Auckland Air Emissions Inventory 2016

Home Heating

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July 2018 Technical Report 2018/018

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Executive summary

Air emissions inventories are a critical component of managing air quality and need to be updated regularly to gauge how emissions are tracking in the region. The Auckland air emissions inventory is a comprehensive inventory that includes all significant sources: transport, domestic heating and industry.

This report estimates emissions to air in the Auckland region for 2016 specifically from domestic home heating. Emissions are estimated for fine particles (PM_{10} and $PM_{2.5}$), oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), sulphur dioxide (SO_2) and carbon dioxide (CO_2).

This report focuses primarily on PM_{10} because, of the air pollutants that are measured in Auckland, fine particles (PM_{10} and $PM_{2.5}$) are still of most concern (Auckland Council, 2016).

The methodology and assumptions for this update were consistent with the previous inventory (Auckland Council, 2014a). The overall number of households burning wood was based on 2013 census data. Information about solid fuel burning appliances was based on the results of home heating surveys, which have been undertaken regularly during winters of 2002, 2007 and 2012 (Wilton, 2002; Auckland Regional Council, 2007; Auckland Council, 2014b). The number of households burning wood and the types of solid fuel burning appliances in 2016 were projected based on analysis of recent trends (because 2018 census data was not available at the time of preparation of this inventory).

Based on the results of census and survey data, it was estimated that in 2016 there were approximately 96,200 households using wood for home heating in the Auckland region. These comprised:

- 44,900 old wood burners (pre-2005)
- 35,200 new wood burners (post-2005)
- 2,700 multifuel burners
- 12,100 open fires
- 1,300 pellet burners.

Regional emissions of PM_{10} from wood burning were estimated at approximately 12 tonnes per winter day or approximately 1200 tonnes per year in 2016. This represents a 34 per cent reduction compared with estimated emissions of 1700 tonnes per year in 2006. This reduction was less than the Auckland Plan target of 50 per cent reduction in emissions compared with 2006 by 2016.

This emissions inventory is underpinned by census data and the results of regular home heating surveys. It is recommended that a home heating survey should be undertaken as soon as possible to update the inventory when 2018 census data becomes available. This

could be significantly simplified compared with previous surveys by collecting data for the Auckland Urban Airshed and the area outside the airshed only (compared to the 2012 survey which collected and disaggregated results for seven different areas). This report includes a number of other specific recommendations to improve future home heating inventories and projections.

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1.0 Introduction

Air quality is affected by emissions discharged into the air. Air pollution causes adverse effects on health, making asthma, lung and heart conditions worse. In order to further improve air quality, we must reduce air emissions. Auckland Council is responsible for the management of air quality in the Auckland region. A suite of strategic plans and statutory regulations require the council to ensure ambient air is clean and healthy to breathe:

- The Resource Management Act 1991
- The National Environmental Standards for Air Quality 2004
- The Auckland Plan 2018
- The Auckland Unitary Plan.

An air emissions inventory identifies and quantifies sources of air pollution and their trends. It is used to:

- determine major sources of air pollutants
- assess if emissions have improved, remained the same, or deteriorated over the reporting period
- evaluate progress towards the emissions reduction target
- provide input for air pollution dispersion and exposure modelling
- inform the efficacy and efficiency of mitigation measures and policy initiatives and strategies.

The main sources of air pollution in Auckland are from transport, domestic sources and industrial discharges. This report compiles an inventory of air emissions from home heating within the Auckland Council boundaries for 2016. The inventory for transport (Sridhar and Metcalfe, 2018), sea transport (Peeters, 2018) and industry (Crimmins, 2018) is reported separately. A summary report is in preparation to integrate these inventories to present an overall picture of air emissions and trends.

The Auckland air emissions inventory was last updated in 2014 for the base year of 2006 (Auckland Council, 2014a). This update (referred to as “the 2016 inventory”) incorporates the results of substantial updates in air emissions estimates for Auckland since 2006 (Auckland Council, 2014a), including:

- Census data for 2013
- Home heating survey undertaken in 2012 (Auckland Council, 2014b)
- Community perception survey undertaken in 2016 (Auckland Council, 2016).

Detailed emissions inventories are powerful tools for policy and science analysis. For example, the Auckland air emissions inventory has been used to assess likely exposure, health effects of air pollution and costs and benefits of mitigation for various policies (Nunns, 2015). It has also been used to estimate background air quality concentrations, down to census area unit level, for assessment of resource consent applications (Auckland Council, 2014d).

1.1 Inventory design

1.1.1 Inventory year

This report estimates emissions to air in the Auckland region for 2016. This estimate is based on the results of the 2012 home heating survey and the 2013 census. A projection was developed to estimate emissions for 2016.

A key objective of this update was to assess progress towards the Auckland Plan target which is:

> *"reduce pollutant emissions (PM_{10}) by 50% by 2016 (based on 2006 levels) in order to meet national and international ambient air quality standards and guidelines, and achieve a further 20% reduction by 2040".*

To allow for comparison with the 2016 target as well as previous emission inventories, this inventory back casts emissions estimates for the following years:

- 2001
- 2006
- 2011.

1.1.2 Sources

This inventory includes emissions from domestic home heating including emissions from burning wood, coal and LPG.

1.1.3 Pollutants

It includes the following key ambient air pollutants:

- particulate matter less than 10 micrometres in diameter (PM_{10})
- particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$)
- carbon monoxide (CO)
- carbon dioxide (CO_2)

- oxides of nitrogen (NOx)
- sulphur dioxide (SO_2)
- volatile organic compounds (VOCs).

Emissions of the following toxic air pollutants were also estimated because they are known to be emitted from burning of wood:

- arsenic (As)
- mercury (Hg)
- benzo(a)pyrene (BaP)
- polychlorinated dioxins and furans (PCDD/F).

1.1.4 Spatial resolution

Emissions are estimated for the Auckland Urban Airshed and the rural area (areas outside the Airshed) separately. The spatial extent of the Auckland region as well as the Auckland Urban Airshed and rural area are shown in Figure 1-1.

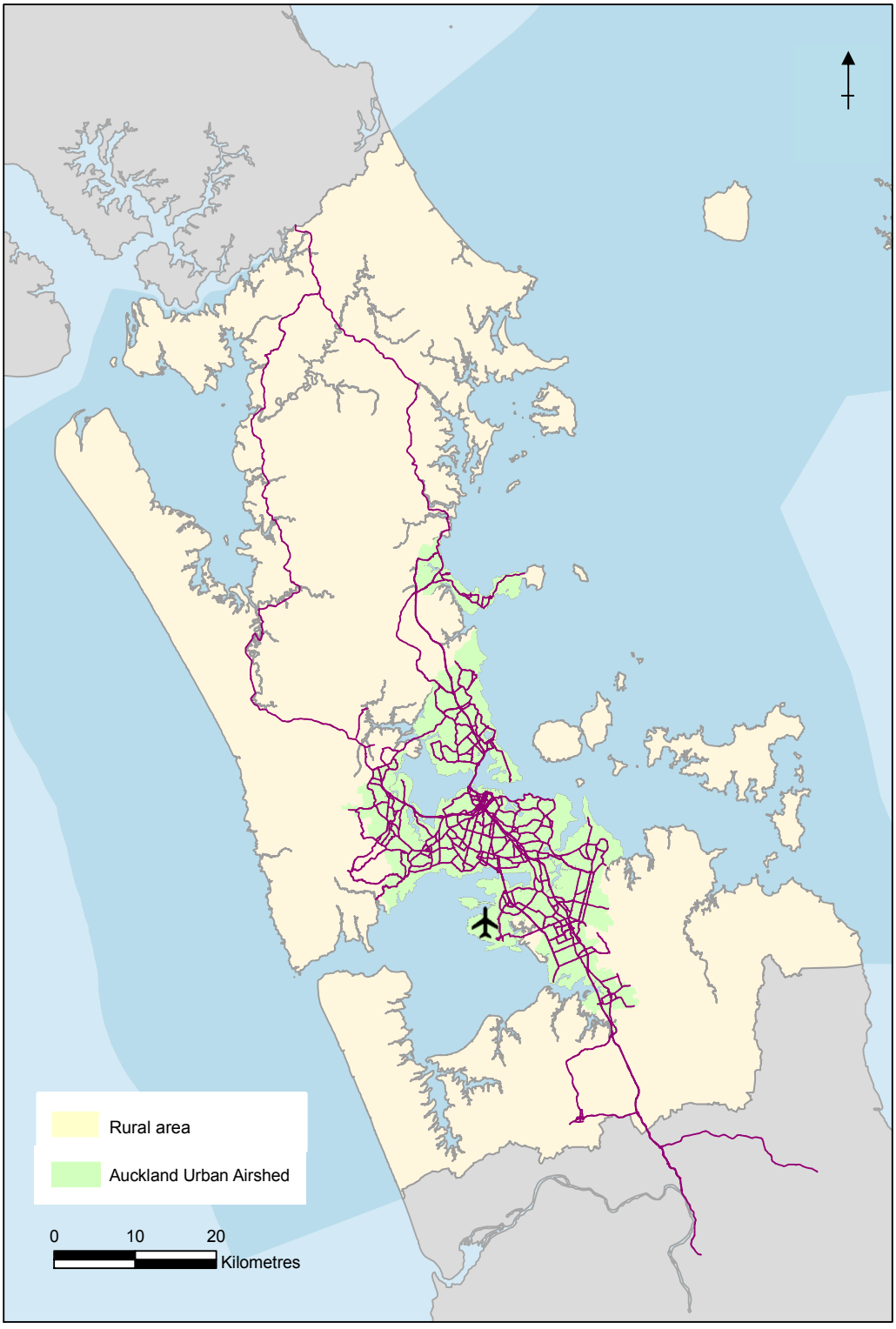

Figure 1-1: Map showing the Auckland Urban Airshed and rural area

1.1.5 Temporal resolution

This inventory provides an estimate of total annual emissions and average winter day emissions.

2.0 Method

This section describes the method for estimating emissions. For wood burning, emissions were estimated based on the following equation:

Emission (g) = number of appliances x emission factor (g/kg fuel) x fuel use per appliance (kg)

For coal, LPG and natural gas, emissions were calculated based on total estimated fuel consumption for the region using the following equation:

Emission (g) = emission factor (g/kg fuel used) x total fuel use (kg)

2.1 Fuel use per appliance (wood)

Table 2-1 presents the hourly and daily fuel consumption rates that were assumed for each burner type. These are based on the fuel use reported in the Estimation of Domestic Fire Emissions in 2006 (Auckland Regional Council, 2010b), which was estimated based on the results of the 2007 home heating survey (ARC, 2010a).

Updated fuel consumption estimates based on the results of the 2012 home heating survey (Auckland Council, 2014b) were not used. The 2012 estimate was approximately 24% less than the estimate based on the 2007 home heating survey (Auckland Regional Council, 2010a). The 2012 survey report concluded that this difference could be due to survey design factors, or it could be due to warmer temperatures in 2012 compared with 2007. Other factors could have contributed to a reduction in daily fuel consumption such as improved household insulation or better efficiency of modern wood burners. However, the 2007 fuel consumption rates were assumed in this 2016 inventory because it was unclear whether the different fuel consumption in 2012 was due to a real trend or another reason such as unusually warm temperatures or changes in the survey methodology. The daily fuel consumption estimated in the 2007 inventory was cross checked using two different methods and was considered robust (Auckland Regional Council, 2010b).

Table 2-1: Fuel consumption rates

Burner type	Fuel consumption per appliance (winter)				Annual
	kg/hr	kg/weekday	kg/weekend day	kg/day (average)	t/yr
All wood burners	3.4	14	20	16	1.7
Open fire	4.2	10	13	11	1.1
Pellet fire	1.25	5.1	7.4	5.8	0.6

Annual fuel use was estimated from the proportion of annual fuel consumption reported for July:

- 29 per cent wood burner / pellet fire
- 31 per cent open fire.

Monthly emissions can be estimated using the seasonal variation shown in Table 2-2 (Wilton, 2002).

Table 2-2: Seasonal variation in fuel use (Wilton, 2002)

Burner type	Proportion of annual fuel consumption by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Wood burners / multifuel / pellet	0%	0%	0%	1%	11%	24%	29%	28%	6%	1%	0%	0%
Open fire	0%	0%	1%	1%	10%	20%	31%	28%	7%	1%	0%	0%

2.2 Fuel use for coal, LPG and natural gas

The 2006 domestic fire emissions inventory (Auckland Regional Council, 2010b) estimated that total coal consumption for the Auckland region was 1740 tonnes per year. This equates to approximately 100 kilogrammes per household per year based on the number of households burning coal for heating from the census in 2006.

For comparison, average coal combustion for New Zealand households was approximately 300 kilogrammes per household per year in 2013[1].

For the 2016 inventory, total coal combustion was calculated based on the number households burning coal for heating (from census), and the assumption that average consumption per household was 100 kg per year.

LPG and natural gas consumption was based on data from the Energy Efficiency and Conservation Authority's (EECA) Energy end use database (for 2012) (EECA, 2017).

2.3 Emission factors

Emission factors used for this 2016 inventory are shown in Table 2-3. These are different to the emission factors used in previous inventories. The rationale for these emission factors is described in Appendix D.

Table 2-3: Domestic fire emission factors (g/kg, wet weight)

Appliance	PM_{10}	$PM_{2.5}$	CO	NOx	SO_2	VOC	CO_2
Old wood burner (pre-2005)	10	10	140	0.5	0.2	39	1,800
New wood burner (post-2005)	4.5	4.5	63	0.5	0.2	15	1,800
Multifuel (wood)	10	10	140	0.5	0.2	39	1,800
Open fire (wood)	12	12	63	1.2	0.2	30	1,800
Pellet fire	1.4	1.4	20	0.5	0.2	0.02	2,000
Coal*	20	18	87	3	8	15	2,600
LPG (kg/t)	0.6	0.6	0.18	1.3	0	0.2	2,500
Natural gas (g/m^3)	0.188	0.188	0.455	1.56	0.01	0.085	1,920

* Coal emission factors are the weighted average of multifuel and open fire emission factors (Auckland Regional Council, 2010b) based on the results of the 2007 home heating survey which found that 57% of coal was burnt in open fires and 43% in multifuel burners.

[1] Based on the number of households in New Zealand burning coal for heating from the 2013 census (60,999 households) and estimated residential consumption of coal (17,805 tonnes in 2013) from the Ministry of Business, Innovation and Employment's coal data tables (MBIE, 2017).

2.4 Estimation of wood burning appliance numbers

The method for estimating appliance numbers was consistent with the 2006 domestic fire emissions inventory (Auckland Regional Council, 2010b).

The appliance types included were:

- open fire
- wood burner
- multifuel burner
- pellet burner.

Wood burners were further categorised by age. Most significantly, wood burners installed after 2005 were assumed to comply with the design standard for new wood burners specified by the National Environmental Standards for Air Quality (AQNES).

2.4.1 Estimation of wood burning appliance numbers 2001, 2007 and 2012

The number of each type of appliance was estimated as:

number of appliances = HH x PT x PA

Equation 1

Where:

HH = no. of households using specified fuel (wood) for heating (from census),

PT = Proportion of households using each appliance type (from home heating surveys),

PA = Proportion of appliance in age group (from home heating surveys).

Burner numbers were estimated for:

- the Auckland Urban Airshed
- rural areas (i.e., area outside the Auckland Urban Airshed)
- the Auckland region, which is the sum of the Auckland Urban Airshed and the rural areas.

2.4.1.1 Number of households 2001, 2007 and 2012

The total number of households (HH in equation 1) using wood for heating was estimated for 2007 and 2012 by interpolating census data for 2006 and 2013 (using

the 2013 census dataset). The number of households was estimated for the Auckland Urban Airshed and rural areas separately as shown in Table 2-4.

Table 2-4: Census and interpolated data for households and wood use 2001-2013

	2001 (census)	**2006** (census)	**2007***	**2012***	**2013** (census)
Auckland region					
Total households	393,429	438,399	443,176	467,060	471,837
Households using wood	117,609	111,813	110,036	101,152	99,375
% of total	30%	26%	25%	22%	21%
Auckland Urban Airshed					
Total households	343,407	380,544	384,254	402,805	406,515
Households using wood	92,007	84,377	82,519	73,226	71,367
% of total	27%	22%	21%	18%	18%
Rural Auckland (outside urban airshed)					
Total households	50,022	57,855	58,922	64,255	65,322
Households using wood	25,602	27,436	27,518	27,926	28,008
% of total	51%	47%	47%	43%	43%

* Data interpolated between 2006 and 2013

Estimation of burner types for two areas only is a simplification compared with previous inventories and projections, which estimated burner types separately for each of the seven areas in the home heating survey.

Table 2-5 presents the margin of error for burner type and age by area in the 2012 home heating survey (Auckland Council, 2014b). The margin of error shows no statistically significant variance for any burner type except the proportion of open fires in central Auckland (30% +/- 6%) and West Auckland (7% +/- 4%) which are significantly different from the regional average (17% +/- 2%). The 2012 home heating survey reported no statistically significant difference in the age of burners between survey areas (Auckland Council, 2014b).

This simplified approach of estimating burner age and type for only urban and rural areas was considered appropriate because, with the exception of open fires in west and central Auckland, there is no statistically significant difference between the age and type of burner numbers between each of the seven survey areas. This means that the extra level of detail in projections for each area would provide very little useful or valid information. This simplification of the method will also simplify and reduce the cost of future home heating surveys.

Table 2-5: Margin of error calculations for 2012 home heating survey

Burner type	South Auckland	East Auckland	Central Auckland	West Auckland
Wood burner	78 +/- 6	78 +/- 6	65 +/- 7	86 +/- 5
Open fire	16 +/- 5	17 +/- 5	30 +/- 6	7 +/- 4
Other	6 +/- 3	5 +/- 3	5 +/- 3	7 +/- 4
Burner type	**Papakura**	**North Shore**	**Rural**	**Total**
Wood burner	77 +/- 6	76 +/- 6	83 +/- 5	77 +/- 2
Open fire	16 +/- 5	17 +/- 5	12 +/- 4	17 +/- 2
Other	7 +/- 4	7 +/- 4	5 +/- 3	6 +/- 1

2.4.1.2 Appliance type and age for 2001, 2007 and 2012.

The proportion of households using each appliance type and the proportion of appliances in age groups was calculated separately for the Auckland Urban Airshed and rural areas for each year based on the results of previous home heating surveys:

- Wilton E, 2002. *Auckland Domestic Home Heating Emission Inventory 2001*.
- Auckland Regional Council, 2010a. *2007 Home Heating Survey Results*.
- Auckland Council, 2014b. *2012 Home Heating Survey.*

2.4.2 Estimation of wood burning appliance numbers for 2016

A projection was developed to estimate home heating appliance numbers for 2016. The projected change in the number and type of wood burning appliances was based on analysis of historical trends from census and home heating surveys. This analysis is described in Sections 3.4 and 3.5 of this report.

3.0 Trends and projections

This section discusses the recent trends in ambient air quality and home heating. This section also includes a projection of the number and type of wood burning appliances to 2016.

3.1 Ambient PM_{10}

Annual average levels of PM_{10} in Auckland have declined since regular measurements began in the late 1990s. Figure 3-1 presents annual average PM_{10} for a number of residential sites compared with peak monitoring sites for traffic (Khyber Pass) and industry (Penrose). Annual average levels of PM_{10} measured at all residential monitoring sites in Auckland have been under the World Health Organisation guideline (20µg/m^3) since 2005.

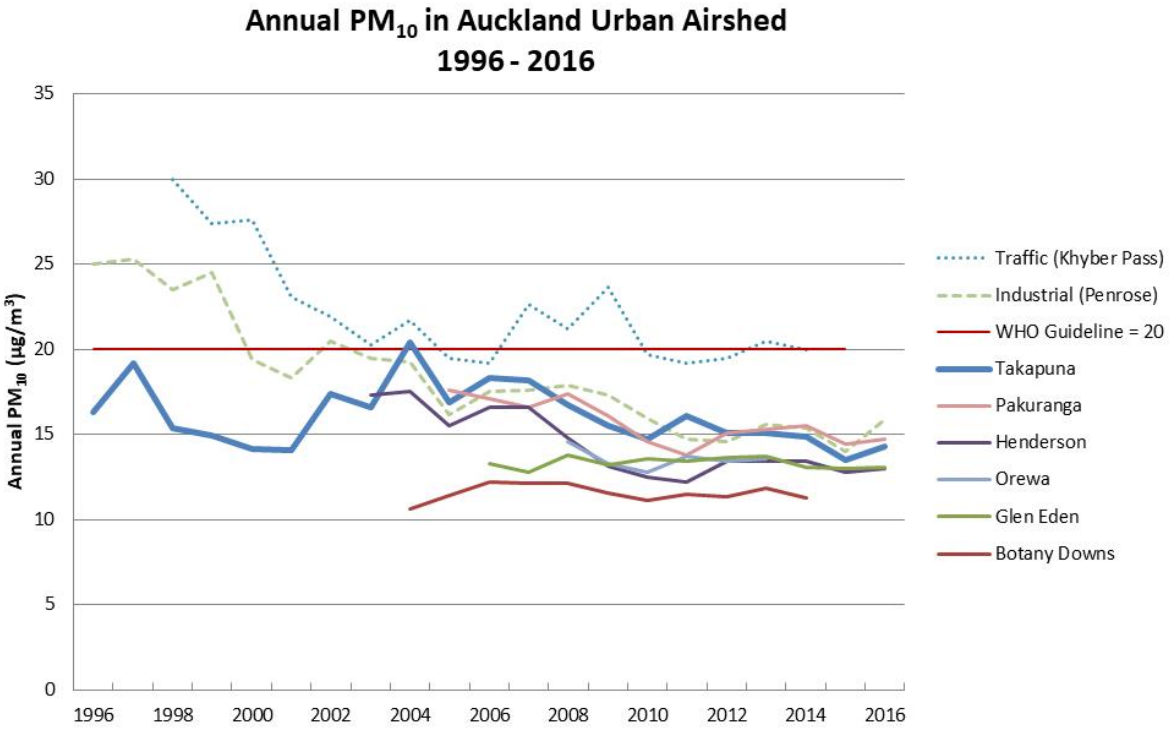

Figure 3-1: Annual average PM_{10} concentrations at selected Auckland monitoring sites from 1996-2016

Figure 3-2 presents annual average PM_{10} as a three-year rolling average to smooth out inter-annual variability due to meteorology. This shows that the decline in long-term PM_{10} in the 1990s appears to have plateaued in recent years.

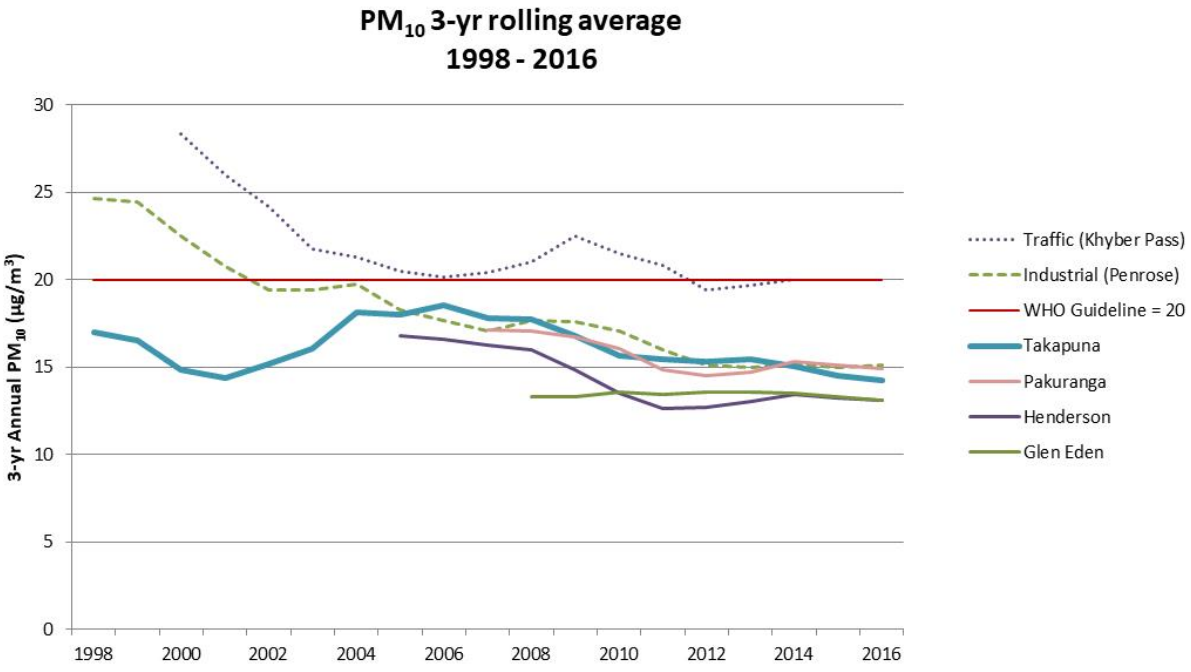

Figure 3-2: Three-year rolling annual average PM_{10} concentrations at selected Auckland monitoring sites from 1998 - 2016

3.2 Ambient $PM_{2.5}$

Annual average levels of $PM_{2.5}$ in Auckland have also declined since regular measurements began in the late 1990s. Figure 3-3 presents annual average $PM_{2.5}$ between 1997 and 2016. This shows that all residential monitoring sites in Auckland have been under the World Health Organisation guideline for $PM_{2.5}$ since 2001.[2]

[2] Kingsland, Mt Eden, Takapuna, Whangaparoa.

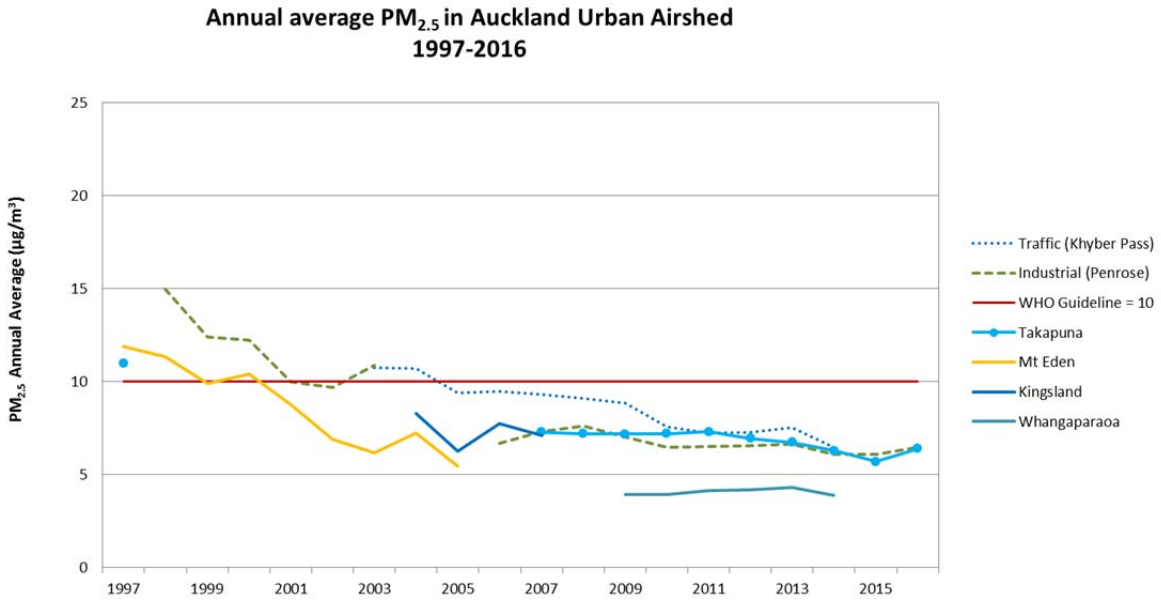

Figure 3-3: Annual average $PM_{2.5}$ in Auckland Urban Airshed from 1997-2016

3.3 Home heating trends

Table 3-1 and Figure 3-4 show trends in census data from 1996 to 2013.[3] This shows that although the number of dwellings in Auckland has increased, the number of dwellings that use solid fuel (wood or coal) for heating has decreased. Whilst the decrease is small year on year (less than 2% each year between 1996 and 2013), the decline is significant over the 17 years between 1996 and 2013.

[3] The 2011 Census was not held as planned due to the Christchurch earthquake.

Table 3-1: Census data for households and fuel use 1996-2013

	1996	2001	2006	2013
Total households	356,649	393,429	438,399	471,837
Households using wood	127,083	117,609	111,813	99,375
Households using coal	31,650	21,744	17,154	10,050
Households using mains gas	28,794	46,149	54,885	56,898
Households using bottled gas	61,122	92,973	105,468	70,932

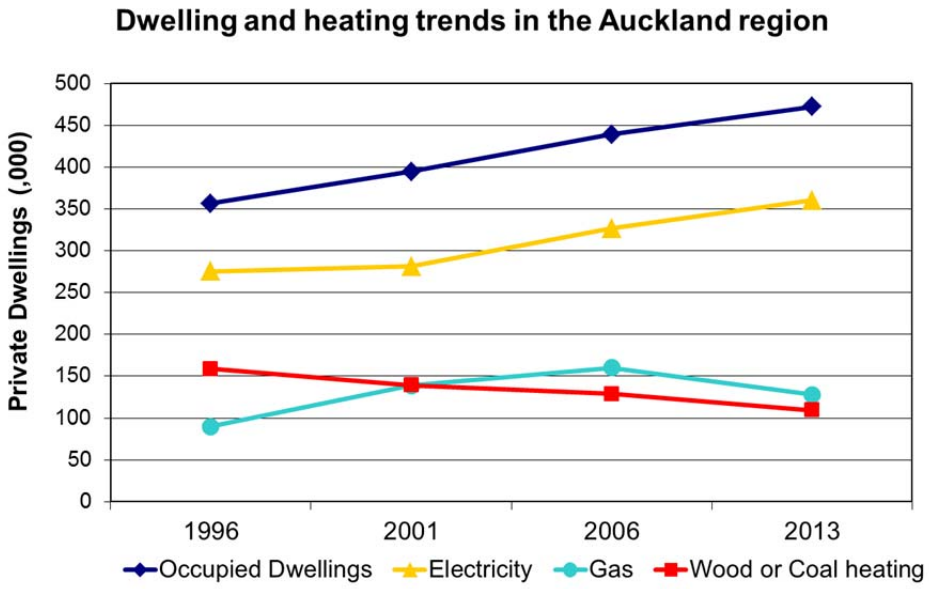

Figure 3-4: Dwelling and heating trends for the Auckland region (Census data)

3.3.1 Difference between home heating surveys and census

Table 3-2 shows census data for the per cent of households using wood for heating compared with home heating survey results for the per cent of households using wood for heating.

Table 3-2: Census data for households and wood use 2001-2013

Census data – Auckland region					
	2001 (census)	**2006** (census)	**2007*** (interpolated)	**2012*** (interpolated)	**2013** (census)
Total households	393,429	438,399	443,176	467,060	471,837
Households using wood	117,609	111,813	110,036	101,152	99,375
% of total households using wood for heating	30%	26%	25%	22%	21%
Home heating surveys – Auckland region**					
	2001		**2007**	**2012**	
% of total households using wood for heating	41%		29%	26%	

* Data interpolated between 2006 and 2013
** Wilton E, 2002. *Auckland domestic home heating emission inventory 2001.*
** Auckland Regional Council, 2010a. *2007 Home Heating Survey Results.*
** Auckland Council, 2014b. *2012 Home Heating Survey.*

As shown in Table 3-2, 21% of households in the Auckland region were using wood to heat their dwelling according to the 2013 census. This is lower than the 26% of households using wood burners[4] in the 2012 home heating survey (Auckland Council, 2014b) and outside the estimated margin of error (± 2%) of the home heating survey. This may be due to a positive bias towards home owners from the home heating survey respondents.[5] This overrepresentation of home owners will positively skew estimated wood burner numbers because home owners are more likely to use a wood burner (28-30%) than renters (17%) (Auckland Regional Council, 2010a; Auckland Council, 2014b).

[4] 26% was the proportion of respondents using wood in the main living area. The proportion using wood for heating anywhere in the home was 28%.

[5] 81% of respondents owned their own home in the 2012 home heating survey (Auckland Council, 2014b), however, the 2013 census identified only 62% home ownership in Auckland (Auckland Council, 2014c).

A similar positive bias was observed in the 2007 home heating survey which identified 29% of households using wood burners (Auckland Regional Council, 2010a) compared with 25% for that year based on the 2006 census.[6] This was also likely due to over-representation of home owners.[7]

This positive bias may be continuing in the 2016 People's Panel survey in which 27% of respondents indicated that they used a wood burner, i.e. the survey may be similarly over representing home owners (Auckland Council, 2016).

Consequently, this inventory used census data in preference to home heating surveys to calculate total wood burning appliance numbers, and used survey data to estimate the split in specific appliance types. This is consistent with the methodology of the 2006 air emissions inventory (Auckland Council, 2014a). The most recent projections report *Domestic Fire Emissions 2012: Options for Meeting the National Environmental Standard for PM_{10}* (Auckland Council, 2013) was prepared prior to the 2013 census data being available. The report used burner numbers from the 2012 home heating survey and therefore likely overestimated the number of wood burners and associated emissions.

3.4 Wood burning appliance trends

The estimated appliance numbers in the Auckland Urban Airshed and rural area for 2001, 2007 and 2012 are illustrated in Figure 3-5 and Figure 3-6 and are tabulated in Appendix B.

As shown in Figures 3-5 and 3-6, the number of wood burners in the Auckland Urban Airshed decreased between 2001 and 2007 and was stable between 2007 and 2012. In the rural area wood burner numbers increased between 2001 and 2012. Open fire and multifuel burner numbers declined in both areas, especially within the Auckland Urban Airshed where the number of open fires halved between 2001 and 2012.

[6] Interpolated from 2006 and 2013 (for the year 2007).

[7] 81% of respondents owned their own home in the 2007 home heating survey (Auckland Regional Council, 2010a), whereas the 2006 census identified only 63% home ownership in Auckland.

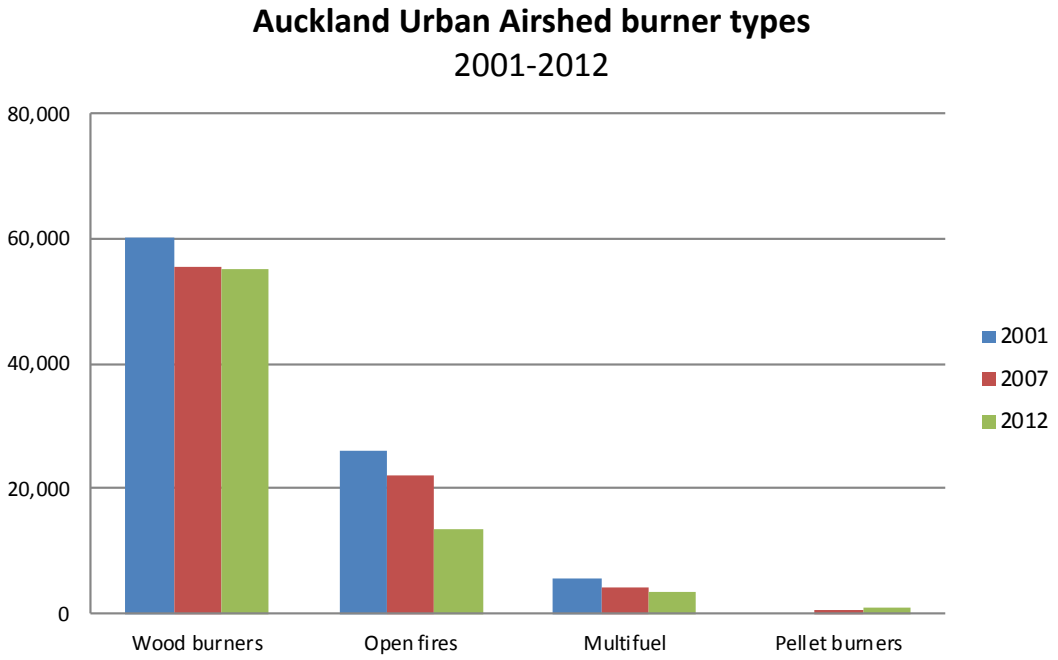

Figure 3-5: Wood burning appliance types for the Auckland Urban Airshed

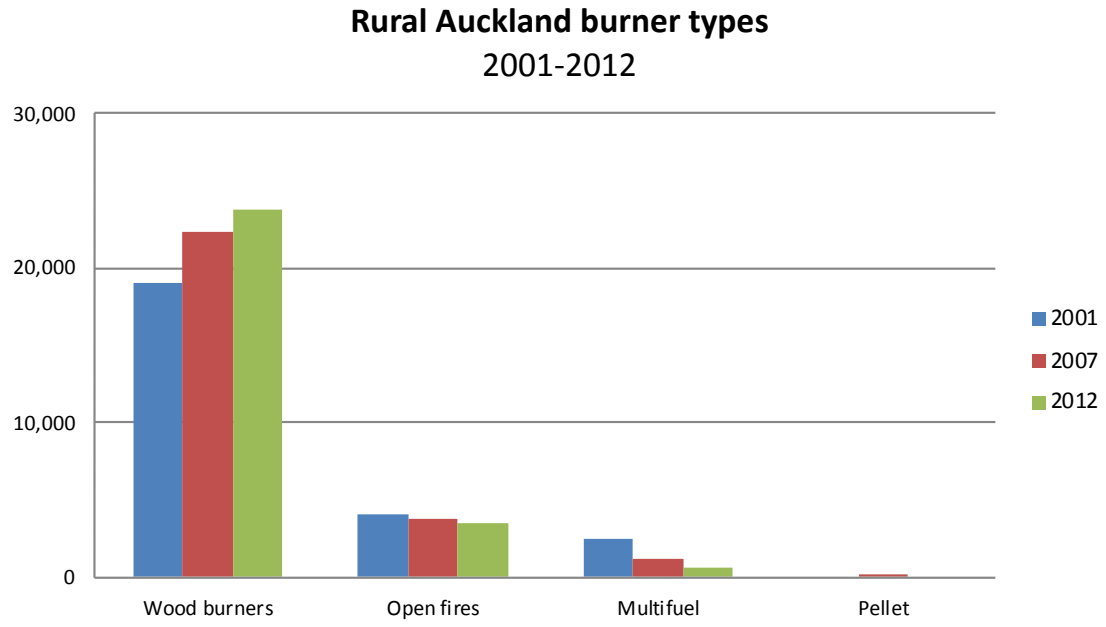

Figure 3-6: Home heating types for rural Auckland

Estimated wood burner appliance numbers for the Auckland region are shown in Table 3-3 and illustrated in Figure 3-7. These are the sum of the appliance numbers for the Auckland Urban Airshed and Rural Auckland.

Table 3-3: Auckland region estimates of burner by type and age

Burner type and age	2001	2007	2012
Total wood burners	79,342	77,915	79,118
Old wood burners (pre-2005)	79,342	73,130	57,427
New wood burners (post-2005)	0	4,784	21,691
Multifuel	8,023	5,426	4,036
Open fire	30,244	25,849	16,962
Pellet fire	0	847	1,036
Total wood	117,609	110,036	101,152

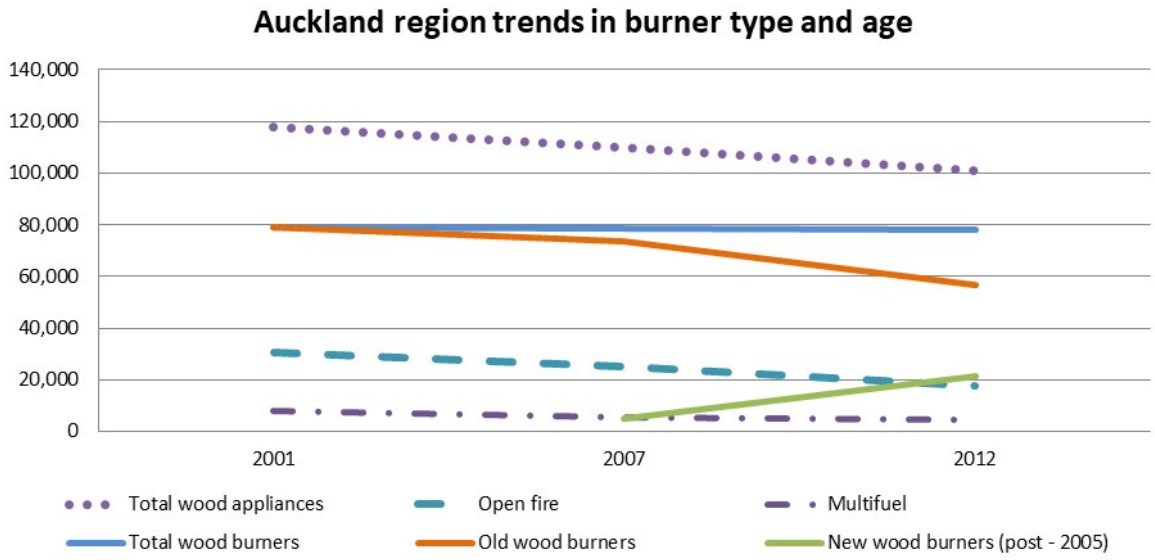

Figure 3-7: Estimated home heating types and ages for the Auckland region

3.5 Projected appliance numbers for 2016

A projection was developed to estimate appliance numbers from 2013 to 2016. Burner numbers were projected separately for the Auckland Urban Airshed and the rural area (outside the urban airshed).

The projection to 2016 was based on the assumption that recent trends in appliance numbers continue. The number of appliances being installed and retired each year was estimated for the Auckland Urban Airshed and the rural area as described in Appendix F.

The assumptions for the 2016 projection are summarised as follows:

- The number of old wood burners (i.e. pre-2005 wood burners) that are retired each year remains the same as the estimated number of old wood burners that were retired each year between 2007 and 2012. That is, 2412 wood burners per year in the Auckland Urban Airshed and 728 wood burners per year in rural Auckland.
- The number of new wood burners (i.e. post-2005) being installed each year remains the same as the estimated number of new wood burners that were installed each year between 2007 and 2012. That is 2348 burners per year in the Auckland Urban Airshed and 1034 wood burners per year in rural Auckland.
- The retirement rate of multifuel burners remains the same as the estimated rate of retirement between 2001 and 2012. That is 196 multifuel burners per annum in the Auckland Urban Airshed and 167 multifuel burners per annum in rural Auckland.
- The retirement rate of open fires remains the same as the estimated rate of retirement between 2001 and 2012. That is 1150 open fires per annum in the Auckland Urban Airshed and 57 open fires per annum in rural Auckland.

The assumed rate of installation and removal of appliances are summarised in Table 3-4.

Table 3-4: Assumed number of appliances installed and removed each year from 2013 to 2016

Burner type and age	Auckland Urban Airshed	Rural Auckland
Old wood burners (pre-2005)	-2,412	-728
New wood burners (post 2005)	+2348	+1034
Multifuel	-196	-167
Open fire	-1150	-57
Pellet Fire	+74	0

Projected burner numbers for 2016 are summarised in Table 3-5. The regional projection is the sum of the urban and rural projections.

Table 3-5: 2016 projection of burner by type and age

Burner type and age	Auckland urban airshed	Rural Auckland	Region
Total wood burners	55,007	25,074	80,081
Old wood burners (pre-2005)	30,465	14,400	44,865
New wood burners (post-2005)	24,542	10,674	35,216
Multifuel	2,672	0	2,672
Open fire	8,870	3,261	12,132
Pellet Fire	1,331	0	1,331
Total Wood	**67,880**	**28,335**	**96,216**

Figure 3-8, Figure 3-9 and Figure 3-10 illustrate the overall number of burners estimated for 2001 to 2012 and projected to 2016 for each category (type/age) in the

Auckland Urban Airshed, the rural area and the Auckland region respectively. These illustrate how recent trends are reflected in the projection to 2016.

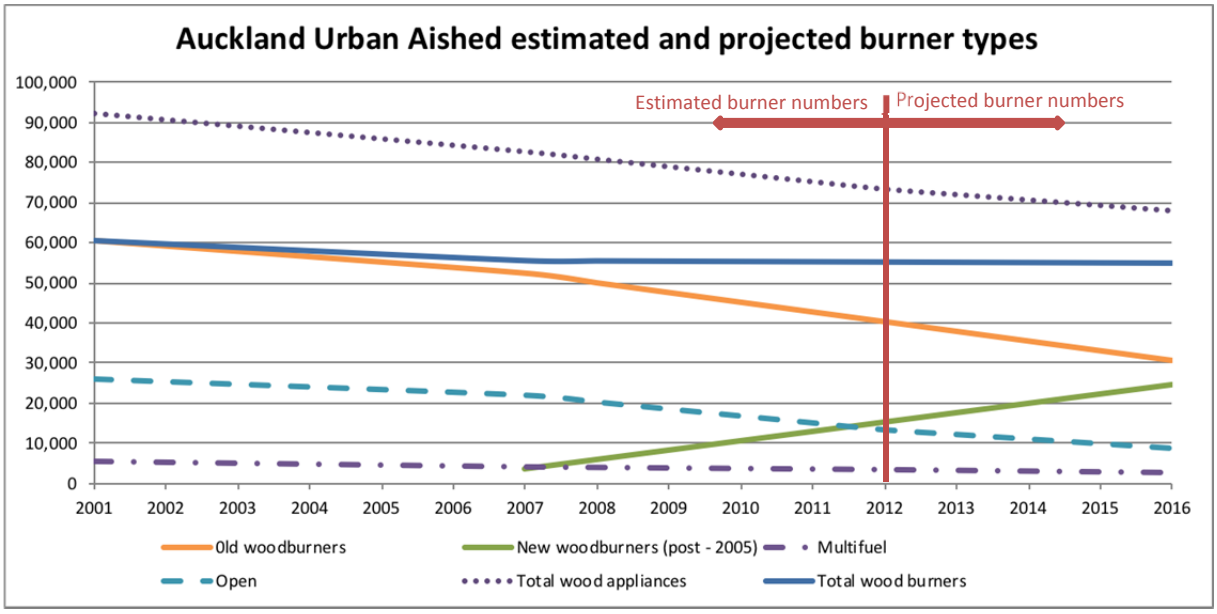

Figure 3-8: Estimated home heating types and ages from 2001 to 2012 and projected home heating types and ages to 2016 for the Auckland Urban Airshed

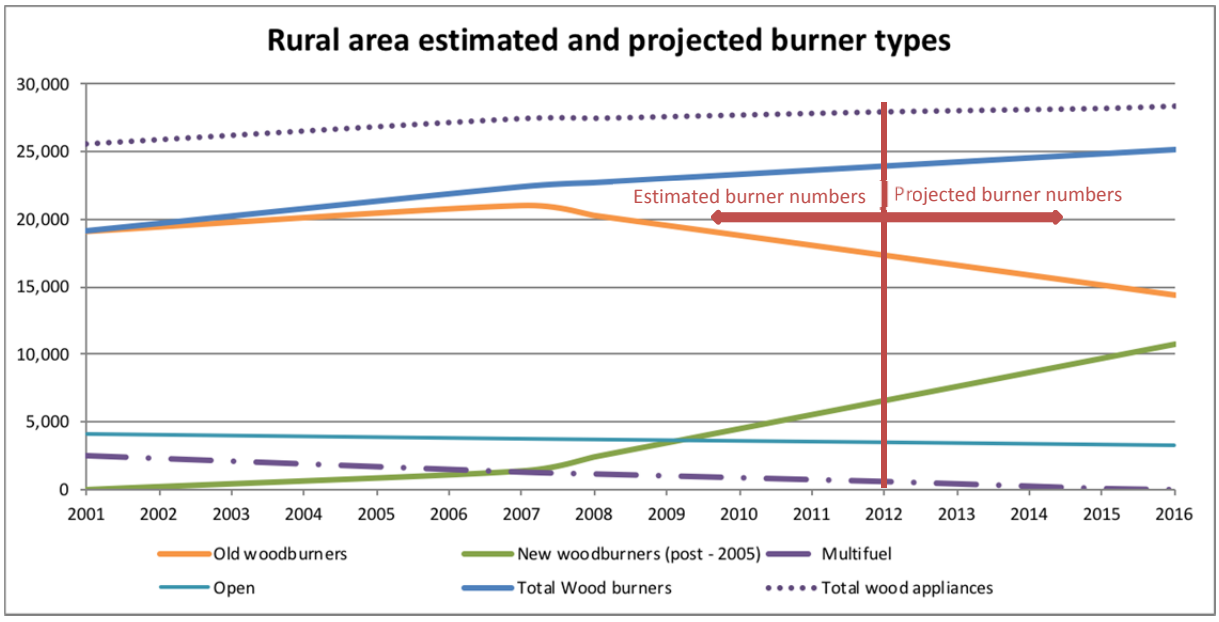

Figure 3-9: Estimated home heating types and ages from 2001 to 2012 and projected home heating types and ages to 2016 for the rural area

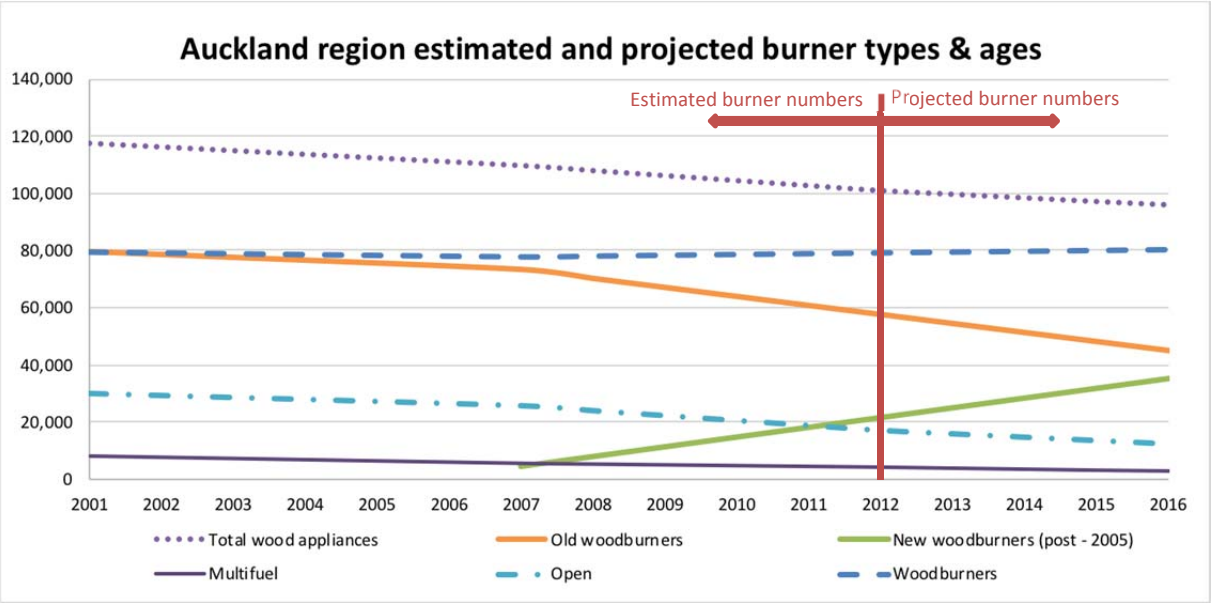

Figure 3-10: Estimated home heating types and ages from 2001 to 2012 and projected home heating types and ages to 2016 for the Auckland region

4.0 Results

Emissions were estimated based on the methodology described in Section 2.

Results by pollutant for 2016 are summarised in Table 4-1.

Table 4-1: Summary of estimated emissions from home heating in 2016

Source	2016 emissions estimate						
	CO (t/yr)	CO_2 (kT/yr)	NOx (t/yr)	SO_2 (t/yr)	PM_{10} (t/yr)	$PM_{2.5}$ (t/yr)	VOC (t/yr)
Home heating - wood	15,752	276	86	31	1,224	1,224	4,397
Home heating - coal	71	2	2	7	16	14	12
LPG use	3	44	23	0	10	10	3
Natural gas use	29	122	99	1	12	12	5
Total - home heating	**15,855**	**444**	**210**	**38**	**1,263**	**1,261**	**4,418**

For 2016 it was estimated that wood burning accounted for 97% of PM_{10} emissions from domestic home heating, with approximately 1% of PM_{10} emissions from coal burning, 1% from LPG and 1% from natural gas.

This section of the report describes estimated emissions from wood burning for 2016 by pollutant. These have also been back cast for all years back to 2001 for comparison with previous emission inventories. PM_{10} emissions from wood burning are summarised in Appendix C for 2001, 2006, 2011, and 2016. Emission estimates for other years and other pollutants are provided in the accompanying spreadsheet.

4.1 PM_{10}

Based on methodology described in Section 2 the appliance projection for 2016 described in Section 3 it was estimated that in 2016 there were approximately 96,200 households using wood for home heating in the Auckland region. These comprised:

- 44,900 old wood burners (pre-2005)
- 35,200 new wood burners (post-2005)
- 2,700 multifuel burners
- 12,100 open fires
- 1,300 pellet burners.

Based on the emission factors and fuel use estimates in Section 2, regional emissions of PM_{10} are estimated at approximately 12 tonnes per winter day[8] or approximately 1220 tonnes per year. The majority of these emissions were within the Auckland Urban Airshed as shown in Figure 4-1.

[8] Average of winter weekday and winter weekend

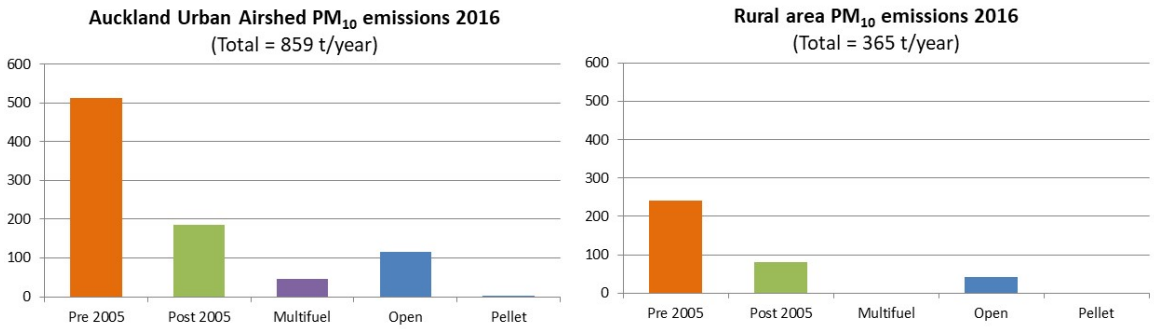

Figure 4-1: Estimated PM_{10} emissions from wood burning in the Auckland Urban Airshed, and rural areas (outside the Auckland Urban Airshed), for 2016

4.2 $PM_{2.5}$

$PM_{2.5}$ comprises 100% of PM_{10} emissions from wood burners and pellet burners. This means that the emissions profile of $PM_{2.5}$ is identical to PM_{10}.

Based on the emission factors and fuel use estimates in Section 2, regional emissions of $PM_{2.5}$ are estimated at approximately 12 tonnes per winter day or approximately 1220 tonnes per year.

4.3 Other pollutants

Emissions estimates of carbon monoxide, nitrogen dioxide, sulphur dioxide, volatile organic compounds and carbon dioxide from wood burning in 2016 are presented in Table 4-2.

Table 4-2: 2016 estimated emissions for other pollutants

2016 (t/yr)	CO	NOx	SO_2	VOC	CO_2
Airshed	11,013	60	21	3,078	193,380
Rural	4,739	25	9	1,319	82,189
Regional	15,752	86	31	4,397	275,569

4.4 Toxics

The European emission inventory guidebook (referred to hereafter as the EMEP/EEA guidebook) contains emission factors for a wide range of toxic pollutants (EEA, 2016). The following toxic pollutants were estimated in this inventory because these are known to be emitted from domestic home heating:

- arsenic – limited monitoring suggests that the concentration of Arsenic in air in Auckland may exceed ambient air quality guidelines (Cavanagh *et al*., 2012);
- mercury
- benzo(a)pyrene – this pollutant is known to exceed national guidelines in other urban areas of New Zealand
- dioxins and furans – wood contains chlorine and can result in significant cumulative emissions of dioxins and furans when combusted.

Emission factors and assumptions are discussed in Appendix E. Based on these emission factors and assumptions, Auckland regional emissions from home heating for 2016 are estimated as:

- Arsenic: approximately 2.1 tonnes per year (this estimate has a high uncertainty because the quantity of treated timber that is burnt each year is unknown).
- Mercury: approximately 5.9 (low 1.1, high 11) kilogrammes per year.
- Benzo(a)pyrene: approximately 280 kilogrammes per year (95% CI 28, 2,800).
- Dioxins and furans: approximately 0.74 grams I-TEQ (International Toxic Equivalents) per year (95% CI 0.05, 5.4).

4.5 Uncertainty

The EMEP/EEA guidebook (EEA, 2016) suggests that emissions inventories should include a first order uncertainty assessment. The guidebook states that it is not necessary to get a precise estimate for the uncertainty of each parameter and each value in the inventory. A reasonably rough characterisation of uncertainties can provide a reasonable estimate of the overall inventory uncertainty, and can identify the parameters that are most important for the overall uncertainty.

The EMEP/EEA guidebook describes two tiers for uncertainty analysis:

Tier 1: estimation of uncertainties by source category using simple equations to aggregate errors.

Tier 2: estimation of uncertainties by source category and in the overall inventory by stochastic simulation (Monte Carlo analysis)

The EMEP/EEA guidebook states that in most cases the Tier 1 approach is adequate.

4.5.1 Method for aggregating uncertainties

The EMEP/EEA guidebook (EEA, 2016) provides two rules for combining uncorrelated uncertainties under addition and multiplication.

1. Rule A: where uncertain quantities are to be combined by addition:

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + \cdots + (U_n \times x_n)^2}}{x_1 + x_1 + \cdots + x_n}$$

   Where:

   x_i are the quantities

   U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval)

   U_{total} is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage)

2. Rule B: where uncertain quantities are to be combined by multiplication

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

   U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval)

   U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage)

These rules are based on the assumptions that variables are uncorrelated with a standard deviation of less than about 30% of the mean. The guidebook recognises that in practice these assumptions are often not valid, but states that under these circumstances the rules may still be used to obtain an approximate result.

4.5.2 Uncertainty assessment

A Tier 1 assessment of uncertainty was undertaken for this inventory. Domestic emissions estimates rely on three key inputs:

(i) Estimated number of burners;

(ii) Estimated emissions per burner, per unit of fuel combusted (emission factor); and

(iii) Estimated fuel use.

4.5.3 Burner number uncertainty

The total number of burners for 2012 was based on census data (interpolated between 2006 and 2013 census).

The 2013 home heating emission inventory for New Zealand (Wilton *et al*., 2015) assumes an uncertainty of less than 5% for census data at the survey level. An uncertainty of 5% was assumed on this basis.

Burner numbers for 2016 were estimated based on a projection from 2013 census data. This introduces extra uncertainty, which is discussed in Section 4.5.6.

4.5.4 Emission factor uncertainty

The 2013 home heating emission inventory for New Zealand (Wilton *et al*., 2015) assumes an uncertainty of 30% for emission factors at the survey area level. This accounts for potential variability in appliance types (which affects the choice of emission factor) Emission factors as well as the method for assigning emission factors based on survey results is largely consistent with the Wilton *et al*., 2015 factors so it is appropriate to assume the same uncertainty.

4.5.5 Fuel use uncertainty

The 2006 domestic fire emissions inventory for 2006 included a qualitative assessment of the uncertainty in fuel use estimates (Auckland Council, 2010b). This assessment concluded that there was reasonable confidence in the fuel use estimate. However, the average weekly fuel use estimate based on the 2012 home heating survey (Auckland Council, 2014b) was 24% less than the estimate based on the 2007 home heating survey (Auckland Council, 2010a). The survey report concluded that this difference could be due to survey design factors, or it could be due to warmer temperatures in 2012 compared with 2007.

For this assessment, fuel use from the 2007 home heating survey was assumed because it was considered more likely to be accurate. However, this is uncertain. The uncertainty in fuel use was assumed to be 30% based on the estimated uncertainty for fuel consumption (30%) reported at the survey area level in the recent New Zealand home heating inventory (Wilton *et al*., 2015).

4.5.6 Projection uncertainty

Emissions were estimated for 2016 based on projections from 2012. This projection was based on the assumption that recent trends in burner removal and installation would continue. Based on this projection it was estimated that PM_{10} emissions reduced by 14% between 2012 and 2016. In reality, if recent trends did not in fact continue, 2016 emissions could be 14% higher than estimated (the same as 2012 emissions).

4.5.7 Overall uncertainty assessment

Using the EMEP/EEA guidebook Tier 1 methodology to aggregate uncertainties, the overall uncertainty in the PM_{10} emissions estimate from domestic fires was estimated at approximately +/- 21% for 2012. The emission estimate for 2016 is based on a projection which is inherently uncertain. The overall uncertainty in 2016 emissions is estimated as approximately – 24% to + 38%.

5.0 Conclusions and recommendations

Based on the results of census and survey data, it was estimated that in 2016 there were approximately 96,200 households using wood for home heating in the Auckland region. These comprised:

- 44,900 old wood burners (pre-2005)
- 35,200 new wood burners (post-2005)
- 2,700 multifuel burners
- 12,100 open fires
- 1,300 pellet burners.

Regional emissions of PM_{10} from wood burning were estimated at approximately 12 tonnes per winter day or approximately 1,200 tonnes per year in 2016. This represents a 29% reduction compared with estimated emissions of 1,700 tonnes per year in 2006. This is a 42% shortfall on the Auckland Plan target of 50% reduction in emissions compared with 2006 by 2016.

This emissions inventory is underpinned by census data and the home heating survey. It is recommended that a home heating survey should be undertaken as soon as possible to enable update of the emissions inventory when 2018 census data becomes available. This could be significantly simplified compared with previous surveys by collecting data for the Auckland Urban Airshed and the area outside the airshed only (compared to the 2012 survey which collected and disaggregated results for seven different areas).

Specific recommendations to improve future home heating inventories and projections include:

- Projections of burner numbers have previously been developed based on the number of wood burners being installed and removed each year in Auckland, which was estimated based on survey results (Auckland Council, 2013). This method is inherently uncertain. Collection and collation of building consent data on wood burner installations would significantly improve the certainty of emission estimates and projections. If possible, data on installation of new wood burners should include:
    - location (address or census area unit)
    - age of the dwelling
    - whether the installation is new, or, is replacing an existing wood burner or open fire.

- The 2012 home heating survey estimated daily fuel consumption approximately 24% lower than the 2007 home heating survey. Further research is required to determine whether household fuel consumption has significantly changed since the 2007 home heating survey. This could include:
    - Investigation of factors that could influence fuel consumption such as wood burner age, dwelling age and household insulation
    - Repeating the home heating survey in 2018 and resolving inconsistencies between the 2007 and 2012 home heating survey methodologies.
- The seasonal variation in fuel consumption has been estimated based on the results of a 2002 home heating survey. Seasonal variation should be updated in the next home heating survey
- Home owners were over represented, and home renters were under represented in the 2012 home heating survey. Alternative survey methods should be considered for the next home heating survey to address this bias.

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Appendix A Comparison with previous inventories

As outlined in previous sections of this report, the methodology and assumptions for this inventory and projection are generally consistent with previous reports. Changes compared with previous versions are:

- Emission factors have been changed for consistency with the 2013 home heating emission inventory for New Zealand (Wilton *et al*., 2015).
- In this report, annual emissions were calculated from average winter day emissions, taking into account the higher fuel consumption reported in weekends. In previous reports, average winter weekday emissions were reported. Annual emissions were incorrectly calculated from this weekday average without taking into account weekend emission rates. Table A-1 includes average winter weekday and average winter day emissions for comparison.
- Estimated burner numbers for 2012 are based on 2013 census data (interpolated to 2012).
- For consistency between census and survey data, burner numbers were calculated for 2007 based on (interpolated) census data and 2007 survey data and for 2012 based on (interpolated) census data and 2012 survey data. In the previous report (Auckland Council, 2013) all burner numbers were calculated based on 2006 census data because 2013 census data was unavailable.
- To ensure consistency and transparency, all burner numbers were recalculated for this report from survey data and the 2013 census dataset (which includes census data for 2001 and 2006).

Comparison of the results in Table A-1 and Table A-2 shows that the estimated number of burners for 2007 was similar for both reports, so the difference in 2007 is largely due to the updated emission factors. For 2012 and 2016, the estimated number of burners is lower for this 2016 inventory compared with the previous projection (Auckland Council, 2013) because it incorporates the results of the 2013 census.

Table A-1: Summary of this inventory (2016) estimate and projection

Year	Winter PM_{10} (t/ winter weekday)	Number of burners			
		Old burners*	Open fires	New burners	Total burners
Current estimates and projections (this report)					
2007 (2007 survey)	16.1	78,556	25,849	4,784	109,857
2012 (2012 survey)	13.4	61,463	16,962	21,691	101,152
2016 (projection)	11.6	47,537	12,132	35,216	96,216

*Includes all pre-2005 burners and all multifuel burners.

Table A-2: Summary of previous estimate and projection

Year	Winter PM_{10} (t/ winter weekday)	Number of domestic fires			
		Old burners*	Open fires	New burners	Total burners
Previous estimates and projections (AC 2013)					
2007 (2007 survey and 2006 census data)	12.5	77,800	26,000	4,500	110,000
2012 (2012 survey and 2006 census data)	11	67,000	18,000	24,000	110,000
2016 (projection)	9.7	56,700	13,100	37,900	109,200

*Includes all pre-2005 burners and all multifuel burners.

Appendix B Estimated wood burner numbers

Auckland Urban Airshed

2012	Census/Survey	% Burners	Margin error
Total HH	402,805		
Total wood	73,226		
Total wood burners	55,265	75%	3.5%
Old wood burners (pre-1991)	10,680	19%	3.2%
Old wood burners (1991-2005)	29,433	53%	4.0%
New wood burners (post-2005)	15,151	27%	3.6%
Multifuel total	3,454	5%	1.7%
Open fire total	13,471	18%	3.1%
Pellet Fire	1,036	1.4%	0.9%

2007	Census/Survey	% Burners	Margin error
Total HH	384,254		
Total wood	82,519		
Total wood burners	55,587	67%	2.4%
Old wood burners (pre-1991)	14,872	27%	2.3%
Old wood burners (1991-2005)	37,302	67%	2.4%
New wood burners (post-2005)	3,413	6%	1.2%
Multifuel total	4,173	5%	1.1%
Open fire total	22,090	27%	2.3%
Pellet Fire	668	0.8%	0.5%

2001	Census/Survey	% Burners	Margin error
Total HH	343,407		
Total wood	92,007		
Total wood burners	60,280	66%	4.6%
Old wood burners (pre-1991)	25,539	42%	4.8%
Old wood burners (1991-2005)	34,741	58%	4.8%
New wood burners (post-2005)			
Multifuel total	5,605	6%	2.3%
Open fire total	26,122	28%	4.4%
Pellet Fire	0		-

Rural Auckland

2012	Census/Survey	% Burners	Margin error
Total HH	64,255		
Total wood	27,926		
Total wood burners	23,853	85%	5.9%
Old wood burners (pre-1991)	4,610	19%	6.6%
Old wood burners (1991-2005)	12,704	53%	8.4%
New wood burners (post-2005)	6,540	27%	7.5%
Multifuel total	582	2%	2.4%
Open fire total	3,491	13%	5.5%
Pellet Fire	0	0.0%	-

2007	Census/Survey	% Burners	Margin error
Total HH	58,922		
Total wood	27,518		
Total wood burners	22,327	81%	3.1%
Old wood burners (pre-1991)	5,974	27%	3.5%
Old wood burners (1991-2005)	14,983	67%	3.8%
New wood burners (post-2005)	1,371	6%	1.9%
Multifuel total	1,253	5%	1.7%
Open fire total	3,758	14%	2.7%
Pellet Fire	179	0.7%	0.6%

2001	Census/Survey	% Burners	Margin error
Total HH	50,022		
Total wood	25,602		
Total wood burners	19,061	74%	5.0%
Old wood burners (pre-1991)	8,076	42%	5.7%
Old wood burners (1991-2005)	10,986	58%	5.7%
New wood burners (post-2005)	0		
Multifuel total	2,418	9%	3.4%
Open fire total	4,122	16%	4.2%
Pellet Fire	0		-

Appendix C PM_{10} emission estimates from wood burning

	2001			2006		
PM_{10} (t/yr)	**Airshed**	**Rural**	**Region**	**Airshed**	**Rural**	**Region**
Pre-1991	429	136	565	280	106	386
Post -1991	584	185	768	619	240	860
Post - 2005	0	0	0	22	9	30
Multifuel	94	41	135	74	24	98
Open	340	54	394	297	50	346
Pellet	0	0	0	0	0	0
Total Wood	1447	415	1862	1292	429	1721
	2007			**2011**		
PM_{10} (t/yr)	**Airshed**	**Rural**	**Region**	**Airshed**	**Rural**	**Region**
Pre-1991	250	100	350	193	82	276
Post -1991	627	252	878	521	221	742
Post - 2005	26	10	36	97	42	138
Multifuel	70	21	91	60	12	72
Open	288	49	337	198	46	244
Pellet	1	0	1	1	0	1
Total Wood	1261	432	1693	1070	403	1473
	2012			**2016**		
PM_{10} (t/yr)	**Airshed**	**Rural**	**Rural**	**Airshed**	**Rural**	**Region**
Pre-1991	179	77	257	123	59	182
Post -1991	494	213	708	389	183	571
Post - 2005	115	49	164	186	81	266
Multifuel	58	10	68	45	0	45
Open	176	45	221	116	42	158
Pellet	1	0	1	1	0	1
Total Wood	1023	396	1418	859	365	1224

Appendix D Emission factors

Emission factors used for this 2016 inventory are shown in Table 2-3. To promote consistency with other inventories in New Zealand, the emission factors used in this 2016 inventory have been updated to be generally consistent with emission factors from the *Home heating emission inventory and other sources evaluation* report prepared for MfE (Wilton *et al.,* 2015). The only exceptions are open fire emission factors, which are discussed later in this section and emission factors for pollutants and fuel types that were not included in Wilton *et al.,* 2015. The basis for these emission factors is summarised as follows:

- Emission factors for PM_{10}, $PM_{2.5}$, CO, NOx and SO_2 for wood burners. Multifuel burners and pellet burners are from Wilton *et al.,* 2015.
- Open fire emission factors, and emission factors for VOC and CO_2 from wood and coal are the same as the 2006 domestic fire emissions inventory (Auckland Regional Council, 2010b).
- Emission factors for LPG and natural gas were the same as those reported in the 2006 Auckland air emissions inventory (Auckland Council, 2014a).

Open fire emission factors

The open fire emission factor used in this inventory is consistent with the emission factor from the previous Auckland inventory (Auckland Council, 2010b). The PM_{10} emission factor (12 g/kg) is significantly higher than the emission factor (7.5 g/kg) used in the *Home heating emission inventory and other sources evaluation* report prepared for MfE (Wilton *et al.,* 2015).

The open fire emission factors used in the previous Auckland inventory were based on a review of AP42 emission factors published for an emissions inventory in the United States (Houck and Eagle, 2006).

Houck and Eagle (2006) emission factor (dry weight) is 15.27 g/kg for fireplaces without inserts burning cordwood. This is comparable to an open fire. For the 2006 Auckland inventory, the Houck and Eagle fireplace factor was divided by 1.2 to convert to a wet wood basis (assuming 20% wood moisture content).

The Houck and Eagle (2006) emission factor (dry weight) for uncertified conventional cordwood heaters is 16.9 g/kg. This appliance type is broadly equivalent to old wood burners in this inventory. So, according to this US study, emission factors for open fires were similar to emission factors from older wood burners.

Open fire emission factors are also similar to wood burner emission factors in published European guidance. The EMEP/EEA guidebook (EEA, 2016) PM_{10} default emission factor for open fireplaces is 840g/GJ (or approximately 12.3g/kg wet weight[9]) compared to the PM_{10} emission factor for conventional wood stoves of 760g/GJ (or approximately 11.1 g/kg wet weight[10]).

While US and European emission factors may not be directly comparable or applicable in New Zealand, the relative emission factor for different burner types are relevant.

The *Home heating emission inventory and other sources evaluation* report prepared for MfE (Wilton *et al.,* 2015) uses an open fire emission factor of 7.5g/kg (wet weight). This is based on limited testing undertaken in New Zealand. This factor is significantly lower than the New Zealand emission factor for conventional (older) wood burners of 10 g/kg (wet weight). The emission factor is also significantly lower than published emission factors for open fires from the US as well as Europe.

New Zealand sources of emission factors should be used wherever possible. However, there is very limited test data for open fires in New Zealand. At this stage, the open fire emission factor has not been changed to the New Zealand factor of 7.5g/kg because this is substantially lower than published international emission factors for open fires.

The New Zealand emission factor of 7.5g/kg is also significantly lower than the New Zealand emission factor for conventional wood burners of 10g/kg. This assumption that open fires have lower emissions (per kg of fuel burnt) compared with a conventional wood burner is not consistent with published emission factors from US or European literature.

[9] Calculated using the EMEP/EEA default net calorific value of 14.6 MJ/kg for partially air dried wood with a moisture content of 20%.

[10] Calculated using the EMEP/EEA default net calorific value of 14.6 MJ/kg for partially air dried wood with a moisture content of 20%.

Appendix E Emission factors and assumptions for air toxics

Arsenic

Burning of treated timber occurs to some extent in Auckland. To estimate arsenic emissions, an emission factor of 278 mg/kg was used (min 255, max 427), this being the mid-point between two experimental studies into emissions from the combustion of treated wood in New Zealand (Mitchell, 2015).

Mitchell further found from a home heating survey in Masterton that 16-17% of households *sometimes* burn treated timber and that 5% *always* burn treated timber. Auckland research shows that 17% of households burn timber offcuts (Auckland Council, 2014b). For this estimate, it was assumed that 5% of all wood burnt was CCA treated timber.

Untreated timber also contains arsenic which, when burnt, is emitted to air. The EMEP/EEA emission factor for arsenic from all wood burners was used to estimate emissions of arsenic from untreated timber (i.e. the remaining 95% of timber burnt). The EMEP/EEA emission factor for arsenic from residential wood combustion is 3.4 µg/kg (95% CI 0.9, 216).

Based on these emission factors, a 5% treated timber consumption rate and fuel use estimates in Section 2, Auckland regional emissions of arsenic from home heating in 2016 were estimated at approximately 2.1 tonnes per year. This has a high level of uncertainty because the amount of treated timber that is burnt each year is not known.

Mercury

Mercury occurs naturally in wood as a result of uptake from the soil and deposition from the atmosphere (from natural and anthropogenic emissions).

Graham and Ducker (2013) estimated that mercury from domestic wood combustion in New Zealand ranged from 0.007-0.07 mg/kg. A mid-point was used in this estimate to establish an emission factor of 39 µg/kg mercury from domestic home heating.

Based on this emission factor, the number of burners and fuel use estimates in Section 2, Auckland regional emissions of mercury from home heating in 2016 were estimated at approximately 5.9 (low 1.1, high 11) kilogrammes per year.

This estimate has a low uncertainty rating because it is based on an emission factor from an international toolkit. For comparison the national estimate of mercury arising from home heating is 12.6 - 126 kilogrammes per year (Graham and Ducker, 2013).

Benzo(ay)pyrene

Benzo(a)pyrene is known to exceed national guidelines in other urban areas of New Zealand (e.g. MfE, 2003).

The EMEP/EEA emission factors for benzo(y)pyrene are (EEA, 2016):

- wood burners 2.2 mg/kg (95% CI 0.22, 22)
- pellet burners 0.19 mg/kg (95% CI 0.1, 0.38).

Based on these emission factors, the number of burners and fuel use estimates in Section 2, Auckland regional emissions of benzo(a)pyrene from home heating in 2016 were estimated at approximately 280 kilogrammes per year (95% CI 28, 2,800).

Dioxins and furans

Incomplete combustion of organic material in the presence of chlorine causes the formation of chlorinated organic by-products, such as polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The EMEP/EEA guidebook includes emission factors for dioxins and furans as follows:

- conventional wood stove 14 ng/kg (95% CI 0.4, 90)
- high efficiency wood stove 4.5 ng/kg (95% CI 0.4, 47)
- advanced/ ecolabel wood stove and pellet burners 1.8 ng/kg (95% CI 0.5, 9.0).

For this assessment it was assumed that a conventional wood stove is equivalent to an old wood burner, that a high efficiency wood stove is equivalent to a new (post-2005) burner.

Based on these emission factors, the number of burners and fuel use estimates in Section 2, Auckland regional emissions of dioxins and furans from home heating in 2016 were estimated at approximately 0.74 grams I-TEQ (International Toxic Equivalents) per year (95% CI 0.05, 5.4).

For comparison, the national estimate of dioxin emissions to air from all sources in 2008 was 32.28 grams I-TEQ per year. The national estimate of dioxin emissions to air from domestic wood burning for 2008 was 0.84 grams per year (MfE, 2011). This estimate of national emissions was relatively low compared to the estimate of regional emissions in this 2016 inventory because the emission factor adopted for domestic wood combustion in the national inventory was comparatively low, and was equivalent to the EMEP/EEA factor (used in this assessment) for advanced/ecolabel wood stoves and pellet burners.

NB: Research indicates that emissions of dioxins and furans from the combustion of contaminated wood were often considerably higher (Hedman *et al*., 2006). The above estimates do not take burning of treated timber into consideration.

Appendix F Projection to 2016

As described in Section 3.5, the burner numbers projection was based on the annual change in estimated burner numbers from survey results. The annual change in the number of wood burning appliance numbers from 2001 to 2012 and from 2007 to 2012 is summarised in Table F-1 and Table F-2. The appliance numbers for each year were estimated as described in Section 3.4.

Open fires and multifuel burners

The burner numbers projection was based on the assumption that the rate of retirement of open fires and multifuel burners stays constant based on the estimated rate of retirement between 2001 and 2012 (as shown in Table F-1 and F-2). This assumption was considered reasonable for open fires and multifuel burners because:

- Trends between surveys have shown consistent reduction in the number of open fires and multifuel appliances. There is no reason to expect that these trends will change in the short term.
- New installations of burners that cannot meet an emission limit[11] are not allowed in Auckland urban areas. Open fires and multifuel burners cannot meet the emission limit so it is expected that the number of open fires and multifuel burners will continue to decline.
- The rate of retirement of open fires and multifuel burners was reasonably consistent between 2001 and 2007 compared with 2007 and 2012, except that the rate of open fire retirements in the Auckland Urban Airshed was significantly higher between 2007 and 2012. For conservatism, the projected retirement rate was based on the average rate between 2001 and 2012.

Wood burners

The number of wood burner installations and removals in the business as usual projection were based on the average number of removals and installations between 2007 and 2012 (as shown in Table F-1 and Table F-2). For wood burners, this assumption that current trends will continue is relatively crude. For example:

- The projection does not account for the proportion of burners that are installed to replace old open fires or multifuel burners. This means that the rate of installation of new wood burners may decline as the population (and rate of retirement) of these older burners declines.

[11] The Auckland Quality Bylaw for Indoor Domestic Fires 2017 specifies that new indoor domestic fires in the Auckland urban air quality area must comply with a particulate emission rate of 4.0 grams per kilogram of fuel burned.

- The projections do not account for the proportion of burners that are installed in new dwellings. This means that the growth in burner numbers could change if the population growth rate and/or the proportion of new dwellings with wood burners changes significantly.

However, the assumption that current trends (in wood burner installation rates) will continue was considered reasonable for this short term projection.

Table F-1: Auckland Urban Airshed estimates of the annual change in appliance numbers by type and age from 2001 to 2012, and from 2007 to 2012.

Burner type and age	2001	2007	2012	Δ/yr 07-12	Δ/yr 01-12
	Number of burners			Burners/year[1,2]	
Old wood burners	60,280	52,174	40,114	-2412	-1833
New (post 2005) wood burners	0	3413	15151	2348	1377
Multifuel	5,605	4173	3454	-144	-196
Open fire	26,122	22090	13471	-1724	-1150
Pellet Fire	0	668	1036	74	94

Notes

1. Numbers shown in black font were used in the projection.
2. Δ 2001 - 2012 not useful for wood burners because this includes times when the number of old woodburners was increasing (up to 2005) as well as decreasing (from 2006 onwards).

Table F-2: Rural Auckland (area outside the Auckland Urban Airshed): estimates of the annual change in appliance numbers by type and age from 2001 to 2012, and from 2007 to 2012.

Burner type and age	2001	2007	2012	Δ/yr 07-12	Δ/yr 01-12
	Number of burners			Burners/year[1,2]	
Old wood burners	19,061	20,956	17,314	-728	-159
New (post 2005) wood burners	0	1,371	6,540	1034	595
Multifuel	2,418	1,253	582	-134	-167
Open fire	4,122	3,758	3,491	-54	-57
Pellet Fire	0	0	0	0	0

Notes

1. Numbers shown in black font were used in the projection.
2. Δ 2001 - 2012 not useful for wood burners because this includes times when the number of old woodburners was increasing (up to 2005) as well as decreasing (from 2006 onwards).
3. Pellet burners were assumed to be zero for all years because sample sizes in all surveys were too small to indicate any trend.

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