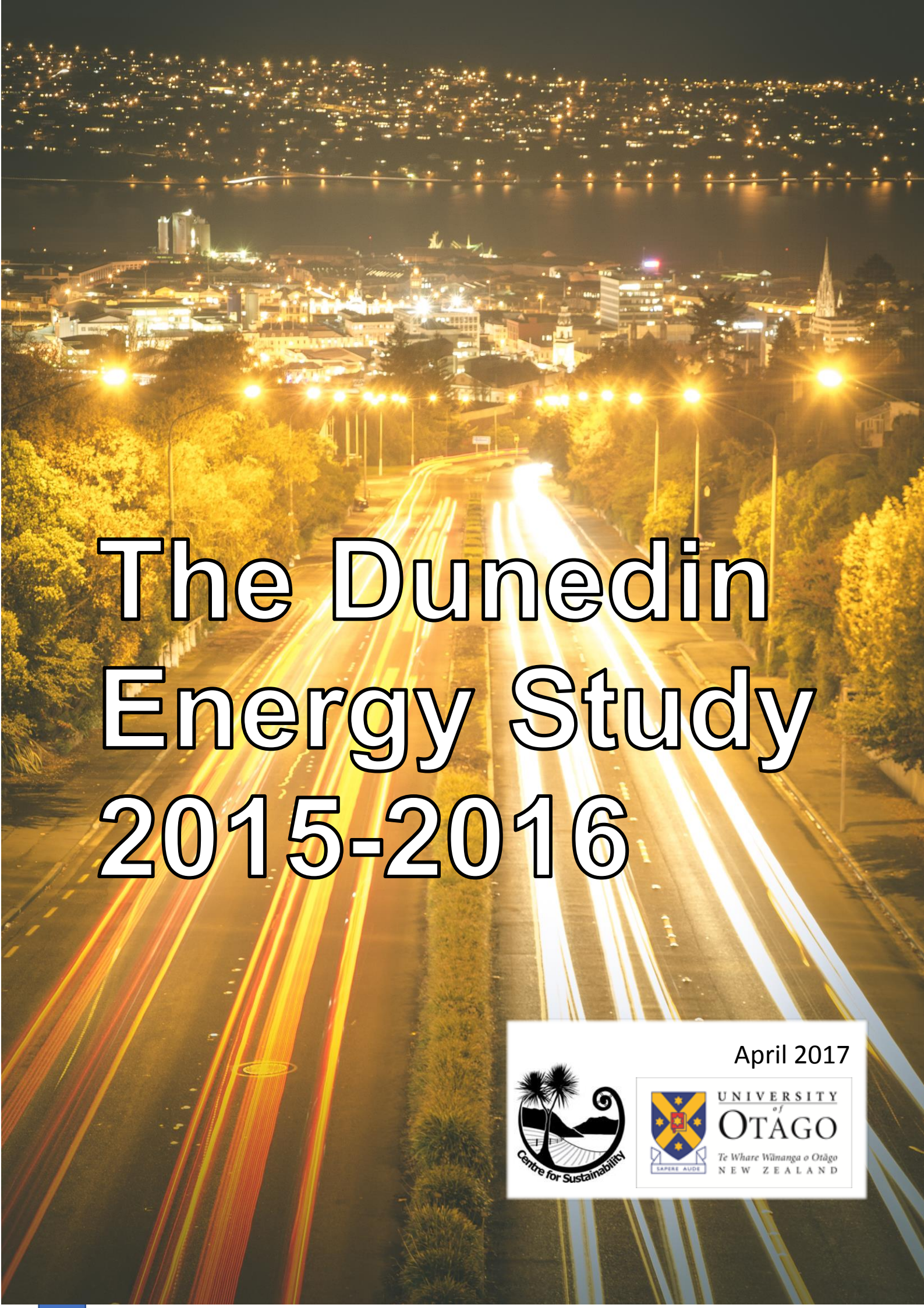

The Dunedin Energy Study 2015-2016

April 2017

Centre for Sustainability

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

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Executive summary

The Dunedin Energy Baseline Study is a joint research project between the Dunedin City Council (DCC) and the Centre for Sustainability at the University of Otago. The study takes stock of and analyses energy inputs to the city of Dunedin for the 2015 calendar year and 2016 financial year. This report builds on the Dunedin Energy Baseline Study which took stock of the year 2014.

This study is an action under the DCC's Energy Plan 1.0, which recognises the need to encourage research that will enable monitoring of Dunedin's energy uses and inputs. This study will also help inform and assist with implementing other Energy Plan 1.0's actions, such as the Night City action (improve lighting efficiency) and Cosy Homes action (improving heating of homes).

The study was conducted between December 2016 and February 2017. The data collected was for inputs of consumer energy to Dunedin from 1 January 2015 to 30 June 2016. The findings provide an estimation of the total amount of each fuel type used within the city, with some indication of the main end uses of energy, and energy-related greenhouse gas emissions. Precise data was not available for some fuel types and where this is the case we explain the method of estimation and reason for the uncertainty.

The project relied heavily on the willingness of many businesses and organisations to supply data. The project partners are extremely grateful to all participating individuals and organisations who dedicated a considerable amount of time to sourcing, compiling and providing relevant data.

Throughout the report, 2015CY refers to calendar year (1 January – 31 December 2015) and 2016FY refers to financial year (1 July 2015 – 30 June 2016).

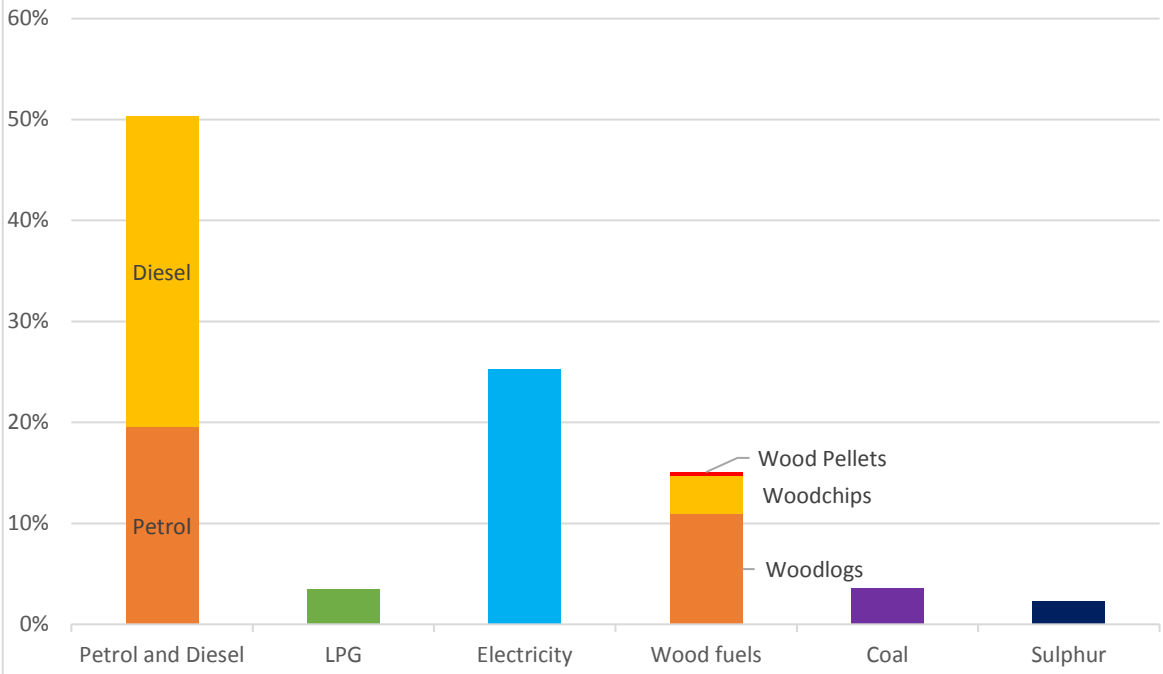
Summary of energy inputs

For the 2015CY, energy inputs into Dunedin totaled 13.1650 PJ

For the 2016FY, energy inputs into Dunedin totaled 13.2416 PJ.

Over the 18 month period 1 January 2015 – 30 June 2016, approximately 51% of Dunedin's consumer energy was derived from petrol and diesel, 25% from electricity, 15% from wood, 3% from LPG, 4% from coal and 2% from sulphur (Figure 1).

Figure 1: Dunedins total estimated energy supplies by proportion of PJ for 2015CY



Sources of energy

Most of the energy used in Dunedin – 84.5% – was sourced from outside the city's boundaries. All petrol, diesel, LPG, coal and sulphur were imported from other regions in New Zealand or imported from overseas. Most electricity is derived from the national grid.

Locally sourced energy comprises some of our electricity, and wood fuels.

In 2015CY, 16% of Dunedin's electricity (0.5495 PJ) was produced from locally embedded generators (mostly from Waipori and Mahinerangi) and in 2016FY this was nearly 18% (0.5967PJ).

Locally sourced wood fuels totaled 1.4228 PJ, of which over 90% was firewood (self-collected or purchased), and the remainder wood chips and other wood products. No wood pellets are locally sourced.

Overall, around 15.5% of total energy used in Dunedin was locally sourced in 2016FY: around 11% being from wood products and 4.5% from electricity.

However, it should be noted that almost all of the electricity from locally embedded generators is derived from the Waipori (hydro) and Mahinerangi (wind) power schemes which, while feeding directly into the Dunedin electricity grid, are located outside the city boundary.

Renewable resources

Around 37% of Dunedin's total consumer energy supply was from renewable resources. (In contrast, approximately 40% of New Zealand's total consumer energy was renewable in 2015[1].)

For Dunedin, 42% of this renewable energy was from wood fuels, and the remainder from electricity.

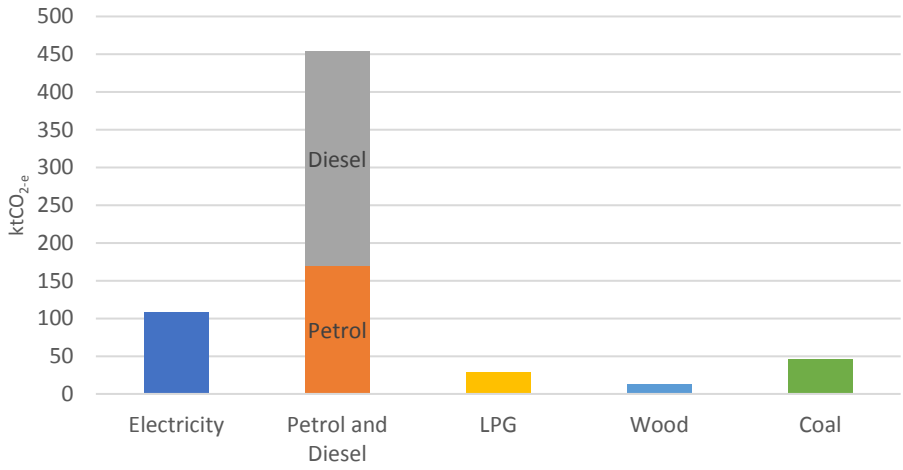
In both 2015CY and 2016FY, around 83% of the electricity supplied to Dunedin was generated from renewable resources – mainly from hydro, geothermal and wind.

Greenhouse gas emissions

For the 2015CY about 648.8 kt $CO_{2\text{-}e}$ (kilotonnes of greenhouses gases) can be attributed to energy use in Dunedin

In 2015CY about 74.4% of these emissions arose from the use of liquid fossil fuels (petrol, diesel and LPG), 17.5% was attributed to electricity use in the city, 1.9% to wood and 7.1% to coal use.

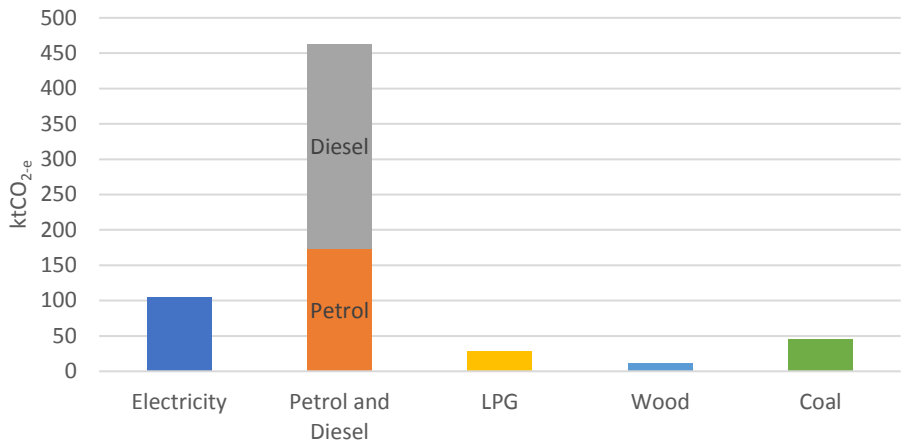
Figure 2: Estimated greenhouse gas emissions associated with Dunedins Energy supplies in 2015CY



[1] Source: https://www.eeca.govt.nz/energy-use-in-new-zealand/renewable-energy-resources/

For the 2016FY, 654.3 kt $CO_{2\text{-}e}$ can be attributed to energy use in Dunedin: 75.1% from the use of liquid fossil fuels, 16.1% attributed to electricity use, 1.8% to wood and 7.0% to coal use.

Figure 3: Estimated greenhouse gas emissions associated with Dunedins Energy supplies in 2016FY



Comparability to the Baseline Dunedin Energy Study

The data collection methods used for this report have evolved since the Dunedin Energy Baseline Study for 2014. This 2015/2016 study has developed and used more comprehensive methods, and the data is thus not directly comparable and therefore not suitable to draw conclusions about energy trends.

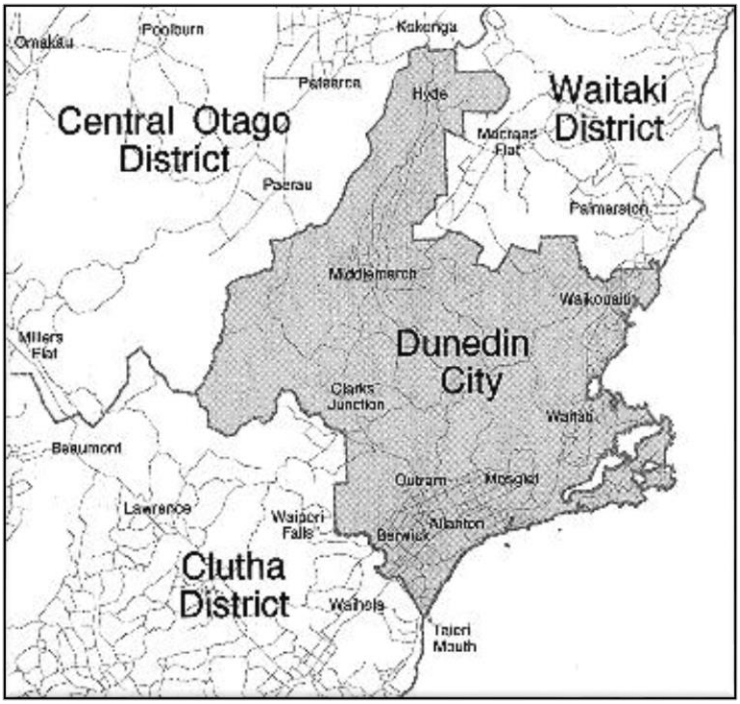
Overview

About Dunedin

Dunedin city had an estimated population of 120,249 in the 2013 Census (Statistics NZ, Census 2013). It is the second largest city in the South Island and the largest city in the Otago region. Dunedin city has 2.8% (Statistics NZ, Census 2013) of New Zealand's population and is the 5th largest in geographic area out of the 67 districts in New Zealand. The Dunedin City Council (DCC) governs this area. In this study, 'Dunedin' refers to the geographic area under jurisdiction of the DCC (Figure 4).

Dunedin is bounded by Waitaki District in the north, Central Otago district in the west, Clutha District in the south and the Pacific Ocean in the east.

Figure 4: Dunedin City Boundaries



The three largest industries that contribute to employment in Dunedin are education and research (6990 FTEs), tourism (3134 FTEs) and primary processing (1687 FTEs) (Otago Economic Overview, 2014)[2].

[2] Soucre: http://www.dunedin.govt.nz/__data/assets/pdf_file/0017/511433/2014-Economic-Profile-of-the-Otago-Region-and-Dunedin-City-FINAL.pdf

Dunedin had a GDP of $5.314 billion in 2014 (Otago Economic Overview, 2014). The University of Otago is Dunedin's largest employer making up approximately 17% of Dunedin's GDP[3].

Comparative growth

Population growth and economic growth can both have significant impacts on energy use. Statistics New Zealand has projected[4] based on the 2013 Census that should Dunedin experience medium population growth, the population will increase by 0.5% a year between 2013 and 2018. In 2014 there was 2.4% economic growth[5].

About the Dunedin Energy Study

In 2015, the Dunedin Energy Baseline Study for the year 2014 was completed. At the time, there was no single source of information for the total energy consumed by Dunedin – including by households, transport, businesses, education, farming and industry. This data is important for informing the development of strategies for the future of the City, including for energy, transport, environment and economic development. Additionally, the DCC joined the Compact of Mayors in 2014, which is global coalition of city leaders who have pledged to cut greenhouse gas emissions (GHGs) and prepare for the future impacts of climate change. Therefore, it is very important that DCC has a thorough understanding of GHGs arising from energy consumption within the city boundaries.

The primary aim of the Dunedin Energy Study 2015/2016 is to update the database of energy inputs into Dunedin as well as address some of the data gaps evident from the baseline study. The baseline study covered the 2014 calendar year, but it is more helpful for some of the users of the study for the data to be in financial year form. This study therefore reports for the 2015 calendar year (2015CY) as well as the 2016 financial year (1 July 2015 to 30 June 2016) (2016FY). The two reporting periods are described separately in each section of the report, so as to allow for future comparisons to be easily made.

The only similar source of information that shows energy use by geographic region is the Energy End Use Database held by the Energy Efficiency and Conservation Authority (EECA). This has an estimate for energy used by the region for the 2012 calendar year. At the end of this report the findings are compared to those from the Energy End Use Database.

The study focuses on end use energy within the Dunedin City boundary, as well as energy imported into Dunedin and energy produced/generated in Dunedin. The study considers consumer energy inputs only, not energy embedded in goods such as the energy used elsewhere in New Zealand or globally to fabricate machines, food or household appliances.

The data used was not readily available from single sources, and the project relied on the willingness of many businesses and organisations who supplied data, including DCC,

[3] Source: University of Otago Annual Report 2015

[4] Source: Statistics New Zealand: Subnational Population Projections: 2013(base)–2043

[5] Source: Business and Economic Research Limited's 2014 Economic Profile of the Otago Region and Dunedin City

retailers, logistics companies, lines companies, electricity generators and individuals who have a great understanding of energy flows in the city. In some cases, more in-depth data was supplied about temporal and spatial patterns of energy use in Dunedin. This has been included where relevant.

The study was undertaken by researchers at the University of Otago. Under the ethical approval granted for the research project, individuals and organisations participating in the study were given options regarding the anonymity and confidentiality of the data provided. Where requested, anonymity has been preserved by aggregating the energy inputs by fuel type. The raw data collected is securely stored and password protected on a server at the University of Otago.

CONVERSION FACTORS

Energy data was originally gathered in the units used in that sector. To enable comparisons, all were converted to the common unit of megajoules (MJ). Conversion factors based on net calorific values were used to convert fuel quantities from the originally reported units as follows:

Energy Form	**Conversion**[6]
Electricity (kWh)	3.6 MJ/kWh
Petrol (litres)	35.08 MJ/L
Diesel (litres)	38.45 MJ/L
LPG (kg)	49.51 MJ/kg
Coal (tonnes)	24303 MJ/tonne
Firewood (tonnes)	16740 MJ/tonne
Wood pellets (tonnes)	17170 MJ/tonne
Wood chips, 35% moisture (tonnes)	8220 MJ/tonne

These conversion rates are consistent with the Baseline Study.

[6] 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).

Liquid fossil fuels

Methods and Assumptions

The main liquid fuels used in Dunedin are petrol, diesel and liquefied petroleum gas (LPG). These fossil fuels are all imported from outside the DCC area.

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

Petrol and diesel

Petrol and diesel supply to Dunedin

Petrol and diesel is imported into Dunedin through Port Otago. There are 10 companies that sell petrol and diesel in significant quantities in Dunedin: BP NZ LTD, Chevron CALTEX, Exxon MOBIL, Z Energy, McKeown & Graham, Allied Petroleum, CRT Farmlands Fuel, RD Petroleum Ltd, GULL NZ Ltd and Nelson Petroleum Distributors.

The data on Dunedin's petrol and diesel supplies were compiled using tax data collected by the DCC. The DCC collects a Local Authorities Fuel Tax under the Local Government Act 1974, whereby all quantities of these fuels sold (that comply with the Act) need to be disclosed and tax files returned. This includes fuel that is distributed through retail outlets as well as fuel distributed directly to customers from wholesale outlets.

The data is collected by the DCC for the Tax Area of Coastal Otago, and includes both the quantities of petrol and diesel sold and the corresponding tax payable.

The tax area of Coastal Otago includes geographical regions outside the jurisdiction of the DCC. The area of Coastal Otago was defined in 1971 as Dunedin City; Oamaru, Port Chalmers, St. Kilda, Green Island, Mosgiel, Balclutha, Kaitangata, and Milton boroughs; and Waitaki, Waikouaiti, Waihemo, Taieri, Bruce, and Clutha counties. Of these territorial areas, Oamaru and Waihemo lie to the north of Dunedin in what is now Waitaki District, and Balclutha, Kaitangata and Milton boroughs and Clutha county lie to the south in what is now Clutha District.

The DCC uses the comparative percentage of rates incomes in the portions of the three districts (Dunedin City, Waitaki District Council and Clutha District Council) that lie within the defined Coastal Otago Tax area to allocate tax revenue. In the 2015FY the Dunedin City percentage was 70.41% and in the 2016 FY was 70.44%. These percentages have been applied to the petrol and diesel tax data to get an approximation for the share of these fuels used in Dunedin.

In contrast, the Baseline study used the relative population of the three areas (from the 2013 Census) to estimate the proportion of these fuels used in Dunedin. We have adopted the 'percentage of rates income' method so as to be consistent with DCC's strategy for allocation of the fuel taxes.

The DCC did not have a robust way of collecting data on fuels tax prior to June 2015 and so data prior to this date does not have the same degree of accuracy as the subsequent data. If the new method is continued, more confidence can be given to future assessments of quantities and trends in petrol and diesel consumption.

Additionally, the DCC data prior to 1 July 2015 does not have the quantities of fuel imported, so the average proportion of 40% petrol and 60% diesel from 2016FY data was applied to estimate the 2015CY use.

Another approximation has had to be made because of transboundary use of transport fuels. Some of the petrol and diesel purchased in Dunedin service stations will be used in vehicles that drive beyond the city, and some vehicles coming into the city will have purchased their petrol and diesel elsewhere. We do not have data on these relative quantities. For the purposes of this study it has been assumed that these quantities are similar and so cancel each other out. Further research on this question would be useful.

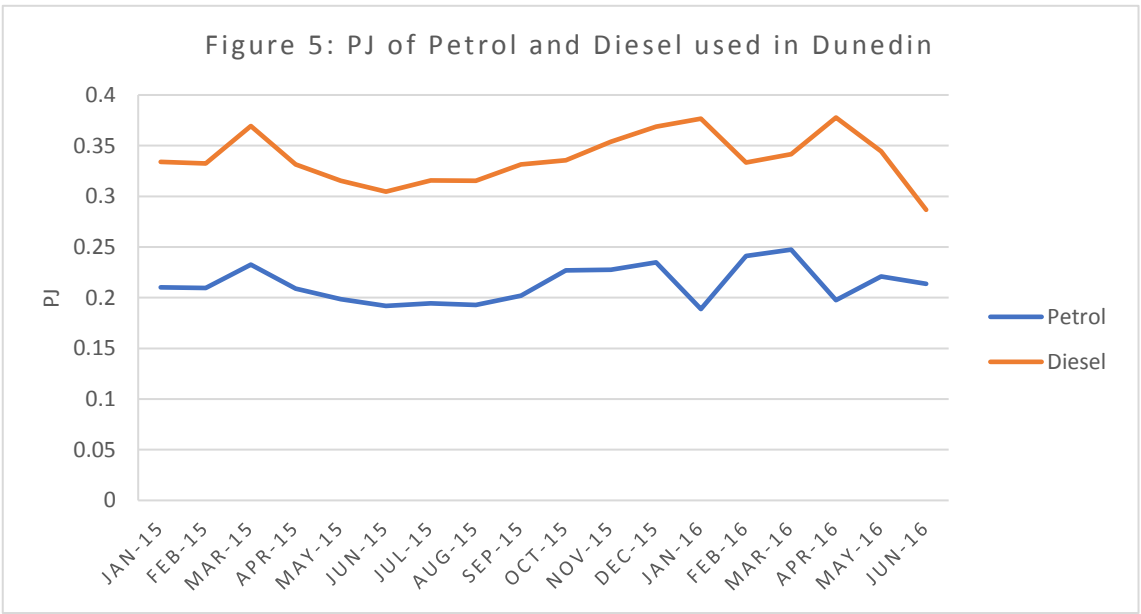
When comparing the total amount of petrol and diesel sold in Dunedin with the tonnes of diesel and petrol that are imported via Port Otago, it is clear that more than half of the petrol and diesel brought in through the Port is transported and distributed for sale in areas outside of the DCC jurisdiction. In 2015CY only 47.2% and in 2016FY only 46.6% of the petrol and diesel reported by Port Otago are accounted for in the DCC tax records.

Total petrol and diesel supplies for Dunedin:

2015CY: 2.53 PJ of petrol and 4.01 PJ of diesel. Total = 6.54 PJ

2016FY: 2.59 PJ of petrol and 4.08 PJ of diesel. Total = 6.67 PJ

Figure 5: PJ of Petrol and Diesel used in Dunedin



This graph shows the monthly breakdown of both petrol and diesel purchased in Dunedin as indicated by the DCC tax records for the 18 month period of this study.

Use of petrol and diesel in Dunedin

We assume that most of the petrol and diesel is used as transport fuels for on-road use. However some will be used for other purposes such as for running machinery, in farm vehicles and for home heating, but the relative quantities are unknown. Further research is needed on this.

LPG

Supply of LPG in Dunedin

Most LPG arrives in Dunedin through Port Otago and is then collected and stored by the logistics handling company Liquigas. There are four LPG wholesalers in Dunedin: Nova, Contact (Rockgas), Elgas and Ongas. Three of these wholesalers receive their LPG supply from Liquigas. However, one wholesaler receives their LPG supplies via rail from elsewhere in New Zealand and so is not included in data received from Port Otago or Liquigas.

As far as can be established, the LPG that arrives through the Otago Port is distributed all around the southern half of the South Island. We have adopted the assumption that this is in proportion to population, and on that basis 36%[7] of the LPG that arrives through the Port has been included in Dunedin's consumption of LPG.

In the absence of any information about the amount of LPG that comes in by rail, we have assumed that the four wholesalers each have 25% market share. We have allocated the total LPG brought in via Port Otago equally across the 3 companies whose supplies are sourced from the Port, and have used the same quantity as an estimate of how much is brought in by rail by the fourth company.

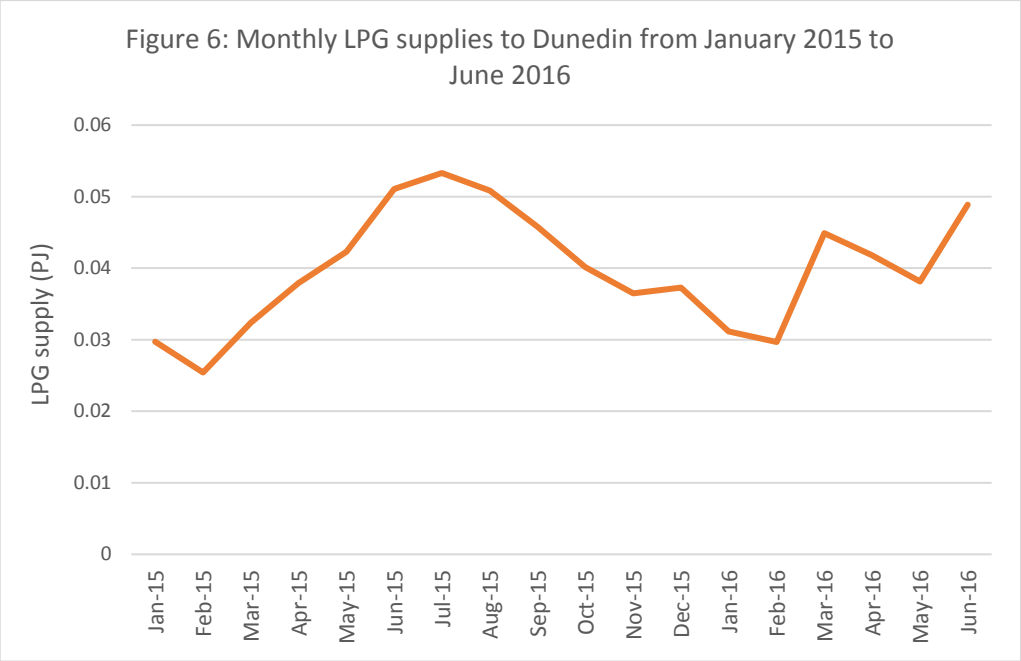
Liquigas, the LPG distributor, has provided a monthly breakdown of LPG quantities uplifted from their tanks. In the Baseline Study the reported LPG data was based on LPG shipments into the city, but because this comes in bulk loads there was enormous variability month by month. In this study, we instead used the data for uplift from the Liquigas tanks by the wholesalers, as we consider this will mirror LPG consumption more closely.

Total estimate for LPG supplied to Dunedin:

2015CY: 0.483 PJ

2016FY: 0.498 PJ

[7] 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.



The above graph shows the monthly data on LPG supplied to Dunedin. This shows increased LPG consumption in winter months, most likely because LPG is a common heating fuel source in the city.

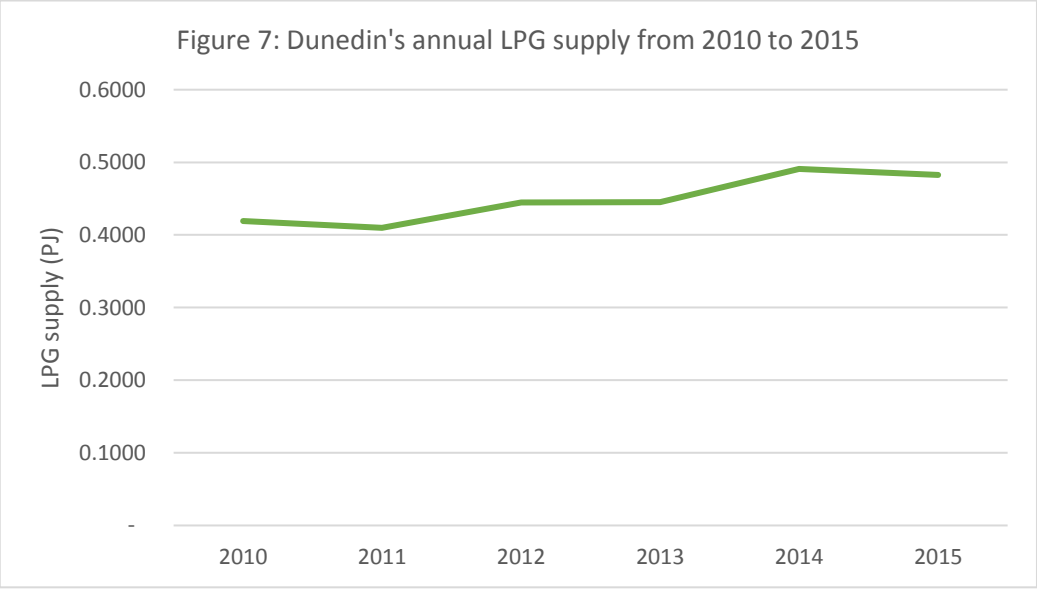


Figure 7 shows the trend of LPG supplies (including LPG arriving through the Port and LPG arriving by rail)[8] in the city over 6 years from 2010 to 2015. The general trend is for increasing LPG consumption over this period.

[8] 75% through Port Otago and the 25% via rail

Use of LPG in Dunedin

LPG is used in Dunedin for multiple purposes including industrial applications, residential use and transport.

LPG boilers in Dunedin

The Energy Efficiency and Conservation Authority (EECA) has a Heat Plant Database that contains publicly available information about boilers in New Zealand.[9] The EECA boiler list showed 12 LPG boilers in the city in 2014, 7 of which belonged to local government. This includes reticulated gas used to heat facilities such as Moana Pool and Dunedin Public Art Gallery. Using figures from the database we calculated the following:

In the 2015CY, large industrial/ commercial users (including the DCC and Otago University) used 0.1400 PJ (38.90 GWh) of LPG.

For 2016FY the equivalent figure was 0.1327 PJ (36.87 GWh).

Residential and business LPG use in Dunedin

Households and businesses in Dunedin use LPG for heating, cooking and heating water. Gas is reticulated in the central city area and elsewhere is provided in gas bottles.

From the 2013 census data, there are 21 households that use reticulated gas as their main heating fuel, 294 households that use bottled gas as their main heating fuel, and 4692 households that use either reticulated or bottled gas as well as another form of fuel for heating. We could find no sources of data on how much LPG is used residentially or any breakdown of its relative use for different purposes. Further research is needed.

The Home Heating Report[10] from 2005 estimated that households that use gas would use on average 2kg of gas per day in both winter and non-winter months[11].

This is equivalent to city wide annual residential LPG use of 0.327 PJ[12].

We don't have any data on business use of LPG, apart from in boilers as above. Further research is needed on this.

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[9] The EECA heat plant database was last reviewed in 2014 and there may be subsequent changes which have not been captured on this list. The Boiler List is currently not updated yearly, therefore the fuel demand figures will not differ between years. The reliance on this database must therefore be cautioned.

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

[11] There is no reasoning in the Warm Homes Technical Report as to why the LPG use is the same in winter and non-winter months. One possibility is that LPG is mainly used for cooking and hot water heating rather than for space heating and therefore is use relatively consistent throughout the year.

[12] This is based on 2013 Census data by Statistics New Zealand and therefore there is no monthly breakdown. It is assumed that the 2013 figures still apply in the 2015CY and 2016FY. The total PJ of LPG used for residential use was calculated by taking the number of households that use gas and assuming that they would use on average 2kg of LPG per day as calculated in the Home Heating Report 2005.

LPG used for transport in Dunedin

LPG is also used as a fuel for transport. In Dunedin, there are 4 petrol stations that sell LPG. These are Burnside Service station, Green Island; Complete Auto Repairs Ltd, Hillside Road; Caltex City North and Mobil Anzac Ave.

As at 2014, there were 83 LPG and 3 CNG vehicles in Otago as a whole[13]. This has been scaled back in proportion to Dunedin's relative share of the population (60%) and on this basis we assume that there are 52 LPG vehicles in the city.

Based on average annual kilometres travelled by light vehicles (and assuming LPG vehicles are used in a similar way to vehicles using other fuels), this corresponds to approximately 619,200km[14] of travel by LPG vehicles. LPG vehicles use 10-20%[15] more fuel per kilometer than petrol vehicles. This calculation results in an approximate LPG consumption of 8.671 litres per 100km.

We conclude that approximately 0.003 PJ of LPG is used for transportation in Dunedin on an annual basis.

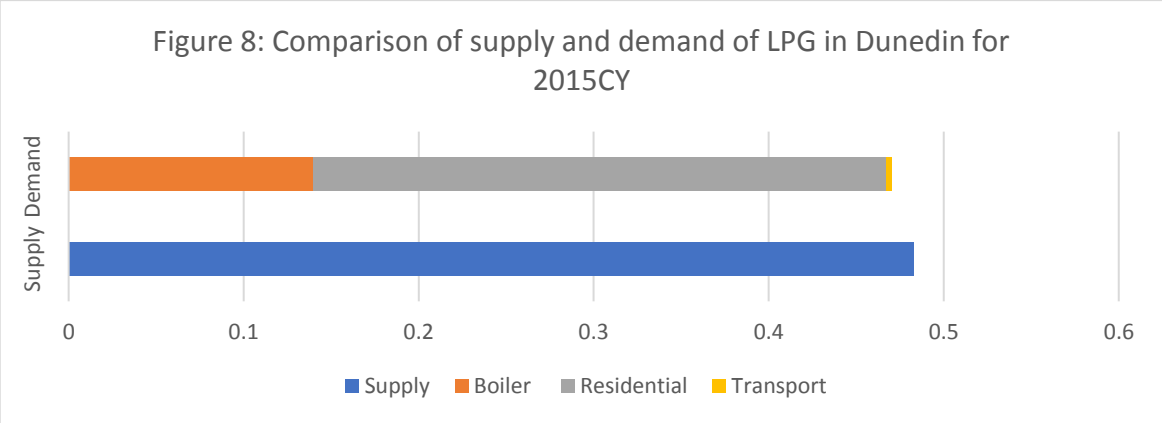
LPG use overall

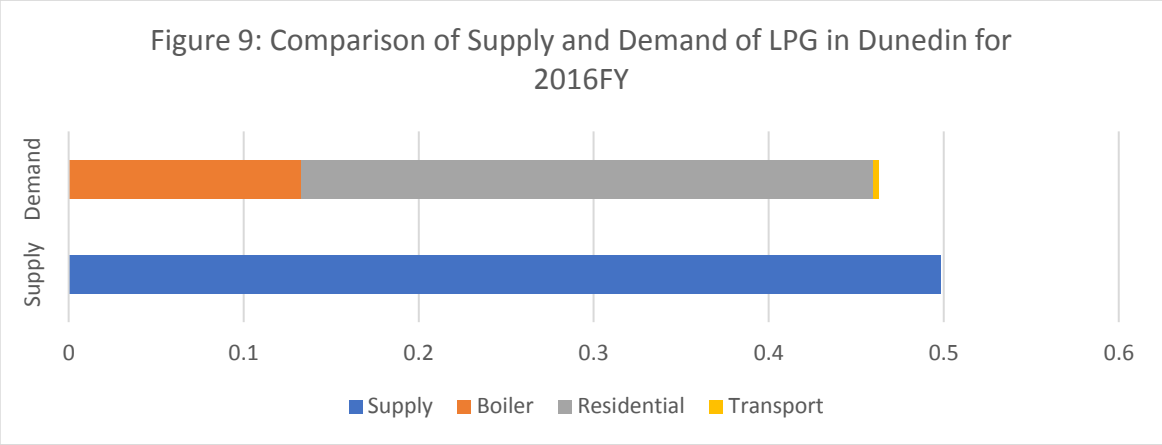
Together, these estimations of LPG use add up to a total that is very close to the estimation of LPG supplied into the city (Figures 8 and 9). **In total, we can account for approximately 0.47 PJ of LPG use in 2015CY, and 0.4627 PJ of LPG use in 2016FY.**

[13] Source: Ministry of Transport. It should be noted that this was a count of light vehicles, it does not included other types of LPG vehicles, for example, forklifts.

[14] Source: http://www.transport.govt.nz/assets/Uploads/Research/Documents/New-Zealand-Vehicle-fleet-stats-final-2013.pdf

[15] http://pafuels.co.nz/lpg-savings-calculator/





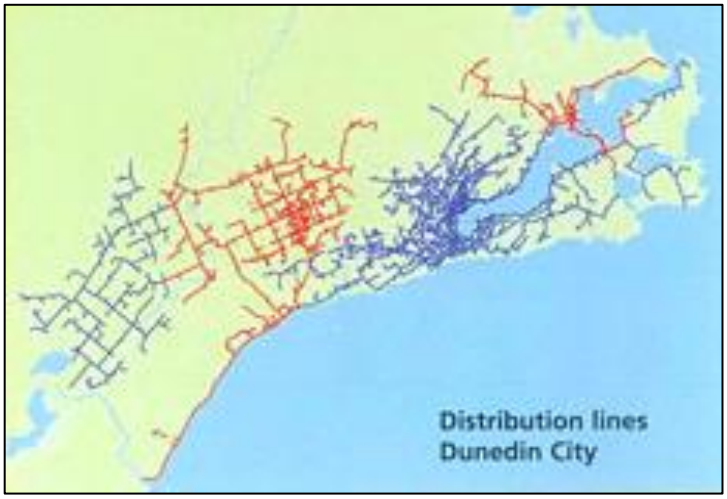
The graphs above compare estimated use and estimated supply of LPG as described in this section. For the 2015CY we have captured 97% of supply in the estimated use figures, and in 2016FY we have captured 93%.

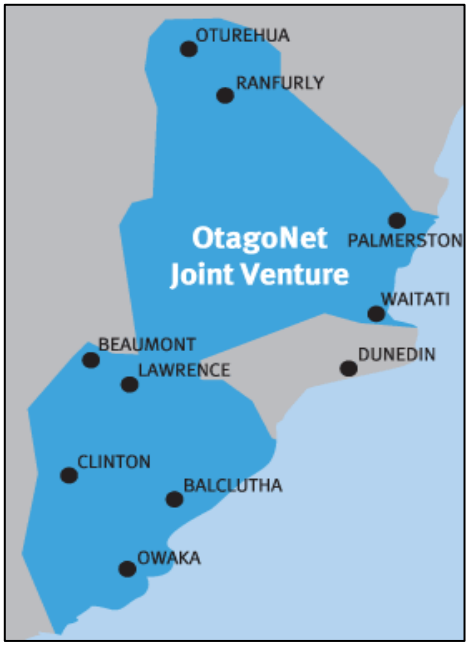
Electricity

Methods and assumptions

The data on electricity supply in Dunedin was provided by the lines companies (Aurora and Otago PowerNet), the energy advisory company Energy Link, and the Electricity Authority database of installed capacity[16] of distributed generation.

Lines companies have responsibilities for electricity distribution networks within geographic areas. Of the two lines companies that operate in the Dunedin area, Aurora covers the urban and suburban areas of Dunedin (Figure 10) whereas Otago PowerNet's coverage within the Dunedin City Boundary includes Hyde, Middlemarch, Clarks Junction, Hindon, Waitati and Karitane, along with extensive areas outside the city boundary (Figure 11).





Above - Figure 10: Aurora Network in Dunedin
Right - Figure 11: Area covered by OtagoNet with includes DCC territory

Aurora reported in 2015[17] that there were 54,495 Individual Connection Points (ICPs[18]) on their network and in 2016 that there were 54,277 ICPs.

OtagoNet had a total of 2,979 connections within the Dunedin area as at December 2016.

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16 Installed capacity is the maximum production capacity.

17 Aurora's reporting period is from 1st April to 31st March whereas the financial year for the rest of this report is 1st July to 31st June.

18 An ICP is an individual connection point. "An ICP is 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, 2016 - http://www.ea.govt.nz/glossary/)

Supply of electricity

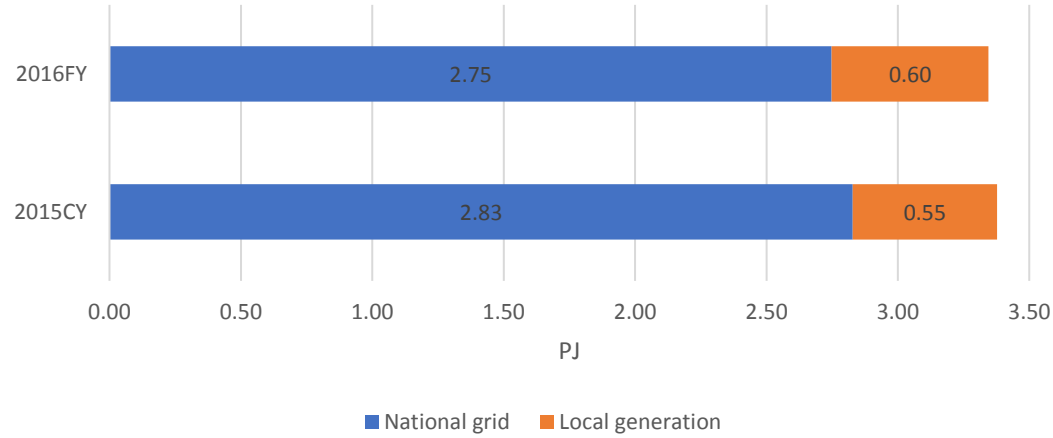
Dunedin was supplied a total of 3.3772 PJ of electricity in 2015CY, and 3.345 PJ in 2016FY.

Electricity supply from the national grid

In 2015CY, 2.8277 PJ of electricity entered Dunedin via the national grid. This was 83.73% of total electricity that was supplied to the city. The other 16.27% or 0.5495 PJ of electricity was supplied from local generation.

In 2016FY 2.7483 PJ or 82.16% of electricity that entered Dunedin was from the national grid. The remaining 0.5967 PJ (17.84%) was local generation.

Figure 12: Breakdown of Electricity sources in Dunedin in PJ



As noted above, over 80% of electricity supplied to Dunedin was sourced from the national grid. Given Dunedin's location relative to the Southern hydro schemes it is likely that this electricity is generated from these renewable sources for most of the time. This will depend on factors such as how much water is stored in the hydro dams, and at times may be supplemented by generation from non-renewable sources based in the North Island. However, we have not found any data on how frequently this occurs and in what quantities.

In the absence of this data we have assumed that Dunedin's electricity that is sourced from the national grid has the same renewable percentage as the grid as a whole. In 2015, 80.8% of New Zealand's national grid was sourced from renewable sources. On this basis, in 2015CY, 83.92% of total electricity used in Dunedin was from renewable sources and in 2016FY 84.23% was renewable.

Local generation

Within Dunedin there are a variety of different forms of electricity generation that are connected to the grid. We have no data on non-connected generators of electricity such as off-the-grid households (this is an area for future research).

Table 1 summarises the known local generators and the forms of energy used to generate electricity.

Table 1: Local electricity generation in Dunedin for 2015 and 2016

	Name of connected generator	Name of company generating	Energy type	Total electricity supplied	Total installed capacity	Total electricity supplied	Total installed capacity
				MWh	MW	MWh	MW
				2015		2016	
Large generators	Waipori 33kV - Deepstream 1A, 2A	TrustPower Ltd	Hydro	50801	53	44525	53
	Waipori 33kV - Mahinerangi	TrustPower Ltd	Wind	99537	36	119490	36
Mid-scale generators	Ravensdown Generation	Ravensdown Ltd	Process Steam	839	3	572	3
	Container Port	Port Otago Ltd	Liquid Fuel	20	1.6	35	1.6
	Waste Water Treatment Plant	Dunedin City Council	Biomass	466	1	13	1
	Dunedin Airport	Dunedin International Airport Limited	Liquid Fuel	0	0.6	0	0.6
Small-scale generators	Various Aurora DG customers	Individual connections	Solar[19]	754.6	0.686 (194 connections)	873.4	0.794 (231 connections)
		7 Individual connections	Wind[20]	37.23	0.017	50.37	0.023
	Various Otago PowerNet DG customers	Individual connections	Solar	156.60	0.1424 (42 connections)[21]	167.78	0.1525 (48 connections)
		3 individual connections	Wind	31.536	0.0144	31.536	0.0144
	Total			**152643**		**165769**	

19 Solar calculations are based on assumption that the solar panels are north facing at are tilted at 45 degrees for a 3kW rated panel. The solar calculator at https://www.energywise.govt.nz/tools/solar-calculator/ was used to find a conversion rate of 1100kWh/kW a year.

20 Energywise assumes that small wind turbines generate at on 10 to 40% of their rated capacity every hour and so for this study it has been assumed that on average wind turbines operate at 25% capacity. Therefore, a conversion rate of 2190kWh/kW a year. https://www.energywise.govt.nz/at-home/generating-energy/small-wind-turbines/ - Energyoutputofsmallwindturbines

21 This assumes there is a linear trend of distributed generation connections on OtagoNet network because there is no monthly data available.

To describe these more fully, we have split the local generation into three scales: larger generators (over 50 MW installed capacity); mid-scale (typically 0.1 MW to 5 MW installed capacity) and small-scale (less than 0.1 MW installed capacity).

Larger generation schemes

There are two large local generation schemes that supply Dunedin with electricity. These are the Waipori hydropower scheme and the Mahinerangi wind power scheme. **Although both lie outside of the Dunedin City Boundary, they feed directly into Dunedin's electricity grid and so have been included in the local generation for Dunedin.**

Waipori hydropower scheme has 53 MW of installed capacity that feeds into Dunedin. In Aurora's 2015FY report[22] (April 2014 – March 2015), it states that the Waipori Deepstream 1A and 2A turbines supplied Dunedin with 50,801 MWh (0.1829 PJ). In their 2016FY (April 2015 to March 2016) these units supplied Dunedin with 44,525 MWh (0.1603 PJ).

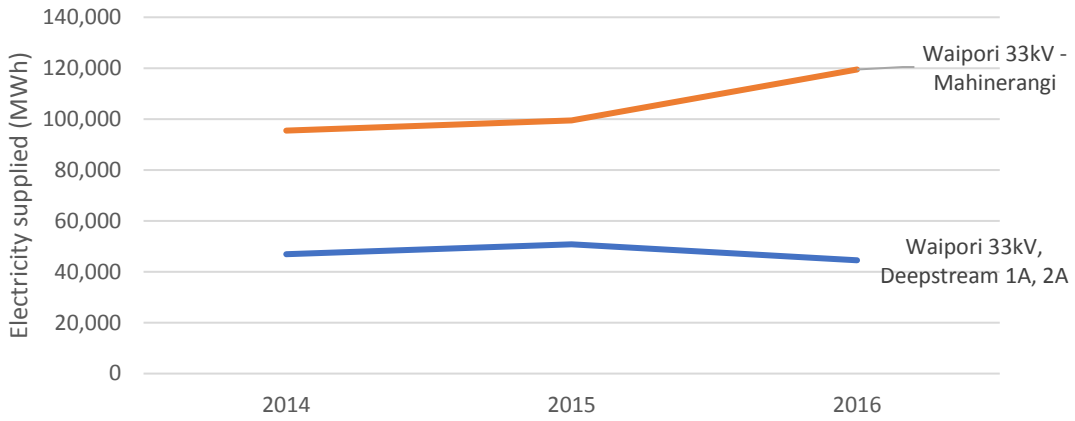
Note: The Trustpower website states that there are 4 turbines at the Waipori hydro station with a combined installed capacity of 83 MW. The Baseline study reported on electricity supplied from all four turbines. However data supplied by Aurora only states that the turbines 1A and 2A feed into Dunedin. This has led to a considerable difference in the electricity calculations overall in comparison to the Baseline Study.

Mahinerangi wind power scheme has 36 MW of installed capacity. In the Aurora 2015FY report, electricity supplied to Dunedin from the windfarm for the year was 99,537 MWh, and in the 2016FY report it was 119,490 MWh.

The trend over the three years [23] covered by the Baseline study and this study is shown in Figure 13. Electricity supplied from Mahinerangi indicates a slight increase in generation in 2016, while Waipori is relatively constant[24].

[22] The Aurora disclosure period is different to that used in the study and so must be careful when making comparisons.
[23] The Baseline Study was based on Aurora's 2014 information disclosure and this study is based on the 2015 and 2016 information disclosures from Aurora meaning there is data for three years even through the Baseline Study and this updated study only specifically look at a two-and-a-half-year period.
[24] The Baseline study figure has been adjusted to represent only Waipori 1A and 2A.

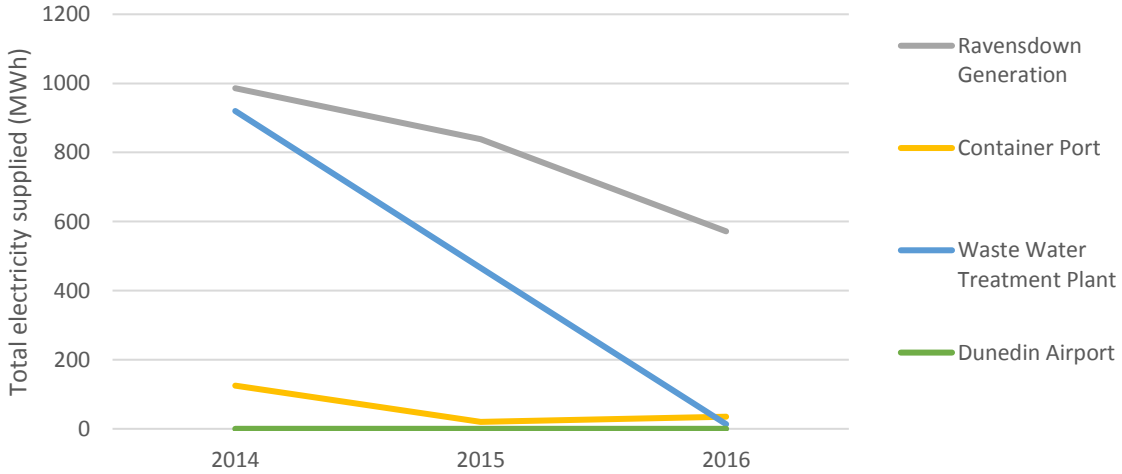
Figure 13: Large scale distributed generation schemes in Dunedin



Mid-scale local generation

Midscale local generators of electricity include Ravensdown Ltd (from process steam), Port Otago's container Port (from liquid fuels), and the DCCs waste water treatment plant (from biogas). The Dunedin airport also has capacity to generate 0.6 MW of electricity (from liquid fuels) but has not produced any in at least the past three reporting years.

Figure 14: Trend of midscale distributed generation from 2014-2016



There has been an overall downward trend in the electricity supplied from these mid-scale distributed generators.

There has been a steady decline in distributed generation from the Waste Water Treatment Plant. The Green Island Wastewater Treatment Plant Gas Engine is supplied by gas produced on site and by gas produced by the Green Island Landfill. The major reason for reduced electricity production has been a steady decline in the quantity of gas able to be supplied by the landfill.

In Aurora's 2015 information disclosure there was 1325 MWh or 0.0048 PJ of mid-scale electricity generation and in Aurora's 2016 information disclosure there was 0.0022 PJ or 620 MWh of electricity generation by mid-scale electricity producers.

Small-scale local generation

Small-scale generators of electricity are those that produce less than 0.1 MW.

2015CY

As at 31 December 2015, the Aurora Network had 194 ICPs that had solar generation and 7 ICPs that had wind generation. OtagoNet reported 48 Solar ICPs and 3 wind ICPs that lay within the Dunedin city boundary as at 16 January 2017. Data was not available on a month-by-month basis for distributed generation on the OtagoNet network, so we have assumed a linear trend from the 2014 total and the data at 16th January 2017. From this we have plotted that there were approximately 42 solar ICPs and 3 wind ICPs within the Otago PowerNet area at December 2015.

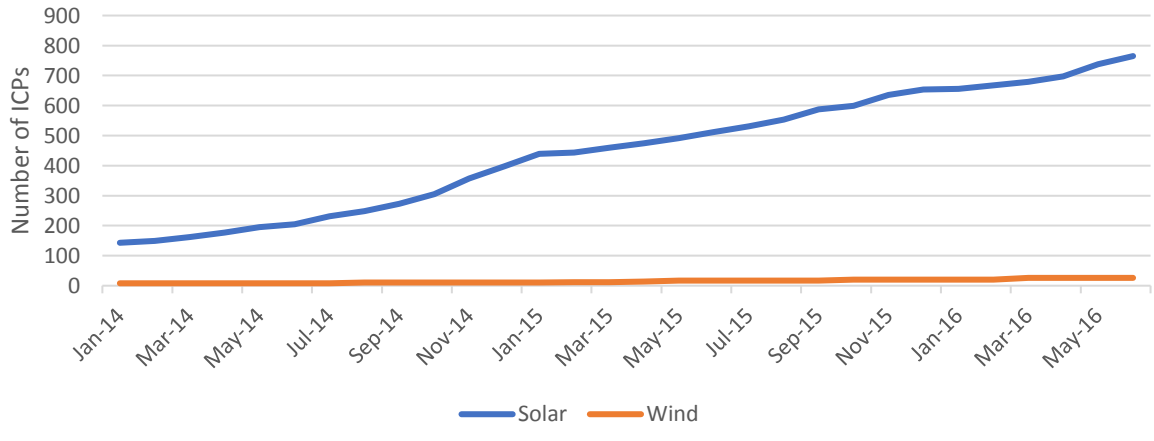
Estimated generation[18] from small-scale units totalled 979.97MWh or 0.0035 PJ for the 2015 year.

2016FY

As at 30 June 2016, the Aurora Network had 231 solar ICPs and 7 wind ICPs. Using the same plotting method as described above, we estimate that at June 2016, Otago Power Net had approximately 45 solar ICPs and 3 wind ICPs.

Estimated generation[18] from small-scale units totalled 1123.086 MWh or 0.0040 PJ for the year to 30 June 2016.

Figure 15: Cumulative Residential Installed Capacity in Dunedin between 2014-2016



Even though the generation by small-scale solar is only around 0.03% of total energy supply in Dunedin, it is notable because of the rate of change. Over the 2½ years covered by the

baseline study and this study, there has been a 567% increase in the estimated generation of solar.

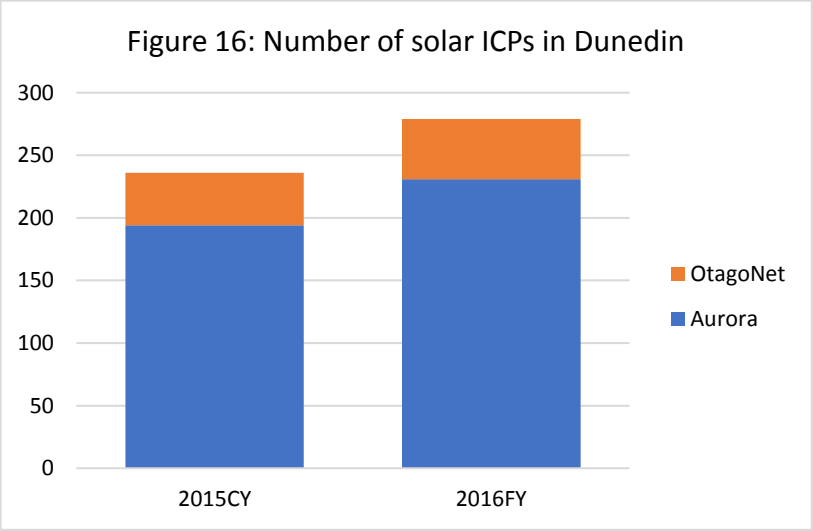
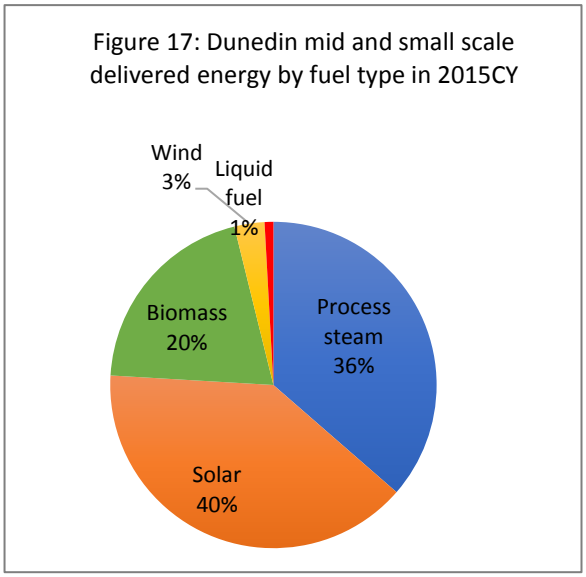
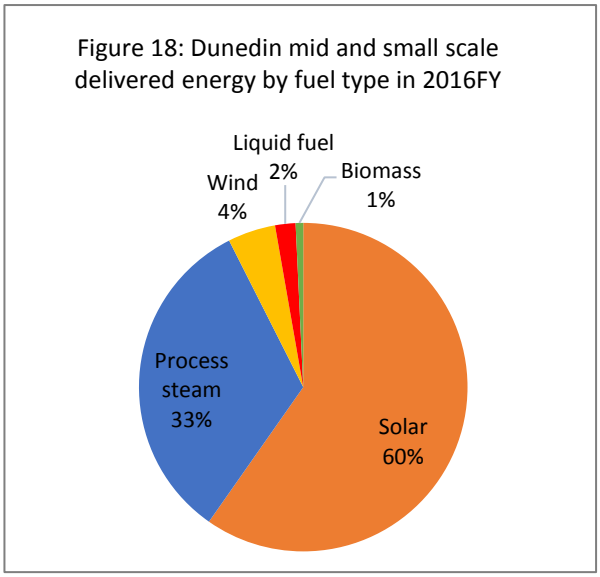


Figure 16 shows the increase in installed solar ICPs between 2015CY and 2016FY.





Figures 17 and 18[25] show that in 2015CY, 60% of mid- and small-scale local electricity generation was from renewable sources (solar, biomass and wind) and in 2016FY this was 66%.

[25] Figures 17 and 18 were calculated using MWh, not MW as was done in the similar graph in the baseline study. MWh shows actual supply whereas MW represents as the installed capacity. Therefore, the figure 11 from the Baseline study and these charts are not comparable.

Electricity demand in Dunedin

In the 2015 financial year, Aurora reported that 48.29% of electricity was used for residential use (across 47,388 ICPs), 50.81% was used at non-domestic usage codes (e.g. industrial, commercial) (across 6,937 ICPs) and 0.89% was used for street lighting.

This 2016 financial year was very similar. Aurora reports that 48.28% (47,496 ICPs) of electricity used in Dunedin was for residential use, 50.38% (6,995 ICPs) was used at non-domestic usage codes and 0.89% for street lighting.

Line losses are included in these figures. In the 2015 financial year Aurora had a 6.3% electricity loss and in 2016 financial year a 5.2% electricity loss from its distribution network. The loss is the difference between the electricity supplied to the network by generators and the electricity supplied by the network to Aurora's customers. The network loss is due to the lines being heated slightly when they carry electrical power.

In 2015CY Otago Net supplied 2.95% of the electricity to Dunedin and in 2016FY supplied 3.27%. Seventy percent of the OtagoNet network (including that which lies within the Dunedin city boundary) is supplied by the Halfway Bush grid exit point and the remainder of input is at the Naseby grid exit point.

In 2015CY 97.05% and in 2016FY 96.73% of electricity in Dunedin was supplied by Aurora. This network supplies most of the urban areas of Dunedin and is served by the Halfway Bush and South Dunedin Grid Exit Points.

In the 2015CY a total of 938.1339 GWh (3.3773 PJ) of electricity was supplied to Dunedin from both the Aurora and OtagoNet networks. In 2016FY this figure was 929.1867 GWh (3.3451 PJ).

Wood fuels

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

Wood pellets

Wood Pellet supply in Dunedin

Wood pellets are supplied from Otago Pellet Fires and other retail outlets from around the city.

These pellets are all imported into the city from manufacturers in Taupo (Nature's Flame) and Nelson (AzWood) as well as smaller manufacturers from Timaru, Tapanui and Invercargill.

It has not been possible to compile data on the supplies of wood pellets into the city, so we have focused on sizing the demand.

Wood Pellet Demand in Dunedin

Organisational wood pellet demand

There are 6 known wood pellet boilers used in the city for heating. Four of these are at schools: Otago Boys High School, Logan Park High School, Taieri College and Balmacewen Intermediate[26]. These four boilers have all been converted from coal to wood pellet use and each has capacity of 1460 kW apart from the Balmacewen boiler which has capacity of 530 kW.

The EECA boiler list only has one 1460kW boiler recorded as being used in a school. This one boiler is recorded as having an annual fuel demand of 1.08 GWh. It has been assumed that usage would be relatively similar across all four schools, relative to boiler capacity, and so this factor has been used to approximate the fuel demand for the other three boilers that aren't recorded on the 2014 EECA boiler list.

Based on this assumption, the four school boilers would demand approximately **3.63 GWh** of wood pellet fuel per annum or **0.0121 PJ per year**.

Otago University also uses wood pellet fuel for heating part of the campus. The university reports an annual fuel demand of 0.548 GWh of wood pellet fuel each year or **0.0020 PJ per year.**

[26] http://www.bioenergy.org.nz/documents/resource/Information-Sheets/IS05-Education-facilities-using-wood-fuel.pdf

There are also two boilers on the EECA boiler list that use a mixture of woodchips and wood pellets. These are listed as being used at the Dunedin hospital. These two boilers have a combined annual fuel demand of 4.98 GWh. There is no indication of how much of this use is woodchips and how much is wood pellets so it has been assumed that there is a half/half split. This means there is 2.49 GWh or 0.**0090 PJ** of annual fuel demand corresponding to wood pellet use.

Overall, we estimate there is around 0.0225 PJ of wood pellet supplied to organisational boilers in the city per annum.

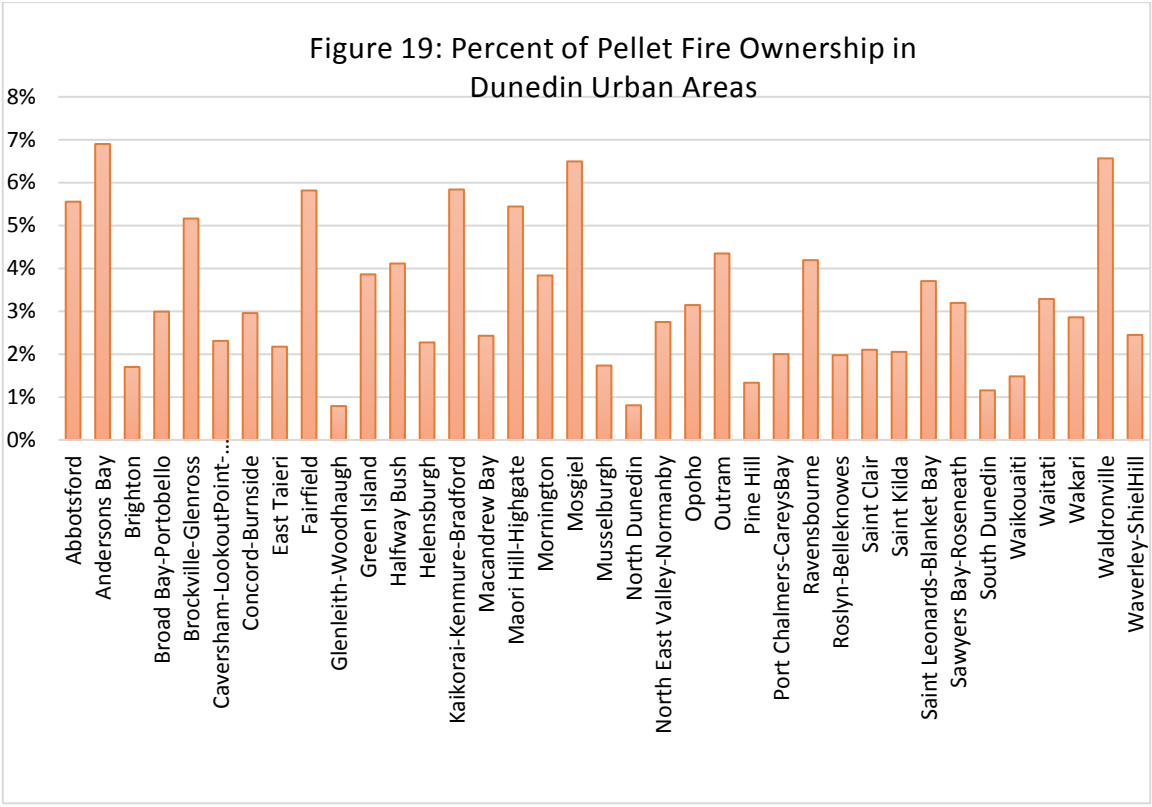
Residential wood pellet supplies

Otago Pellet Fires is the primary supplier of pellet fires to Dunedin. Pellet fire installations are increasing: in 2015CY 129 pellet fires were installed by Otago Pellet Fires and in 2016FY 147 pellet fires were installed by Otago Pellet Fires. This brings the total number of recorded pellet fires in Dunedin up to 1375 fires in the city as at 30 June 2016. There are a few smaller retailers who also sell and install pellet fires.[27]

Based on data collected from retailers of wood pellets in Dunedin, in 2015 Dunedin resident were supplied approximately 1600 tonnes of wood pellets and in 2016FY were supplied approximately 1000 tonnes of wood pellets. We don't know the reason for this apparent drop in demand, and more research is needed on this.

We estimate that in 2015CY 0.0273 PJ of pellet fuel was consumed for residential use and in 2016FY this was 0.0170 PJ.

[27] There is no data regarding how many pellet fires smaller installers sold during this time.



The above chart shows the percentage of households that have pellet fires installed in Dunedin suburbs. The lowest uptake of pellet fires is in the student areas of the city (e.g. Woodhaugh, North Dunedin) and areas with higher levels of social deprivation (e.g. South Dunedin, Pine Hill).

Total wood pellet use

Overall, we estimate there was approximately 0.0498 PJ of wood pellet fuel used in Dunedin in 2015CY and 0.0395 PJ in 2016FY.

Woodchips and Firewood

Supply of woodchips and firewood in Dunedin

Wenita and City Forests are the two main forest owners and suppliers of forest products in the Dunedin area (see Figure 20). These two firms provide wood for firewood and woodchips to processors who further process the wood, to retailers who sell these, and directly to customers.

Firewood can also be self-collected or obtained from private sources. This is harder to assess as it is not recorded anywhere. A survey by the Ministry of Environment[28] in 2005 concluded that over 60% of wood used in solid fuel burners and open fires and 40% of wood used in multi-fuel burners was self-collected. The initial Baseline study did not include any self-collected firewood.

In order to obtain insights into self-collected and privately purchased firewood, we worked with DCC to survey their 'people's panel', which is a panel of DCC residents who are regularly surveyed. The survey asked about firewood use and sources (as well as use of coal and wood pellets), and was completed by 349 Dunedin residents. It found that, of those who used firewood[29], 58% obtained it through non-retail channels (self-collected on own property or obtained from other private sources). In 2016, 42% of firewood was brought from either a specialty firewood store or a retail store.

Woodchip and firewood supply to Dunedin

There are many retailers in Dunedin of firewood, so our data relies on wholesale and retail wood fuel sales reported by Wenita and City Forests. We do not have data on other smaller forest owners as shown in Figure 20. More research is needed here.

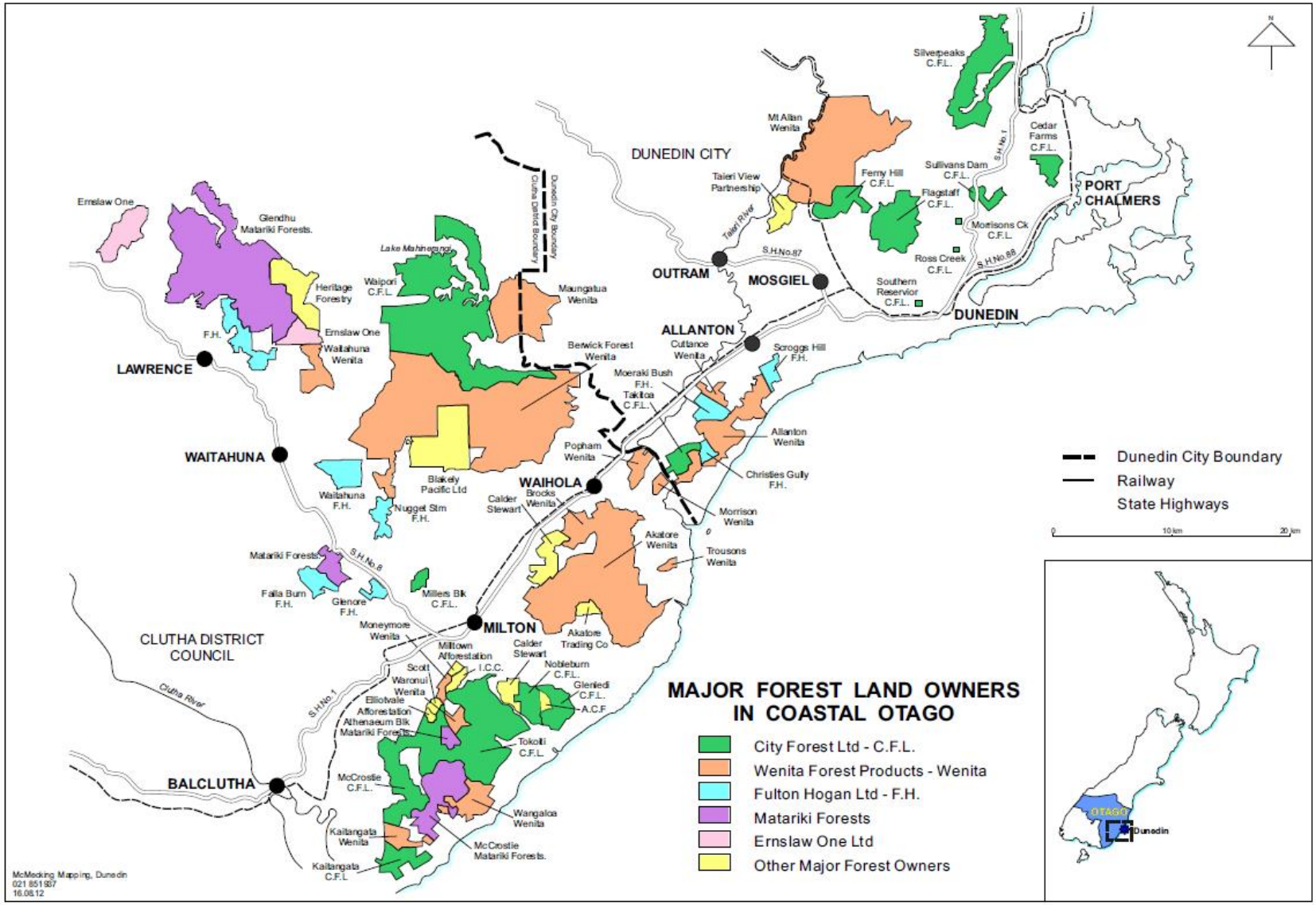
Firewood: In 2015CY there was 0.3242 PJ of wood for firewood supplied in Dunedin by Wenita and City Forests. In 2016FY this was 0.319 PJ.

Woodchips: In 2015CY there was 0.1495PJ of woodchips supplied in Dunedin by Wenita and City Forests. In 2016FY this was 0.1573 PJ.

[28] Source: Ministry for Environment, 2005. Warm Homes Technical Report: Home Heating Methods and Fuels in New Zealand.

[29] 221 out of the 349 respondents to the Peoples Panel survey used firewood in 2016.

Figure 20: Map of forestry areas around Dunedin



Demand for woodchips and firewood in Dunedin

Organisational demand

The EECA boiler list states there are 17 boilers in Dunedin that use wood as their fuel source. This includes solid wood, wood chips, wood pellets, wood waste and dry wood shavings. This is the most up-to-date reliable data that can be found.

These wood boilers from the EECA boiler list have a combined annual fuel demand of 18.89 GWh or 0.068 PJ. This is broken down as follows:

Fuel types	GWh
Wood	10.21
Woodchip	3.62
Wood pellet	1.23
Woodchip and pellet	0.42
Wood waste	1.25
Dry wood shavings	2.15

The EECA boiler spreadsheet figures show boiler use of woodchips and drywood shavings add up to 5.98GWh (inclusive of half of the woodchip/wood pellet boilers) or 0.0215 PJ per annum. Otago University reports woodchip demand of 3.732 GWh in 2015CY and 3.666 GWh in 2016FY. This is a subset of the 5.89 GWh that the EECA boiler spreadsheet reports.

Solid wood and wood waste used in boilers adds up to 11.46 GWh or 0.0413 PJ per annum.

Residential firewood demand

The 2013 census data shows that 1734 households use wood as the main fuel for heating and 19,248 households used wood plus some other fuel type for heating. This equates to 45% of Dunedin households using wood. [30]

The 2017 People's Panel survey showed that on average, each household that used firewood consumed 7.17 cubic meters per year. This includes both households that only use firewood for heating and households that use firewood and other fuels for heating purposes.

[30] The Peoples Panel survey showed 64% of households using firewood for heating. This is a higher percentage than the Census results and may reflect a non-random sample.

Therefore, applying these averages[31] across the number of households that use firewood for heating across the Census data, Dunedin residents use **150,440.94 cubic meters of firewood** on an annual basis. This is **1.40 PJ of firewood per year**.

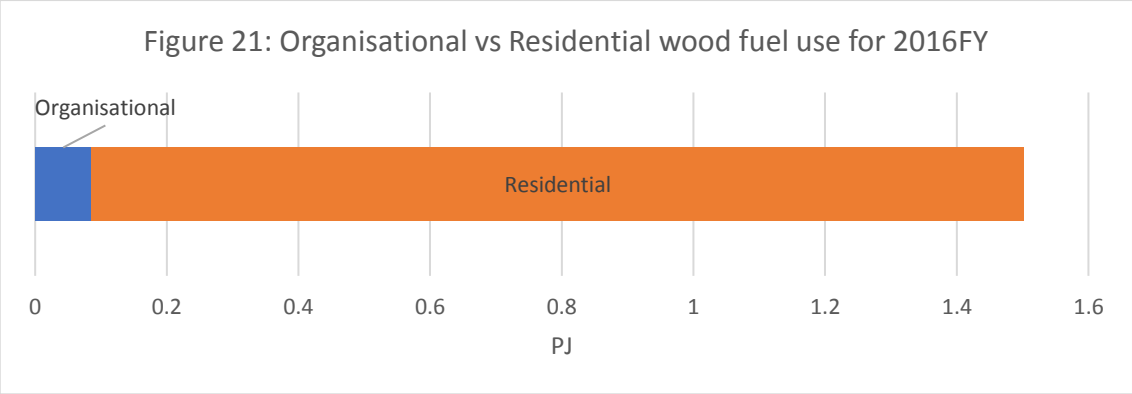


Figure 21 shows the ratio of organizational wood fuel use to residential wood fuel use for Dunedin in 2016FY. Six percent of wood fuels consumed in Dunedin is used by large organizational boilers, and 94% of wood fuels are used by residential households.

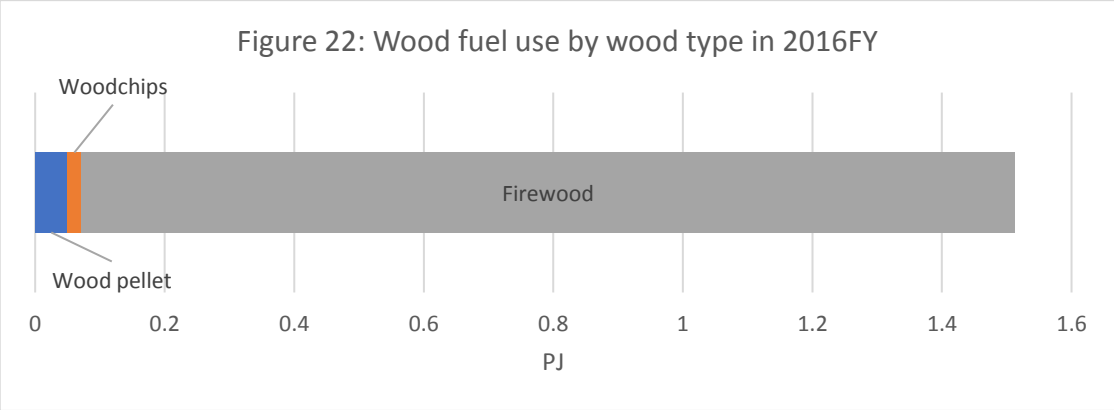


Figure 22 shows the breakdown of wood fuel use by wood type for 2016FY across all users. Firewood makes up 95% of wood fuels used in the city.

[31] The Peoples Panel Data did not indicate how many heating sources the residents of Dunedin use as only asked about coal, wood pellets and firewood. Therefore, an average cubic meters of firewood has been applied to all households that use firewood as at least one source of heating.

Coal

Supply of coal to Dunedin

There are no active coal mines in Dunedin, the closest coal mine being located Kaitangata. It is likely that coal used for residential and industrial purposes in Dunedin comes from the South Island based coal mines. As well as Kaitangata these include Taylor Coal (at Rolleston), Solid Energy (in Southland and on the West Coast) and Minerals West Coast (on the West Coast).

We were not able to find figures for coal supplies into Dunedin, so attempted to compile figures by looking at demand.

Demand for coal in Dunedin

Coal boilers

The EECA boiler list shows that as at 2014 there were 47 coal boilers in Dunedin, of which 40 are used in educational facilities, 3 are used for meat processing and 2 are used in the chemical industry. Data from the Ministry of Education shows at least 30 Dunedin schools use coal for heating purposes.

Otago University, the largest educational facility, reports coal use of 5.237 GWh for 2015CY and 5.022 GWh for 2016FY.

The EECA boiler list estimates that all boilers combined have a total annual fuel demand of 54.14 GWh per annum or **0.1949 PJ per annum.**

The Dunedin Heat Centre is a district heating scheme. The Centre burns coal and supplies steam and hot water to 8 customers around the central city including the Otago District Health Board, Cadburys and University of Otago as well as several smaller customers. It is estimated that this scheme has annual fuel demand of 64GWh per annum[32] or **0.2304PJ per annum.**

Overall, we estimate that coal boilers in Dunedin have annual fuel demand of 0.4253PJ.

[32] The coal boiler capacity in the Dunedin heat plant is about 27 MW.
We can estimate the coal consumption as follows:
27 MW * 8000 hours *30% utilization = 64 GWh per annum. With a boiler efficiency of 0.7 and calorific value for coal at about 24 GJ/t this gives about 13,000 tonnes of coal.

More research is needed to confirm which organisations are using coal and to update the amounts being used.

Residential coal demand

The 2013 census shows that there are 60 households in Dunedin using coal as their sole heating fuel and another 4638 households that use coal plus at least one other type of fuel for heating.

The Peoples Panel survey results indicated that an average household that uses only coal for heating would use 353kgs of coal a year.

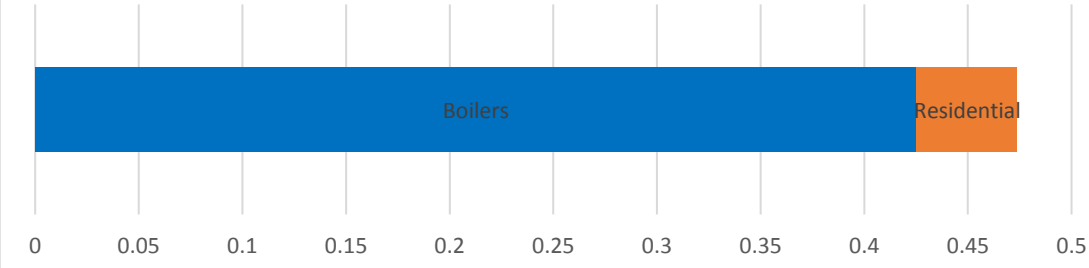
We have estimated that this equates to residential coal consumption of **0.0486 PJ per annum** (including both sole users of coal and households that use coal and other fuels for home heating).

Total coal demand

Total coal consumption in Dunedin is estimated to be 0.47395PJ per annum.

Of this, 80% is used in organisational boilers (Figure 23).

Figure 23: Organisational vs residential coal use in Dunedin



Sulphur

Ravensdown Fertiliser Co-operative Limited combusts elemental sulphur in their boiler at the plant in Ravensbourne. The combustion products are processed into acid for use in the manufacturing of fertiliser at this plant. This fuel value of this sulphur is 87.28 GWh or **0.2962 PJ per annum**.

The combustion of sulphur in the boiler produces heat and steam as co-products which are used for electricity generation and industrial heat. Ravensdown Ltd generated 830 MWh of electricity in the 2015 disclosure year and 572 MWh in the 2016 disclosure year. This electricity is included in the electricity section of this report.

It is not known whether greenhouse gas emissions are associated with this process. Further research is needed on this.

Greenhouse Gas Emissions

Methods and assumptions

The following emissions factors were used to determine the greenhouse gas (GHG) emissions in terms of the energy use (i.e. kgCO2-e/unit)[33] :

- 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

These conversions are consistent with the 2014 Dunedin Energy Baseline Study.

Wood

The emissions factor used for calculating the emissions from wood assumes the associated carbon dioxide emissions as sequestered, as the wood is assumed to have removed CO_2 from the atmosphere during its lifetime. If replanting was not assumed to be occurring, the total CO_2-e would be considerably higher.

Petrol and diesel

We have used the emissions factors for the use of petrol and diesel for transportation, given transport is the predominant use of these fuels in Dunedin. As noted earlier we have no data on the proportion of petrol and diesel used for non-transport purposes. Other end uses are likely to have different emission factors. This area requires further research.

[33] 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.

LPG

The emissions for LPG have been calculated by applying different emissions factors for the relative proportions of the three end uses of LPG that were found in this study: industrial boilers, residential and transportation.

Electricity

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).

The electricity sourced from Mahinerangi, Waipori and other local renewable sources is taken as having zero emissions.

Greenhouse gas emissions associated with Dunedin's energy use

The breakdown of the emissions associated with fuels used in Dunedin is provided below:

Table 2: Breakdown of emissions by fuel type for 2015 and 2016

	2015CY			***2016FY***		
	Total kt CO2-eq	Share of emissions	Share of energy inputs	**Total kt CO2-eq**	Share of emissions	Share of energy inputs
Electricity	**108.4**	16.71%	25.65%	**105.35**	16.10%	25.25%
Petrol	**170.26**	26.24%	19.22%	**174.15**	26.62%	19.55%
Diesel	**283.53**	43.70%	30.46%	**288.69**	44.12%	30.80%
LPG	**28.75**	4.43%	3.57%	**28.3**	4.33%	3.49%
Wood	**12.03**	1.85%	15.25%	**11.98**	1.83%	15.08%
Coal	**45.81**	7.06%	3.60%	**45.81**	7.00%	3.58%
TOTAL	**648.78**			**654.28**		

Diesel use has the greatest share of emissions at 44%, followed by petrol at 26%, and electricity at 17%.

Comparison with other databases

How does Dunedin's energy use compare to other studies?

To answer this question we have compared the data collected in this study with two national data sets: the national Energy Balance tables produced by the Ministry for Business, Innovation and Employment[34], and the Energy End-Use Database produced by the Energy Efficiency and Conservation Authority[35]. Due to demographic, climatic, infrastructural and economic differences between Dunedin and other parts of New Zealand we do not expect a perfect match between the figures, but this comparison does provide a useful cross-check to see whether the Dunedin figures are in the right order of magnitude, and invites consideration of why any differences might exist.

Energy Balance Tables

We compare the Energy Balance tables for the 2015 calendar year with the data collected in this study for the 2015CY. Note that the NZ figures cover a much more varied set of activities than occurs in Dunedin including big manufacturing enterprises and larger cities as well as major rural regions.

Electricity

In 2015 New Zealanders consumed 143.28 PJ of electricity. Dunedin's per capita consumption is 106% of the national average.

Petrol and Diesel

NZ consumed 109.61 PJ of petrol in 2015. Dunedin per capita consumption was 88% of the national average.

New Zealanders consumed 122.59 PJ of diesel in 2015. Dunedin per capita consumption was 125% of the national average.

LPG

NZ consumed 7.88 PJ of LPG in 2015. Dunedin per capita consumption was 228% of the national average. It should be noted that LPG is much more prevalent in the South Island, as in the North Island piped natural gas is widely available.

Coal

New Zealander consumed 26.09 PJ of coal in 2015. On a per capita basis, Dunedin only consumed 64% of the national average. Note however that most coal use in New

[34] Source: http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-in-new-zealand

[35] Source: http://enduse.eeca.govt.nz/default.aspx

Zealand is for manufacturing and electricity generation, mainly based in the North Island.

Wood

New Zealanders consumed 54.1 PJ of wood in 2015. Dunedin's per capita consumption was 141% of the national average.

Energy End Use Database

The Energy Efficiency and Conservation Authority (EECA) has an Energy End Use Database, which provides estimates of the energy used by New Zealand regions. The most recent version of this database is 2012.

EECA's figures for the Otago region[31] for 2012 were compared to the energy inputs calculated for Dunedin's Energy Study for 2015CY and 2016FY. The results of this comparison are provided in Table 3.

Table 3: A comparison of the Baseline Study's energy input findings to EECA estimates

	Est. Delivered Energy (TJ) for Otago Region)[36]	Est. Delivered Energy (TJ) for Dunedin[37]	Calculated Energy Inputs (TJ) for Dunedin Energy Study 201CY	EECA / Energy Study Ratio for 2015CY	Calculated Energy Inputs (TJ) for Dunedin Energy Study 2016FY	EECA/ Energy Study Ratio for 2016FY
Coal	1,098	659	473.9	**1.39**	473.9	1.39
Diesel	5,759	3,455	4010	**0.86**	4080	0.85
Petrol	6,354	3,812	2530	**1.51**	2590	1.47
Electricity	4,958	2,975	3377.2	**0.88**	3345	0.89
LPG	1,502	901	470	**1.92**	462.7	1.95
Wood	1,510	906	2007.64	**0.45**	1997.34	0.45

The table suggests that:

- Our calculated coal consumption is nearly a third less than that estimated in the End-Use Database.
- Our calculated diesel and electricity are in the same order of magnitude as estimated in the End-Use Database, but a slightly higher consumption.
- Our calculated petrol consumption is around a third less than that estimated in the End Use Database.
- Our calculated LPG use is almost half of the estimate in the End Use Database.
- Out calculated wood use is over double the estimate in the End Use Database.

[36] Source: http://enduse.eeca.govt.nz/default.aspx

[37] 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%).

Some of the differences may relate to changes between 2012 and 2015, but the largest differences invite further research, both into the assumptions underlying the End Use Database, and in improving the methods used for data gathering for the Dunedin Energy Study.

Greenhouse gas emissions

EECA's Energy End Use database also provides estimates of the greenhouse gas emissions associated with energy used in the Otago region. EECA's figure for the Otago region were scaled back on a per capita basis to represent Dunedin and then compared to the greenhouse gas emissions calculated for the Dunedin Energy Study for both 2015CY and 2016FY. The results of the comparison are shown in Table 4:

Table 4: Breakdown of Greenhouse Gas emissions by fuel type for 2015CY and 2016FY

	Est. total t CO2-e for Otago Region *(EECA Energy End Use Database*[38]	Est. total t CO2-e for Dunedin (based on EECA Energy End Use Database)[39]	Calculated total t C02-e for Dunedin in 2015CY	EECA / Baseline Study Ratio for 2015CY	Calculated total t C02-t for Dunedin in 2016FY	EECA/ Baseline Study Ratio for 2016FY
Coal	98,670	59.20	45.81	**1.29**	45.81	**1.29**
Diesel	402,006	241.20	283.53	**0.85**	288.69	**0.84**
Petrol	424,098	254.46	170.26	**1.49**	174.15	**1.46**
Electricity	254,459	152.68	108.40	**1.41**	105.35	**1.45**
LPG	86,750	52.05	28.75	**1.81**	28.30	**1.84**
Wood	161,541	96.93	12.03	**8.06**	11.98	**8.09**
TOTALS	1,427,524	856.52	648.78	**1.32**	654.29	**1.31**

As expected, there are significant differences between the 2012 greenhouse gas emissions calculated for Energy End Use data base and those found in the Dunedin Energy Study. These relate in part to the different estimates of energy consumption.

A standout is the 13-fold difference between this study's wood emissions and those calculated by EECA. This relates to the use of different emissions factors, as the EECA calculations do not assume that the CO_2 produced while wood is being used as a fuel will be offset through forest replanting.

The End Use Database emissions from electricity use is significantly greater than that calculated in this study. We assume that national average emission factors were applied, rather than accounting for the local renewable generation component. Additionally, the proportion of renewables in the national electricity system has risen since 2012.

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38 Source: http://enduse.eeca.govt.nz/default.aspx

39 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%).

Conclusions

This study has attempted to gather data on all energy inputs into Dunedin, to update the Baseline Study for 2014, and to improve on the coverage and accuracy of the data. The data reported here is as fulsome as could be gathered within the time and scope of this project, and there are some data gaps and uncertainties including the following aspects:

- Petrol and diesel use for non-transport purposes
- The relative proportions of petrol and diesel purchased in Dunedin that is consumed elsewhere, and the petrol and diesel purchased elsewhere that is consumed in Dunedin
- The amount of LPG brought into Dunedin overland, and the amount of LPG that is distributed elsewhere in the South
- The proportion of Dunedin's electricity sourced from the national grid that is renewable, and a correction of Dunedin's electricity-related GHG emissions accordingly
- Local electricity generation that is not connected to the grid
- Coal and wood consumption by households (the People's Panel data is helpful but not representative; a survey covering a larger proportion of households would be helpful)
- Coal consumption by businesses and organisations, including schools

With these caveats, our best estimate of total consumer energy supplied to Dunedin city during the 2015 calendar year is 13.1650 PJ. In the 2016 financial year (1 July 2015 to 30 June 2016) it was 13.2416 PJ. Across the 18 months, 51% of the energy was sourced from petrol and diesel, 25% from electricity, 15% from wood, 3% from LPG, 4% from coal and 2% from sulphur. These percentages were consistent across the two periods analysed in the report.

Significant changes from the Baseline Study (2014) due to improved data collection methods are the substantial increase in the proportion of energy sourced from wood (up from 3%), and the addition of sulphur as an energy source (not previously included). We are also more confident of the LPG figures, although further refinement is needed. We note that the Baseline Study acknowledged clear shortcomings in 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. Some of these have been at least partially addressed in this study, but more research is needed to ensure that the database continues to improve in accuracy.

Due to the fact that some data collection methods have been adjusted between this study and the Baseline study, it is not appropriate to draw any conclusions about trends over time. In future years, we hope that the continued improvement in data collection and the establishment of consistent measures will allow for year-on-year comparisons in energy use and energy-related GHG emissions.

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.

Strengths

Around 37% of Dunedin's total consumer energy supply (all fuels) was from renewable sources. This is close to the national figure of 40% in 2015.

In both 2105CY and 2016FY, around 83% of electricity supplied to Dunedin was generated from renewable resources.

If the electricity fed into Dunedin's grid from Waipori and Mahinerangi are included, a total of 15.5% of Dunedin's energy was locally sourced in the 2015 year. Around $^1/_3$ of this is from local electricity generation and $^2/_3$ from local wood supplies.

Over the two and a half years covered by the Baseline Study and this study, there has been a 567% increase in installed capacity of small-scale solar generation and a 360% increase in installed capacity of small-scale wind generation.

Electricity use has remained relatively stable at 3.3773 PJ for the 2015CY, and 3.3451 PJ for the 2016FY.

When comparing the 2015CY and the 2016FY, total energy consumption has increased from 13.1650 to 13.2416 PJ, while greenhouse gas emissions have decreased from 648.8 to 654.3 kt-CO_2-eq. However these are very minor differences and may be within the bounds of error. Data for future years will be needed before we can understand whether this is the start of a positive trend.

Weaknesses

Diesel use makes up 44% of the city's energy-related GHG emissions, followed by petrol use (26%), electricity use (17%), coal use (7%) and LPG use (4%). Around ¾ of Dunedin's GHG emissions are produced from transport.

Petrol and diesel use have both increased slightly, from a combined total of 6.54 PJ for 2015CY to 6.67 PJ for 2016FY.

Coal not only has a high GHG emissions factor, but also produces particulate emissions that can have serious health impacts. Its use in educational institutions is particularly concerning. Every effort should be made to reduce coal use and replace it with other less problematic fuels.

89% of energy used in Dunedin was sourced from outside the city's boundaries. All petrol, diesel, LPG, coal and sulphur was imported from other regions in New Zealand or imported from overseas.

Opportunities

As stated above, 77.7% of Dunedin's greenhouse gas emissions are from liquid fossil fuels (petrol, diesel and LPG) with a further 2.9% of emissions arising from coal use. There is an opportunity here for Dunedin to significantly reduce its carbon emissions by moving away from the use of fossil fuels.

Almost ¾ of Dunedin's greenhouse gases arise from the use of petrol and diesel for transport. Shifting to a lower carbon transport system for Dunedin would have a number of associated benefits besides emissions reductions, including:

- greater energy efficiency through the adoption of electric vehicles and other efficient vehicles
- health co-benefits from more use of walking and cycling and other forms of active transport
- health co-benefits from less particulate emissions from burning diesel
- greater efficiency through shared mobility (e.g. car-sharing) and public transport
- less reliance on imported fossil fuels (e.g. through use of electricity)
- reduced impact of carbon pricing

Households and businesses reliant on coal can reduce greenhouse gas and particulate emissions through adoption of other energy sources, with co-benefits of improved air quality.

Dunedin's forest resources offer an opportunity to replace coal with wood products in boilers. There may also be an opportunity to develop a local pellet production facility rather than import pellets from other regions, especially given the growth in pellet fire use in Dunedin.

There are many cost-effective opportunities to improve the efficiency of energy use, including changing to different fuels (e.g. use of electricity rather than fossil fuels), reducing heat losses (e.g. improving insulation) and improving the efficiency of energy conversion processes (e.g. using heat pumps rather than resistive heaters) as well as changes in behaviour. Targeted advice can assist households and businesses in making these changes, but supportive policies and infrastructure are also required.

Dunedin has significant opportunities for increasing the local supplies of electricity, especially from wind and solar.

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, along with potential increases in costs due to carbon pricing in the long run. Opportunities to reduce that risk should be sought.

Inefficient use of energy is a cost to business. Unless businesses take the opportunity to improve efficiency (within their buildings, equipment and transport) they may see themselves losing productivity compared to competitors.

The small amount of longitudinal data so far suggests that there is little change occurring in Dunedin's energy use. The city's aspirations to improve efficiency, increase renewables and decrease GHG emissions will not be realised until significant changes start to occur. The city's growing reputation for environmental quality could be challenged if the status quo continues, especially as cities worldwide are actively moving to low-carbon energy systems.

Outlook for the next study

This study presents further insights into the energy used to run Dunedin, and some of the major uses of the energy. The Baseline study identified a number of data shortcomings and we have attempted to address these in this study. Due to improvements in methods we believe the data is more reliable in some areas (e.g. firewood, LPG) than in the Baseline Study, and that the difference between the 10.5 PJ reported for 2014 in the Baseline Study and the 13.16 PJ reported for 2015 in this study is largely to do with methodological improvements (e.g. use of census data; People's Panel survey; the EECA boiler list) as well as new information not previously available (e.g. DCC's method of allocation of petrol taxes; rail deliveries of LPG).

There are significant benefits to Dunedin in continuing this study on an annual basis, ideally based on financial years (i.e. the next study would collect data on the period 1 July 2016 – 30 June 2017). With the methodology now established and more targeted to reliable data sources, future years' data will be able to start to provide insights on trends in energy use, energy generation, and energy-related GHG emissions. This will provide the basis for identifying areas requiring action as well as tracking the effectiveness of interventions such as policies and new infrastructure.

Further research is still needed to fill some data gaps or resolve some inconsistencies, as identified at the start of the Conclusions section. Further work is also needed to map the energy flows in Dunedin from supplies to end-uses; to identify areas in which energy could be used more efficiently; and to track the relationship between energy use and economic growth. Extensions of this work could also explore more innovative opportunities for energy sharing (e.g. district heating or utilisation of waste heat from industrial processes) and for smart grid services (such as local energy markets).