

As also indicated in Figure 45, the demand for low-temperature process heat is very small, and therefore is not considered further in this report.

High-temperature process heat comprises a reasonable proportion of industrial process heat requirements in New Zealand. However, the choice of fuel is generally driven by process-specific considerations, such that other fuels are generally not practicable (e.g. for foundries, etc). That said, Figure 47 below indicates there may be some opportunities for fuel switching away from coal to gas in the long term. However, it is not a large source of potential demand, and thus not considered in detail in this report.

Figure 47: Fuel shares for the delivery of high-temperature end-use process heat split by technology and sector



Source: Concept analysis using EECA energy end-use database data

Accordingly, the principal focus in this report is the extent to which gas is likely to be competitive against alternative fuel sources for the production of intermediate-temperature process heat. (i.e. heat delivered at 100°C to 300°C).

As is indicated in Figure 45 above, the principal technology for raising such heat is via boilers. This is considered to be the main practicable technology option for raising such intermediate-temperature heat for the foreseeable future given that the intermediate process heat is generally required as steam. Therefore, this report considers the extent to which gas is likely to be competitive against alternative fuels for fuelling boilers.

Electricity is not considered to be a practicable alternative option for raising intermediate-temperature process heat because:

- heat pumps are not well suited to producing the large quantities of ‘high quality’ process heat required by such applications;⁴⁹ and
- the relatively high \$/kWh variable costs of electricity make it an expensive option for raising steam via standard resistance heating boilers relative to combustion boilers.⁵⁰

Therefore, it is considered that the main alternatives to gas for industrial process heat combustion boilers are:

- solid fuel options (coal or biomass); and
- liquid fuel options (diesel, LPG, or fuel oil).⁵¹

⁴⁹ Heat pumps are well suited for space heating because they only need to raise the air temperature by a relatively small amount (i.e. increasing the temperature of the air by approximately 10 to 20 °C). Their coefficients of performance are materially poorer for water heating because they need to raise the water temperature by a greater amount (i.e. by approximately 50 to 60°C). However, heat pump water heating is still practicable.

Using heat pumps to raise large volumes of water to temperatures of between 100 to 300°C for intermediate-temperature water heat is currently not practicable due to the materially poorer coefficients of performance that this would entail.

⁵⁰ For example a delivered variable gas price of \$10/GJ, passing through an 85% efficient boiler gives rise to a variable end-use cost of \$11/GJ, or 4.2 c/kWh. This compares with a delivered variable electricity price of approximately 10 to 15 c/kWh for industrial and commercial consumers (noting that resistance electric heating is 100% efficient, and thus doesn’t need to be factored by boiler efficiency to give an end-use cost of useful heat).

⁵¹ Black liquor is also a liquid fuel, but as it is a by-product of wood processing, it is only available for such users, and thus not considered further in this discussion of the general economics of such options.