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NEW ZEALAND CENTRE FOR ADVANCED ENGINEERING

Understanding the Contribution of Direct Use of Gas to New Zealand's Future Energy Efficiency Objectives

A report produced for the
Gas Association of New Zealand

by the New Zealand
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EXECUTIVE SUMMARY

The analysis reported here clearly demonstrates that when considered in terms of the total energy supply chain the direct use of natural gas in the residential, commercial and industrial markets has considerable merit, both from a carbon emission perspective and resource efficiency.

In this respect, the report reinforces the importance of LPG and Natural gas as contributors to the total New Zealand energy mix. Overall, gaseous fuels contribute approximately twenty percent of the New Zealand primary energy supply and nine percent of total consumer energy demand in the residential and commercial sectors. Importantly, with over thirty years of investment and operation in the sector, this country has available to it a world-class production and distribution infrastructure based upon established reserves of energy and international standards of reliability and security. The nature of the industry is thus well understood and its performance certain.

New Zealand thus has a strong strategic interest in ensuring a robust domestic gas industry is in place for the medium to long term as the country looks to respond to the emergent risks of climate change, supply security and the challenges of meeting our future energy needs in a sustainable way.

From a risk point of view this requires that consumers, industry and government think more broadly about the role of natural gas and LPG in meeting New Zealand's future energy needs, and the climate change implications that might arise from their increased direct use.

This study, commissioned by the Gas Association of New Zealand (GANZ), seeks to answer that question by providing a comparison of the efficiency and carbon emission characteristics of gas appliances with their competitive energy counterparts in the residential, commercial and light industrial markets.

In order to present such an analysis a full energy chain analysis is necessary, not just a comparison of end use appliance efficiencies.

The analysis reported here, therefore, takes into account the quantity of primary energy resource being consumed for a range of appliance types to meet desired service levels and duty across each of the market segments examined.

To achieve this, care must be taken in defining the typical performance of different appliances. Some renewable energy technologies, because of their very nature, cannot provide an acceptable level of reliability whereas the performance of other technologies will be strongly dependent on ambient conditions and patterns of use. In order to take these variables into account a broad analysis framework has been adopted to ensure that comparisons have been made with a defensible data and methodological basis. The development of this analysis methodology forms a major part of this report.

The use of natural gas can result in significantly lower levels of CO_2 emissions for most of the residential, commercial and industrial applications examined. Applications where competitive technologies resulted in fewer emissions were identified as electric heat pumps used for heating, but only when operating under favourable conditions, and wood and wood pellets if the fuel has been sourced from a truly renewable source.

Review of recent New Zealand studies on energy end use efficiencies indicated a number of cases where the apparent advantages of electric heat pumps had been erroneously reported. The outcome of this analysis, taking into account climatic condition throughout the country, is that gas and heat pump resource efficiencies are roughly on a par when averaged over the country as whole.

Qualitative factors related to the level of service obtained and flexibility of operation are also strong determinants in establishing overall efficacy and consumer preferences. Examination of these issues reinforces the importance of ensuring diversity in our future energy mix. Alongside other energy forms, gas has an important role to play in this future.

CONTENTS

GLOSSARY

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BRANZ	Building Research Association of New Zealand
CAENZ	New Zealand Centre for Advanced Engineering
CCGT	Combined Cycle Gas Turbine
DUOG	Direct Use of Natural Gas
E&P	Exploration & Production
GCV	Gross Calorific value
GIC	Gas Industry Company
GSPA	Gas Supply Pricing Arrangements
GWP	Global Warming Potential
HEEP	Household Energy End-Use Project
HVAC	Heating, Ventilation and Air Conditioning
IGCC	Integrated Gasification Combined Cycle
LNG	Liquefied Natural Gas
LPG	Liquified Petroleum Gas
MED	Ministry for Economic Development
MEPS	Minimum Energy Performance Standards
MfE	Ministry for the Environment
NZES	New Zealand Energy Strategy
RMA	Resource Management Act
WHO	World Health Organisation

1 INTRODUCTION

Whilst the recently released New Zealand Energy Strategy recognises the continuing importance of natural gas as a source of primary energy, it is apparent that current policy directions are not particularly favourable towards an increase in the direct use of natural gas. Rather, policy action strongly favours renewable fuels and primary renewable resources for electricity generation, with emphasis given to the promotion of renewable energy solutions such as solar water heating, plus also favouring the uptake of more efficient electrical appliances such as heat pumps.

This view is borne out by CAENZ's own observations. Too often studies related to New Zealand's energy future focus on new and emergent technology forms and ignore the important role of natural gas in improving energy efficiency and reducing CO_2 emissions. Notwithstanding coal and oil both having significantly inferior performance in terms of carbon emissions, little distinction is made between gas and the other fossil fuels.

Such views take no account of the role of natural gas in today's energy markets, the reality of increasing LPG penetration in the domestic market, nor the comparative supply chain efficiencies of the competing fuel types; from production, through to distribution and final delivery to the end user. In this respect the direct use of gas has some considerable advantage over competing fuel types.

From a New Zealand supply perspective there is a need to better quantify these benefits and provide the supporting data that will allow a proper comparison of the different options. This can only be assessed on the basis of the efficiency, performance and reliability of the total supply chain. Failure to do so may well lead to erroneous conclusions about national effects and benefits.

This report summarises the key findings of a study undertaken by CAENZ on behalf of the Gas Association of New Zealand (GANZ) to review the efficiency and effectiveness of the direct use of gas in the New Zealand retail energy market. The report is intended as a resource document to allow consumers and others to better evaluate the role that the direct use of gas might have in meeting this market segment. The development of the methodology used to describe the energy chain analysis forms a major part of the report.

The key outcome of this analysis is the comparison of the efficiency and carbon emission characteristics of gas appliances with competitive energy counterparts in the residential, commercial and light industrial markets.

2 STUDY APPROACH

2.1 Methodology

The focus of this study has been on better understanding the end use efficiency of a range of appliances in common use within the New Zealand domestic, commercial and light industrial markets and their comparative performance when assessed under consistent load conditions. In order to do this a representative selection of energy services was defined and efficiency data gathered from available published data. The data collected was examined for accuracy and, where necessary, re-established to a common basis. The benchmark data derived was then further evaluated against known thermodynamic performance and end-use efficiencies in order to ensure a valid comparison could be made of appliance efficiency for the stated duty.

There are, of course, a wide range of efficiencies that might apply to any one technology type, depending on configuration, manufacturing tolerances, maintenance condition and a range of operational factors. Typical ranges of efficiencies are described graphically in Figure 1.

A major concern in undertaking this study relates to the way in which appliance efficiencies are reported in the public domain. The industry sponsor, GANZ, wanted to be able to refer to a trusted information source on appliance efficiency. A good example of this particular issue is the treatment of heat pumps as arises from the above analysis. Too often, reported appliance coefficient of performance measures are taken at face value. The more detailed analysis presented in the text box over the page offers a more refined view of heat pump performance as calculated through model simulation of the typical operating condition for domestic space heating throughout New Zealand.

It was not intended that this study should extend to a detailed appraisal of individual appliance types or that comparison be made of different brands but, instead, that the implications of different consumer options be objectively weighed. A standardised analysis framework was thus adopted, as described in the next section, so as to allow a direct comparison between the different fuel options for delivering the required energy service.

2.2 Framework for Analysis

Carbon emissions cannot be calculated simply by the efficiency of end use appliances alone. Instead a broader analysis framework is required:

- The most important factor determining carbon emissions is the quantity of primary energy resource being consumed to meet desired service levels. Contributing factors include the quantities of the primary fuel used in the manufacture and delivery of the final fuel delivered to the consumer. Thus a

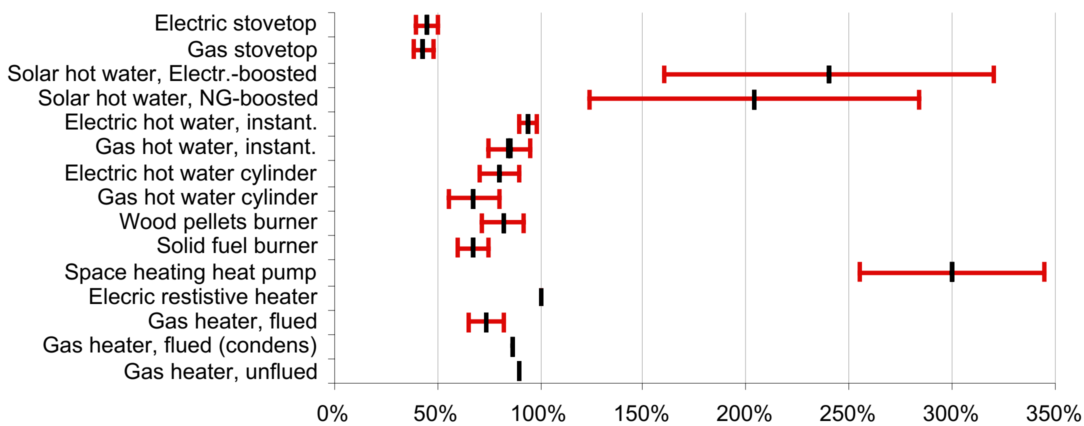

Figure 1: Range of technology efficiencies

Determining Heat Pump Efficiency for NZ Conditions

Coefficient of Performance versus Appliance Efficiency

Heat pumps are different from any other heating appliance, because heat is not generated from electricity or a fuel, but heat is extracted from one source (normally outside air or soil), raised in temperature level, and released where needed. Heat pumps rely on electricity for compressing the vapour of a working fluid.

As heat is not actually generated from the energy content of a fuel, it is possible that heat pumps have 'efficiencies' in excess of 100%. As an efficiency of more than 100% is not possible by definition, efficiencies of heat pumps are expressed as the so called coefficient of performance (COP), where a COP of 1 corresponds to an efficiency of 100%.

While heat pumps can have COPs in excess of 3, it is important that this does not mean that a heat pump is generally 300% efficient. In contrast to efficiencies of combustion heating appliances or electric resistive heating, the COP is strongly temperature dependent. For example, if the difference between outside and room temperature was to approach O°C, the COP of the heat pump would increase significantly.

In order to compare the relative efficiencies of different heat pump models, the Australian Minimum Energy Performance Standard define that heat pump COPs be compared at an outside temperature of 7°C.

Simulation of best case Coefficient of Performance

While the appliance efficiencies of electric resistive heaters, gas, or wood burners are directly comparable, it is a fallacy that a COP could be directly compared to efficiency. For example, a gas heater of 90% efficiency can operate at 90% efficiency anywhere in the world, while a heat pump with a rated COP of 3.0, might operate at a COP of 3.5 in a warm place or at a COP of 2.0 in a cold place.

Location must be taken into account if comparing a COP and an efficiency.

CAENZ has developed a simple model to simulate the maximum annual effective mean COP of air sourced heat pumps. The simulation is based on ASHRAE hourly air temperature data for different locations in New Zealand. The model calculates the COP and the heat load to maintain the house temperature for every hour of the year, based on the outside air temperature. This enables the energy inputs and outputs of the heat pumps to be calculated.

Key parameters are the indoor temperature level, the rated COP of a heat pump as a function of temperature, and heat loss of a typical house, based on findings of the HEEP study (BRANZ 2006). Hourly energy requirements are summed up over the year, and an annual effective mean COP is calculated for the location. The simulation only considers heating, not cooling. The overall result represents the maximum average achievable COP obtained in a geographical area.

Typical Results

Preliminary simulation results show the maximum annual effective mean COPs of heat pumps at a rated COP of 3.0 for different locations in New Zealand.

	Auckland	Wellington	Christchurch	Dunedin
Annual average	COP 3.2	COP 3.1	COP 2.8	COP 2.7
June/Jul only	COP 3.1	COP 2.8	COP 2.5	COP 2.4

The maximum achievable COP for a location is now directly comparable to the efficiency of another appliance. It is now possible to say, a heat pump in Christchurch is 2.8 times more efficient than an electric resistive heater based on annual average temperature differential, but performance falls to 2.5 times over the June/July period.

Reference

BRANZ (2006). *Energy Use in New Zealand Households*, Report on the Year 10 Analysis for the Household Energy End Use Project.

full energy chain analysis is necessary, not just a comparison of end use appliance efficiencies.

- There are behavioural and qualitative factors that also impact on the amount of energy being consumed. For example, technologies which automatically provide space central heating may be more thermally efficient than manually operated dispersed units, but will result in a greater total use of energy because they deliver more heat, some of it unnecessarily. It is therefore desirable to compare technologies in terms of the service or utility delivered.
- Care must be taken in defining the typical performance of appliances. Efficiencies of heat pumps depend on ambient conditions, delivering a lower quality of heat at a lower efficiency under low ambient temperatures. Any assessment of appliances must reflect performance under all conditions.
- Some renewable energy technologies, such as wind power and solar heating, because of their very nature, cannot provide a sufficient level of reliability and must be complemented by electricity or a fossil fuel.
- This report makes a clear distinction between the quantitative and qualitative comparisons between the different fuels and application technologies. The former provides the concrete comparison based on referenced technical data using a methodology developed around that used by the New Zealand government to calculate greenhouse gas emissions. The discussion of qualitative factors is provided to illustrate further the comparison between fuels, but doesn't, on its own, provide a definitive argument in favour of any fuel.

These are the framework conditions within which the performance of natural gas needs to be evaluated compared to other fuels. With a defensible data and methodological basis, the quantitative analysis in Chapter 5 sets out CAENZ's findings on the relative emissions from different fuels.

In addition to the technical comparison of the fuels, the report addresses some of the broader issues that CAENZ considers of importance in taking a view on the competitive position of natural gas as a contributor to the mix of primary energy used in New Zealand, and the strategic requirement to ensure a sustainable level of industry activity going forward. Specific issues covered in Chapter 6 of the report include:

- The risk associated with some of the assumptions and targets used in the New Zealand Energy Strategy (NZES) for the development of renewable energy and the possible negative implications they may have on the New Zealand energy sector and the strategic sustainability of the natural gas industry.
- The record of the New Zealand natural gas industry over the past 30 years in providing a reliable supply of energy to the New Zealand energy market through a system built to international standards. In comparison, the performance of renewable technologies is subject to greater uncertainty, either through climatic uncertainties or the novel nature of the technology.
- The importance of New Zealand policy makers keeping a long term perspective of the gas industry in the current context of the declining Maui gas field and the diminishing reserves to production ratio. New Zealand remains relatively under-explored and the emerging higher gas price structure provides incentive for exploration for gas, particularly as Maui's dominance of domestic markets has now been relinquished.

3 DEFINING THE ENERGY DELIVERY SYSTEM

3.1 Sources of Emissions

Carbon dioxide emissions from the use of fuels result from the conversion of the carbon contained in the fuel to carbon dioxide during combustion.

$$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$$

Fossil fuels, such as natural gas, oil and coal, are comprised principally of carbon and the large majority of this carbon[1] is converted to carbon dioxide during the combustion process. Emissions of carbon dioxide occur at all stages of the supply chain, from the production of the raw fuel resource to the final application of the fuel by the end user:

- During production CO_2 is extracted from some raw gases and vented directly to the atmosphere. This occurs especially at the Kapuni gas production station where the high CO_2 content of the raw gas is reduced to pipeline quality levels.
- From 'Own Use' of the fuel and combustion of fuel components through activities such as flaring during the production, processing and transportation of the fuel to the end user. Own use involves the combustion of some of the fuel being processed or transported to provide energy to carry out these activities. Examples include oil refinery fuel produced from oil products, gas components burnt during gas processing to provide process heat and gas used to drive gas compressors for pressurising transmission pipelines.
- From the use of other fossil fuels during the production, processing and transport of the fuel. Examples are the use of diesel fuels during the road transportation of solid and liquid fuels and diesel used for drying during the manufacture of woodchips.
- During the combustion of the fuel by the end user. At the point of application, energy supplied into the appliance is either directed to the energy service required or lost as waste heat or energy, the split between the useful and waste energy depending on the efficiency of the particular appliance.
- From fugitive emissions of CO_2 and methane due to leakages from the gas distribution network and the release of methane during the mining of coal. As gas has a higher content of methane than CO_2 and methane has a higher global warming potential (GWP), the climate change impact of CO_2 emissions from gas leaks is insignificant compared to those from methane and is not calculated in this study[2]. Similarly there will be some methane emitted during the combustion of gas, coal and oil but these quantities are insignificant compared to CO_2 emissions from combustion and therefore are not calculated.
- Emissions from the combustion of the carbon contained in renewable fuels such as wood and wood chips are set at zero as these are considered to be re-sequestered in new tree plantings or are waste product. However emissions from fuels such as diesel or fuel oil used in the transport or manufacture of renewable fuels must be accounted for.
- Emissions resulting from the use of electricity occur at the power stations where gas, oil or coal is combusted. No emissions occur during the transmission, distribution or application of electricity although losses of electricity will occur at each step, adding to the amount of electricity which must be generated to deliver a given quantity of electricity and hence the quantity of fuels required for generation.

The specific emissions used to determine the "carbon footprint" of each appliance evaluated in this study are summarised in Table 1.

The emissions in Table 1 can be combined into three basic forms of emissions:

[1] Over 99% for natural gas

[2] Methane is the primary constituent of pipeline quality natural gas (about 84 %vol) and is a greenhouse gas like CO2, but 1 tonne of methane is equivalent to 21 tonnes of CO2 because of methane's higher global warming potential (GWP). Most New Zealand gas consists of less than 5 %vol CO2, the principal exception being raw Kapuni gas which has a CO2 content of about 42 %vol prior to being treated at the Kapuni production station.

	Gas	LPG	Oil Products	Coal	Wood/Wood pellets	Electricity
Extraction of CO_2 During Processing	Extraction/ Venting of CO_2 at Kapuni Production Station	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant, except where high CO_2 gas is used for electricity generation
CO_2 Emissions from Fuel Use During Production/ Processing	Flaring and Own Use of gas at gas production station	Flared, Losses & Own Use of Raw LPG at gas production station	Fuel & Losses of Crude Oil Components at the Refinery	Diesel fuel use by excavators and trucks during mining	Electricity and diesel use for drying and preparation of pellets	Resource (Gas, Coal) Consumed during Conversion to Electricity
CO_2 Emissions from Fuel Use During Transmission and Distribution	Own use of gas for transmission system Compression - no own use in distribution.	Diesel and fuel oil for transport by truck and ship	Diesel and fuel oil for transport by truck and ship	Diesel for transport by truck	Diesel for transport by truck	No Emissions but losses of Electricity during both T&D
CO_2 Emissions from Fuel Losses During Application	Fuel consumed due to losses at point of application					No emissions but loss of electrical energy at point of application
CO_2 emissions from fuel energy delivered during application	Emissions attributable to energy service delivered					No emissions from energy service delivered
Methane Emissions: Fugitive and Combustion	Methane from leakage of gas during distribution. None during transmission	Insignificant	Insignificant	Methane released from the coal seam during mining	Insignificant	Insignificant

Table 1: Sources of Greenhouse Gas Emissions During the Production, Delivery and Application of Fuels

- CO_2 emissions from the fuel being delivered and consumed in the end users' appliance. These emissions are the sum of the combustion emissions from the energy delivered from the appliance, energy losses in the appliance and emissions from own use and flaring of the fuel during the transmission, distribution and production of the fuel, including, in the case of gas, any CO_2 extracted and vented during production and processing.
- By mass balance the total carbon in these emissions, with the exception of methane leakage from the gas distribution network, is equivalent to the carbon contained in the raw gas or coal resource extracted from the ground or raw LPG extracted at the gas production station[3].
- Fuels, other than that being delivered to the appliance, used during fuel production and delivery.
- Fugitive methane emissions from coal mining and gas leakage arising from local pipeline distribution.

3 As noted above, thermal fuel requirements and consequent CO_2 emissions from the generation of electricity can be determined in a similar manner by summing the delivered electrical energy and the electricity losses at the appliance and energy losses during transmission and distribution.

3.2 Accounting for Greenhouse Gas Emissions

The New Zealand government reports regularly on the national emissions of greenhouse gases from all sources of emissions of carbon dioxide, methane, nitrous oxide and halocarbons[4]. In the reporting on energy use, which includes emissions from the use of fossil fuels, two methodologies are used to determine overall emissions:

- ***Sectoral Approach***. This methodology disaggregates energy use into energy subsectors such as energy industries, manufacturing and construction, commercial and residential, combining emissions from all fuels. It also disaggregates emissions on a vertical basis[5] and applies different emission factors for gas at different stages in the supply chain. Although this is the official methodology for reporting emissions internationally, it does not directly show emissions from different fuels.
- ***Reference Approach***. This is included in the inventory document as a check for combustion related emissions determined in the sectoral approach. The methodology is simple in that it determines emissions from the quantity of the energy source produced, in the case of natural gas the quantity of raw gas produced at the gas fields. A CO_2 emission factor is calculated based on the production-derived weighted average of emission factors for each of New Zealand's gas fields. These emissions factors are based on the carbon content of the raw gas so include all CO_2 emissions from CO_2 extraction and gas processing to end use of the fuel. In the latest inventory report, for 2005, there was only a 0.38% difference between the emissions determined by the reference and sectoral approaches confirming the validity of the methodologies employed.

The methodology used in the reference approach has been adopted in this study as it clearly identifies all emissions from each type of fuel, is relatively easy to calculate and conforms to the basic emission types summarised at the end of Section 3.1. Appropriate emission factors for gas and other fuels are available from government sources and the determination of own use and other losses can be derived from MED's energy data series.

3.3 Methodology Used to Calculate Carbon Emissions

As far as possible, the methodology and data used is designed to conform as closely as possible with that of government, in particular the calculation of carbon dioxide emissions follows the greenhouse gas inventory reference approach outlined above and fuel properties and losses during production, processing, transmission and distribution are derived from the MED's Energy Data series.

The following methodology is used for each appliance type:

- A level of service is defined for each appliance, i.e. the quantity of delivered energy to provide a certain function typical of the appliance.
- The quantity of energy which must be delivered to the consumer to provide the service is determined using the appliance efficiency.
- The amount of energy resource required to provide the service is determined by adding the losses incurred (during production, processing, transmission and distribution) to the energy delivered to the consumer.
- This procedure is followed for each gas appliance and its competitive counterparts.

Carbon dioxide emissions are determined for each appliance service by combining the following sources of emissions:

- Emissions from the resource used as calculated above.
- Emissions from other fuels utilised in the production and delivery of fuels.
- Fugitive methane emissions from gas leakage and coal mining.

The schematic in Figure 2 summarises the delivery system and carbon footprint methodology adopted for each of the fuels under consideration in this study. The schematic shown is based on emissions incurred by a standard defined service provided by gas or electricity.

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[4] Latest version: New Zealand's Greenhouse Gas Inventory 1990-2005, Ministry for the Environment, July 2007.

[5] For example separating gas used during gas processing from gas supplied to end consumers and including CO_2 removed from raw gas with fugitive emissions. Other complications include the classification of oil refinery fuel gas as a gaseous fuel although it is produced from crude oil.

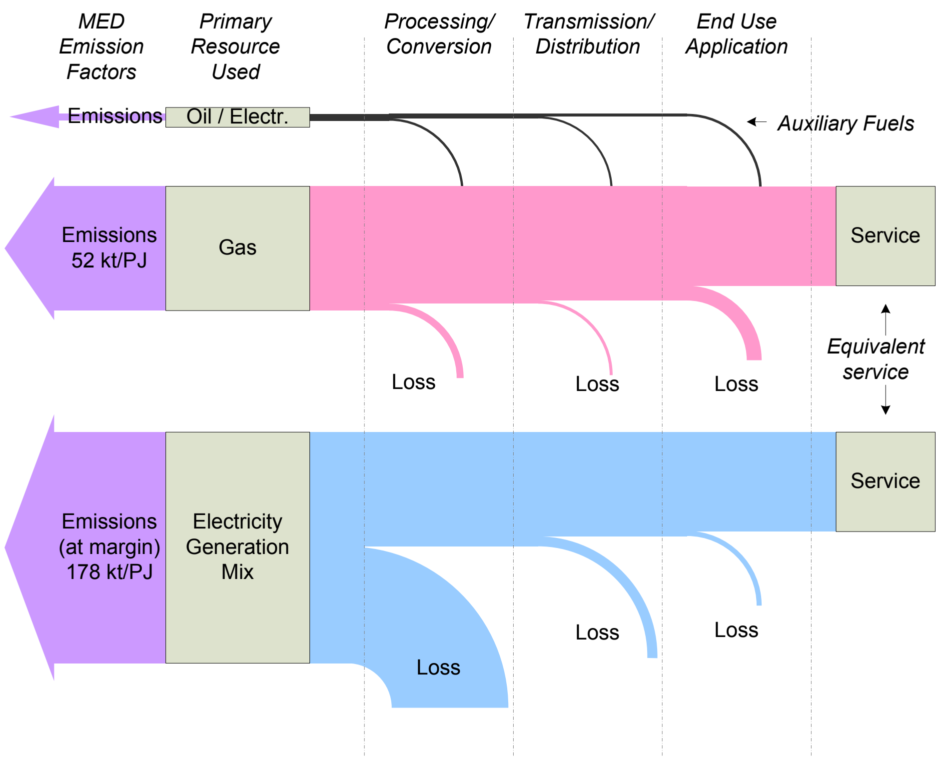

Figure 2: Carbon footprint methodology, DUOG vs electricity

4 DETERMINATION OF EMISSIONS TO POINT OF DELIVERY

4.1 Emissions from Energy Sources

Emission factors used in this study from the various fossil fuel energy sources are taken from the national inventory data and summarised in Table 2. The table also shows the weighted average emission factor for source natural gas based on the gross gas production data for 2006 as contained in the MED energy data series.

The high emissions for raw Kapuni gas reflect its high CO_2 content of 42%. It has been assumed that all Kapuni gas is treated at the Kapuni production station to remove CO_2. In practice, some of the high CO_2 gas can be sent directly to the Taranaki petrochemical plants where the CO_2 has a value as a feedstock. This effectively reduces the weighted average of the emission factor for gas supplied for other applications.

4.2 Own Use and Other Fuel Losses

Own use of fuel and losses during processing, transmission and distribution must be added to the gas delivered to the end user to determine the total amount of raw energy source consumed.

Natural Gas

Gas Processing: Gas consumption during production is taken as the sum of "Flared" and "Production Losses & Own Use" in Table 3 of the MED gas tables. These average 3.35% of the net gas production in the years 2004 to 2006 and can be attributed to the heat energy requirements and waste associated with bringing the gas to pipeline quality. Gas used for LPG extraction and reinjection in this table are not included as losses.

Gas Transmission: Table 4 of MED Gas Tables shows an average 0.50% transmission loss in

	Emission factor (t CO_2/TJ)	2006 Gross Gas Consumption (PJ/yr)
Gas: Maui	51.7	92.87
Gas: Kapuni LTS	84.1	28.15
Gas: Kaimiro	65.2	0.13
Gas: Ngatoro	46.3	1.51
Gas: Rimu	53.7	5.17
Gas: Pohokura*	54.0	14.04
Gas: TAWN	54.2	6.32
Gas: McKee	54.2	7.52
Gas: Mangahewa	52.3	5.49
Gas: Other*	54.0	1.48
Gas: Weighted Average	*57.8*	
LPG	60.4	
Diesel fuel	69.5	
Heavy fuel oil	73.5	
Coal: sub-bituminous	91.2	
Coal: bituminous	88.8	

** Emission Factor Estimated*

Table 2: CO_2 Emissions Factors from New Zealand Fossil Fuels

2004 and 2005 of gas sent through the transmission network. As the physical leakage from the transmission system is considered to be negligible[6], it is assumed that this loss represents gas firing the compressors used to pressurise the pipelines.

Gas Distribution: Residual gas pressure in the transmission system is used to move gas through the distribution networks so no gas is combusted for this purpose. Although no reference is made to distribution system losses in the MED gas tables, GANZ has estimated that losses of gas during distribution represent 1.75% of throughput[7], which is declining as technology is improved. It should be noted that these losses are of unburnt gas and are included in the fugitive emissions discussed below but not in the calculation of CO_2 emissions.

LPG

LPG Processing: Consumption of LPG during production at the gas production stations is calculated from "Flared, Losses & Own Use" LPG in Table 13 of the MED oil tables. This consumption averages 9.1% from 2004 to 2006 of gross LPG production after re-injection back into the gas stream.

LPG Distribution: LPG is transported by ship (to the South Island) and truck to end consumers. During transportation and storage it is contained in pressurised steel containers with virtually no losses nor own use. Emissions from fuels used in transporting LPG are estimated in Section 4.5.

Oil Products

Oil Processing: Own use consumption of oil products is determined from refinery fuels and losses as a proportion to refined product output at the refinery. This averages 4.65% of output based on the data for 2004 to 2006 contained in Table 3 of the MED oil tables.

Oil Product Distribution: Oil products are carried by road or sea-going tanker, or transferred via the Wiri white-products pipeline. The fuel consumption is determined as for other liquid or solid fuels and described in Section 4.5 below. Own use of oil products during distribution is therefore considered to be negligible.

Coal

Coal Production: A small amount of coal is lost during production. This is estimated to be 0.0175% of coal production based on the data in Table 2 of the MED coal tables. Significant amounts of diesel are consumed during coal mining to operate trucks and excavators. This is estimated in Section 4.5.

Coal Distribution: Coal used in the New Zealand light industrial, commercial and residential markets is generally carried by truck. The associated diesel consumption is estimated in Section 4.5. Own use of coal during transportation is negligible.

Wood and Wood Pellets

No net CO_2 emissions will result from the use of these fuels as they are both either renewable or made from the waste of renewable resources (sawdust). There will be emissions from associated fossil fuels consumed during the production and transportation of these fuels. These are described in Section 4.5.

Electricity

Electricity Generation: Emissions from electricity generation are discussed separately in Section 4.3.

Electricity Transmission: Transmission losses by the national grid operator Transpower for the March year end 2005 were 3.4%[8].

Electricity Distribution: For the year ended March 2006, the national average losses across all electricity distribution networks was 6.3%[9]. These losses ranged for individual network companies from over 10% to less than 4%.

4.3 Electricity Generation

Emissions from electricity generation are determined on the basis of the mix of electricity generation capacity which would be closed down when electricity is replaced by a fuel

6 Comment by GANZ contained in New Zealand's Greenhouse Gas Inventory 1990-2005, MfE

7 Ibid

8 Table 7 MED electricity data tables.

9 Ibid

such as natural gas. A study commissioned by the MED[10] simulated the response of New Zealand's generation capacity to a reduction in electricity demand of 50 MW. The mix of marginal generation capacity which would close down in this simulation consists primarily of coal and gas fired plant with lesser amounts of hydro and oil capacity. This mix of marginal generators is shown in Table 3.

For the purposes of this study, the effective emissions from the use of electricity are equivalent to the emissions from the marginal mix of generators shown in Table 3. To determine these emissions for each unit of electricity output, the marginal quantities of coal, gas and oil resource required are calculated by applying the appropriate thermal efficiencies of the power plants. Using the emissions factors shown in Table 2, the weighted average emissions are then determined as shown in Table 3.

The effective marginal emissions from electricity generation is 177.4 kt/PJ[11] of electricity generated, which is substantially more than the 105.1 kt/PJ for gas generation alone because of the significant contribution of coal to the marginal mix of generation capacity.

4.4 Emissions from Energy Delivered to Consumers

Own use consumption of fuels and losses during processing and transportation will compound CO_2 emissions when determined at the point of delivery to the end user rather than at the point of energy source production. This is illustrated in Table 4 using the losses from production, transmission and distribution described in Section 4.2 and shown diagrammatically in Figure 2.

It should be noted that natural gas losses during distribution have not been included in the determination of CO_2 emissions from delivered energy as these losses are fugitive emissions of unburnt gas which is not converted to CO_2. Fugitive emissions are described in Section 4.6.

The CO_2 emissions arising from the final delivery of energy from the fuel can be determined by dividing the emission factors at the point of fuel delivery to the consumer by the efficiency of the appliance. This is done in Section 5, where the performance of appliances is compared.

4.5 Other Fuels

The consumption of other fuels during the production, processing and delivery of fuels will make a contribution to CO_2 emissions from fuel use. In general these emissions are relatively small compared to the emissions from the fuel itself as will be illustrated in the analysis in Section 5. They also will be subject to a number of variables: distances travelled and type of truck or vessel and fuel used when delivering fuels and the energy intensity of mining and processing operations. Some assumptions have been developed to portray typical fuel uses. These are shown in Table 5 for transport and mining activities, along with the calculated CO_2 emission factors for energy delivered to consumers.

Table 6 shows the estimated CO_2 emissions

[10] Concept Consulting Group 2003.

[11] Equivalent to 638 tonnes of CO_2 per GWh generated. Concept Consulting estimated a range of 600 to 650 tonnes of CO_2 per GWh.

	Mix of Marginal Generators	Generation Efficiency [1]	Emissions kt CO_2/PJ fuel	Emissions kt CO_2/PJ electricity generated
Hydro	12%	100%	0.0[2]	0.0
Oil	8%	32%	69.5	218.9
Coal	44%	33%	91.2	276.4
Gas	35%	55%	57.8	105.1
Average		49%		177.4

1 MED Statistics
2 Renewable technologies with no carbon content such as hydro, geothermal and wind have zero CO_2 emissions

Table 3: Marginal CO_2 Emissions from Electricity Generation

	Resource Emission Factor: kt CO_2/PJ	Processing Loss	Transmission Loss	Distribution Loss	Delivered Energy Emission Factor: kt CO_2/PJ[1]
Natural Gas	57.8	3.35%	0.50%	1.75%	60.1
LPG	60.4	9.10%	0.00%	0.00%	66.4
Oil/diesel	69.5	4.65%	0.00%	0.00%	72.9
Coal	91.2	0.02%	0.00%	0.00%	91.2
Electricity	177.4	N/A	3.40%	6.30%	196.0
Wood	0.0	0.00%	0.00%	0.00%	0.0
Pellets	0.0	0.00%	0.00%	0.00%	0.0

1 Not including other fuels used in processing and delivery

Table 4: CO_2 Emissions from Energy Delivered to Consumers

	LPG		Diesel		Coal		Pellets Trucking	Wood Trucking
	Shipping	Trucking	Shipping	Trucking	Mining	Trucking	Trucking	Trucking
Ship/Truck capacity (tones)	2000	20	30000	30	100	40	27	20
GCV of delivered fuel (MJ/kg)	49.73	49.73	49.73	49.73	25.00	25.00	17.30	13.00
Round Trip (km)	630	400	2000	250	10	150	100	100
Truck Fuel Consumption (km/L)	0.013	3	0.003	2	0.3	2	2	3
Transport Fuel GCV (MJ/L)	40.9	38.2	40.9	38.2	38.2	38.2	38.2	38.2
Fuel Emissions (kt CO_2/PJ)	73.5	69.5	73.5	69.5	69.5	69.5	69.5	69.5
Transport Emiss. Component, normalized for PJ of delivered fuel (kt CO_2/PJ)	0.84*	0.36	1.34	0.22	0.04	0.20	0.28	0.34

* Assumes 60% of LPG supplies distributed by ship within New Zealand

Table 5: Emissions from Fuels Used in transportation and Mining

during the production of wood pellets using diesel fuel as the primary fuel for drying the sawdust feedstock. Emissions from the diesel fuel must be included in the emissions inventory as it is a fossil fuel, as must the emissions from transportation even though wood pellets are based on a renewable fuel resource.

4.6 Fugitive Emissions of Methane

Methane is a significant greenhouse gas as it has a much greater impact on climate change than CO_2, one tonne of methane being equivalent to 21 tonnes of CO_2. The most significant sources of methane emissions in the energy sector are gas escaping from the distribution network and the release of methane during coal mining:

- ***Gas Distribution:*** Some 1.75% of gas entering the distribution network is estimated to escape to the atmosphere. As pipeline quality gas typically contains about 66 % weight of methane, this release is equivalent to 4.98 kt of CO_2 per PJ of delivered gas when methane's GWP of 21 is taken into account or 8.26% of the CO_2 released during the combustion of the delivered gas. The CO_2 escaping with the methane from the distribution network has

Annual production	1202 tonne
Pellet GCV	18.2 GJ/tonne
Annual electricity energy use	570 GJ
Electricity emission factor	177.4 kg CO_2 / GJ
Annual diesel use	190,080 litres
Diesel GCV	38.2 MJ/litre
Diesel energy use	7261.1 GJ
Diesel emission factor	69.5 kg CO_2 / GJ
Specific emissions	27.7 kg CO_2 / GJ (pellets energy)

Table 6: Emissions from the Production of Wood Pellets

a climate change impact less than 1% than that of the methane so is ignored in the calculation.

- ***Coal Mining:*** The rate of release of methane from coal during mining varies considerably with the type of mining and the rank of the coal. Release factors ranging from 0.84 to 13.7 tonnes of methane per kt of coal mined for surface mining and underground sub-bituminous mining respectively are quoted in the national greenhouse gas inventory. These release figures are equivalent to 0.706 and 11.5 kt CO_2 per PJ of delivered coal or 0.77% and 12.6% of the emissions from the combustion of the coal itself. To be conservative, the lower figure is used in this study.

5 GAS APPLIANCES: EFFICIENCY AND CARBON EMISSION FACTORS

As previously described, the different appliance classes covered by the study have been compared on the basis of their overall resource efficiency and carbon emission factors. For each class of appliance the principal energy resource consumed in the delivery of the energy service was defined as well as the carbon emissions along the energy supply chain. The appliance end-use efficiency used for these comparisons is provided in Appendix 1.

The comparative results thus obtained for each of the energy services examined are described in the following sections. Also included is a comparative price analysis based on fuel costs as set out in Appendix 2.

5.1 Dispersed Space Heating

The baseline energy service is defined as the energy required to heat a typical lounge from an outside temperature of 10°C to 20°C and maintaining that temperature for three hours. The lounge is assumed to be 5 x 5 meters in size with a ceiling height of 2.4 m. Heat losses to the outside are normalised New Zealand average values taken from the HEEP study (BRANZ 2006). Concessions are made for a heat gain from electronic equipment and to reflect an average occupancy of 1.6 people.

The resulting energy service was calculated to be 18.4 MJ.

Appliances in the dispersed space heating category cover a range of portable or smaller installed gas heaters, electric heaters, heat pumps, as well as solid fuel burners.

In order to cover a reasonable range of realistic conditions, two efficiencies of heat pumps were considered (COP of 3.0 and COP of 2.5); as earlier described a heat pump with a rated COP of 3.0 might only achieve a COP of 2.5 or less in the colder parts of New Zealand.
The solid fuel burner category encompasses enclosed coal, wood, and wood pellet burners. Open fires are not included because they are no longer a relevant technology for new home heating installations.

The energy resources used, incurred carbon emissions, and energy costs to provide this service are given in Figures 1 - 3.

The resource use is highest for electric resistive heating appliances. Flued natural gas and LPG appliances have resource efficiencies comparable with those of coal and wood. Wood pellet heaters and unflued gas or LPG heaters are slightly more resource efficient. Because heat pumps have coefficients of performance greater than one, the appliance loss in the chart is

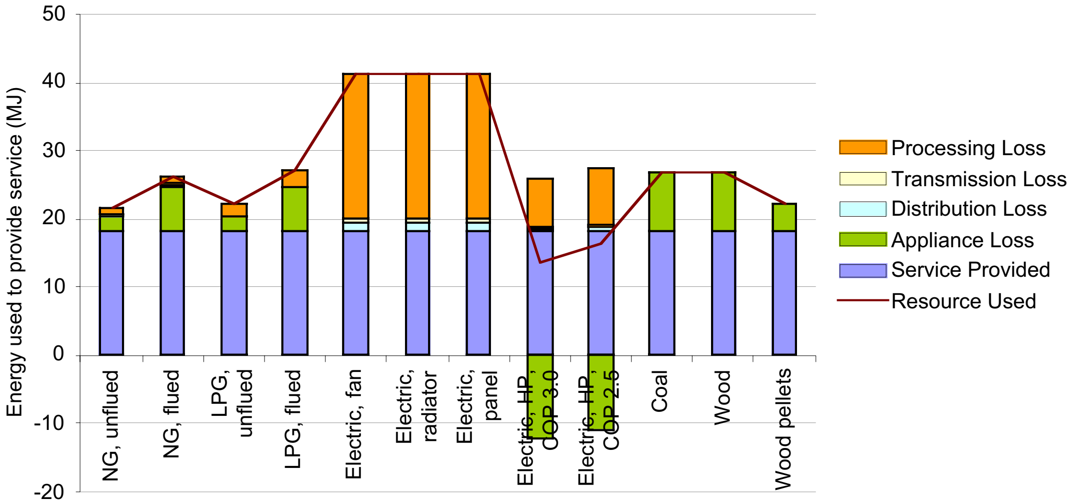

Figure 1: Domestic dispersed space heating - energy used to provide service

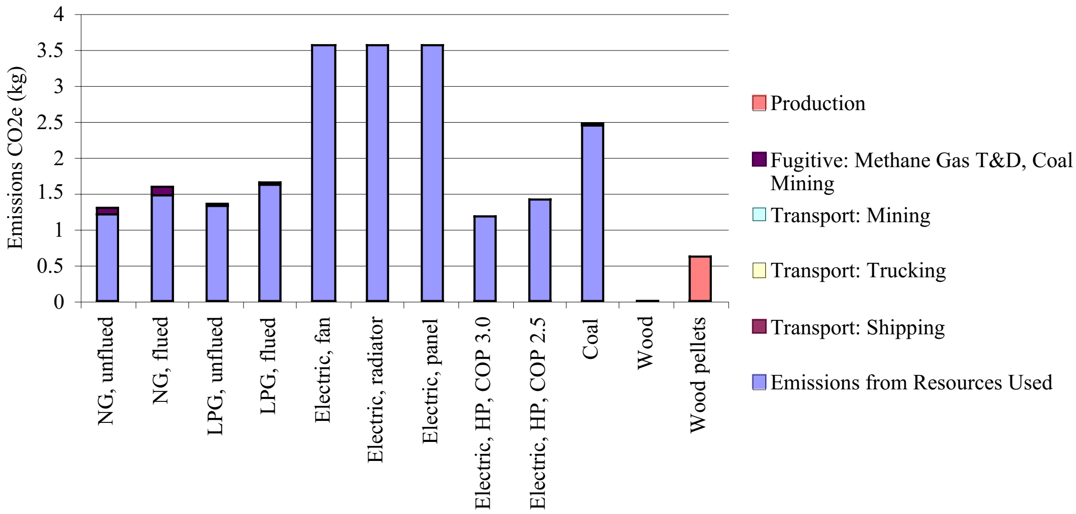

Figure 2: Domestic dispersed space heating - emissions CO_{2e}

shown as a negative value, with the effective energy utilisation described by the superimposed line. Heat pumps are less resource intensive than unflued natural gas heaters.

The emission analysis shows the lowest levels for wood and wood pellets, since emissions from burning biofuels are generally discounted in emissions accounting. The relatively high emissions for pellet burners are mainly due to a fossil fuel input in pellet production, in particular for drying wet saw dust.

Apart from biofuels, the next least emissive technologies are heat pumps, and gas heaters. Heat pumps tend to be slightly less emissive than gas heaters, particularly in the warmer parts of New Zealand. Both, gas heaters and heat pumps are significantly less emissive than coal or resistive electric heating appliances.

Figure 3 shows indicative fuel costs for different forms of heating. Capital costs for appliance and installation are not included.

The range of gas appliances tends to be more expensive to operate than other dispersed space heating appliances. Wood, coal and heat pumps offer cheaper fuel costs. It should be noted that the running costs of the more efficient gas appliances are approaching the operating costs of heat pumps in the colder parts of New Zealand.

Other considerations

Apart from resource efficiency, emissions and costs, other criteria can and should play an important role in appliance selection. These criteria are not readily quantified, but some important considerations are discussed below.

While in national accounting CO_2 emissions

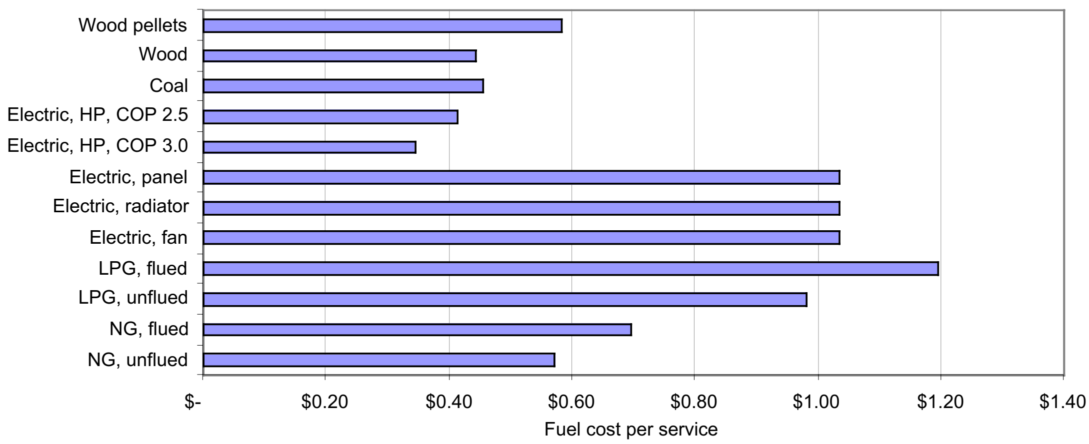

Figure 3: Domestic dispersed space heating - fuel costs

from biofuels are generally discounted, other emissions can play an important role at the local level. For example, log burners have disproportionately high particulate emissions and can cause local air pollution problems. While pellet burners are generally considered "clean burning", proper operation is required. One out of four pellet burners in a recent emissions test had particulate emissions at a level ten times higher than average, due to a faulty pellet feeding mechanism (MfE 2007).

A consideration of national importance is the load on local electricity networks seen elsewhere from the rapid uptake of heat pumps. While gas heaters and heat pumps incur comparable emission levels, heat pumps can add significantly to the peak load on the distribution network (Buckett 2007). In some networks incremental diesel generation is conventionally used to manage this increased load factor.

Quality is a very important consideration on a household level. For example, unflued gas heaters are cheaper and more flexible than flued models, but they do release toxic emissions, including nitrogen oxides and carbon monoxide, into living spaces. Small portable electric heaters have low power ratings and their use is limited by the ampere rating of the grid connection to the house. With some forms of heating, minimum indoors temperatures in compliance with World Health Organisation (WHO) standards are simply not achieved. BRANZ (2006) found that indoor temperatures depend on the forms of heating employed, and small portable resistive or LPG heaters delivered the lowest winter temperatures. The quality of the heat itself is also important. Small electric heaters might deliver uneven heating with hot and cold spots. Electric fan heaters are often noisy and may result in dry air.

For direct comparability it is essential to calculate resource use factors, emissions, and fuel costs by means of the same energy service delivered. In reality, however, different appliances deliver different levels of service; whether it is more, equal, or less than required.

For example, small electric heaters with limited power output might never deliver desirable indoor temperatures. However, for this reason they may use less energy overall than more efficient appliances with higher power outputs. On the other hand there are forms of heating that tend to deliver higher temperatures than required. For example, log or coal burners have limited flexibility in temperature control.

The power output of air source heat pumps decreases significantly at ambient temperatures below 7°C, and decreases further to a point where no heat is generated at all as ambient temperatures drop. Heat pumps can deliver high indoor temperatures if it is warm outside, but may deliver less than the desired duty if ambient temperatures drop.

On the other hand, a high flexibility in heat output without substantial decline in the overall efficiency is obtained with gas and electric heaters.

5.2 Central Space Heating

The service is defined as the amount of energy equivalent to heat a house from 10°C to 20°C and maintain this temperature for three hours at an outside temperature of 10°C. The resulting energy service comprises a heat up energy of 35 MJ and heat maintenance energy of 52 MJ, i.e. a total of 87 MJ. The model for heat up energy assumed all interior walls and furniture are heated to the target temperature of 20°C.

On the appliance side, the use of resistive electric appliances for central heating has been excluded, as it is no longer a preferred option for new installations. Oil and coal fired appliances have been discounted for the same reason. As typical candidate appliances for central heating systems, natural gas and LPG heaters, heat pumps and pellet burners were analysed. The natural gas and LPG heaters are assumed to be condensing units, which have higher efficiencies than standard units. While condensing units are not used for dispersed space heating they are becoming increasingly more significant in central heating applications (industry sources).

The energy resource profiles and supply chain emission factors are shown in Figures 4 - 6.

As illustrated in Figure 4, the total resource used is lowest in the case of heat pumps. Depending on operating conditions, the

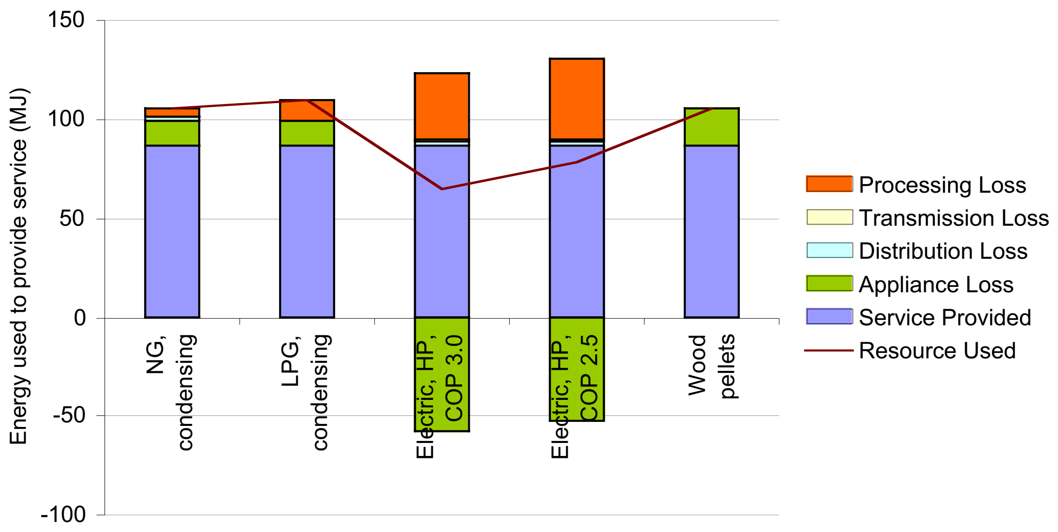

Figure 4: Domestic central space heating - energy used to provide service

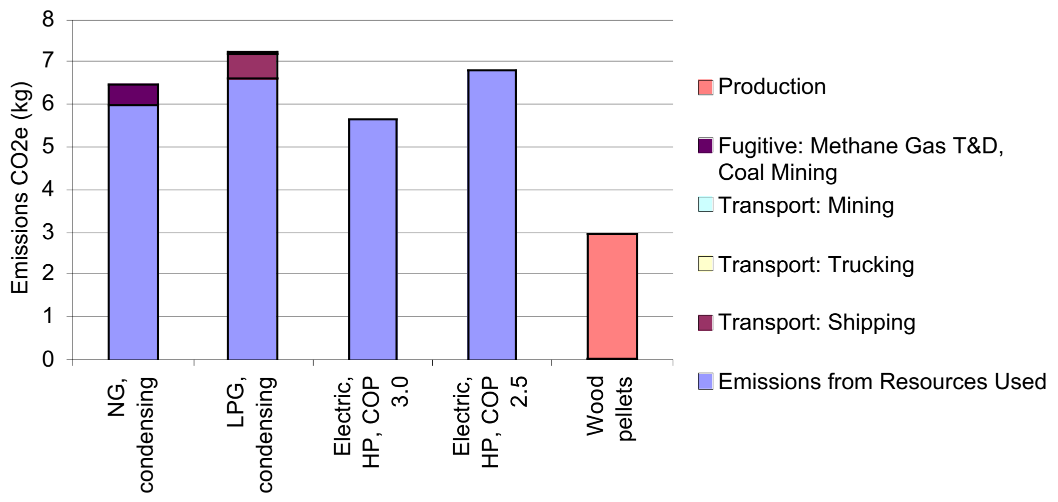

Figure 5: Domestic central space heating - emissions Co_2

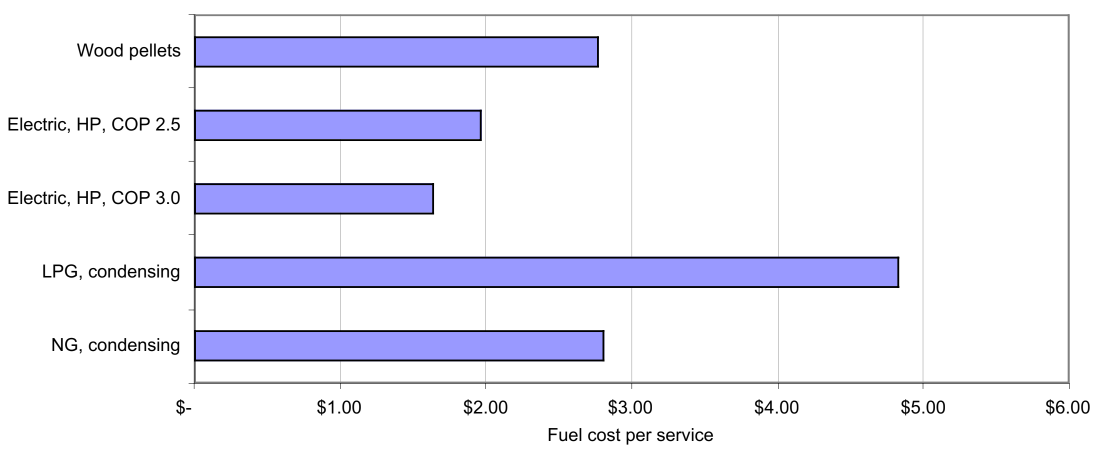

Figure 6: Domestic central space heating - fuel costs

resource used is roughly 30% lower than is the case for wood pellets or gas. Gas and wood pellets have comparable resource efficiencies, although there is a significant fossil fuel component necessary for drying the feed supply of wet saw dust as part of the wood pellet processing chain[13].

As discussed in the dispersed space heating case, no emissions are counted for the combustion of wood pellets. The wood pellet emissions shown in the chart are incurred in preparing and drying the wood feedstock. Emissions from heat pumps and gas are on comparable levels. Depending on the local climate, heat pumps might be less emissive than gas in warmer parts of New Zealand, or more emissive in colder areas.

Energy costs are shown in Figure 6. Due to the relatively high cost of LPG, the natural gas option is more cost attractive. Wood pellets and natural gas are on the same level, while heat pumps are about 40% cheaper to operate, depending on geographical location.

Other considerations

The same considerations discussed under dispersed space heating also apply to the central heating case.

[13] The commercial value of wood pellet product means that it is unlikely it would be economic as a fuel for drying.

5.3 Domestic Cooking Service

The baseline energy service is taken as the energy required for cooking 500g of spaghetti, boiled in 2 litres of water. The total energy service of 1.1 MJ for heat up energy and 10 minute boiling time takes into account heat losses through the wall of the pot as well as evaporation. These combined heat losses were determined to be in the order of 600W for a typical pot.

Appliances in this section are gas burners and electric resistive elements.

As shown in Figure 7, total resource use is comparatively low for LPG and natural gas, with roughly double this resource use for electric elements. Only slightly better resource performance would be achievable with ceramic cook tops.

As Figure 8 shows, gas or LPG provide the same cooking service at nearly 65% less emissions than electricity.

While cooking with natural gas is nearly 50% cheaper than electricity, the cost of cooking with LPG is roughly 20% lower than electricity.

Other considerations

In terms of quality, many households prefer natural gas over electricity due to superior heat control, faster response, and more uniform

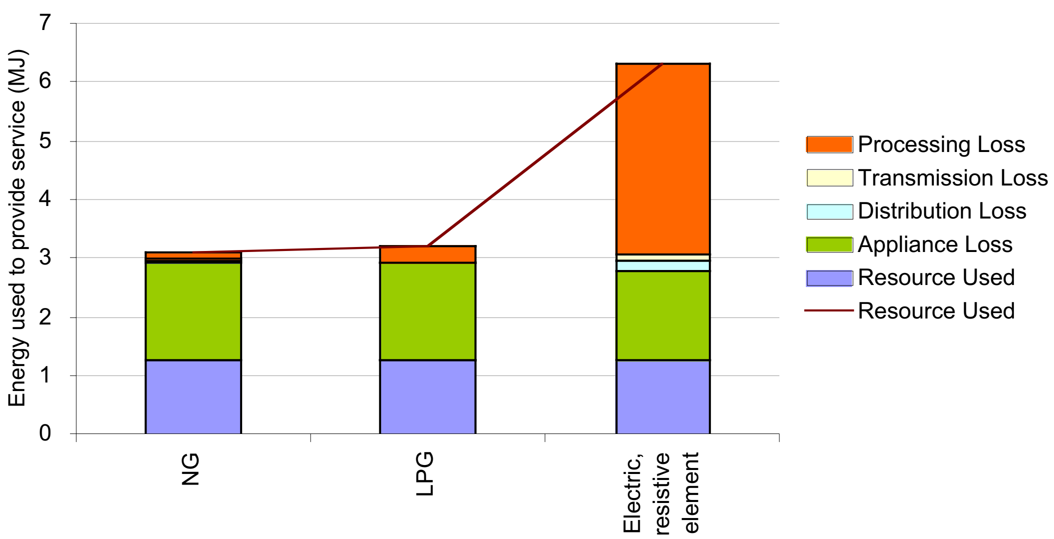

Figure 7: Domestic cooking - energy used to provide service

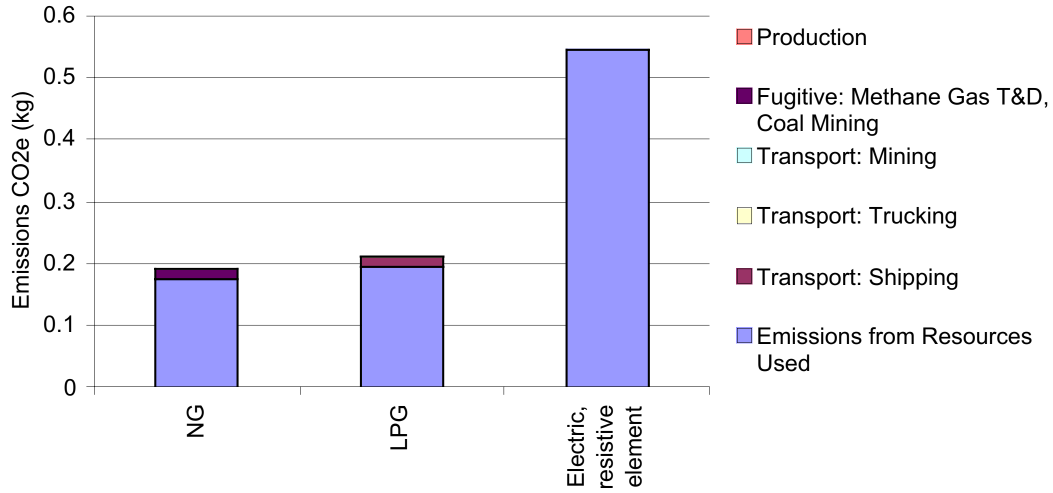

Figure 8: Domestic cooking - emissions Co_2

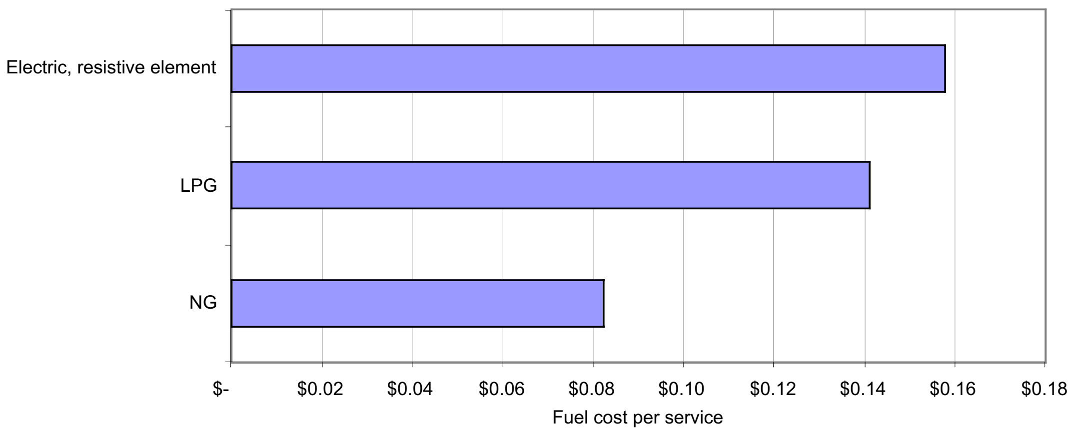

Figure 9: Domestic cooking - fuel costs

heat distribution. Gas burners also provide the greatest flexibility in terms of cooking vessels. For example, pans do not have to have a smooth bottom in order to heat up evenly.

5.4 Domestic Hot Water

A five minute shower was chosen as the baseline service for domestic hot water. Assuming a flow rate of ten litres per minute, a cold water supply temperature of 15°C and a shower temperature of 40°C, the total energy service required is 5.4 MJ.

Appliances compared are continuous or storage cylinder gas and electric heaters, as well as a solar hot water system boosted with gas or electricity. The 80% efficiency used for electric cylinders describes a mid value for A-grade cylinders (CAE 1996). For gas cylinders, an efficiency of 68% was assumed, a conservative estimate according to industry sources. The coefficient of performance of solar hot water systems is strongly dependent on the local climate. The COP value of 2.0 used in this study should be considered indicative only, but is internally consistent with assuming a COP of 2.4 for solar electricity boosted systems.

Energy resource use and supply chain emissions towards the delivery of this service are shown in Figures 10 - 12.

Of all analysed cases, the most resource efficient form of providing a hot water service is to use a solar/gas-boosted system. The next best options are solar electricity boosted systems followed by natural gas or LPG continuous heaters, which avoid standing losses incurred in any cylinder storage system. Regardless of the continuous/cylinder question,

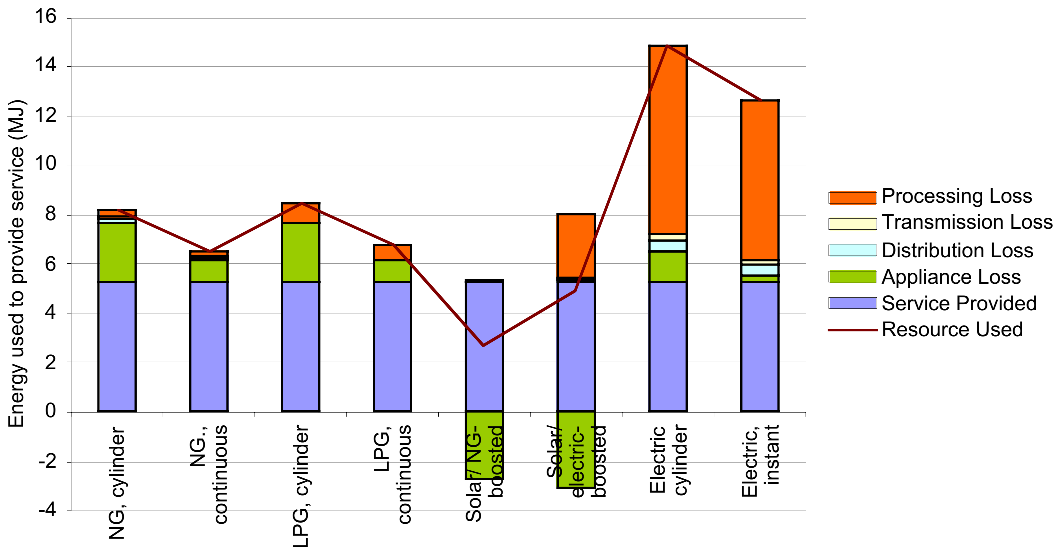

Figure 10: Domestic hot water- energy used to provide service

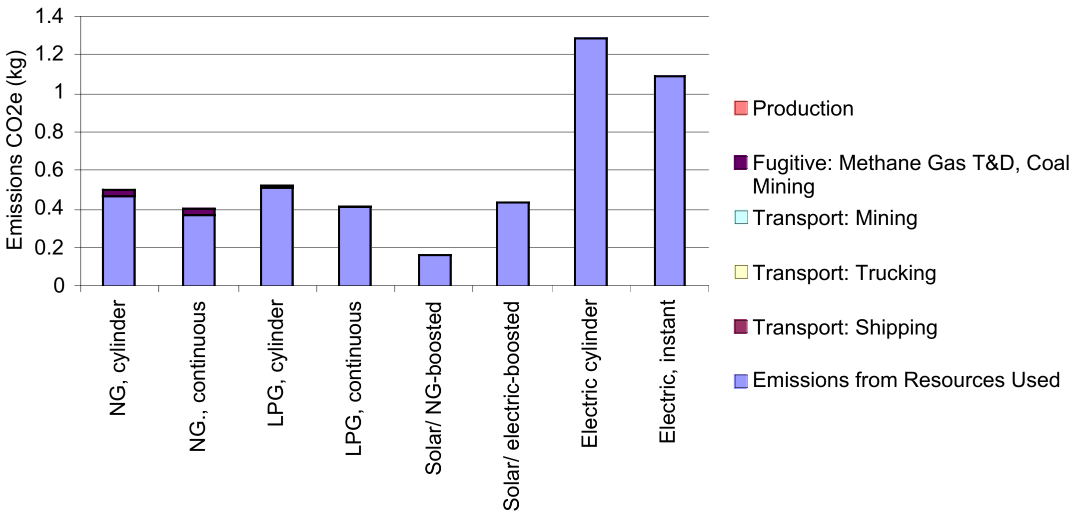

Figure 11: Domestic hot water- emissions Co_2

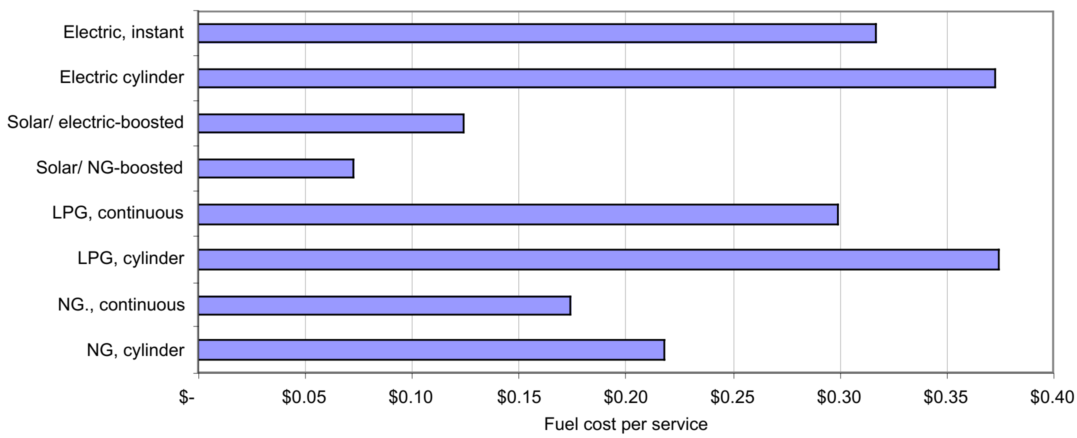

Figure 12: Domestic hot water- fuel costs

any gas system is significantly more resource efficient than the best case electricity option.

Trends in resource efficiency are exacerbated in terms of supply chain emissions. This is because of the higher emission factors from electricity over gas. Clearly, the solar-gas option is least emissive if the local climate allows and is generally superior to the solar electricity boosted system.

The large differences in resource efficiency and emissions are less pronounced when comparing costs. However, gas options typically provide the same hot water service at lower cost than the equivalent electricity option. Heating water with natural gas is about 50% cheaper than using electricity.

This analysis did not consider special electricity plans. For example, an electric storage cylinder on a night plan might in some cases be as cheap, or cheaper to run than gas.

Other considerations

The quality of a hot water service mainly differs in two ways: the maximum flow rate and, in the case of instantaneous or continuous heaters, the uniformity of the hot water temperature over time. Both gas and electric cylinders are available as high pressure systems that allow for high flow rates. However, in contrast to continuous gas heaters, instantaneous electric heaters can have unsatisfactory flow rates and temperature fluctuations (Department of Building & Housing 2007).

5.5 Commercial/Light Industrial Steam

The energy service is defined as the energy it takes to produce one tonne of steam. The energy service demand of 2630 MJ is composed of the energy it takes to heat one tonne of water to boiling point and the energy to completely evaporate the water. The service is kept at a generic level, because actual applications tend to be very specific.

Energy conversion efficiencies were chosen in line with (CAE 1996), while concessions were made for improved efficiencies aligned with new industry sources.

Energy resource use and supply chain emissions towards the delivery of this service are shown in Figures 13 - 15.

The resource use chart shows that natural gas, LPG, diesel, and coal, all have comparable resource efficiencies with the notable exception of electricity. Electricity is almost twice as resource intensive as any of the alternatives.

Because of this efficiency factor, steam generation with electricity incurs roughly 80% more emissions than the direct use of natural gas. LPG follows gas closely. Even the direct use of coal is significantly less emission intensive than the supply chain emission factors arising from the generation and supply of electricity.

Fuel prices are by far the lowest for coal, followed by natural gas. Fuel costs for diesel

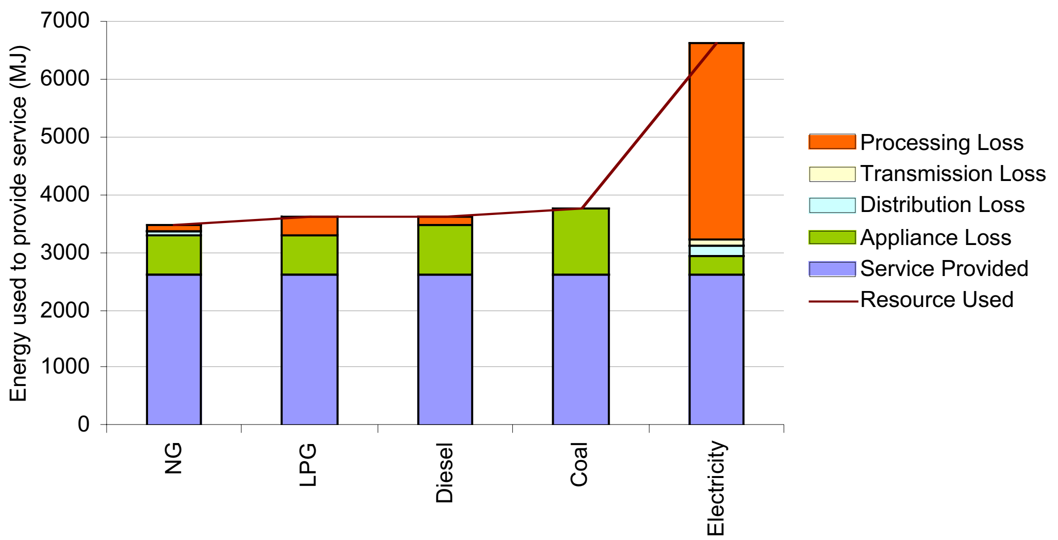

Figure 13: Commercial/Industrial steam - energy used to provide service

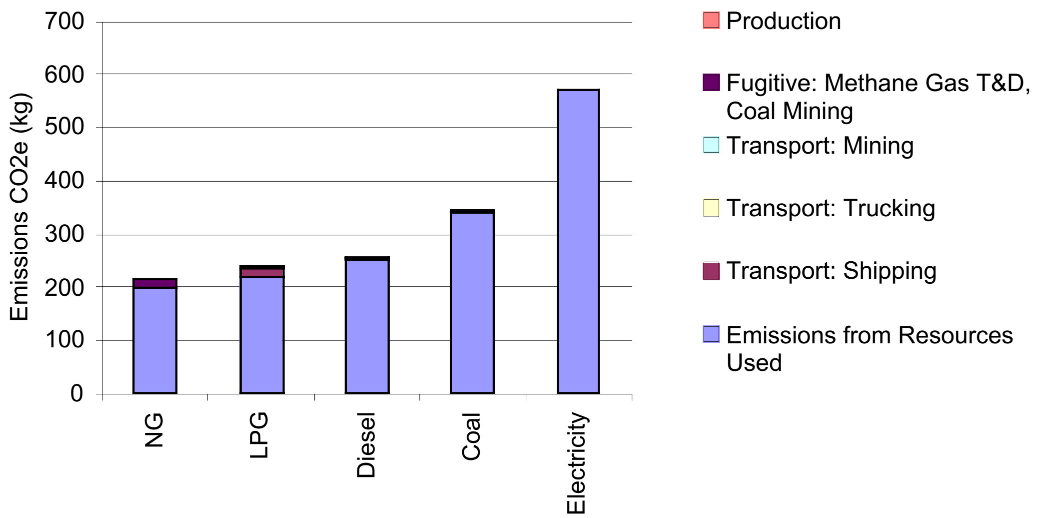

Figure 14: Commercial/Industrial steam - emissions Co_2

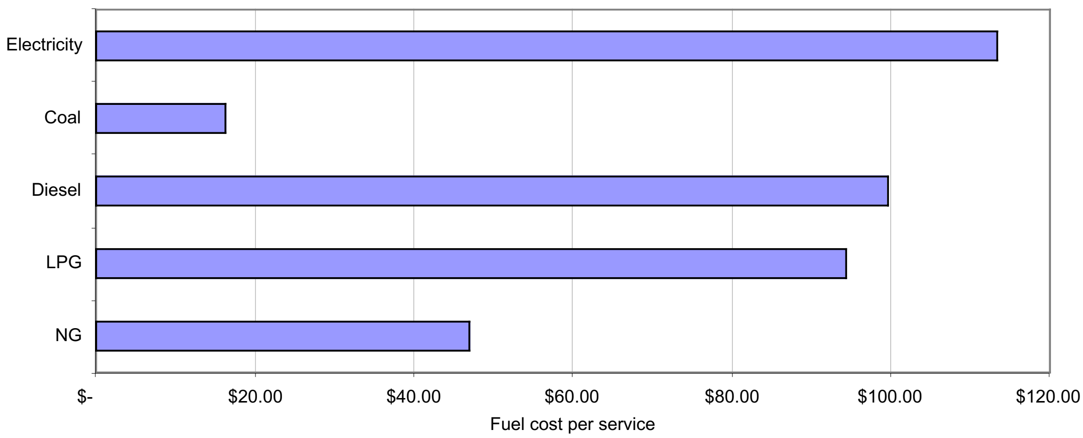

Figure 15: Commercial/Industrial steam - fuel costs

and LPG are more than 50% higher than for natural gas, with electricity being the most expensive option.

Other considerations in the technology selection for commercial steam production are highly case specific.

5.6 Commercial/Light Industrial Hot Water

The energy service is defined as the energy it takes to produce one tonne of 75 degrees C hot water. This 252 MJ energy service demand represents the energy it takes to heat one tonne of water 75 degrees C.

Energy resource use and supply chain emissions through to the delivery of this service are shown in Figures 16 - 18.

The technology selection for production of commercial hot water is the same as for commercial steam production, except that coal is not included for hot water. Coal burners are more likely to be used in high energy applications such as the generation of steam or large industrial hot water production.

The resource efficiency and supply chain emissions show the same trend observed in the case of steam generation.

Fuel prices are lowest for natural gas. The next cheapest option, diesel, is more than twice as expensive. A bulk supply of LPG may lower the cost to that of diesel.

Other considerations in the technology selection for commercial hot water production are highly case specific and have not been discussed in this report.

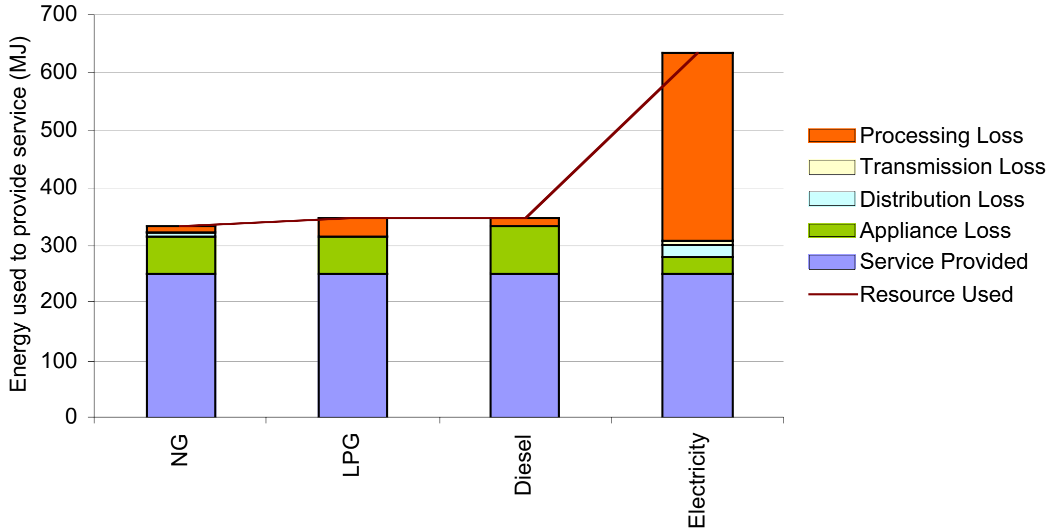

Figure 16: Commercial/Industrial hot water - energy used to provide service

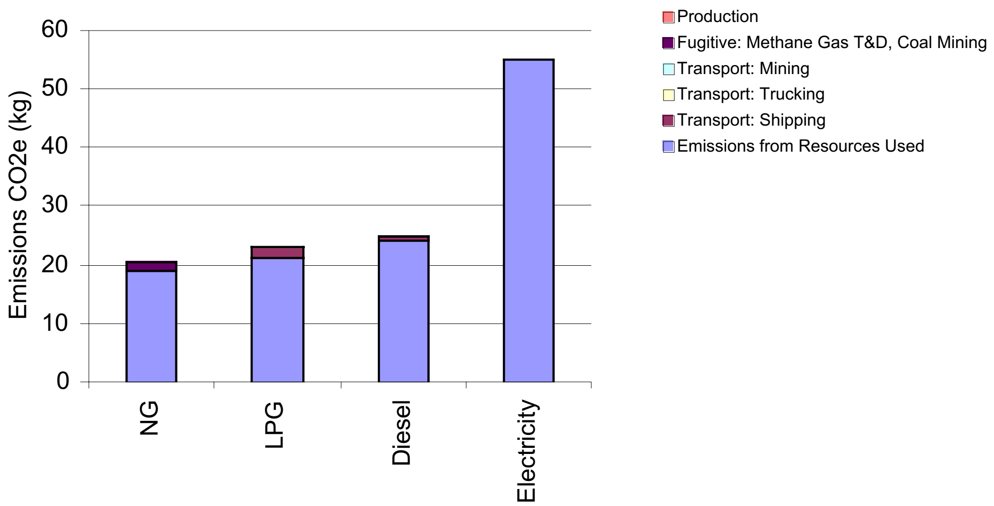

Figure 17: Commercial/Industrial hot water - emissions Co_2

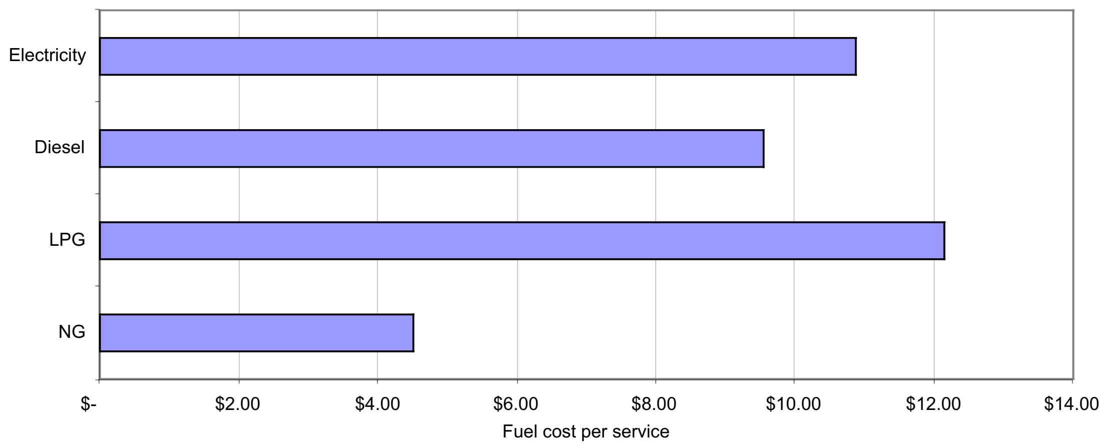

Figure 18: Commercial/Industrial hot water - fuel costs

5.7 Commercial Heat Ventilation and Air Conditioning (HVAC)

The baseline energy service is defined as the energy equivalent of keeping a 100 m^3 office space air conditioned at an outside temperature of 30 degrees C for 8 hours. The energy equivalent for this service is 227 MJ.

On a generic level, technologies for commercial HVAC services were chosen as absorption heat pumps (gas) and electric compressor heat pumps.

The overall resource intensity in providing the cooling service is slightly lower for gas than for electricity. Electric heat pumps generally achieve higher coefficients of performance than their heat-driven absorption counter parts. However, the supply chain contribution from generating and distributing electricity instead of using natural gas directly negates the apparent benefits of the higher end use efficiency.

Natural gas shows a significantly lower level of emissions.

Fuel costs for providing the same cooling service are significantly lower in the case of natural gas than for electricity.

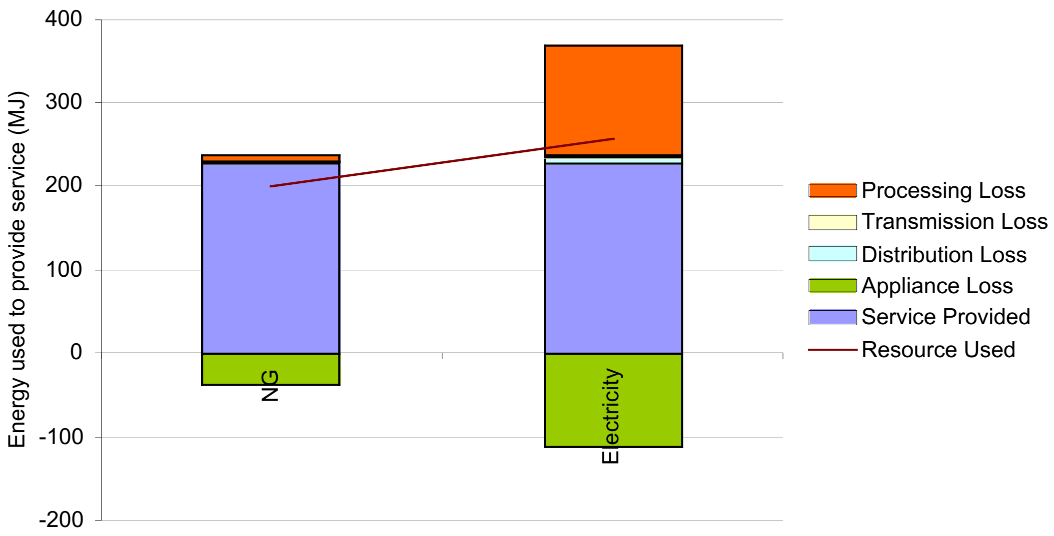

Figure 19: Commercial HVAC - energy used to provide service

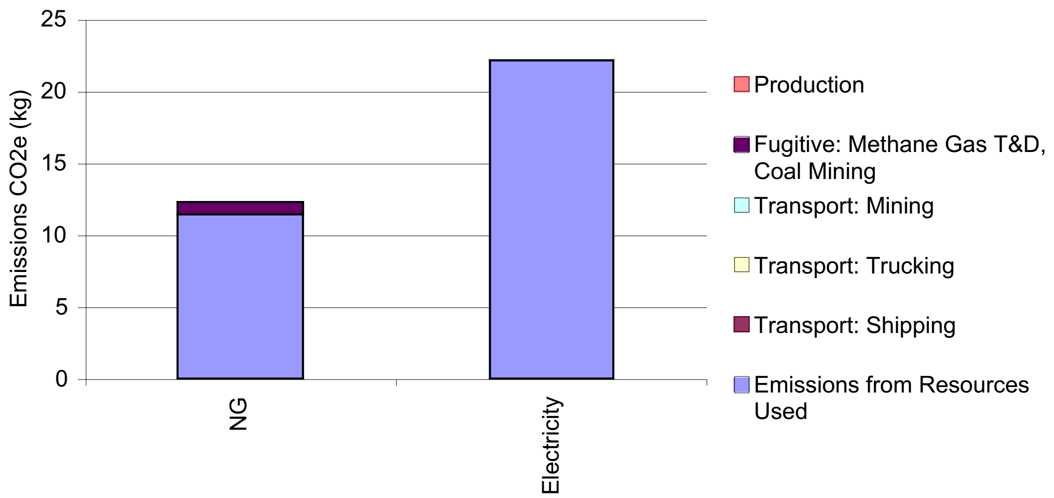

Figure 20: Commercial HVAC - emissions Co_2

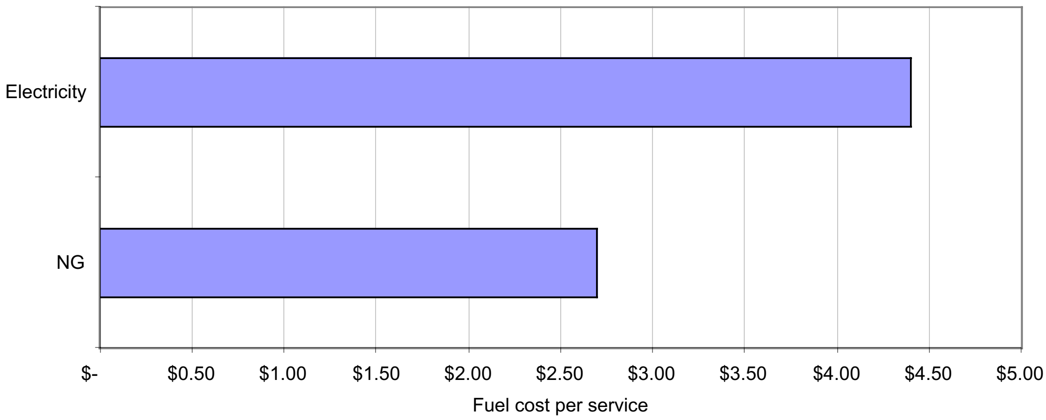

Figure 21: Commercial HVAC - fuel costs

5.8 Conclusions

The above analyses clearly demonstrate that, when considered in terms of the total fuel supply chain, the direct use of natural gas in the residential, commercial and industrial markets has considerable merit. This is true for all three perspectives: carbon emissions, overall resource efficiency, and costs.

As one would expect, the principal source of emissions is from the consumption of fossil fuel resources, especially the generation of electricity at the margin. Incidental fuel use, such as diesel in the transport of coal and LPG, and fugitive emissions from coal mining, are very small in comparison. The principal exception to this conclusion is the level of emissions arising from the production of wood pellets.

The use of natural gas can thus result in significantly lower levels of CO_2 emissions for most of the residential, commercial and industrial applications examined. This includes, in many instances, electrical appliances because of the high level of carbon dioxide emissions associated with the generation of electricity based on the marginal emission factors. Applications where competitive technologies result in fewer emissions were identified as:

- Electric heat pumps when used for domestic heating, but only when operating under favourable conditions.
- Wood and wood pellets used for domestic heating.

The advantage of wood/ woodchips arises as its CO_2 emissions are assessed as zero because these are deemed to have arisen from a renewable/waste resource. However, wood application is becoming more limited because of concerns with particulate emissions.

Qualitative factors are also an important determinant in overall efficacy and desirability. The major complicating factor is the level of service obtained and the flexibility to control the duty supplied to match actual requirements. In this respect the direct use of gas has significant advantages over most competing energy forms; both in terms of controllability and the relatively stable efficiency profile over typical operating conditions. Overall, the quantitative factors of carbon emissions, overall resource efficiency and cost make a strong case for the direct use of gas in many applications.

6 DISCUSSION

6.1 The Current Policy Context

The New Zealand Energy Strategy (NZES) to 2050 released by the MED in October 2007 reflects the same fundamental principles as the draft document circulated for consultation in December 2006. These include:

- protect security of supply;
- promote energy efficiency measures; and
- promote low emissions energy sources.

In particular, the strategy places considerable emphasis on the important role the energy sector will play in meeting New Zealand's international climate change obligations. This underpins other guiding principles and targets contained in the document:

- In the foreseeable future, Government believes it is preferable that all new electricity generation be renewable, except to the extent necessary to maintain security of supply. Government has adopted a target for renewable electricity generation of 90 per cent by 2025 and is considering limiting new baseload fossil fuel generation over the next ten years.
- A target has been adopted to halve domestic transport emissions per capita by 2040. It is government's intention that New Zealand will be one of the first countries in the world to widely deploy electric cars fuelled by renewable resources.
- Government has decided in principle to proceed with an emissions trading scheme, consistent with its policy of "utilising markets and focused regulation".
- A National Policy Statement is being developed under the RMA for renewable energy.
- Energy efficiency should be favoured where it is cheaper than new generation capacity.
- The pathway foreseen by the NZES to 2025 includes "low cost renewable technologies (including wind, geothermal and possibly some marine) will help to achieve the renewable electricity target" and "electricity and heat for industry will be produced from low carbon sources and near-zero process emissions".

Natural gas is recognised in the NZES as having continued importance as a source of primary energy and the potential reduction of emissions by the direct use of gas is noted. Specific mention of gas is made in the following context:

- Gas will continue to play an important role in meeting energy supply requirements during transition to the "sustainable energy future ... in which supply is increasingly met by renewables" and will play a key role in maintaining security of supply in the electricity sector.
- Gas produces fewer emissions than other fossil fuels, which makes it the fuel of choice for fossil fuel generation. The direct use of gas in industrial, commercial and residential applications provides increased diversity and flexibility of supply and opportunities for reducing emissions.
- Whilst acknowledging the potential to reduce emissions by the direct use of gas rather than electricity, the Government's support is lukewarm, stating "the comparative costs of gas appliances and their associated installation can be high. The growth of efficient forms of electric heating, such as heat pumps, may offset some of the potential gains from switching to gas".

The NZES contains many action points for the government to follow up. As would be expected many of these relate to the promotion of renewable fuels and the establishment of a market structure to facilitate their use. Those relating to the gas industry are limited to improving the operation of the gas market, rather than any active encouragement of the direct use of gas, despite its acknowledged importance as a primary source of energy in the future. The Government "believes the current gas market settings, particularly the co-regulatory regime, will enable the market to make an efficient transition to the post-Maui era" and limits actions to "bedding-in (of) existing gas market arrangements":

- Development of gas wholesale and transmission market arrangements by GIC.

- Review by GIC of current arrangements in the case of a national gas outage.
- The NZES does allude to a need to clarify "the long-term role of gas (including LPG), oil and coal and other alternative energy sources in New Zealand's energy mix" in regard to energy security but defines no specific action plans.

Whilst the NZES recognises the continuing importance of gas as a source of primary energy and the potential reduction of emissions by the direct use of gas it is passive with regard to any action or plan to secure the position of the gas industry except to make relatively minor changes to the functioning of the gas market. Rather, it strongly favours renewable fuels and primary renewable resources for electricity generation.

The active promotion and expansion of renewable energy's share of the market implies the reduction of the share of fossil fuels. Gas does have a favoured position amongst fossil fuels but that is only manifested in the policy by gas's implicit advantage in the carbon trading scheme. The policy does not address the potential impact of promoting renewables on the continued operation of the gas industry and the future investment necessary to maintain it nor does it address the likely implications of reducing the load factors of thermal electricity generation plants.

CAENZ believes that a number of issues beyond the comparison of greenhouse emissions need to be emphasised to more fully understand the importance of the gas industry to New Zealand energy markets. These involve assumptions made in the NZES in respect of the limited end use opportunity and the need to recognise the performance of the gas industry and how it operates; particularly in the context of uncertain gas reserves.

6.2 Assumptions in the NZES

Amongst the targets set by the NZES is the generation of 90% of electricity requirement by renewable resources and the halving of the per capital emissions from transport largely through the introduction of renewable fuels.

These targets run counter to historical trends and represent a major structural change to both these energy sectors. Similarly there is a desire to increase renewable energy use in other energy market sectors.

- Both these stated targets must be considered aspirational given the degree to which the market structure must change against established trends and the major effort which must go into their implementation in a relatively short time. There is a high level of risk that these targets will not be met.
- CAENZ estimates that biomass as a thermal fuel will only become generally competitive outside existing 'own-use' markets when the cost of carbon dioxide emissions is in the order of $60 to $70 per tonne, significantly higher that those signalled in the NZES, adding to the uncertainty of reaching the renewable energy targets.
- The NZES does not have a parallel strategy to ensure other forms of energy will fill any shortfall in renewables uptake. The most likely candidates to fill this gap are the existing fossil fuel suppliers who face increased uncertainty and little incentive to continue with the investment necessary to maintain their businesses. This creates a new vulnerability in the New Zealand energy market.
- A further vulnerability arises from the failure to recognise the importance of process heat demand within the industrial and processing sectors. This segment of the energy market already has a large renewables/waste component as well as a strong reliance on natural gas in direct use applications which, in many instances, is not substitutable by other energy forms. In addition, the portability of LPG offers considerable advantage for remote locations.
- Gas industry sources indicate that a minimum gas market size of 80 to 100 PJ/y is required to sustain the investment necessary to keep the existing natural gas supply network maintained to its high engineering and operational standards[13]. Current gas consumption is in the order of 150 PJ, of which 40% is used in electricity

[13] A parallel can be drawn with the old town gas industry which went into a spiral of decline when demand fell and the industry had difficulty maintaining the network to adequate standards.

generation, 30% in industrial, commercial and residential use, and 15% in each of cogeneration and petrochemicals production. With the long-term future of the last category uncertain, a significant reduction in the gas used in electricity generation could have far-reaching effects on the ability of the gas network to continue to operate in its present form. The failure of the domestic gas industry would provide opportunities for coal with its high carbon footprint, contrary to the emissions priorities outlined in the NZES.

- Diminishing the New Zealand gas industry will reduce the flexibility of the domestic market to respond to international energy market and price volatilities.
- The NZES does not sufficiently differentiate between gas and other thermal fuels and electricity. Whilst DUOG is recognised as a means of reducing carbon emissions, this study shows that gas creates fewer emissions in a range of applications.

  Additionally, it can be argued that gas's ability to substitute for peak electricity demand in the home helps reduce to some extent thermal generation of peak loads and lowers the costs of electricity supply.
- Finally we comment that government strategy to accelerate the deployment of electric vehicles may, in fact, have the unintended consequence of increasing our dependence on electricity. Without a parallel strategy to ensure the reliability of future supply the transport sector remains vulnerable to supply shortfalls. The use of CNG/LPG as alternative transition strategies has been ignored.

New Zealand has a strategic interest in ensuring that a robust domestic gas industry survives, as the alternatives to domestic gas are not necessarily renewable energy forms but a greater dependence on less desirable fossil fuels such as oil, coal and imported LNG.

Proven Record of Gas Industry

The natural gas industry has been operating in New Zealand for over 30 years. The nature of the industry and its performance is well understood. In particular, gas quality, availability, performance of plant, its costs and environmental impacts can be quantified with a high degree of confidence. In comparison, the performance of renewable technologies is subject to greater uncertainty, either through climatic or market uncertainties, or the novel nature of some technology to be used in the expanded renewables markets. Whereas the climate change implications of natural gas can be easily calculated, those from the fossil fuels required for the cultivation and processing of biofuels are less well understood and can vary considerably with location and the nature of the operation. The food versus biofuels debate illustrates this uncertainty and potential for unintended consequences from biofuels use.

Reliability of Gas Supply

Natural gas has been delivered to the residential, commercial and industrial markets in the North Island for over 30 years with a high level of reliability. It is also a major source of primary energy for the generation of electricity and gas supply has to conform to the reliability criteria of that industry. This reliability is underwritten by a transmission and distribution system built to recognised construction and operating standards with gas deliverability based on established field reserves. Failures of the gas supply system have been very infrequent and quickly rectified[14].

Delivery of gas is not affected by factors outside the gas field and delivery system whereas the availability of renewable energy is directly influenced by the climatic conditions and competition for natural resources. Gas effectively is used as a standby for hydroelectricity in dry years when there is insufficient water in the hydro reservoirs to meet demand and wind and solar energy systems must be complemented by more reliable generation capacity using fossil fuels.

The above comments apply equally to LPG, which is extracted during the processing of natural gas and shipped to New Zealand using well-proven technology. There is plentiful availability of LPG in the Asia Pacific region for New Zealand's purposes.

Sustainability

The concepts of sustainable development and sustainable management of resources and the environment are well established within New

[14] The NZES implies that the reliability of the gas supply system as a potential weakness of gas but does not quantify this.

Zealand government policy and are most particularly articulated in the Resource Management Act (RMA). The broad objective of the RMA is the management of natural resources whilst avoiding or mitigating adverse environmental impacts. It acknowledges the need for economic growth and increasing standards of living and particularly identifies the efficient end use of electricity, effects of climate change and the benefits from the use of renewable energy amongst the considerations to be made by decision-makers. Whilst sustainable management includes sustaining the potential of natural and physical resources (for future generations), it specifically excludes minerals (including gas) in this regard, recognising the fact that finite resources cannot be replaced. Rather, it calls for their efficient use.

The RMA does not therefore exclude the use of finite resources to the advantage of renewable energies, but does imply the consideration of climate change matters as evidenced in the recent hearing on the Marsden B power station. Energy efficiency of gas use and its contribution to security of overall energy supply should be points emphasised by the gas industry in discussions on sustainability.

Gas Reserves and Production

With the decline in production from the Maui gas field, the supply side of the New Zealand gas industry has changed significantly over the last ten years. The reserves of the Maui field were large in comparison to national demand, providing a 20 year period with high levels of supply security and cheap gas. Development of the field was structured around long-term take or pay contracts which gave little incentive for extensive exploration for additional gas reserves with only small onshore fields being brought into production during the Maui era. Operationally, the Maui field was very flexible, with deliverability easily being able to match short-term fluctuations in demand.

The removal of such a dominant field in the gas supply side has seen major adjustments to the way the gas industry now operates:

- Several new fields, notably Pohokura and Kupe, are being brought on stream. These have significantly smaller reserves than Maui and individually cannot supply the total demand for gas, even with the continuing availability of the Kapuni field.
- The negotiated wholesale price of gas from these fields is significantly higher, estimated at over $6/GJ, than the Maui gas price of $2-2.50/GJ[15]. The market has also become less transparent, with prices not being disclosed publicly for the new fields whereas the Maui Gas Supply Pricing Arrangements (GSPAs), including the price provisions, were public knowledge.
- Whilst the reserves of Maui were always subject to interpretation, the uncertainties only became significant in the latter stages of the field operation. The industry now operates in a climate of increased uncertainty about existing and future reserves and a much reduced reserves to production ratio.
- The expiry of some of the long-term Maui sales contracts during the early part of this decade, the lack of suitable replacement gas and the increased wholesale price of gas has resulted in a major reduction in consumption of natural gas, from a peak of about 240 PJ/y to a current level of 150 PJ/y. This reduction has occurred predominantly within the petrochemical industry (Methanex methanol production) and the reduced use of gas in old conventional power stations (Huntly and New Plymouth).
- Continuity of market opportunities for gas is a primary incentive for the on-going investment in exploration and development activities necessary to provide new gas reserves. A reduction in gas demand resulting from the renewables policy will break this continuity, leading to a reduction in gas exploration and development investment, particularly in the short to medium term.
- A "critical mass" of gas consumption will be required to sustain the gas transmission system. This will be in excess of the quantities of gas supplied through the distribution networks to the residential, commercial and industrial markets, implying that the continuation of gas supply to these sectors must be supplemented by gas supplied to electricity generation[16].

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15 CAE Comments 2004: Energy Supply in the Post-Maui Era.

16 Gas supplied to the residential, commercial and industrial markets, including cogeneration and large industrial users supplied directly off the transmission network is in the order of 60 PJ/y.

Any analysis of current New Zealand gas reserves indicates that production from existing reserves of gas will decline sometime in the next decade. This takes account of any upside potential in the remaining Maui reserves in excess of those included in the economically recoverable reserves, the development of the Kupe field and reduction in demand through the closure of the petrochemical plants.

The low gas reserves to production ratio is obviously an immediate concern for the gas industry and perhaps a partial reason for the lack of enthusiasm for gas in the NZES. It is important that policy makers keep a longer-term view of the importance of gas in the primary energy mix:

- There will be a continuing need for thermal fuels to be part of the electricity generation mix to ensure the necessary reliability of electricity supply to consumers and to supplement the inherent uncertainty in generation from renewable sources such as hydro and wind.
- Failure of the gas market will result in residential, commercial and industrial consumers switching to alternative energy sources such as electricity and coal, both of which will result in greater emissions of carbon dioxide[17].
- The emerging higher gas price structure has provided more incentive for exploration for gas (and oil) and has already resulted in the successful addition of new gas reserves in the transition to the post-Maui era. New Zealand remains relatively under-explored, even in the Taranaki basin which is the most heavily explored area, which provides optimism that further reserves will be discovered. However, the future policy environment must ensure this is complemented by on-going market opportunities for gas to incentivise the necessary investment in petroleum exploration and development to maintain a continuity of gas supply to fulfil its role in the energy mix.
- The oil and gas industry is used to operating in an environment of reserves uncertainty and the generation of new reserves through E&P activities is an integral part of the industry. Gas has been quick to adapt to previous energy supply concerns, for

[17] Without a gas industry, the marginal CO_2 emissions from electricity generation intuitively will be higher than those given in Section 3 as all the thermal generation will be from coal.

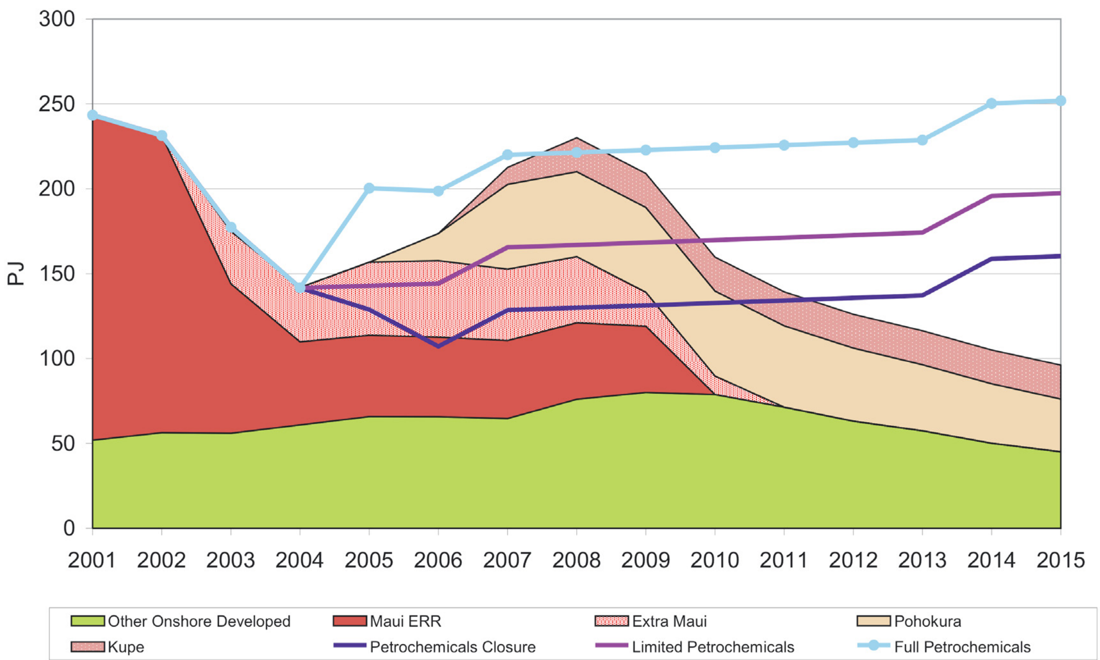

Figure 22: Forecast Gas Production Projected Again Gas Consumption (Figure 3, CAE Comments 2004: Energy Supply in the Post-Maui Era. The data has not changed substantially since publication in 2004. Other, more recent, publications show slight differences, but the cross-over to insufficient production output changes only about 2 to 3 years.)

example the filling of the generation capacity "gap" in the 1990s through the introduction of IGCC technology.

- Diversity of energy supply is an important element in energy policy. Any reduction in the role of gas in the primary energy mix will inevitably reduce the flexibility of the energy markets to adapt to any future changes or new priorities in policy which are not foreseen at present. Because of their complementary nature and potentially similar role in energy supply, the most likely replacement for gas will be coal, which results in higher carbon dioxide emissions in any situation. If a major gas discovery is made sometime in the future, the possible reinstatement of gas after a hiatus in its use could be problematic because of the difficulty in matching a large resource development with the small size of the New Zealand market[18].

- LNG remains a backstop to provide gas to the existing gas market without the need to find and develop further gas resources. The well proven and continually improving processing and delivery technology and the existence of a number of potential suppliers (Australia and Indonesia are the most likely sources) makes this a relatively risk-free option. It is probable that it will come at a cost, the prices for regasified LNG delivered to the New Zealand pipeline system are anticipated to be higher than those for domestic natural gas (and compared to electricity generated from coal), with subsequent impacts on gas demand[19]. LNG projects are large in comparison with the New Zealand gas market and are generally underwritten by long-term contracts, which would likely suppress interest in exploration for new gas reserves in much the same manner as during the Maui era.

[18] The Maui gas field was developed only through the government's commitment to take all the gas from the field developers at prescribed rates of production and prices.

[19] CAE Comments 2004: Energy Supply in the Post-Maui Era.

7 A REVIEW OF SELECTED POLICY/TECHNICAL DOCUMENTS

This section presents a review of recent New Zealand studies that have reported on the relative efficiencies, carbon emissions, and comparative merits of heating technologies studied in this report. Whilst this does not purport to be a comprehensive literature search, it offers an up-to-date compendium of relevant data. Findings from these studies and from this report are compared against New Zealand government policy statements.

7.1 Technical reports

Some examples of recent studies on efficiencies and emissions are shown in Table 7.1. There is no significant variation in the comparative appliance efficiency values reported. Since CAENZ's energy efficiency study, an upward trend in appliance efficiency has occurred. This is confirmed by industry sources.

A point of discussion is the choice of electricity emission factors. The Department of Housing used an emission factor of 100t/TJ (of CCG) arguing that, if new electricity generation was required, this would be most likely supplied by Combined Cycle Gas (CCG) technology. However, in 2003, the Ministry for the Environment (MfE) commissioned a study to determine an electricity emission factor (referring to factors: 167 kg/TJ, 2004 update: 167 to 181 kg/TJ (Concept Consulting Group 2003; Concept Consulting Group 2004)). This factor "is to be used in estimating the likely reduction in CO2 emissions from thermal power stations between 2008 and 2012 should new renewable supply or alternative demand side initiatives be supported during the forthcoming Climate Change Office tender round" (Concept Consulting Group 2003).

The analysis undertaken by Otago University's Housing and Health Research Programme has

Year	Study	Significant efficiency numbers	Electricity emission factors
1996	CAE: Energy Efficiency… (CAE 1996)	Gas: 50 to 80% HP: COP 3.0 Log burners: 60 to 75%	-not studied-
2005	Otago University: Housing, Heating & Health Study (Chapman 2005)	HP: COP 2.5 to 3.5 Gas heating: 80% Pellet fires: 75%	Marginal generation: 174 t CO_2/TJ_{el}
2006	HEEP Study	HP: COP 3.0 NG heating: 80% LPG heating: 94% Coal/Log burners: 60%	-not studied-
2007	DBH: Energy Efficiency of Buildings (Department of Building & Housi ng 2007)	-undisclosed-	Assume additional new generation is CCG: 100 t CO_2/TJ_{el}
2007	Melhuish: Submission to Otago Council (Melhuish 2007) (data based on HEEP study)	HP: COP 2.4 NG heating: 80% LPG heating: 94% Coal/Log burners: 60%	Marginal generation: 195 t CO_2/TJ_{el}

Table 7.1: Reports accounting for emissions and efficiencies

some internal inconsistencies. Chapman (2005) compares flued natural gas heaters with heat pumps for carbon dioxide emissions.

For CO_2 emissions the conversion factor used is the same 625 tonnes carbon dioxide per gigawatt hour (GWh) or 173.6 t CO_2 per TJ used in this report. Chapman shows graphically that the COP decreases significantly for an outside temperature below 7˚C (see Figure 23).

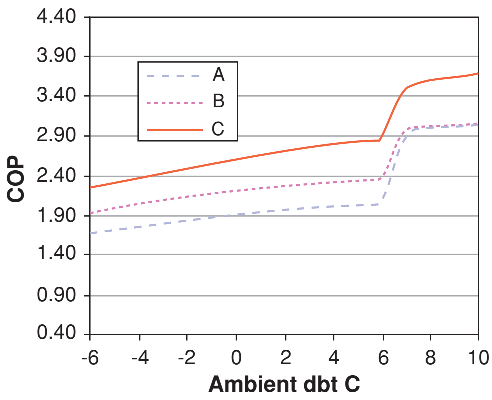

Figure 23: The COP of air source heat pumps as a function of ambient (dry bulb) temperature (Reproduced from (Chapman 2005), originally published in a presentation of Adrian Hall to the MEPS steering committee on 18 September 2003).

Chapman uses two COP values for heat pumps in order to mark a range. His values of 3.4 and 2.2 result in 184 and 284 grams of CO_2 emissions per kWh of heat output respectively, which is independent of the 7.2kW output unit considered.

When flued gas heaters are considered, the typical 120W electric circulating fan incurs emissions of 75g CO_2 per hour. The studied 7.2kW output heater emits 1750g of CO_2 from the gas combusted at an efficiency of 78%, the value used in this report. Combined emissions of heater and fan thus amount to 254g CO_2 per kWh. However, Chapman omitted to account for the 7.2kW basis in determining his final outcome. So, while his emission results for heat pumps in Figure 1, p.13 are consistent, emissions for flued natural gas heaters are overstated by a factor of seven.

In a further note, the analysis by Chapman (2005) was based on delivered energy to the home, but did not consider transmission losses for both gas and electricity as covered in this report.

In summary, while there is little variation in input assumptions, two reports surveyed were found to be based on erroneous analysis: The "Energy Efficiency of Buildings" study (Department of Building & Housing 2007) understates emissions for electric appliances by 40% by using low emissions factors for electricity generation. Otago University's "Housing Heating and Health" study's (Chapman 2005) natural gas emissions are approximately 700% too high due to inconsistent bases for comparison.

7.2 Comparative merits of heating and related technologies

Table 7.2 provides an overview of a range of recent reports on domestic or small commercial uses of gas and electricity. The important role of gas is acknowledged in almost all reports, after allowing for the inconsistencies in the University of Otago study. The general conclusion is that gas and heat pumps are roughly on par in terms of emissions. However, heat pumps were found to be problematic in the colder areas of New Zealand due to their poor performance when the ambient temperature drops below 7°C. Paradoxically it could be argued that the main credit for increased use of gas is concurrently the main critique on heat pumps: while the direct use of gas decreases the load on the grid, the widespread adoption of heat pumps has already incurred significant increases in electricity demand and peak load.

7.3 NZ government policy

While all the relevant studies above explain and support the importance of gas to the NZ energy market, these findings are not taken fully into account in past government strategy statements. While the Energy Efficiency and Conservation Authority (EECA) originally acknowledged the potential merits of the direct use of gas, their latest NEECS (EECA 2006), like MED's 2006 NZES, does not address the potential of the direct use of gas and instead focuses on heat pumps and renewable energies instead. Government policy is open to criticism that it has not fully referenced all

Year	Study	Key findings
2005	MfE: Warm Homes Technical Report: Social Drivers: Phase 1: Interim Progress Report (Taylor Baines & Associates 2005)	Points out great potential of gas for air quality and high quality heating/central heating
2005	MfE: Warm Homes Technical Report: Social Drivers: Phase 2: Report (Taylor Baines & Associates 2005)	Heat pumps are consumers' first choice in government promotion packages, but add to peak load of grid
2005	Otago University: Housing, Heater, and Health Study (Chapman 2005)	"In summary, taking into account the range of performance characteristics reviewed here, heat pumps and pellet fires score similarly overall and generally better than flued gas heaters." (note: erroneous result)
2006	BRANZ: National Impacts of the Widespread Adoption of Heat Pumps in New Zealand (Buckett 2007)	"Heating fuels (e.g. natural gas, wood or coal) used directly in an efficient burner reduce the load on the electricity system, notably by reducing the baseload and the winter peak, and ultimately need less generation."
2007	Private Analysis: Clean wood burning policy for homes, school/ commercial boilers (Melhuish 2007)	Heat pumps cause higher emissions than gas
2007	Sustainability Forum: Submission on NZEECS and NZES (The Sustainable Energy Forum 2007)	Gas is more efficient than electricity. "Household energy sources that compete with electricity … are barely mentioned" (in the NEECS) "The Electricity Commission is a system of self-governance by electricity market participants, and represents their interests at public expense"
2007	GANZ/LPGA: Submission on the draft NZES and the draft NZEECS (JT Consulting 2007)	Gas has significant strategic advantages. Gas is preferred fuel for space and water heating, and cooking
2007	DBH: Energy efficiency of buildings (Department of Building & Housing 2007)	It is very important to look at supply chain efficiencies. Gas and electricity are roughly equally efficient.
2007	BRANZ: The need for New Electricity Generation - The Role Of Demand (Isaacs 2007)	Direct use of gas for heating instead of heat pumps would decrease load on grid. "Most importantly, this analysis shows that the real debate is not about the most desirable way to generate electricity … but rather what is the best way to use our many different, abundant fuels.
2007	AberGas: AberGas Roadshow (AberGas 2007)	Gas is as efficient as most efficient electric appliances, but does not add to peak load of grid.
2007	MfE: Warm Homes Technical Report Real-life Emissions Testing of Pellet Burners in Tokoroa (MfE 2007)	Pellet burners can have high particulate emissions if not properly operated. Improper operation can occur due to size-variability in current New Zealand pellet production.

Table 7.2: New Zealand studies concerned with domestic uses of gas versus electricity

possible alternatives promoted by prominent reports from government and other agencies (Taylor Baines & Associates 2005; Buckett 2007; Department of Building & Housing 2007; JT Consulting 2007; The Sustainable Energy Forum 2007).

An example of misleading promotional material is given by the Auckland Regional Council (2007) where heat pumps are presented to the consumer as being 4 to 5 times more efficient than the direct use of gas or pellet fires.

The most recent New Zealand Energy Strategy (MED 2007), published at the time of writing, includes the direct use of gas, but only on the periphery of the principal recommendations focusing on renewable fuels. Also, the strategy implies that the use of gas for home heating might be too expensive in New Zealand. The strategy also calls for a phase-out of fossil fuels in electricity generation. The withdrawal of a significant gas market makes further gas exploration in New Zealand less desirable, and thus jeopardises the viability of the residual New Zealand gas market in the medium-term future.

Year	Report	Comments
2001	EECA: National Energy Efficiency and Conservation Strategy (EECA 2001)	NEECS proposes: "The electricity and gas sectors involve networks that are natural monopolies. Because these network elements can create barriers to energy efficiency the electricity and gas sectors are the focus of a number of Strategy measures." Report recognizes that the direct use of gas can yield national energy efficiency gains, but provides no further clarification.
2004	Government: Sustainable Development for New Zealand: Programme of action (MED 2004)	Gas is important for energy security; no further clarification.
2006	EECA: National Energy Efficiency and Conservation Strategy - Situation assessment (EECA 2006)	Report claims that progress has been made on encouraging the more direct use of gas. Should try to promote third party access (TPA) in order to make gas more widely available.
2006	EECA: Draft National Energy Efficiency and Conservation Strategy (EECA 2006)	Importance of direct use of gas is no longer recognized. The objectives are now clean, green, and efficient.
2006	MED: Powering Our Future - Draft of NZ Energy Strategy to 2050 (MED 2006)	Report acknowledges heat pumps as most efficient form of home heating. Gas is mentioned indirectly: "potential of gas may be offset by high efficiency of heat pumps".
2007	Auckland Regional Council's Quarterly: EECA heat pump and pellet promotion (Auckland Regional Council 2007)	Erroneous promotion material, citing EECA in saying that heat pumps are 4 to 5 times more efficient than gas.
2007	MED: Powering Our Future - New Zealand Energy Strategy to 2050 (MED 2007)	Promotes direct use of gas to replace direct use of coal; states that direct use of gas might be more efficient than electricity, but is very expensive; recognizes potential in reducing load of grid.

Table 7.3: Reports describing New Zealand Government policy

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APPENDIX 1: APPLIANCE COMPARISON

Service Measure	Fuel	Technology	Efficiency	Typ. Power	Source/Comments
The amount of energy equivalent to heat a 5 by 5 meter lounge from 10 to 20 degrees C and maintain Temp for 3 hrs	Gas	Flueless	90%	5.0 kW	(CAE 1996), accounts for add. ventilation needs
		Flued	74%	5.0 kW	(CAE 1996), upward corrected in line with industry sources
	LPG	Flueless	90%	4.2 kW	(CAE 1996), accounts for add. ventilation needs
		Flued	74%	5.0 kW	(CAE 1996), upward corrected in line with industry sources
	Electricity	Fan heater	100%	1.5 kW	
		Radiant heater	100%	1.5 kW	
		Panel heater	100%	4.0 kW	
		Heat pump	300%	7.0 kW	(Energy Consult 2004), COP 3.0 is 7degC average for ANZ market
	Wood	Enclosed burner	68%	11.0 kW	(CAE 1996), average at medium burn rate
	Coal	Enclosed burner	68%	11.0 kW	(CAE 1996), average at medium burn rate
	Wood pellets	Enclosed burner	82%	11.0 kW	(Chapman 2005), average of current market models
The amount of energy equivalent to heat a house from 10 to 20 degrees C and maintain Temp for 3 hrs	Gas	Condensing burner	87%	17.0 kW	(CAE 1996) and industry sources
	LPG	Condensing burner	87%	17.0 kW	(CAE 1996) and industry sources
	Electricity	Heat pump	300%	17.0 kW	(Energy Consult 2004), COP 3.0 is 7degC average for ANZ market
	Wood pellets	Enclosed burner	82%	17.0 kW	(Chapman 2005), average of current market models
Cook 500g of spaghetti pasta	Gas	Cooktops	43%	n/a	
	LPG	Cooktops	43%	n/a	
	Electricity	Cooktops	45%	n/a	
Take a 5 min shower	Gas	Cylinder	68%	n/a	(CAE 1996) and industry sources
		Instantaneous	85%	n/a	(CAE 1996) and industry sources
	Solar	Gas booster	200%	n/a	COP 2.0 accounts for solar contribution, number indicative because strongly site specific
	Electricity	Cylinder	80%	n/a	(CAE 1996) mid value for A-grade cylinder
		Instantaneous	94%	n/a	(CAE 1996)

Service Measure	Fuel	Technology	Efficiency	Typ. Power	Source/Comments
Deliver 1t of steam	Gas	Boiler	80%	n/a	Industry sources
	LPG	Boiler	80%	n/a	Industry sources
	Oil (diesel)	Boiler	76%	n/a	Industry sources
	Coal	Boiler	70%	n/a	Industry sources
	Electricity	Boiler	90%	n/a	Industry sources
Deliver 1t of 75 deg water	Gas	Boiler	80%	n/a	Industry sources
	LPG	Boiler	80%	n/a	Industry sources
	Oil (diesel)	Boiler	76%	n/a	Industry sources
	Electricity	Boiler	90%	n/a	Industry sources
Keep $100m^2$ office space air conditioned at outside Temp 30 deg C for 8 hours	Gas	Absorption chiller	120%	n/a	Industry sources
	Electricity	Electric compressor	200%	n/a	Industry sources

APPENDIX 2: FUEL COSTS

Fuel cost Data, domestic, $/GJ, INCL GST		
Electricity	$56.72	Average 2006 residential electricity price (MED 2007)
NG	$28.22	Average 2006 residential NG price (MED 2007)
LPG	$48.48	Based on $92/45kg bottle, plus bottle rental at $96/annum at demand of 6 bottles/annum
Coal	$17.00	Based on bagged coal prices, 20kg = $10/bag (http://www.ablazenz.com/)
Fire wood	$16.50	Based on delivered price for firewood of $70/m^3 for pine
Wood pellets	$26.22	Based on delivered pellet price, 20kg bags, $8.95/bag + GST
Fuel cost Data, commercial, $/GJ, EXCL GST		
Electricity	$38.83	Average 2006 commercial electricity price (MED 2007)
NG	$14.29	Average 2006 commercial NG price (MED 2007)
LPG	$38.59	Based on $78.30/45kg bottle, incl. bottle rental ($4.44 * 12bottles), at demand on order of 2.5 to 5 t/annum
LPG, bulk	$28.68	Based on $1.42/kg for bulk at demand on order of 10t/annum
Diesel	$28.79	Average 2006 commercial NG price (MED 2007)
Coal	$4.35	Coal price ex mine = $3/GJ + freight at $0.005/km at 300km (industry sources)

Understanding the Contribution of Direct Use of Gas to New Zealand's Future Energy Efficiency Objectives

Addendum for the first printing, May 2008

Pages 22 and 24, Section 5.4 Domestic Hot Water: replace paragraphs 2-7 with the following

Appliances compared are continuous or storage cylinder gas and electric heaters, storage hot water heat pumps, as well as a solar hot water system boosted with gas or electricity. The 80% efficiency used for electric cylinders accounts for standing losses and describes a mid value for A-grade cylinders (CAE 1996).

These standing losses also apply to storage cylinder heat pump systems: If the hot water heat pump is rated at a COP of 2.5, then for the overall system the COP becomes 2.0[14]. For gas cylinders, an efficiency of 68% was assumed, a conservative estimate according to industry sources. The coefficient of performance of hot water heat pumps and particularly of solar hot water systems is strongly dependent on the local climate. The COP value of 2.0 for gas boosted solar systems used in this study should be considered indicative only, but is internally consistent with assuming a COP of 2.4 for solar-electric systems.

Energy resource use and supply chain emissions towards the delivery of this service are shown in Figures 10 - 12.

Of all analysed cases, the most resource efficient form of providing a hot water service is to use a solar/gas-boosted system. The next best are solar electricity boosted systems followed by hot water heat pumps. Hot water heat pumps are only marginally more resource efficient than natural gas of LPG continuous heaters, which avoid standing losses incurred in any cylinder storage system.

Regardless of the continuous/cylinder question, any gas, solar, or electric heat pump system is significantly more resource efficient than traditional electric systems.

Trends in resource efficiency are exacerbated in terms of supply chain emissions. This is mainly due to the high emission factor from electricity over gas. Clearly, the solar-gas option is least emissive and if the local climate (sunshine) allows and is generally superior to

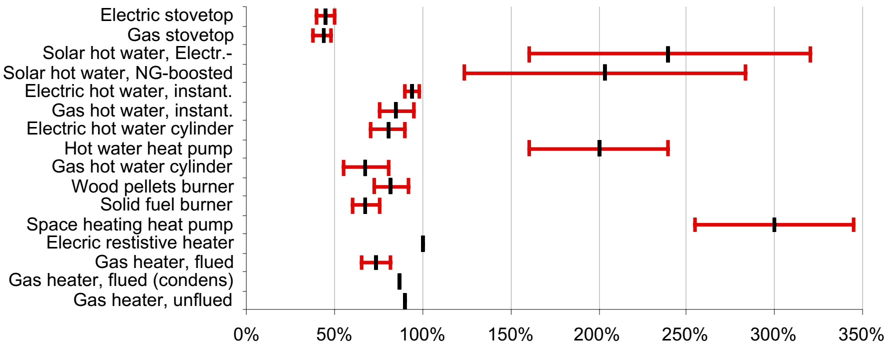
[14] It is assumed that the overall average efficiency of hot water production without storage is at a COP of 2.5. This number also accounts for efficiency losses due to resistive heat boosting. Consistent with the other hot water systems in this analysis, cylinder standing losses are assumed to be 20%. Therefore to take into account for the standing losses of the hot water cylinder that the heat pump serves, the average complete system COP will be 2.0.

the electricity boosted solar system.

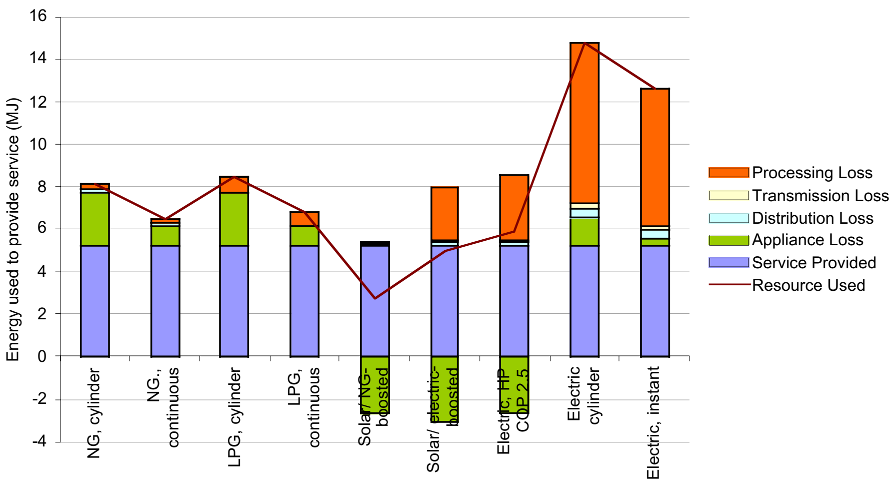
The large differences in resource efficiency and emissions are less pronounced when comparing costs. However, the natural gas boosted solar system stands out as the cheapest option. Continuous or storage type electric or LPG systems are the most expensive to run.

The analysis did not consider special electricity plans. For example, an electric storage cylinder system on a night plan might in some cases be as cheap, or cheaper to run than gas.

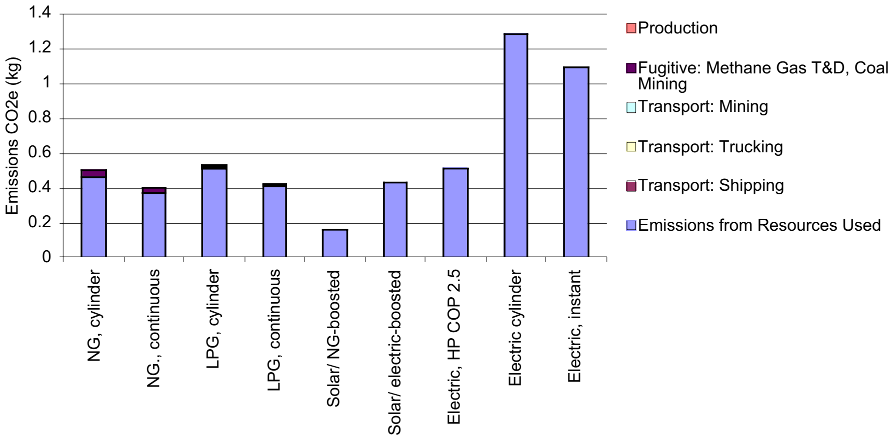
Page 3, Figure 1: replace with revised figure



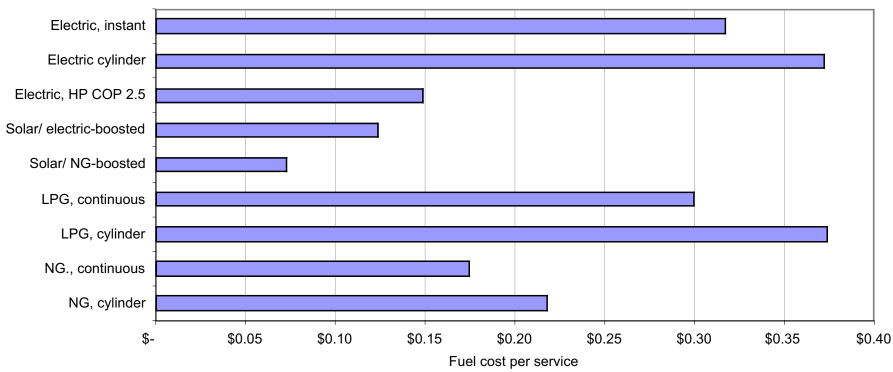
Page 23, Figure 10: replace with revised figure



Page 23, Figure 11: replace with revised figure



Page 23, Figure 12: replace with revised figure



This addendum sheet applies to the May 2008 printing of *Understanding the Contribution of Direct Use of Gas to New Zealand's Future Energy Efficiency Objectives*, published by the New Zealand Centre for Advanced Engineering. Subsequent printings incorporate the changes listed in this addendum.

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