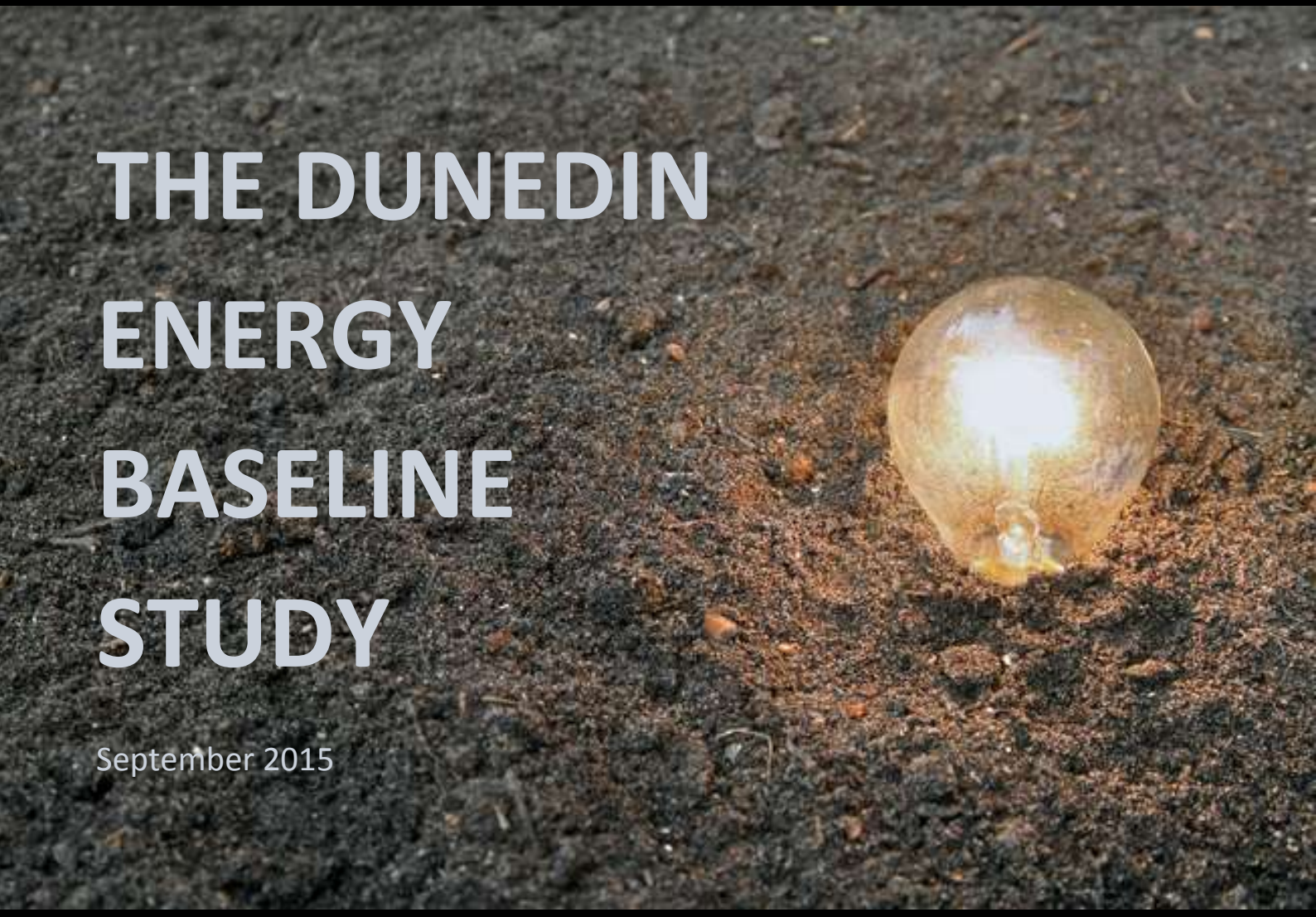

THE DUNEDIN ENERGY BASELINE STUDY

September 2015

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Prepared for:

Otago Chamber of Commerce, Dunedin, New Zealand
Dunedin City Council (DCC), New Zealand

Prepared by:

Cle-Anne Gabriel, Janet Stephenson and Gerry Carrington
Centre for Sustainability, PO Box 56, University of Otago
Dunedin, New Zealand

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EXECUTIVE SUMMARY

The Dunedin Energy Baseline Study was a joint project between Dunedin City Council (DCC), the Otago Chamber of Commerce and the Centre for Sustainability at the University of Otago. It involved stocktaking and analysis of the energy inputs to the city of Dunedin, to assist with planning for the future development of the city. Dunedin city is taken as the geographic extent of the city council's jurisdiction, i.e. including the Middlemarch, Taieri Plain and Waikouaiti regions, as well as the urban area of the city itself.

The study was conducted between May and September 2015, and the data collected were for inputs of consumer energy to Dunedin for the year 2014. The study is a high-level estimation of the total amount of each energy type used within the city and, where data is available, an indication of the most significant end uses.

In compiling this report we were largely dependent on the good will of numerous organisations and firms that shared data with us. The project's partners are extremely grateful to all participating individuals and organisations, who dedicated a considerable amount of time to sourcing, compiling and providing relevant data.

Summary of energy inputs

The estimated total energy inputs to Dunedin city during 2014 totalled approximately 10.5 PJ (petajoules). Of this, 58% were transport fuels (petrol and diesel), 31% electricity, 3% LPG, 5% coal and 3% wood fuels. These energy inputs are summarised in Figure 1.

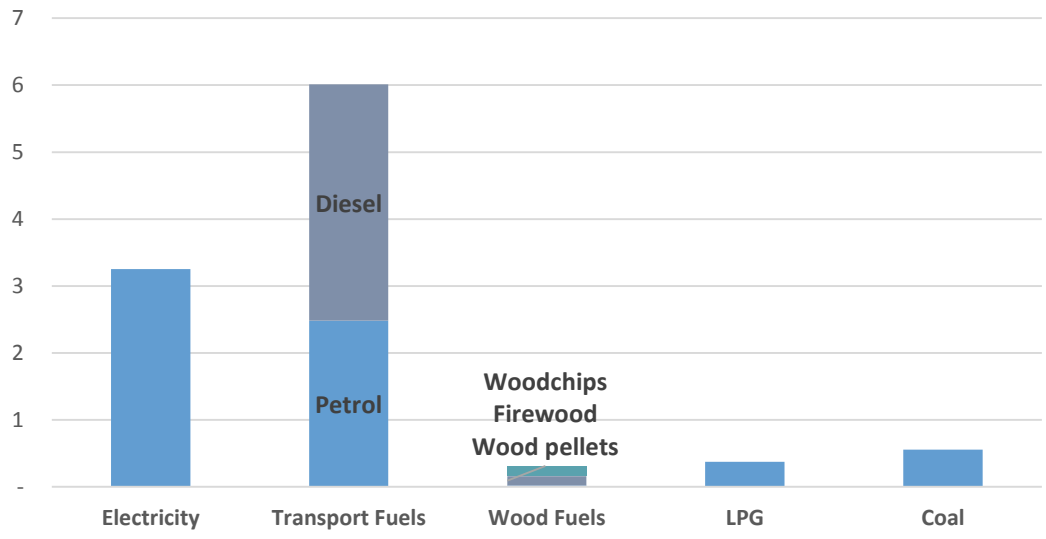


Figure 1 Dunedin's total estimated energy supplies in 2014 (PJ)

Sources of energy

Almost all of the energy used in Dunedin is sourced from outside the city's boundaries. All coal, LPG and transport fuels are imported from other regions or from outside New Zealand.

Dunedin's electricity is predominantly sourced from the national grid (68%). The Waipori (hydro) and Mahinerangi (wind) generation schemes lie just outside Dunedin's boundaries, within Clutha County, but their power supply enters the grid within the DCC boundaries at Berwick, on the Taieri Plain. This provided nearly 32% of the total electricity used within the city in 2014. Local electricity generation (such as the DCC's methane-to-electricity scheme at the Green Island landfill, and household-scale wind and solar installations) contributed only 0.2%. Notably, distributed solar capacity increased by 280% and wind capacity by 60% during 2014, while there was no growth in installed capacity of other forms of local distributed generation.

Our inquiries did not reveal any commercially-sourced wood fuels that were harvested within Dunedin's boundaries. This excludes self-collected firewood as this data was not available.

Overall, we estimate that less than 0.1% of energy used in Dunedin was sourced within Dunedin's city boundaries.

Renewables portion

Around 86% of Dunedin's electricity supply was generated from renewable resources. This estimate is based on Dunedin's electricity supply comprising 32% renewable from Waipori and Mahinerangi, and 68% from the national grid which averaged 80% renewable in 2014.[1]

Around 30% of Dunedin's total consumer energy supply was from renewable sources - 27% from electricity plus 3% from wood fuels. Nationally, New Zealand's consumer energy supply was 31% renewable (mainly from electricity and biofuels).

[1] Based on Energy in New Zealand: 2014 Calendar year Edition (MBIE, 2015). More detailed calculations looking at what percentage of Dunedin's electricity comes from the hydro dams, and at what times of the year there was a net inflow or outflow from North Island generation, was outside of the scope of this report.

Greenhouse gas emissions

About 599 kt $CO_{2\text{-}e}$ (kilotonnes of greenhouse gases) may be attributed to Dunedin's energy use. About 76% of these greenhouse gas emissions come from liquid fossil fuels (petrol, diesel and LPG), 14% may be attributed to the city's electricity supplies[2], and 9.7% may be attributed to coal (Figure 2). Wood accounted for about 0.3% of greenhouse gas emissions.

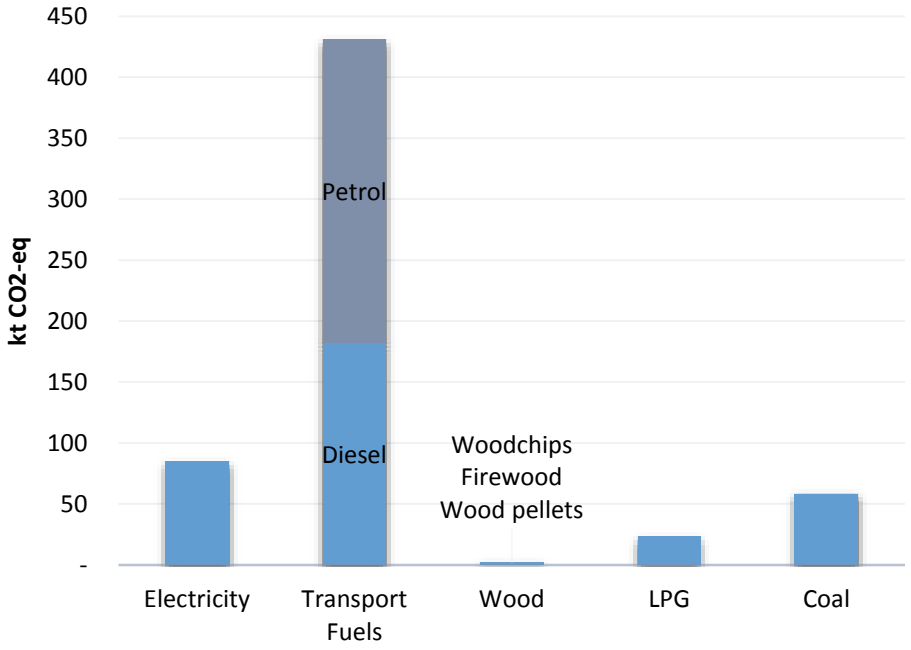


Figure 2 Estimated greenhouse gas emissions (kt $CO_{2\text{-}e}$) associated with Dunedin's energy supplies

[2] The emissions factor used for electricity supplied from the grid was taken from the Ministry for Environment, whose estimations are described as being based on the 2014 Energy in New Zealand report. No emissions were attributed to electricity supplied by Waipori and Mahinerangi generators.

OVERVIEW

IN THIS SECTION:

- About Dunedin
- About the Energy Baseline Study
- Conversion Factors

Pages 7-10

ABOUT DUNEDIN

The city of Dunedin has a population of 120,249 (Statistics NZ, 2013 census) and is the largest and principal city of the Otago Region, and the second largest in the South Island. Dunedin city has 2.9% of New Zealand's population (NZ Statistics, 2013), but is the country's largest city by area as it includes a large rural hinterland. It is governed by the Dunedin City Council (DCC). In this study, "Dunedin" refers to the area under the jurisdiction of the DCC (Figure 3).

Geographically, Dunedin is surrounded by the Pacific Ocean to the east, Waitaki District to the north, Central Otago District to the west, and Clutha District to the south.

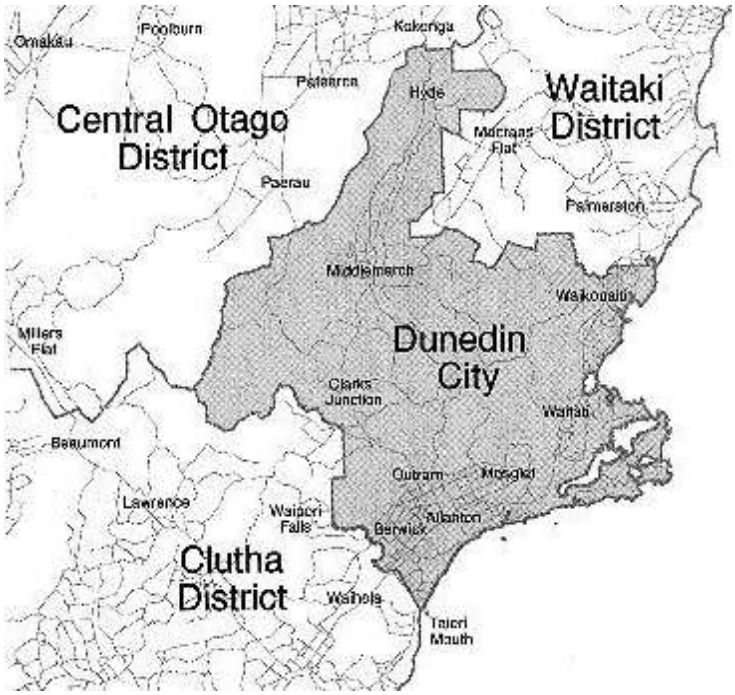


Figure 3 Dunedin City's Boundaries

The main contributors to employment are education and research, primary industry and tourism. The main employers in Dunedin are tertiary education (4,139 FTEs), hospitals (3,098 FTEs) and professional scientific and technical services (2,912 FTEs) (Otago Economic Overview, 2012)[3]. The University of Otago is the city's largest employer.

The city had a GDP of $4.84 billion in 2012, with the University of Otago contributing about 16% (Otago Economic Overview, 2012).

[3] http://www.dunedineconomy.co.nz/our-economy/

Producers of electricity in Dunedin, with installed capacity greater than or equal to 1 MW, include Port Otago's container port (125 MWh in 2014), Ravensdown Fertiliser Cooperative (986 MWh in 2014) and the Dunedin City Council (920 MWh in 2014). The University of Otago is one of the city's major energy consumers.

ABOUT THE ENERGY BASELINE STUDY

There is currently no single source of information on the sources of energy supplied to run Dunedin's activities – including households, transport, businesses, education, farming and industry. This information is needed to inform the development of strategies for the future of the city. The only source of similar data is the Energy End Use Database held by the Energy Efficiency and Conservation Authority (EECA), which has an estimate of energy used by the region for 2012. The results of the Baseline Study are compared with the Energy End Use Database in the final section of this report.

The primary aim of the Energy Baseline Study is to establish a database of consumer energy[4] inputs to Dunedin for the 2014 calendar year. The database shows, primarily, the quantities of energy imported into Dunedin and generated/produced in Dunedin. Some data about the end uses of the energy were gathered where the information was readily available, but this was not the primary focus of the study. This report describes the methodology and describes the key findings from the energy database.

The study looked at consumer energy inputs only, *not* the energy embedded in goods such as, for example, the energy required to make machines, food or household appliances.

The study establishes the baseline and methodology for tracking in future years how energy supply changes over time, and also provides the basis for a potential more detailed study of Dunedin's energy metabolism (i.e. its energy inputs, outflows and net consumption, as well as how energy is used).

The data needed to conduct the study were not readily available, so the project relied on the willingness of many businesses and organisations who shared data. The project's participants were the main electricity and fuel importers, producers and distributors in Dunedin, as well as other organisations and individuals possessing relevant data. Data were collected about the participating organisations' contribution to, or knowledge of, Dunedin's

[4] For the purpose of this study, 'energy' refers to the electricity, as well as solid, liquid and gaseous fuels that are used within the city's boundaries.

energy flows – that is, energy that is supplied or produced. In some cases, participants were able to supply further details, such as the main energy users, main purposes of use, or spatial or temporal patterns of use. Where relevant and available, this is also reported on.

The research was undertaken by University of Otago researchers. In keeping with the ethical approval for the research, individuals and organisations participating in the study were given options regarding anonymity and also the confidentiality of the data provided. Where requested, this anonymity has been preserved by ensuring that each company's contribution to the city's energy inputs is aggregated by fuel type. The raw data collected is securely stored and password protected on a server at the University of Otago. Only the study's main investigators are able to gain access to it.

CONVERSION FACTORS

Data gathered were originally in units used for that sector (e.g. electricity in GWh, coal in tonnes, etc). To enable comparisons, all were converted to a common unit, megajoules (MJ). Conversion factors, based on net calorific values, were used to convert fuel quantities from the originally reported units to MJ, as follows[5]:

- Electricity (kWh): 3.6
- Petrol (litres): 35.08
- Diesel (litres): 38.45
- LPG (kg): 49.51
- Coal (tonnes): 24,303
- Firewood (tonnes): 16,740
- Wood pellets (tonnes): 17,170
- Woodchips, 35% moisture (tonnes): 8,220

[5] Sources: (1) Statistics New Zealand "New Zealand Energy Use: Services sector 2013" (http://www.stats.govt.nz/browse_for_stats/industry_sectors/Energy/EnergyUseSurvey_HOTP13/Data%20Quality.aspx#energy); (2) EECA Business "Biomass calorific value calculator" (http://www.eecabusiness.govt.nz/wood-energy-resources/biomass-calorific).

ELECTRICITY

IN THIS SECTION:

- Methods & Assumptions
- Electricity Supplied on Dunedin Network
- Local Electricity Generation

Pages 11-21

METHODS AND ASSUMPTIONS

There are two lines companies (owners and operators of the electricity distribution network) operating within Dunedin: *Aurora* and *Otago PowerNet* (also referred to as OtagoNet). The extent of the companies' networks are shown in Figures 4 and 5.

Figure 4 Areas of Dunedin City covered by the Aurora network[6]

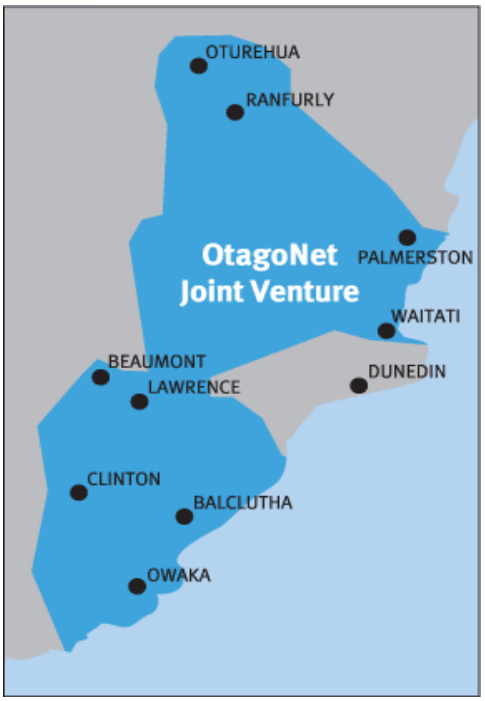


Figure 5 Area covered by the Otago PowerNet network, which extends into DCC territory[7]

[6] SOURCE: Aurora Energy (2015) http://www.auroraenergy.co.nz/content/location.php
[7] SOURCE: Otago PowerNet (2015) http://www.powernet.co.nz/line-owners/otagonet/

There are 53,946 connections (ICPs[8]) on Dunedin's *Aurora* network, and 5,674 ICPs on the *Otago PowerNet* network. It is important to note that while Aurora's network supplies mainly the urban and suburban areas of Dunedin, the Otago PowerNet network is comprised of rural areas and small settlements.

The findings presented in this section were developed from analysis of data provided by the lines companies (*Aurora* and *Otago PowerNet*), as well as the energy advisory company *Energy Link*. In addition, data was drawn from the *Electricity Authority*'s database of installed capacity[9] of distributed generation.

About 2 PJ (68%) of electricity enters Dunedin via the national grid, and 1 PJ (32%) via generation from Waipori and Mahinerangi plus other smaller distributed generation schemes. The smaller distributed schemes generate around 0.01 PJ.

The sources of the electricity supplied to Dunedin in 2014 are shown in Figure 6.

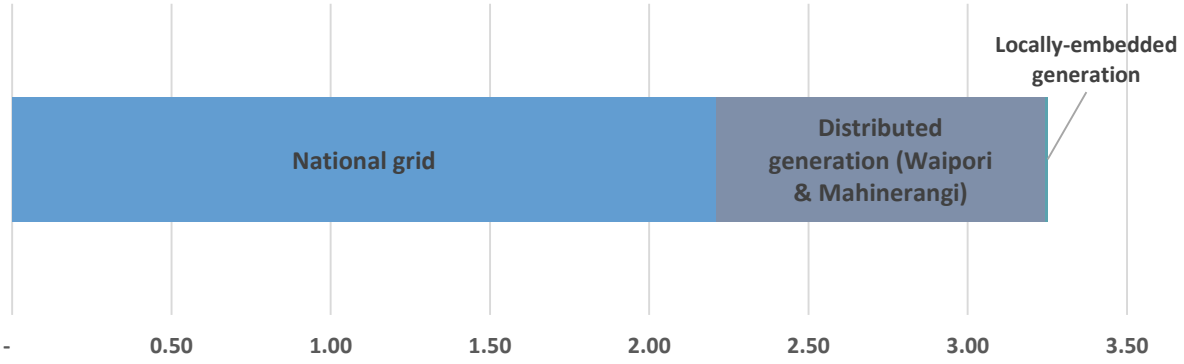


Figure 6 Breakdown of electricity supplied to Dunedin in 2014, by source

[8] An ICP is an Installation Control Point, i.e. "a physical point of connection on a local network or an embedded network that the distributor nominates as the point at which a retailer will be deemed to supply electricity to a consumer" (Electricity Authority, 2015 - https://www.ea.govt.nz/glossary/).

[9] Installed capacity refers to the maximum production capacity of a power plant.

As shown in Figure 6, nearly sixty-eight percent of Dunedin's electricity was supplied from the national grid. Given Dunedin's location relative to the southern hydro schemes, the electricity supplied here is likely to be predominantly generated from these renewable sources, but this will vary according to factors such as the amount of water in the hydro dams, and at times may be supplemented by generation from non-renewable sources. The relative proportion of renewable versus non-renewable electricity from the national grid is not known, but for the purposes of this study we have adopted the average percentage of renewable generation for the grid in 2014 for all of New Zealand, which was 80%.

The Waipori (hydro) and Mahinerangi (wind) generation schemes are physically located within Clutha District Council boundaries, but the electricity generated from both sources is embedded into the Aurora network at Berwick, which is located within DCC boundaries. As these two fully renewable generation schemes feed directly into the Dunedin network, their generation (for the purposes of this study) is included as being part of the DCC supply. These schemes supplied nearly 32% of Dunedin's electricity consumption in 2014.

Distributed generation refers to any method of producing electricity from many small energy sources located near to where the electricity is used. The generated electricity may either be used directly by the generator, or fed into the electricity grid. The Electricity Authority lists potential fuels for distributed generation as including biomass (includes wastes and residues); electric vehicles (includes fuel cells); fresh water (includes stored, pumped and run of river); geothermal; industrial process (includes heat, excludes bio-mass); liquid fuel (includes diesel, petrol and fuel oil); natural gas; solar; tidal; wave; wind; and other (any process that doesn't fit neatly into another category) (Electricity Authority, 2014).

ELECTRICITY SUPPLIED ON THE DUNEDIN NETWORK

A total of 903 GWh of electricity was supplied to Dunedin by *Aurora* and *Otago PowerNet* in 2014.

Of this total, about 4% was supplied on the Otago PowerNet network. *Otago PowerNet*'s network, which serves mostly the rural areas and smaller towns in Dunedin city, is supplied mainly at the Halfway Bush grid exit point, with some input at Naseby.

About 96% was supplied through the *Aurora* Dunedin network. This network, which serves mostly the urban area of Dunedin city, has grid exit points at Halfway Bush and South Dunedin.

The Aurora network has seen a decrease in electricity supply over the past 7 years, which is consistent with national trends of a flattening in demand since around 2007 (Figure 7). However the 11% drop between 2012 and 2014 is surprising and is worth exploring further.

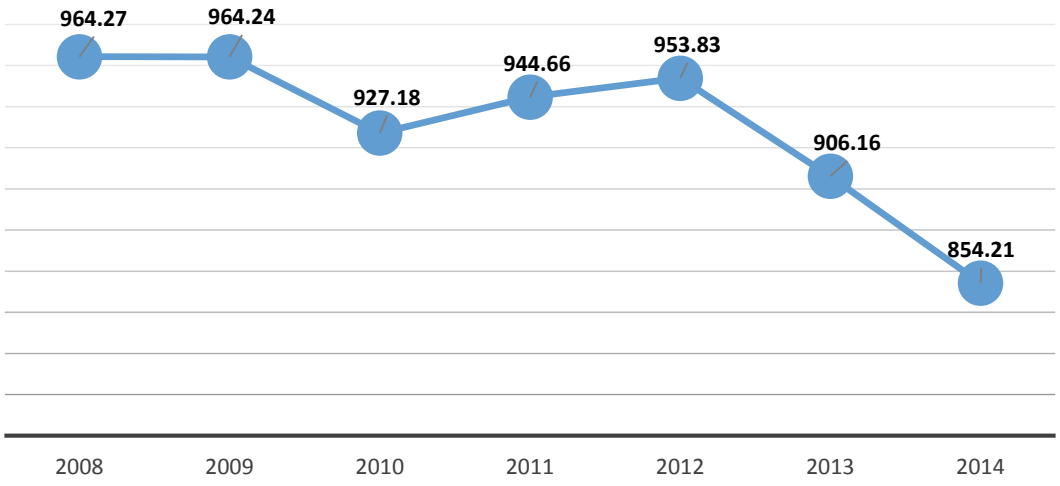


Figure 7 Electricity supplied to Dunedin on the Aurora network (GWh)[10]

[10] Calculated based on half-hourly demand figures available through the Scheduling, Pricing and Dispatch (SPD) model.

The monthly demand estimated by *Energy Link* on the *Aurora* network for 2014 shows that use peaked around mid-year, consistent with the winter months[11] (Figure 8).

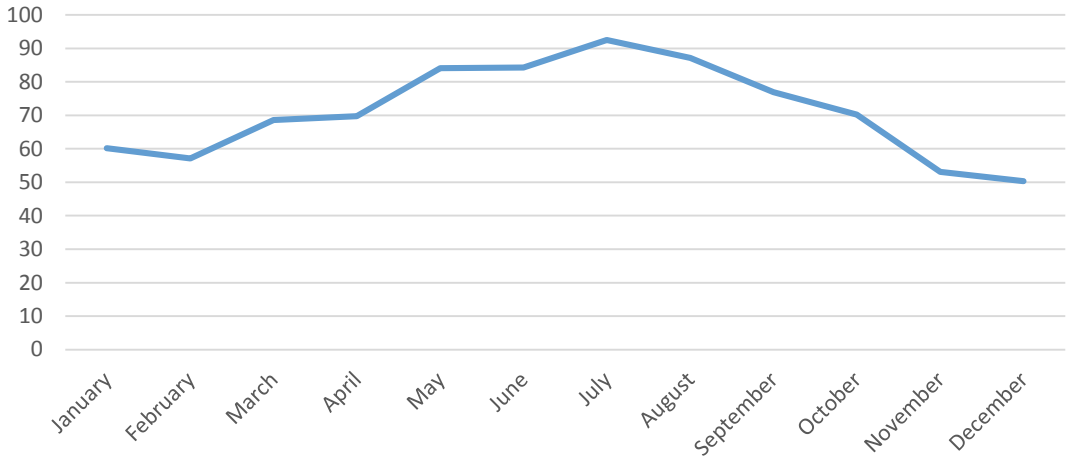


Figure 8 Monthly SPD Demand on the Aurora network for CY2014 (GWh)

By comparison[12], demand on the more rural *Otago PowerNet* network shows smaller variations, with small peaks in July, December and March[13] (Figure 9).

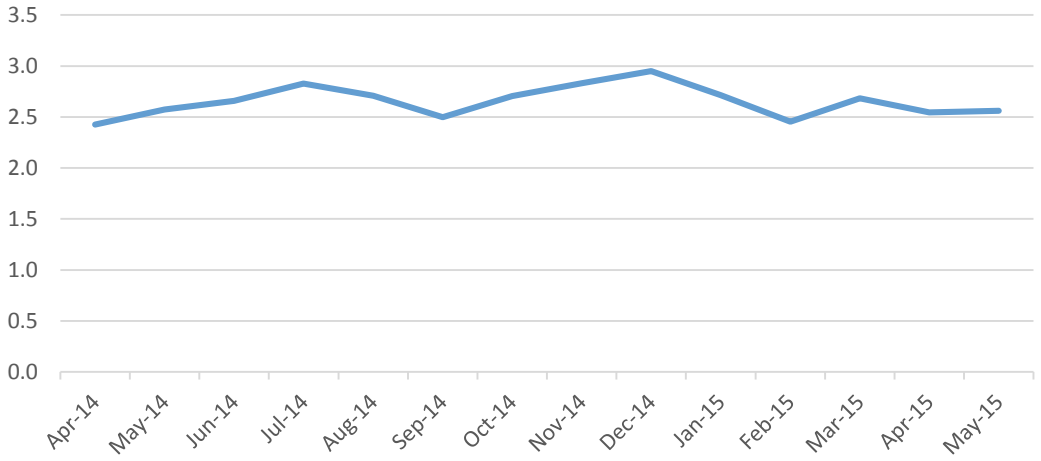


Figure 9 Monthly demand on the Otago PowerNet network for FY2014 (GWh)

[11] Calculated by summing the hourly supply through Dunedin's grid exit points. Information on this half-hourly supply is available through the SPD system.

[12] Please note that trends for the Aurora network are for the 2014 CALENDAR year, while those for the PowerNet network are for the 2014 FINANCIAL year.

[13] Calculated by summing the monthly injection to the Halfway Bush and Naseby GXPs by Otago PowerNet.

LOCAL ELECTRICITY GENERATION

As of the end of 2014, the total installed capacity of distributed generation (on both Aurora and Otago PowerNet's networks) within Dunedin and equal to or more than 0.1 MW, was 125 MW (EA, 2014; MBIE, 2014; Trustpower, 2015). Installed capacity of smaller units (less than 0.1 MW) totalled 0.4 MW. It should be noted that this does not include distributed generation which is not connected to the grid (e.g. off-grid homes).

The main distributed generation is shown in Table 1.

Table 1 Summary of distributed generation (DG) Note: Waipori and Mahinerangi schemes generate outside of Dunedin but feed in to the grid within Dunedin (Sources: Aurora, Otago PowerNet and the Electricity Authority)

	NAME OF CONNECTED GENERATOR	NAME OF COMPANY GENERATING	ENERGY TYPE	TOTAL ELECTRICITY SUPPLIED (MWH)	TOTAL INSTALLED CAPACITY (MW)
AURORA	Waipori 33kV - 1A, 2A, 3 & 4	TrustPower Ltd	Hydro	192,000	83.0
	Waipori 33kV – Mahinerangi	TrustPower Ltd	Wind	95,475	36.0
	Ravensdown Generation	Ravensdown Ltd	Process Steam	986	3.0
	Container Port	Port Otago Ltd	Liquid Fuel	125	1.6
	Waste Treatment Plant	Dunedin City Council	Biomass	920	1.0
	Dunedin Airport	Dunedin International Airport Limited	Liquid Fuel	-	0.6
	Various Aurora DG Customers	84 individual connections (est.)[14]	Solar		0.3
OTAGO POWERNET	Various Otago PowerNet DG Customers	38 individual connections (35 solar, 3 wind), with an average installed capacity of 3.58 kW	Solar & Wind		0.1

[14] Assumed to be the difference of the Electricity Authority's reported total of 119 individual connections in Dunedin, and Otago PowerNet's reported 35 connections. However, note that these are 2014 figures, and as of October 2nd 2015, Aurora has 132 individual PV connections on the Dunedin network.

Larger distributed generation schemes

The Electricity Authority has included the Waipori hydropower and Mahinerangi wind schemes in the figures for Dunedin's total distributed generation[15]. These have 83 MW (Waipori) and 36 MW (Mahinerangi) installed capacity respectively (Table 1).

From small beginnings in 1907, the four stations of the Waipori Hydroelectric Power Scheme now have a maximum capacity of 83 MW, and deliver an average annual output of 192 GWh. The Mahinerangi wind farm was commissioned in 2011. Stage One of the wind scheme is now operational, with 12 turbines each with a capacity of 3 MW.

Mid-scale distributed generation

Mid-scale local generators of electricity (0.1 to 5 MW) include Ravensdown Fertiliser Cooperative (from process steam), Port Otago's Container Port (from liquid fuels), the DCC's waste treatment plant (from biogas), and the Dunedin airport (from liquid fuel) (Table 1). Local generation which is entirely for the generator's own use is not included.

Small-scale distributed generation

At the end of 2014, small-scale distributed generation (less than 0.1 MW) in Dunedin consisted of 119 solar connections (with combined installed capacity of 0.395 MW) and 3 wind connections (with combined installed capacity of 0.008 MW)[16]. These are mostly linked to residential ICPs. The number of residential ICPs grew 240% (for solar) and 50% (for wind)[17] from January to December 2014. These trends are illustrated in Figure 10.

[15] The Waipori hydropower and Mahinerangi wind schemes are reported by the Electricity Authority under the category "Other".
[16] This is according to the Electricity Authority: http://www.emi.ea.govt.nz/
[17] Please note that this trend refers to the number of ICPs, not trends in installed capacity.

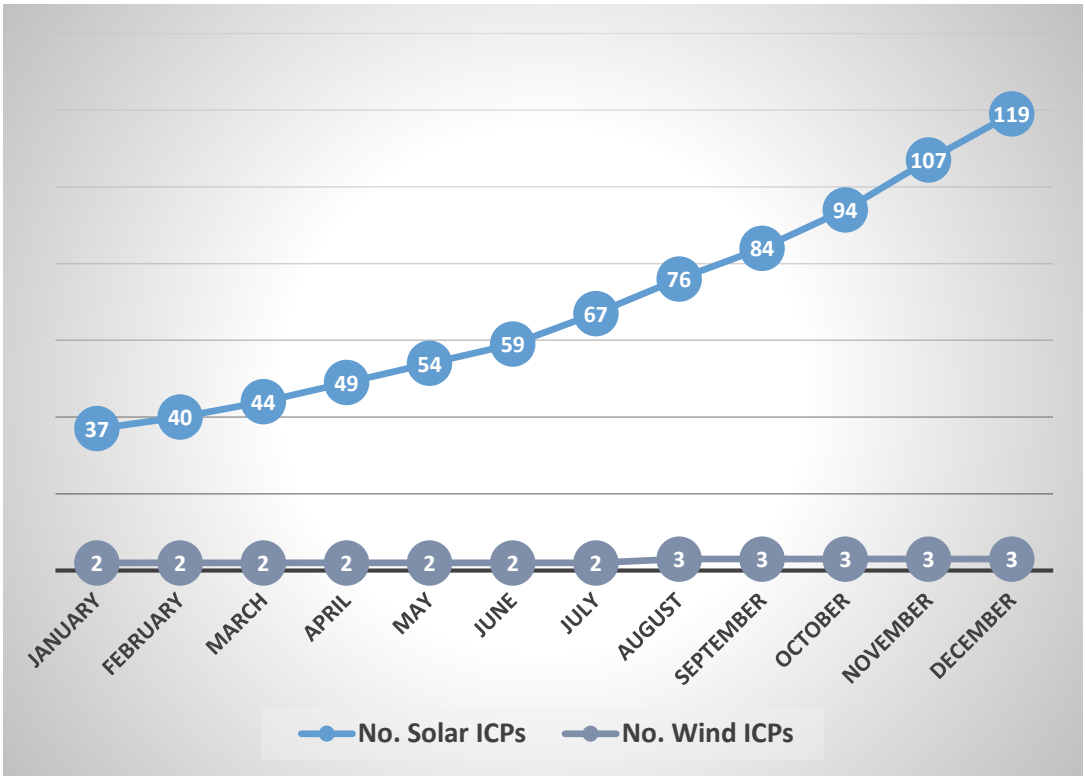


Figure 10 Growth in number of solar and wind connections (ICPs) in 2014

Note this does not include small-scale installations that are not connected to the electricity grid.

When Waipori and Mahinerangi are excluded, the breakdown of Dunedin's distributed installed capacity is as shown in Figure 11.

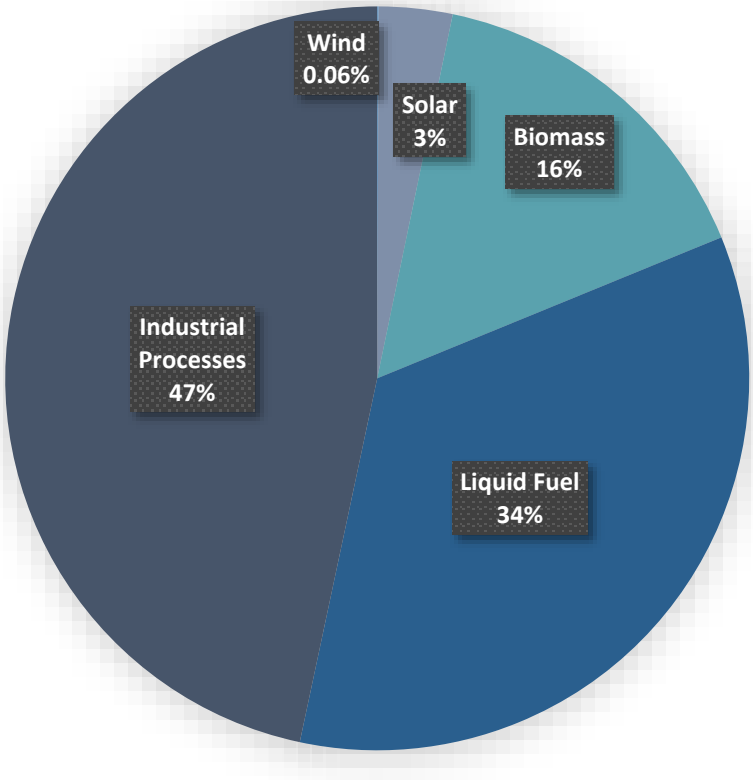


Figure 11 Dunedin mid-scale and small-scale installed capacity for electricity generation by fuel type for 2014 (excludes the larger Waipori and Mahinerangi schemes)

As shown in Figure 11, eighty-one percent of medium and small-scale installed capacity used non-renewable sources (industrial processes and liquid fuels). Renewables therefore made only a minimal contribution to total installed capacity within the city boundaries. However, while installed capacity for all other fuel types remained unchanged throughout the year, installed solar and wind increased by 280% and 60%, respectively. According to *Otago PowerNet*, a considerable number of the gains on its network may be attributed to installations in the Blueskin area.

Residential installations of solar and wind generation were the biggest growth area for installed capacity, as shown in Figure 12.

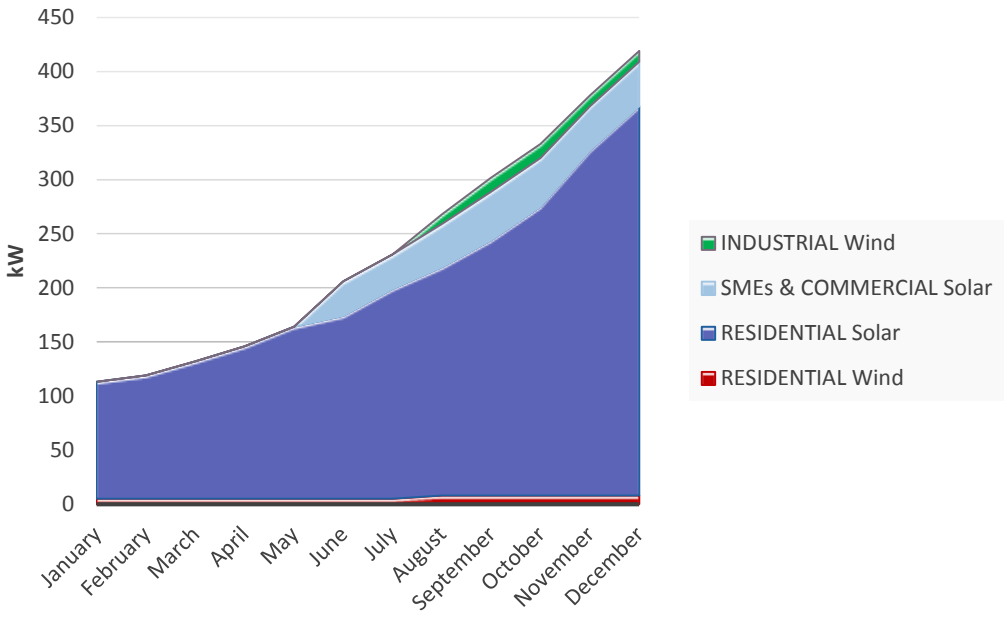


Figure 12 Cumulative increases in wind and solar installations in 2014 by sector (kW)

Electricity use

Aurora reports that 47.5% of supply was to household connections (47,023 ICPs), 51.5% to connections with non-domestic usage codes (6,921 ICPs), and 0.88% for the purpose of street lighting (2 ICPs). Line losses, which made up about 5.7%, are included

The following (Table 2) shows the major electricity customers on the *Otago PowerNet network*.

Table 2 Major electricity customers on the Otago PowerNet network

Customers	**kVACapacity**
DCC Community Centre, Waikouaiti	300
Mainland Poultry, Waikouaiti	1,450
Hawkesbury Village Management, Waikouaiti	200
Oceana Gold Pumps, Hyde	1,850
Lone Star Farms Pumps, Middlemarch	300

FUELS I: LIQUID FOSSIL FUELS

IN THIS SECTION:

- Methods & Assumptions
- Petrol & Diesel Inputs
- Liquefied Petroleum Gas (LPG) Inputs

Pages 22-27

METHODS AND ASSUMPTIONS

All liquid fuels supplied to Dunedin are fossil-derived, i.e. petrol, diesel and liquefied petroleum gas (LPG), and are imported from outside of the DCC area. As far as can be ascertained, all of the petrol and diesel destined for Dunedin arrives through Port Otago. There are no known liquid biofuels produced in the Dunedin area.

In this section, petrol and diesel are presented separately from LPG.

The data on Dunedin's petrol and diesel inputs were compiled based on fuel tax data for 2014 – that is, the returns filed by wholesale distributors for petrol and diesel "delivered within the tax area […] pursuant to any sale", as well as for petrol and diesel "used by any wholesale distributor within the tax area" Schedule 7, under Section 189 of the Local Government Act 1974.

The returns filed report both the quantities of liquid fuel sold and the corresponding taxes payable. The data is collected by the Dunedin City Council for the Tax Area of Coastal Otago.

However, the 'Coastal Otago' area includes geographical regions that are outside the Dunedin City Council's jurisdiction and therefore outside the scope of the study[18]. In the absence of any other guide to apportioning use, Dunedin's share was approximated based on population. **Dunedin city's share of Coastal Otago's petrol and diesel consumption was assumed to be equal to its share of the population, i.e. 68.6%.**

Some of the petrol and diesel purchased within Dunedin's boundaries will be used by people driving through on the state highway, and some Dunedin-based drivers will have fuelled up elsewhere. We do not have data to calculate whether these amounts are similar or disproportionate, so have not accounted for this in the figures below.

Additionally, it was found that almost half (46.7%) of the petrol and diesel entering Dunedin via Port Otago remains unaccounted for in the fuel taxes paid to the DCC. This was found by comparing the quantities reported by Port Otago with those shown in the DCC's tax records. This is likely to be because the fuel is transported to wholesale distributors in other regions outside the DCC's jurisdiction.

[18] In addition to Dunedin City, the Coastal Otago tax area includes the Waitaki (the town of Oamaru and former Waitaki and Waihemo counties; total population 20,826 according to the 2013 census) and Clutha (Kaitangata, Balclutha, Bruce and Milton; total population 16,890 according to the 2013 census) Districts.

PETROL AND DIESEL SUPPLIES

There are 9 companies that sell petrol and diesel within Dunedin in significant quantities: Allied Petroleum, BP Oil NZ Ltd, Chevron NZ, Exxon Mobil, Farmlands Fuel, McKeown Group Ltd, Nelson Petroleum Distributors, RD Petroleum, Z Energy and Gull NZ Ltd. These companies supplied around 6 PJ of petrol and diesel within Dunedin in 2014 – 3.5 PJ of diesel, and 2.5 PJ of petrol.

Aggregated data from these distributors show that the 2014 supply fluctuated slightly with peaks in March and the end of the year (Figure 13).

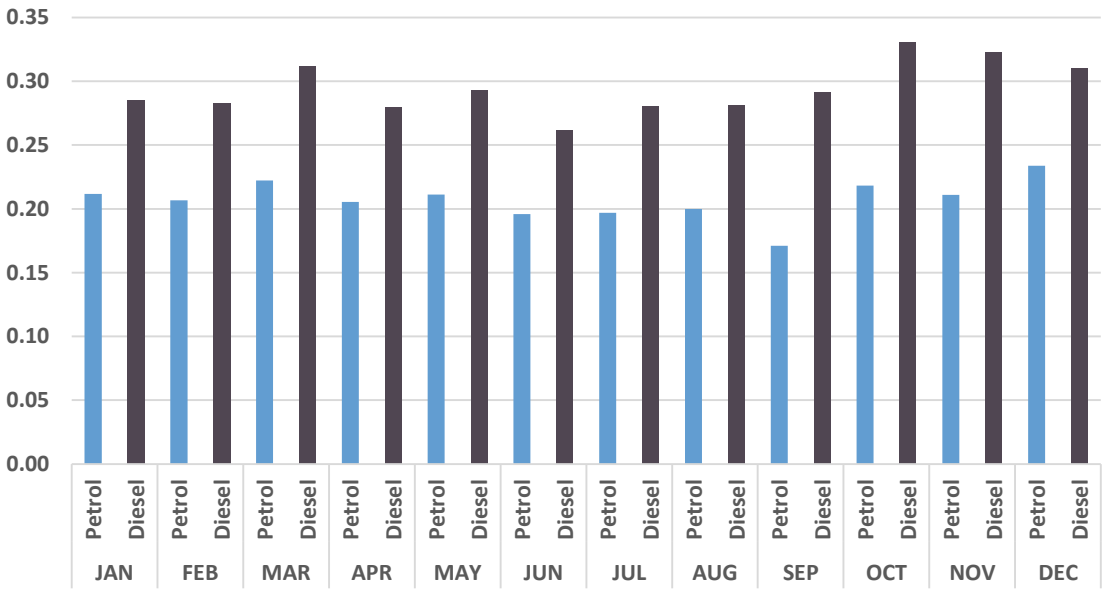


Figure 13 Total petrol & diesel supplied to Dunedin in 2014 (PJ)

Petrol and diesel use

The tax data does not specify the end uses of the petrol and diesel supplied by the companies. Therefore, although the tax data used is not *road tax* data, it is assumed that the majority of the liquid fuels are used for transportation purposes and sold through service stations, but the data does not confirm this. The amount used for non-transport purposes (e.g. industrial uses, heating, etc) and off-road transport (e.g. on-farm use) is also unknown.

LIQUEFIED PETROLEUM GAS (LPG) INPUTS

Liquefied Petroleum Gas (LPG) is the only gas fuel used in the city. LPG enters Dunedin via Port Otago, and is then handled by a logistics company from whom the city's LPG wholesalers receive their supplies.

There are four LPG wholesalers operating in Dunedin: *Nova*, *Contact (Rockgas)*, *Elgas* and *Ongas*.

Data on the city's LPG inputs were collected from the companies handling Dunedin's LPG import logistics. Both organisations providing LPG input data reported the same figures: total LPG supplies via Dunedin's Port Otago in 2014 totalled 1 PJ.

However, the proportion of LPG entering Port Otago that is transported for sale outside of Dunedin is unknown. Information gathered from the city's main LPG wholesalers (*Nova* and *Rockgas*) suggests that the LPG entering Dunedin is transported throughout the southern half of the South Island[19], with the northern half being supplied via Christchurch.

Therefore, in the absence of any other guide to apportioning use, Dunedin's share was approximated based on population. Dunedin's share of the southern South Island's LPG consumption was assumed to be equal to its share of the population, i.e. 36% or 0.36 PJ.

Dunedin's direct LPG inputs over the last 5 years show a general upward trend, with a dip in 2011 (Figure 14).

[19] The areas supplied by Port Otago roughly correspond to the districts of Dunedin City, Clutha, Central Otago, Queenstown Lakes (2013 census population: 202,467), Southland, Invercargill City, Gore (2013 census population: 93,339), roughly half of Westland (i.e. 4,153 based on 2013 census) and about two-thirds of Timaru (i.e. 28,993 based on 2013 census). The total population supplied was therefore estimated to be 328,952. Dunedin's 120,249 population amounts to approximately 36% of this total.

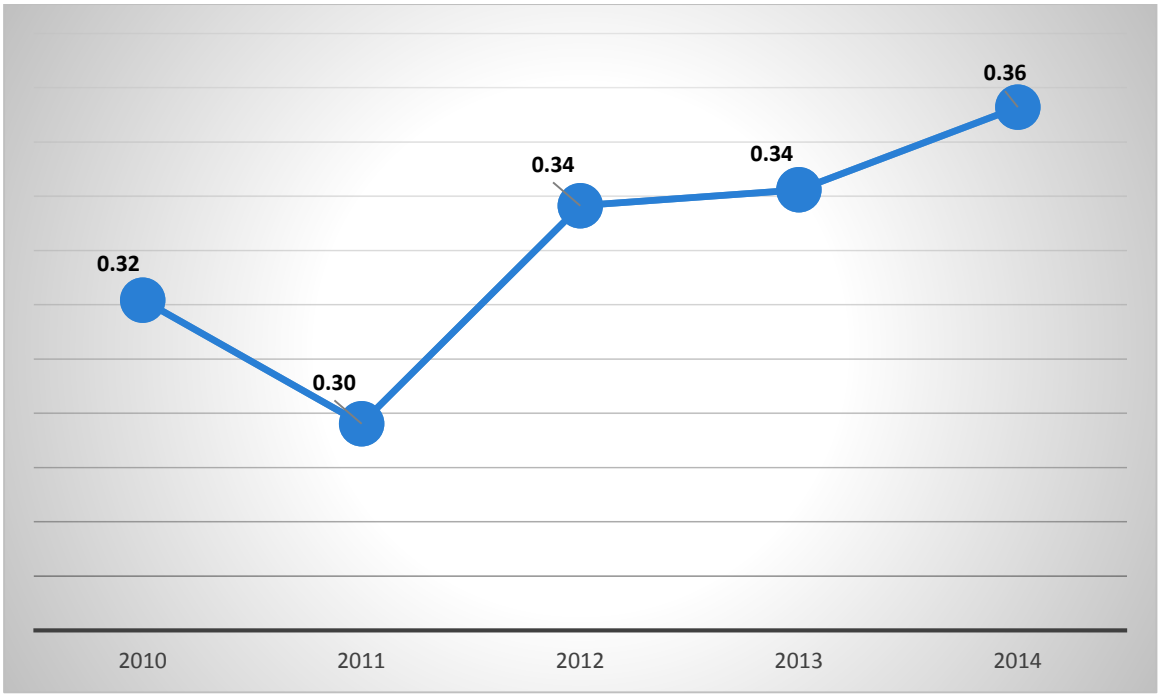


Figure 14 Dunedin's annual LPG consumption for the last 5 years (PJ)

Dunedin's monthly LPG use (Figure 15) show a highly variable trend over 12 months, with alternating highs and lows generally peaking around the winter months.

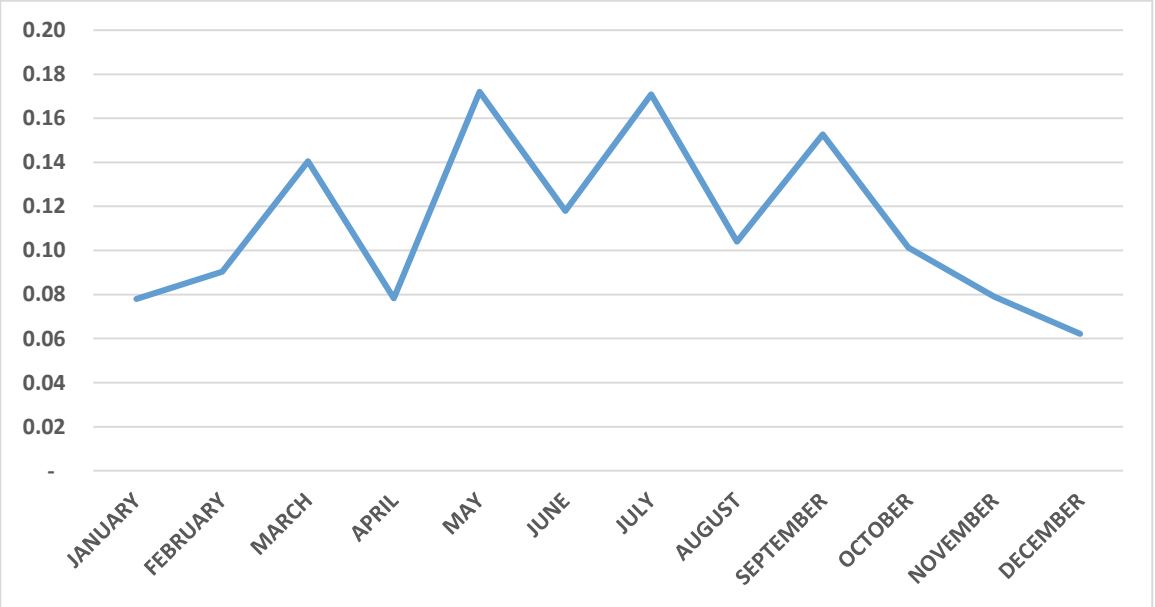


Figure 15 Dunedin's monthly LPG inputs in 2014 (PJ)

The University of Otago's Energy Manager suggests that the bimonthly variation in LPG supplies, in the winter months, might be due to the university's 5 MW gas boiler, which is used to supplement its heat supplies when the normal delivery system from the coal-fired boiler house is out of commission during maintenance and repair work, or there are issues with heat supply. He suggested that the need to use this gas boiler roughly corresponds to the variable consumption shown in Figure 15.

LPG use

LPG can be used for multiple purposes including transport, heating and industrial applications. The breakdown of the uses of LPG in Dunedin is not known.

Dunedin's use of LPG is around twice the national per capita average, and this may in part be because piped natural gas is used in many parts of the North Island, and is used for similar purposes there.

FUELS II: WOOD FUELS

IN THIS SECTION:

- Methods & Assumptions
- Woodchip and Firewood Inputs
- Wood Fuel Pellet Inputs

Pages 28-34

METHODS AND ASSUMPTIONS

There are 3 main categories of wood fuel used in Dunedin: woodchips, firewood and wood pellets.

Woodchips are supplied by the two main forestry product suppliers, and two firms manage and distribute the bulk of woodchips used for commercial- and organisational-scale heating. Data was sourced from one of these forestry product suppliers and one of the local distributors.

Firewood (logs) is sourced by residential Dunedin consumers in two main ways. The first way is by purchasing directly from firewood merchants around the city, who are supplied by the main forestry product suppliers. Data on this avenue of supply were collected from one of the city's forestry product suppliers, local distributors and, where possible and appropriate, large users.

The second source of firewood is where consumers harvest it themselves. A survey conducted by the Ministry for Environment in 2005[20] reported that over 60% of the wood use in solid fuel burners and open fires in Dunedin was self-collected. For multi-fuel burners, around 40% of the wood was self-collected. We were not in a position to update this data. T**he reported wood data therefore does not include self-collected firewood**.

Data on wood pellets was supplied by Otago Pellet Fires (OPF) and other retailers around the city.

[20] Ministry for Environment, 2005. Warm Homes Technical Report: Home Heating Methods and Fuels in New Zealand. (Prepared by Emily Wilton)

WOODCHIP AND FIREWOOD INPUTS

The forests which supplied the logs used to derive wood chips and solid wood in 2014 were located outside the city's boundaries. Major forests within the Dunedin area include Mt. Allan, Ferny Hill, Flagstaff, Sullivan's Dam, Silverpeaks, Cedar Farms and the area around Allanton, but were not being harvested for wood fuels during 2014.

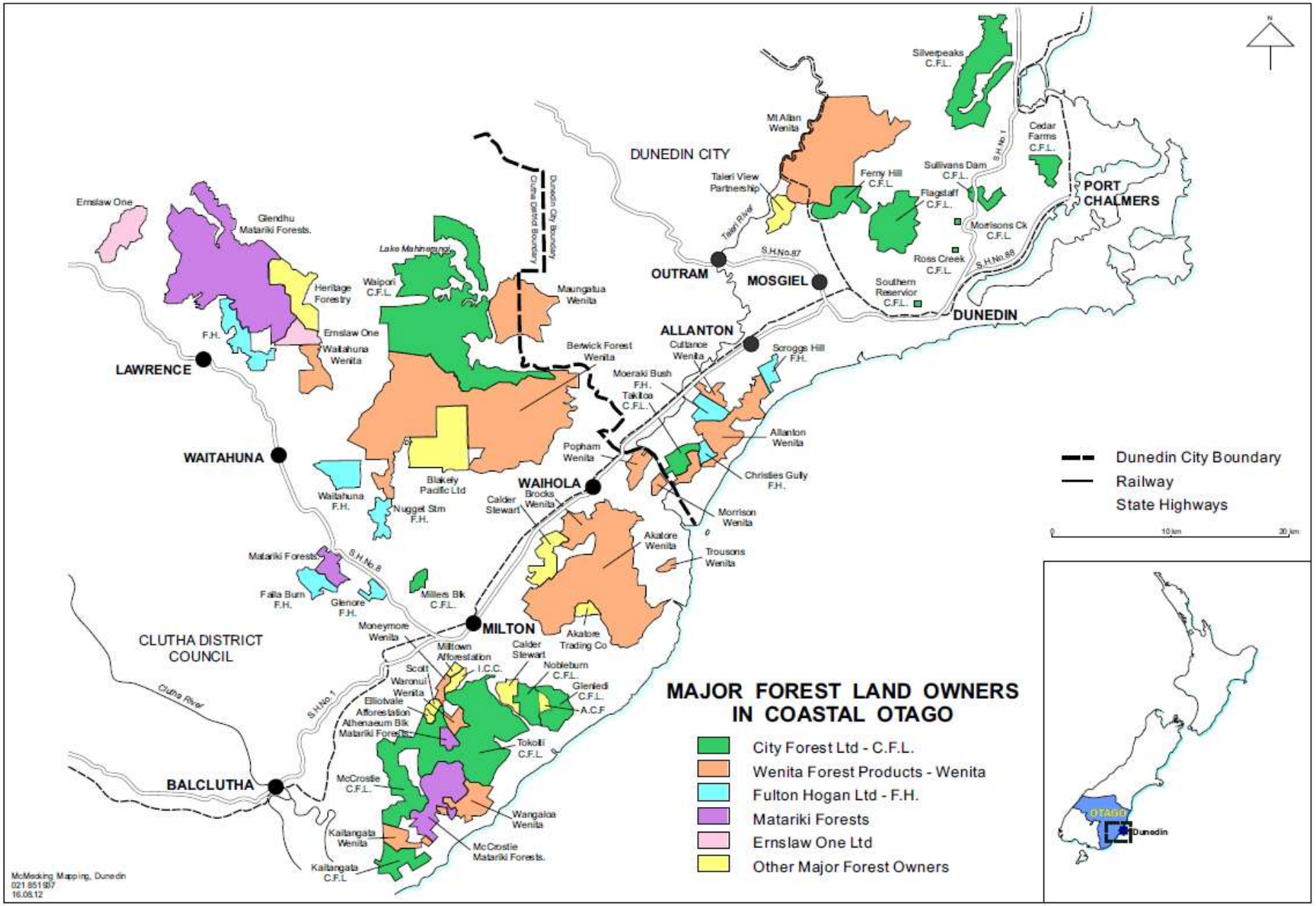
There are six major forest owners in Coastal Otago. Two of these supply the majority of Dunedin City's firewood and woodchips.

These companies supply **about 139 TJ of firewood, and about 148 TJ of woodchips to Dunedin users per year**.

The firewood is mainly sold through a wide variety of retailers. The data collected from the major suppliers suggests that, **in total, about 6,950 tonnes of solid wood fuel are supplied to Dunedin annually**.

For the purpose of cross-checking, Otago Regional Council (ORC)'s report *'A High Level Assessment of the Risks and Vulnerabilities to Energy Supply in the Otago Region'* was consulted. In it, the ORC estimated that about 10,000 tonnes of firewood is consumed in Otago annually (CAENZ[21], 2006). As Dunedin's share of the Otago region's population is 60%, **6,950 tonnes was taken as a reasonable estimate**. However the ORC data is nearly a decade old and consumption levels may have changed. Additionally, the ORC's report does not specify whether this estimate includes self-collected wood.

[21] CAENZ refers to the New Zealand Centre for Advanced Engineering


DUNEDIN CITY
CLUTHA DISTRICT COUNCIL
Dunedin City Boundary
Clutha District Boundary
Railway
State Highways
0 10 km 20 km
LAWRENCE
WAITAHUNA
BALCLUTHA
MILTON
WAIHOLA
ALLANTON
OUTRAM
MOSGIEL
DUNEDIN
PORT CHALMERS
Clutha River
Taieri River
Lake Mahinerangi
S.H.No.1
S.H.No.8
S.H.No.87
S.H.No.88
Ernslaw One
Glendhu Matariki Forests.
Heritage Forestry
Waipori C.F.L.
Maungatua Wenita
Ernslaw One Waitahuna Wenita
F.H.
Berwick Forest Wenita
Moeraki Bush F.H.
Takitoa C.F.L.
Cuttance Wenita
Scroggs Hill F.H.
Allanton Wenita
Popham Wenita
Christies Gully F.H.
Blakely Pacific Ltd
Waitahuna F.H.
Nugget Stm F.H.
Calder Stewart
Brocks Wenita
Morrison Wenita
Akatore Wenita
Trousons Wenita
Matariki Forests
Falla Burn F.H.
Glenore F.H.
Millers Blk C.F.L.
Moneymore Wenita
Milltown Afforestation
I.C.C.
Scott
Waronui Wenita
Elliotvale Afforestation
Athenaeum Blk Matariki Forests
Akatore Trading Co
Nobleburn C.F.L.
Glenliedi C.F.L.
A.C.F.
Tokoiti C.F.L.
McCrostie C.F.L.
Wangaloa Wenita
Kaitangata Wenita
McCrostie Matariki Forests.
Kaitangata C.F.L
Taieri View Partnership
Mt Allan Wenita
Ferny Hill C.F.L.
Flagstaff C.F.L.
Silverpeaks C.F.L.
Cedar Farms C.F.L.
Sullivans Dam C.F.L.
Morrisons Ck C.F.L.
Ross Creek C.F.L.
Southern Reservoir C.F.L.
MAJOR FOREST LAND OWNERS IN COASTAL OTAGO
City Forest Ltd - C.F.L.
Wenita Forest Products - Wenita
Fulton Hogan Ltd - F.H.
Matariki Forests
Ernslaw One Ltd
Other Major Forest Owners
OTAGO
Dunedin
McMecking Mapping, Dunedin
021 851 937
16.08.12

WOOD FUEL PELLET INPUTS

There is no local production of pellet fuel; all pellets are currently imported into Dunedin from manufacturers in Taupo (*Nature's Flame*) and Nelson (*AzWood*), as well as from Timaru and Tapanui, where smaller manufacturers are located.

It is estimated that **about 23 TJ (1500 ton/annum) of pellet fuel is supplied to Dunedin customers annually**, with each pellet fire owner using on average about 1 tonne/annum.

Over the last 8 years, about 1600 pellet fires have been sold in Dunedin, with **150-200 installed every year**.

The Dunedin suburb of Kaikorai (including Kaikorai Valley, Kenmure and Bradford) has the highest number of pellet fires per household. This might be due to the suburb's proximity to Otago Pellet Fires. The next highest numbers of pellet fires per household can be found in Waldronville, Mosgiel, Mornington, Maori Hill-Highgate and Anderson's Bay.

A comparison with 2013 census data (NZ Statistics, 2014) reveals that **the 13 suburbs with the highest number of pellet fires all have** a **median annual household income that is at least twice the Dunedin average**.

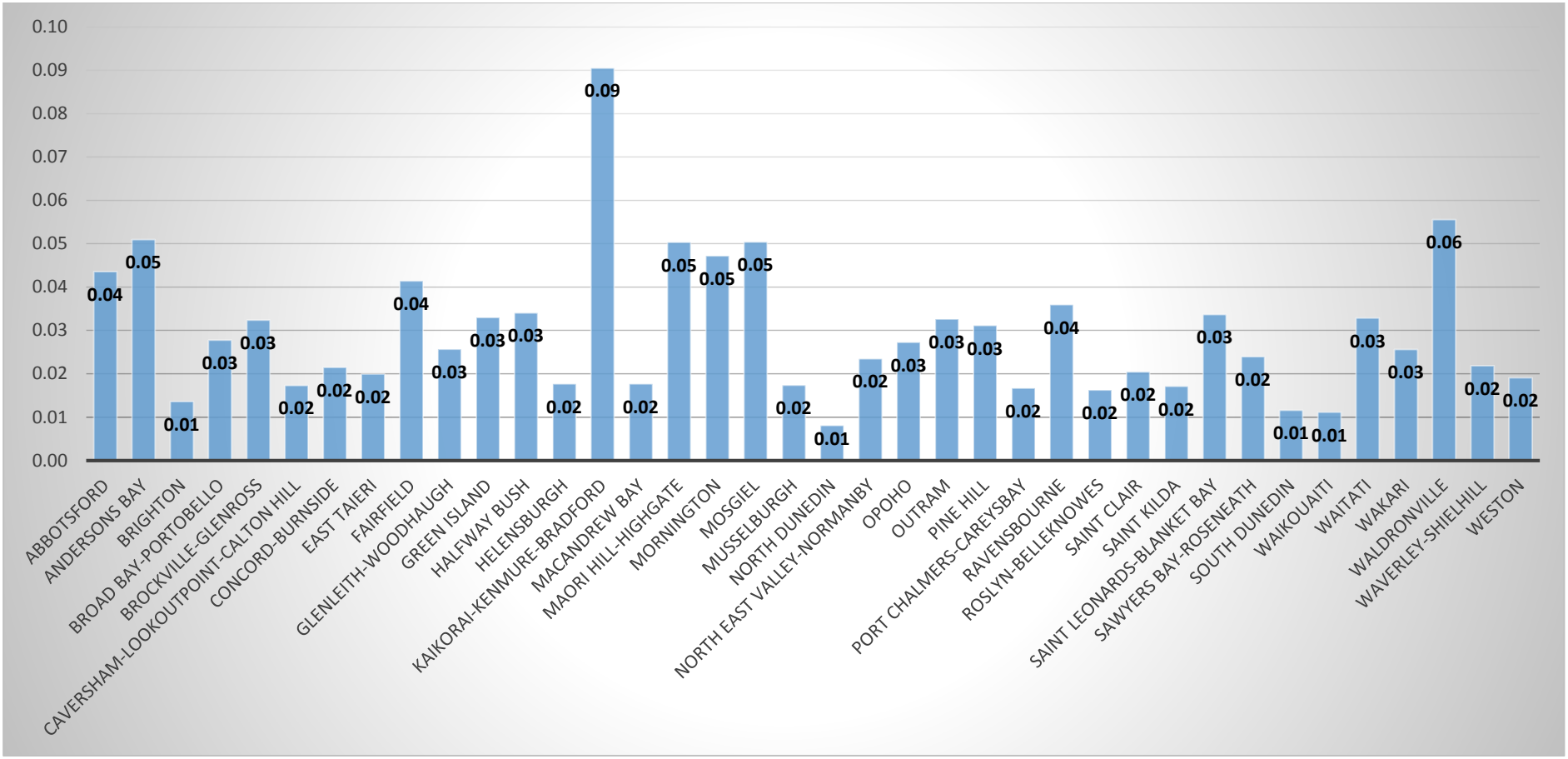


Figure 16 Number of pellet fires per household

The data collected on Dunedin's wood fuel inputs are summarised in Figure 17.

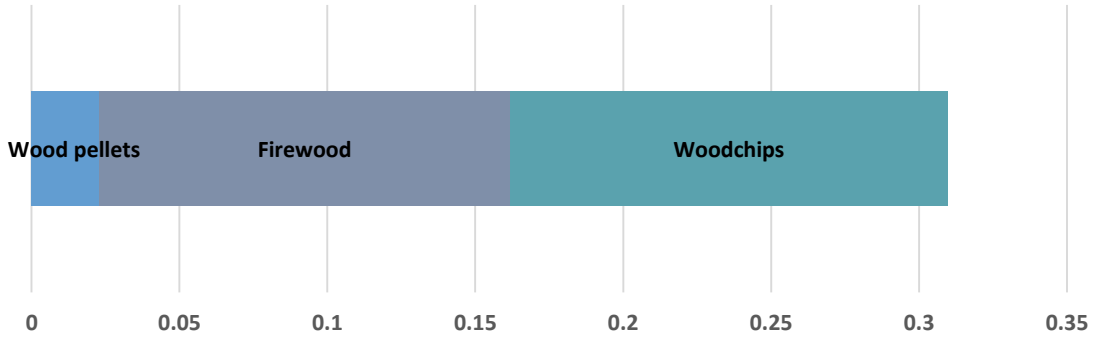


Figure 17 Estimated wood fuel inputs to Dunedin in 2014 (PJ)

Wood fuel use

Woodchips are mainly used for heating purposes. Organisations using woodchips for heating include educational, health- and aged-care facilities. For example, though mainly coal-fired, the Dunedin Energy Centre, from which the University of Otago sources its heat, used woodchips to supplement its supply in January, February, March and December of 2014.

Solid wood is mainly supplied to residential customers who use it as firewood for heating. The number of consumers is not known but the DCC reports that approximately **600 permits are issued for new wood burners every year**.

While the majority of wood pellet consumers are likely to be residential, some are used for heating purposes at a larger scale, including schools, residential colleges and some campus buildings at the University of Otago. The relative amount that is used for residential and non-residential purposes is not known.

FUELS III: COAL

IN THIS SECTION:

- Methods & Assumptions
- Coal Inputs

METHODS AND ASSUMPTIONS

There are no active coal mines in Dunedin. The closest source of coal is Kai Point Coal, located in Kaitangata. Other likely suppliers of the coal used in Dunedin include Taylor Coal (Rolleston), Solid Energy, and Minerals West Coast, which supply mainly West Coast coal.

There are three main ways by which coal supplies enter the Dunedin market: purchasing from commercial suppliers; having it delivered in bulk by commercial suppliers; or picking up coal directly from source (most likely from Kai Point in Kaitangata as the closest source).

Data about coal purchased from commercial suppliers were obtained from two types of sources: (1) the two main coal retailers whose customers are, largely, households, and (2) organisational consumers, who have their coal supplies delivered. The organisational consumers include Dunedin high schools and the Dunedin Energy Centre, which supplies heat to major customers including the University of Otago and the Southern District Health Board.

The figures presented here for coal are unlikely to reflect the whole supply picture, for several reasons. Firstly, this report only includes supply data from one mining company where people directly purchase coal supplies. Secondly, bagged coal is sold in small quantities by many different retailers and collecting this data was beyond the scope of the study. Thirdly, some industrial heating plants may be fuelled by coal which is brought in in bulk. Our data in this area is not comprehensive.

The coal supply figures are therefore likely to under-represent the actual situation.

COAL INPUTS

From the sources reported, an estimated 557 TJ of coal was supplied to Dunedin in 2014. **This accounts for 5% of the total estimated energy supplied to Dunedin**. As noted above, the data is not comprehensive so this is likely to under-represent the amount of coal supplied to Dunedin.

The mining company supplying data for the study considered that **just over a third of the coal they supplied to Dunedin was chunky domestic coal**, which is sized for multi-fuel burners.

They estimated that just under two thirds was pea coal, sized for boilers (most of this coal is blended with other coal by consumers in Dunedin).

The mining company also reported that coal sales fell 25% in 2014, and are expected to fall a further 20% in 2015.

Coal use

In Dunedin, coal is used mainly for household and commercial heating. The Dunedin Energy Centre uses mainly coal (and some wood) to supply heat to the Southern District Health Board (Dunedin Hospital), the University of Otago, and a number of manufacturing and processing businesses.

GREENHOUSE GAS EMISSIONS

IN THIS SECTION:

- Methods & Assumptions
- Greenhouse gas emissions associated with Dunedin's energy inputs

METHODS AND ASSUMPTIONS

Emissions factors were used to determine the greenhouse gas (GHG) emissions in terms of the energy use (i.e. kgCO2e/unit), as follows[22]:

- Electricity from national grid (kWh): 0.138
- Local renewable electricity (kWh): 0.00
- Petrol (litres): 2.36
- Diesel (litres): 2.72
- Liquefied Petroleum Gas (LPG) (kg): 3.03
- Wood (kg): 0.0795
- Coal – sub-bituminous (kg): 2.15

As noted in the Coal section, coal use is likely to be under-counted and thus emissions due to coal will be under-estimated. Electricity from Mahinerangi, Waipori and other local renewable sources is taken as having zero emissions.

The emissions factor used for calculating the emissions from wood considers the associated carbon dioxide emissions as sequestered, as the wood is assumed to have removed CO_2 from the atmosphere during its lifetime. This should be taken into account when considering the emissions for wood, as the total $CO_{2\text{-}e}$ could be considerably higher depending on the factor used.

Without knowing the final end uses of the fuels supplied, it is difficult to determine which emissions factor provides the most accurate estimate of the emissions associated with the use of the fuels. For example, for petrol and diesel, the emissions factor for transportation was used, with the assumption that this is the major use of these fuels in Dunedin.

The calculated LPG emissions should also be considered with caution. The emissions calculated are relatively high due to the use of the higher Ministry for Environment (MFE) general emissions factor for stationary combustion of LPG. This emissions factor was used in the absence of detailed data on the end uses of LPG in Dunedin. Understanding the proportions of different end uses of LPG would enable future emissions calculations to select emissions factors that more accurately represent the purpose for which it is used.

[22] Emissions factors were based on those supplied in the New Zealand Ministry for the Environment's *Summary of Emissions Factors for the Guidance for Voluntary Corporate Greenhouse Gas Reporting - 2015* (MFE, 2015). It should also be noted that the authors also had the option to use MBIE (2013) emissions factors, but used those supplied by MFE for two reasons: (1) MFE's emissions factors are more recent, and (2) whereas MBIE provides emissions factors in CO2 and non-CO2 units only, MFE's emissions factors are reported in total CO2-equivalents, which provide a more complete picture of emissions. However, as a consequence of using MFE's emissions factors, our reported emissions for wood and LPG are considerably lower and higher, respectively, than they would be had MBIE's emissions factors been used.

The emissions estimated to be associated with electricity use were calculated with the assumption that Dunedin electricity supplied from the national grid is the same as the national average (the emissions factors used are national emissions factors). As reported in the electricity section, though, Dunedin's electricity supply has a higher renewable proportion because 32% is directly sourced from Waipori and Mahinerangi, for which no emissions were allocated.

GREENHOUSE GAS EMISSIONS ASSOCIATED WITH DUNEDIN'S ENERGY INPUTS

The breakdown of the emissions associated with each of the fuel types used in Dunedin is provided in Table 3.

Table 3 Estimated greenhouse gas emissions associated with the energy supplied to Dunedin in 2014

	Total kt $CO_{2\text{-eq}}$	Share of emissions	Share of energy inputs
Electricity	85	**14.1%**	30.9%
Petrol	182	**30.4%**	23.6%
Diesel	249	**41.6%**	33.6%
LPG	23	**3.8%**	3.6%
Wood	2	**0.3%**	2.9%
Coal	58	**9.7%**	5.3%
TOTAL	**599**		

Petrol and diesel produce the largest proportion of greenhouse gas emissions in Dunedin (72%).

CONCLUSIONS & OUTLOOK

IN THIS SECTION:

- How does Dunedin compare to the rest of New Zealand?
- How do the findings compare to existing data?
- Conclusions
- Outlook

HOW DOES DUNEDIN COMPARE TO THE REST OF NEW ZEALAND?

As reliable data were gathered on Dunedin's electricity supplies and liquid fossil fuel inputs, the Dunedin figures were compared to the overall New Zealand average. Figures on coal and wood are less reliable and are likely to be under-representative of actual supplies.

Electricity

In 2014, the total electricity demand for New Zealand[23] was 39,410 GWh. Electricity supplied to Dunedin in that year totalled 903 GWh. Dunedin's per capita electricity consumption is 87% of the national average.

Petrol and Diesel

In 2014, New Zealand consumed around 23.8 GJ of petrol and 27 GJ of diesel, per capita (MBIE, 2015). By comparison, Dunedin's 2014 consumption is estimated to be 20.6 GJ of petrol per capita (87% of the national average), and 29 GJ of diesel per capita (109% of the national average).

LPG

New Zealand-wide, 7.52 PJ of LPG was consumed in 2014. Dunedin's estimated LPG demand[24] is twice the national per capita average. However, it should be noted that LPG is much more prevalent in the South Island than in the North Island, where piped natural gas is widely available.

[23] Measured at the point of consumption

[24] As mentioned in the LPG section, Dunedin's LPG demand was estimated to be proportional to its share of the total South Island population supplied via Port Otago.

HOW DO THE FINDINGS COMPARE TO ENERGY END-USE DATA?

Energy consumption

The Energy Efficiency and Conservation Authority (EECA) has an Energy End Use Database, which provides estimates of the energy used in various New Zealand regions. EECA's figures for the Otago region for 2012 were compared to the energy inputs calculated for Dunedin's Baseline Study for 2014. The results of this comparison are provided in Table 4.

Table 4 A comparison of the Baseline Study's energy input findings to EECA estimates

	Est. Delivered Energy (TJ) for Otago Region *(EECA Energy End Use Database)*[25]	Est. Delivered Energy (TJ) for Dunedin *(based on EECA Energy End Use Database)*[26]	Calculated Energy Inputs (TJ) for Dunedin *(Baseline Study)*	EECA / Baseline Study Ratio
Coal	1,098	659	558	1.18
Diesel	5,759	3,455	3,528	0.98
Petrol	6,354	3,812	2,484	1.53
Electricity	4,958	2,975	3,251	0.92
LPG	1,502	901	374	2.41
Wood	1,510	906	309	2.93

The energy inputs calculated for Dunedin's Energy Baseline Study for diesel and electricity are a reasonable match with EECA's estimates of delivered energy.

For wood, however, EECA's estimates are almost 3 times higher than our calculations. This might reflect the difficulty of gathering reliable wood fuel data, particularly data on self-collected firewood, which has been ignored in this study. Because of the implications of wood use for air quality and health, there is a case for investigating firewood use in Dunedin in more detail. Our shortfall with the EECA estimate is in keeping with the report by the Ministry

[25] SOURCE: http://enduse.eeca.govt.nz/default.aspx

[26] Calculated based on EECA's estimates for Otago (http://enduse.eeca.govt.nz/default.aspx) – i.e. it was assumed that the delivered energy to Dunedin would correspond to its share of Otago's population (i.e. 60%).

for Environment, which suggests that self-collected firewood may account for between 40% and 60% of firewood consumption.

For LPG, the difference between our calculated figure and EECA's figure might suggest that our population-based estimate might considerably underrepresent the true supply picture for Dunedin in 2014. It is possible that Dunedin's share of LPG consumption exceeds its share of the total population.

The difference in estimated petrol consumption is also considerable. This may reflect local variants not accounted for in the EECA database, but invites further investigation.

Reliable supply information is also lacking for coal, and the EECA data suggests that our figures may under-represent actual coal consumption in Dunedin. Because of the implications of coal combustion for air quality and health, there is a case for investigating coal use in Dunedin in more detail.

Greenhouse gas emissions

EECA's Energy End Use Database also provides estimates of the greenhouse gas emissions associated with the energy used in the Otago region. EECA's figures for the Otago region were compared to the energy inputs calculated for Dunedin's Baseline Study. The results of this comparison are provided in Table 5.

Table 5 A comparison of the Baseline Study's greenhouse gas emissions findings to EECA estimates

	Est. total t CO2-e for Otago Region *(EECA Energy End Use Database)*[27]	Est. total t CO2-e for Dunedin *(based on EECA Energy End Use Database)*[28]	Calculated total t CO2-e for Dunedin *(Baseline Study)*	EECA / Baseline Study Ratio
Coal	98,670	59,202	58,002	1.02
Diesel	402,006	241,203	249,146	0.97
Petrol	424,098	254,459	181,822	1.40
Electricity	254,459	152,676	84679	1.81
LPG	86,750	52,050	22,899	2.27
Wood	161,541	96,925	2,089	46.39

[27] SOURCE: http://enduse.eeca.govt.nz/default.aspx

[28] Calculated based on EECA's estimates for Otago (http://enduse.eeca.govt.nz/default.aspx) – i.e. it was assumed that Dunedin's emissions would correspond to its share of Otago's population (i.e. 60%).

Unsurprisingly, the figures differ in part because of the different input figures.

The comparison further emphasises the need for caution when considering the wood fuel data reported here. Both wood fuel use and the associated greenhouse gas emissions are likely to be underrepresented in the findings from the study. Another potential reason for the difference between this study's wood emissions and those calculated by EECA is the use of different emissions factors. The one used by this study produced fewer emissions per CO_{2eq}, as it was assumed that the emissions produced while wood is being used as a fuel were neutralised by the removal of CO_2 during growth in the forest.

The comparison also highlights that our estimate of the emissions calculated as being associated with LPG are notably lower than EECA's estimates. This is likely associated with our lower population-based estimate of LPG supply. Further study of the specific uses of LPG in Dunedin and their relative proportions would uncover any potential uses that may be causing Dunedin to use more than its population share of LPG.

Additionally, a region-specific greenhouse gas emissions factor that more accurately reflects Dunedin's specific energy mix would enable more reliable estimation of the emissions associated with the city's electricity supplies.

CONCLUSIONS

This study is an initial effort to gather data on all energy inputs into Dunedin. The data reported here is as fulsome as could be gathered within the time and scope of this project, and there are some clear shortcomings in some aspects which must be acknowledged. These include the lack of data on self-collected wood; shortfalls in data on coal use; and lack of data on the proportion of liquid fossil fuels used within the city.

With these caveats, the estimated total consumer energy supplied to Dunedin city during 2014 totalled approximately 10.5 petajoules (PJ). Of this, 58% comprised petrol and diesel, 31% electricity, 3% LPG, 5% coal and 3% wood fuels.

Based on the insights gained through the study, the following is a summary of Dunedin city's main energy-related strengths, weaknesses, opportunities and threats in 2014.

STRENGTHS

- Around 30% of Dunedin's total consumer energy supply was from renewable sources
- Around 86% of Dunedin's electricity supply was generated from renewable resources; the number of renewable energy installations have risen continuously over the last 2 years.
- Distributed solar capacity increased by 280% and wind capacity by 60%. Residential installations of solar and wind generation were the biggest renewables growth area.

WEAKNESSES

- Less than 0.1% of total consumer energy was sourced from within Dunedin's boundaries.
- High dependence on fossil fuels, which account for about 80% of greenhouse gas emissions
- The city does not currently monitor consumer energy variables over time – this is important for understanding current trends and for forecasting, to inform plans for the future.

OPPORTUNITIES

- Potential to reduce transport emissions through incentives and infrastructure for alternatives such as electric vehicles, cycling and public transportation
- Potential for local production of wood pellets and woodchips

There are also indications of potential for growth in the renewables sector:

- Notable increase in distributed solar and wind capacity
- Approximately 600 permits are issued for new wood burners every year
- Replacement of coal with wood fuels

THREATS

- Petrol and diesel make up more than half of the total energy supplied to Dunedin. This suggests that Dunedin has some vulnerability to price volatility in these imported fuels.
- Informality of / lack of data on wood fuel self-collection suggests that wood harvesting for heating is not closely monitored. There might be some vulnerability to unsustainable wood harvesting.

Figure 18 The strengths, weaknesses, opportunities and threats to Dunedin's energy system in 2014

In 2014, around 30% of Dunedin's total consumer energy supply was from renewable sources, which is close to the national figure of 31%.

Around 86% of Dunedin's electricity supply was generated from renewable resources. This is assuming that Dunedin's electricity supply comprises 32% renewable from Waipori and Mahinerangi, and 68% from the national grid which averaged 80% renewable in 2014.

Approximately 0.2% of the electricity used was generated from within Dunedin's boundaries. There was a notable growth in small-scale solar and wind installations in 2014. Although, in absolute terms, these installations are not a significant part of Dunedin's electricity production, they indicate the potential for further growth in this area.

The fact that a high proportion of electricity supplied to Dunedin is generated from renewable sources is not represented in the national emissions factors used to calculate greenhouse gas emissions from grid electricity. Further research is needed on this to determine a more representative local figure for electricity-related emissions.

Most of the wood harvested for commercial supply to Dunedin was from outside of the Dunedin area, but no figures for self-collection were available. Given the number of forests within Dunedin's boundaries, there may be opportunities to increase supplies from local forests and save transport costs. In particular there may be an opportunity to develop a local pellet production facility given the growth in pellet fire use in Dunedin.

Although wood pellets are responsible for the lowest amount of greenhouse gas emissions, their use for household heating is concentrated in high-income households. This might present an opportunity to align social planning and strategies with Dunedin's sustainable household heating initiatives.

Coal is a non-renewable energy resource. It accounted for 5% of total energy inputs and 9.1% of the total greenhouse gas emissions. Coal supply figures collected for this study are likely to under-represent actual use, and further investigation into supply, end uses and the specific coal blends used is likely to shift these figures upward. From a sustainability perspective, the continuing decline in coal sales may be an indication of increased use of low-carbon alternatives. This decline may also present an opportunity for the development of synergies and incentives that encourage and enable coal-centred businesses to diversify into more sustainable business avenues.

Liquid fossil fuels (petrol, diesel and LPG) are a non-renewable energy resource, and together are estimated to account for 76% of Dunedin's greenhouse gas emissions, with coal contributing a further 9.7% of emissions.

Petrol and diesel make up more than half of the total energy supplied to Dunedin. This suggests that Dunedin has some vulnerability to price volatility in these imported fuels, and opportunities to reduce that risk should be considered.

Better data is needed on end-uses of liquid fossil fuels, because although it is safe to assume that most is used as transport fuel, diesel in particular is also used for many other purposes including space heating. The breakdown of uses of LPG is also unknown.

Better knowledge of end-uses would assist in identifying opportunities for fuel shifting and efficiencies. For example there may be opportunities to (a) reduce transport consumption through incentives and infrastructure for alternatives such as electric vehicles, cycling and public transportation; (b) support shifts to biofuels once these become cost-effective; and (c) encourage users of liquid fuels for heating to shift to low-carbon alternatives.

Only a tiny proportion (estimated as less than 0.1%) of total consumer energy in 2014 was sourced from within Dunedin's boundaries. This is not necessarily a weakness, but there are certainly opportunities to increase local supplies through distributed electricity generation, and through use of biofuels, particularly wood resources.

Although this was beyond the scope of the study, we have roughly estimated that the value of energy inputs into the city for 2014 was in the region of $500 million: around 10% of Dunedin's GDP. A useful further step would be to calculate the value of the various energy inputs into Dunedin. This would enable an understanding of the relative cost of different energy types, the implications of price changes (e.g. in liquid fossil fuels) and the potential impact on the local economy of actions to use energy more efficiently.

Finally, it would also be useful to know and map the energy flows in Dunedin that either go to waste or could be used more efficiently. An example is waste heat from industrial processes such as that of the Ravensdown Fertiliser Cooperative. Also of potential interest would be the locations and demands of potential users of this wasted energy.

OUTLOOK

The Baseline Study presents a number of opportunities to gain further insight into Dunedin's energy system. Although the study focused on quantifying the consumer energy inputs to the city, for some of the data collected some high-level insight into consumption was gained. For instance, the study provided a breakdown of the proportions of different kinds of electricity end uses, as well as the geographic distribution of wood pellet fires in Dunedin. Being able to gain a deeper understanding of what is happening with regards to the consumption of Dunedin's energy inputs would greatly enrich the understanding of Dunedin's energy flows, and would be an ideal next step of the study should the opportunity arise. For this, a more comprehensive assessment of the current flows, uses and transformations of energy in Dunedin (i.e. a study of Dunedin's 'energy metabolism') is needed.

'Urban metabolism' is a model for quantifying and analysing the flow of materials and energy through urban systems that is used to keep the system running. An *energy* metabolism study is a version of an urban metabolism study, but one which focuses only on energy flows[29].

For example, assumptions have been made about the proportion of LPG that is used within Dunedin compared to that which is trucked to other parts of Otago and Southland. A study of the city's metabolism would trace this flow to its end use. The dilemma of the proportion of firewood that is self-harvested may also be solved by an energy metabolism study. More reliable estimates of the stocks and flows of materials such as firewood and coal may be gained by directly surveying a sample of the households and institutions that use them.

We therefore recommend that the city continue to track these variables over time, and that further data collection is needed to fill the stated holes in the available information.

Nonetheless, this study is a first step towards knowing the amount of energy used to run Dunedin's activities, as well as understanding the city's relationship with and dependence on neighbouring regions and the globe for its energy supplies.

[29] http://www.urbanmetabolism.org/