Technical Report No. 4

Air Emissions Inventory for the Greater Metropolitan Region in New South Wales

2008 Calendar Year

Domestic-Commercial Emissions: Results

NSW EPA

ACKNOWLEDGMENTS

This study was performed with the help of organisations and individuals who should be recognised for their efforts.

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EXECUTIVE SUMMARY

An air emissions inventory project for domestic-commercial sources has taken over 2 years to complete. The base year of the domestic-commercial inventory represents activities that took place during the 2008 calendar year and is accompanied by emission projections in yearly increments up to the 2036 calendar year. The area included in the inventory covers the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The inventory region defined as the GMR measures 210 km (east–west) by 273 km (north–south). The inventory region is presented in Table ES-1 and shown in Figure ES-1.

Table ES-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA[1] coordinates		North-east corner MGA coordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

The domestic-commercial air emissions inventory includes emissions from the following sources/activities:

- Aerosols and solvents (domestic and commercial);
- Barbecues (domestic);
- Cutback bitumen;
- Gaseous fuel combustion (domestic and unaccounted);
- Graphic arts (domestic and commercial);
- Lawn mowing and garden equipment (domestic and public open space);
- Liquid fuel combustion (domestic);
- Natural gas leakage;
- Portable fuel containers (domestic and public open space);
- Solid fuel combustion (domestic); and

[1] Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2006).

- Surface coatings (domestic, commercial and industrial).

The pollutants inventoried include criteria pollutants specified in the Ambient Air Quality NEPM (NEPC, 2003), air toxics associated with the National Pollutant Inventory NEPM (NEPC, 2008) and the Air Toxics NEPM (NEPC, 2004), and any other pollutants associated with state-specific programs, i.e. Load Based Licensing (Protection of the Environment Operations (General) Regulation 2009 (PCO, 2010b)) and the Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011).

Figure ES-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Table ES-2 presents total estimated annual emissions (for selected substances) from all domestic-commercial sources in the whole GMR and the Sydney, Newcastle and Wollongong regions. Total estimated annual emissions are also presented for the region defined as Non Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. The selected substances were chosen because they:

- Are the most common air pollutants found in airsheds, according to the National Pollutant Inventory NEPM (NEPC, 2008);
- Are referred to in the NEPMs for ambient air quality (NEPC, 2003) and air toxics (NEPC, 2004); and
- Have been classified as priority air pollutants (NEPC, 2006).

Table ES-2: Total estimated annual emissions from domestic-commercial sources in each region

Substance	Emissions (tonne/year)				
	Newcastle	Non Urban	Sydney	Wollongong	GMR
1,3-BUTADIENE	7.19	18	89	4.81	119
ACETALDEHYDE	18	44	215	12	289
BENZENE	47	116	585	31	779
CARBON MONOXIDE	6,554	16,226	82,186	4,412	109,377
FORMALDEHYDE	43	109	528	29	709
ISOMERS OF XYLENE	187	453	2,657	133	3,430
LEAD & COMPOUNDS	6.79×10^{-2}	0.17	0.83	4.53×10^{-2}	1.12
OXIDES OF NITROGEN	184	445	2,531	130	3,290
PARTICULATE MATTER ≤ 10 µm	504	1,262	6,088	334	8,189
PARTICULATE MATTER ≤ 2.5 µm	485	1,214	5,853	321	7,873
PERCHLOROETHYLENE	4.67	12	73	3.44	92
POLYCYCLIC AROMATIC HYDROCARBONS	14	35	186	9.59	244
SULFUR DIOXIDE	11	26	131	7.07	175
TOLUENE	185	449	2,619	131	3,384
TOTAL SUSPENDED PARTICULATE	539	1,348	6,501	357	8,745
TOTAL VOLATILE ORGANIC COMPOUNDS	3,757	9,213	53,178	2,660	68,809
TRICHLOROETHYLENE	0.28	0.69	4.38	0.21	5.56

Figure ES-2 shows the proportions of total estimated annual emissions (for selected substances) from domestic-commercial sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions.

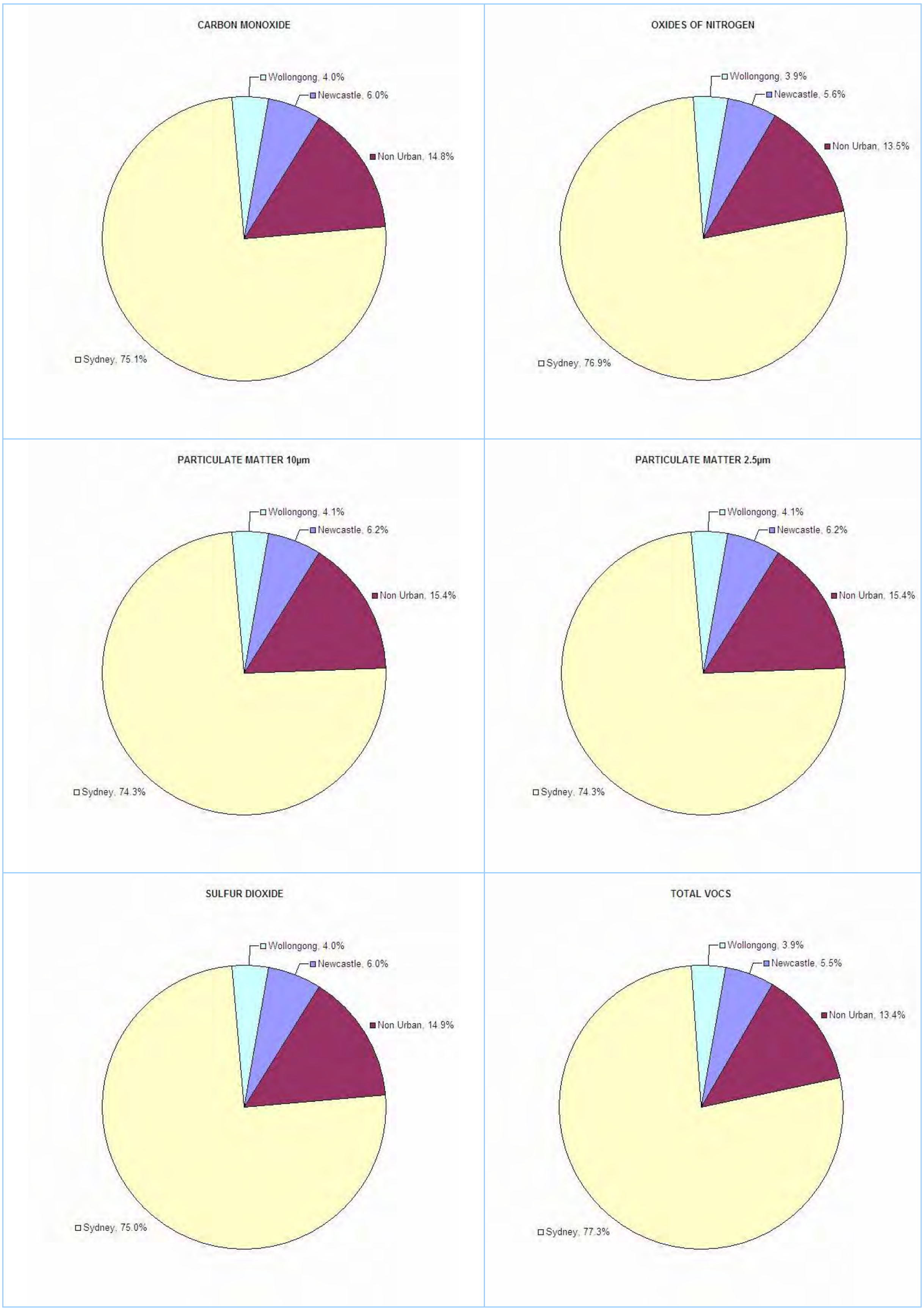

Figure ES-2: Proportions of total estimated annual emissions from domestic-commercial sources in each region

Table ES-3, Table ES-4, Table ES-5, Table ES-6 and Table ES-7 present total estimated annual emissions (for selected substances) from each domestic-commercial source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Figure ES-3, Figure ES-4, Figure ES-5, Figure ES-6 and Figure ES-7 show the proportions of total estimated annual emissions (for selected substances) from each domestic-commercial source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Table ES-3: Total estimated annual emissions by domestic-commercial source type in the GMR

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	1.25	-	-	-	44	-	-	-	73	-	119
ACETALDEHYDE	-	18	-	2.78×10^{-4}	-	27	7.54×10^{-3}	-	-	243	0.27	289
BENZENE	1.13×10^{-2}	4.10	-	4.40×10^{-2}	-	389	3.23×10^{-4}	-	17	369	-	779
CARBON MONOXIDE	-	520	-	861	-	54,003	7.70	-	-	53,985	-	109,377
FORMALDEHYDE	12	13	-	1.57	-	70	5.17×10^{-2}	-	-	612	9.07×10^{-2}	709
ISOMERS OF XYLENE	681	0.84	21	-	80	1,167	1.57×10^{-4}	-	12	57	1,412	3,430
LEAD & COMPOUNDS	-	3.04×10^{-3}	-	1.05×10^{-2}	-	0.33	1.94×10^{-3}	-	-	0.77	-	1.12
OXIDES OF NITROGEN	-	100	-	1,996	-	356	28	-	-	811	-	3,290
PARTICULATE MATTER ≤ 10 µm	-	34	-	159	-	347	3.66	-	-	7,645	-	8,189
PARTICULATE MATTER ≤ 2.5 µm	-	31	-	159	-	320	3.28	-	-	7,359	-	7,873
PERCHLOROETHYLENE	92	4.83×10^{-5}	-	-	-	-	-	-	-	-	9.52×10^{-2}	92
POLYCYCLIC AROMATIC HYDROCARBONS	91	0.47	-	1.46×10^{-2}	7.30	3.53	1.84×10^{-3}	-	-	135	5.90	244
SULFUR DIOXIDE	-	11	-	13	-	10	11	-	-	129	-	175
TOLUENE	846	1.69	11	7.12×10^{-2}	10	1,134	8.91×10^{-3}	-	41	103	1,237	3,384
TOTAL SUSPENDED PARTICULATE	-	46	-	159	-	358	5.08	-	-	8,177	-	8,745
TOTAL VOLATILE ORGANIC COMPOUNDS	25,274	162	169	115	3,475	14,916	1.10	2,973	2,136	8,027	11,561	68,809
TRICHLOROETHYLENE	5.56	-	-	-	-	-	-	-	-	-	-	5.56

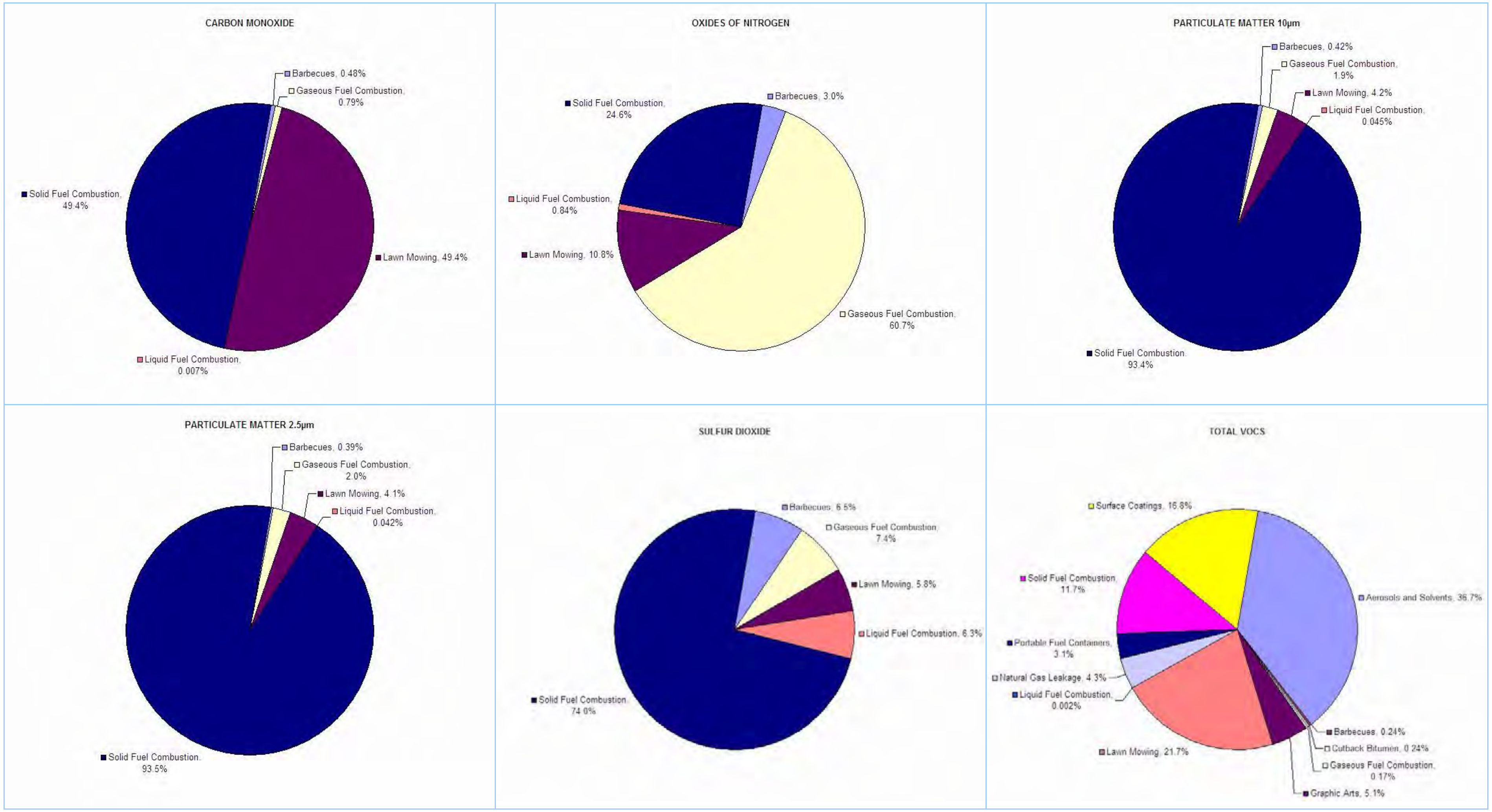

Figure ES-3: Proportions of total estimated annual emissions by domestic-commercial source type in the GMR

Table ES-4: Total estimated annual emissions by domestic-commercial source type in the Sydney region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	0.98	-	-	-	33	-	-	-	54	-	89
ACETALDEHYDE	-	14	-	2.17×10^{-4}	-	21	5.88×10^{-3}	-	-	180	0.21	215
BENZENE	8.91×10^{-3}	3.20	-	3.43×10^{-2}	-	295	2.52×10^{-4}	-	12	274	-	585
CARBON MONOXIDE	-	406	-	671	-	41,069	6.00	-	-	40,034	-	82,186
FORMALDEHYDE	9.08	9.76	-	1.22	-	53	4.03×10^{-2}	-	-	454	7.07×10^{-2}	528
ISOMERS OF XYLENE	536	0.65	16	-	63	890	1.22×10^{-4}	-	8.74	42	1,101	2,657
LEAD & COMPOUNDS	-	2.37×10^{-3}	-	8.16×10^{-3}	-	0.25	1.51×10^{-3}	-	-	0.57	-	0.83
OXIDES OF NITROGEN	-	78	-	1,556	-	275	22	-	-	601	-	2,531
PARTICULATE MATTER ≤ 10 µm	-	27	-	124	-	265	2.86	-	-	5,669	-	6,088
PARTICULATE MATTER ≤ 2.5 µm	-	24	-	124	-	245	2.56	-	-	5,457	-	5,853
PERCHLOROETHYLENE	73	3.77×10^{-5}	-	-	-	-	-	-	-	-	7.42×10^{-2}	73
POLYCYCLIC AROMATIC HYDROCARBONS	72	0.37	-	1.14×10^{-2}	5.75	2.68	1.43×10^{-3}	-	-	100	4.60	186
SULFUR DIOXIDE	-	8.91	-	10	-	7.71	8.52	-	-	96	-	131
TOLUENE	666	1.32	8.48	5.55×10^{-2}	8.21	863	6.95×10^{-3}	-	30	76	965	2,619
TOTAL SUSPENDED PARTICULATE	-	36	-	124	-	273	3.96	-	-	6,064	-	6,501
TOTAL VOLATILE ORGANIC COMPOUNDS	19,905	126	132	90	2,737	11,317	0.86	2,318	1,589	5,952	9,012	53,178
TRICHLOROETHYLENE	4.38	-	-	-	-	-	-	-	-	-	-	4.38

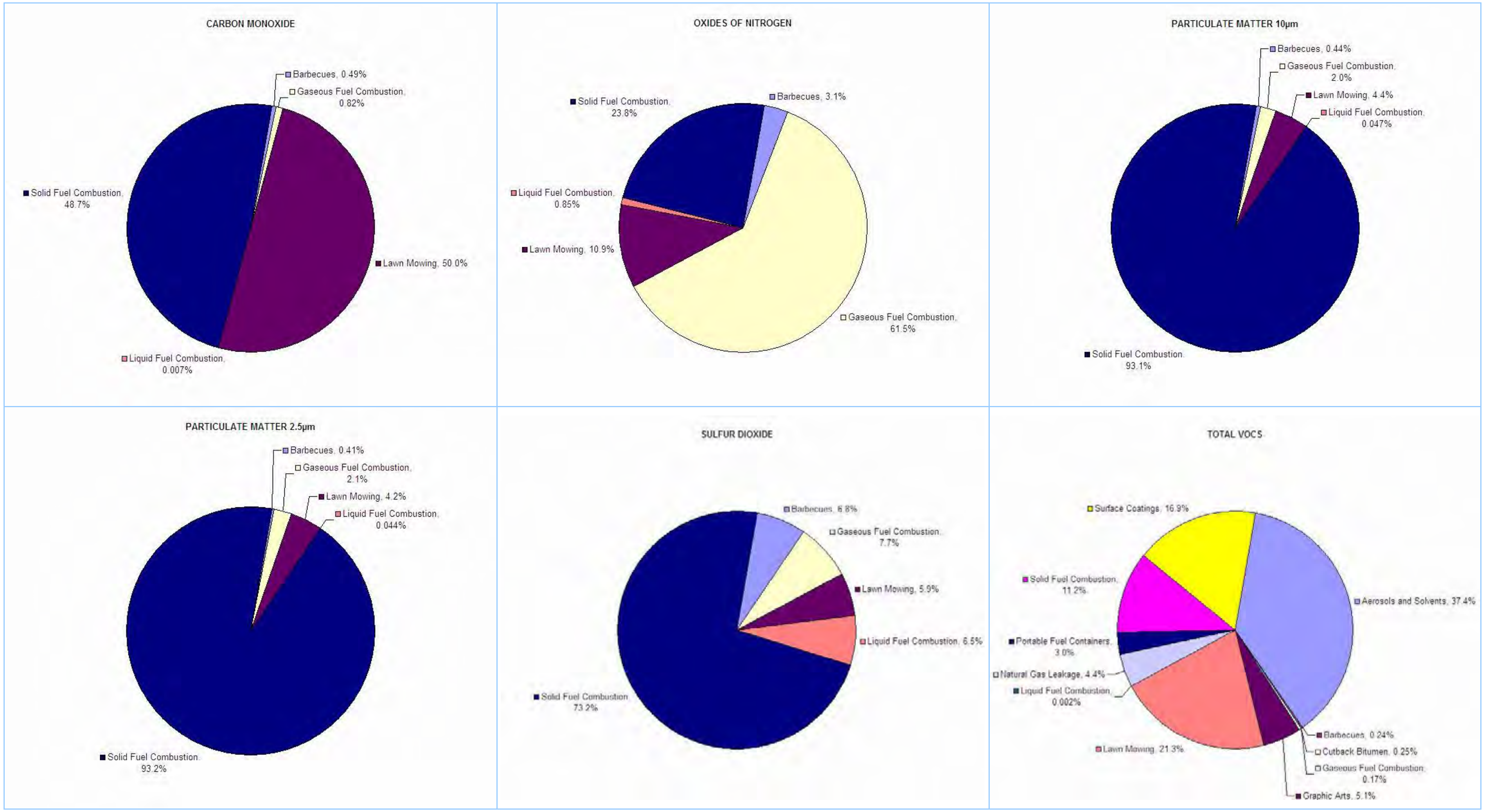

Figure ES-4: Proportions of total estimated annual emissions by domestic-commercial source type in the Sydney region

Table ES-5: Total estimated annual emissions by domestic-commercial source type in the Newcastle region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	6.74×10^{-2}	-	-	-	2.57	-	-	-	4.55	-	7.19
ACETALDEHYDE	-	0.98	-	1.50×10^{-5}	-	1.57	4.06×10^{-4}	-	-	15	1.46×10^{-2}	18
BENZENE	5.71×10^{-4}	0.22	-	2.36×10^{-3}	-	23	1.74×10^{-5}	-	1.02	23	-	47
CARBON MONOXIDE	-	28	-	46	-	3,134	0.41	-	-	3,345	-	6,554
FORMALDEHYDE	0.58	0.67	-	8.45×10^{-2}	-	4.10	2.78×10^{-3}	-	-	38	4.88×10^{-3}	43
ISOMERS OF XYLENE	34	4.50×10^{-2}	1.16	-	4.04	67	8.42×10^{-6}	-	0.72	3.53	76	187
LEAD & COMPOUNDS	-	1.63×10^{-4}	-	5.63×10^{-4}	-	1.92×10^{-2}	1.04×10^{-4}	-	-	4.79×10^{-2}	-	6.79×10^{-2}
OXIDES OF NITROGEN	-	5.35	-	107	-	20	1.49	-	-	50	-	184
PARTICULATE MATTER ≤ 10 µm	-	1.84	-	8.57	-	20	0.20	-	-	474	-	504
PARTICULATE MATTER ≤ 2.5 µm	-	1.65	-	8.57	-	18	0.18	-	-	456	-	485
PERCHLOROETHYLENE	4.66	2.60×10^{-6}	-	-	-	-	-	-	-	-	5.12×10^{-3}	4.67
POLYCYCLIC AROMATIC HYDROCARBONS	4.61	2.53×10^{-2}	-	7.86×10^{-4}	0.37	0.21	9.89×10^{-5}	-	-	8.38	0.32	14
SULFUR DIOXIDE	-	0.61	-	0.69	-	0.60	0.59	-	-	8.01	-	11
TOLUENE	43	9.11×10^{-2}	0.61	3.83×10^{-3}	0.53	66	4.79×10^{-4}	-	2.50	6.36	67	185
TOTAL SUSPENDED PARTICULATE	-	2.46	-	8.57	-	21	0.27	-	-	507	-	539
TOTAL VOLATILE ORGANIC COMPOUNDS	1,276	8.71	9.42	6.19	175	871	5.90×10^{-2}	160	131	497	622	3,757
TRICHLOROETHYLENE	0.28	-	-	-	-	-	-	-	-	-	-	0.28

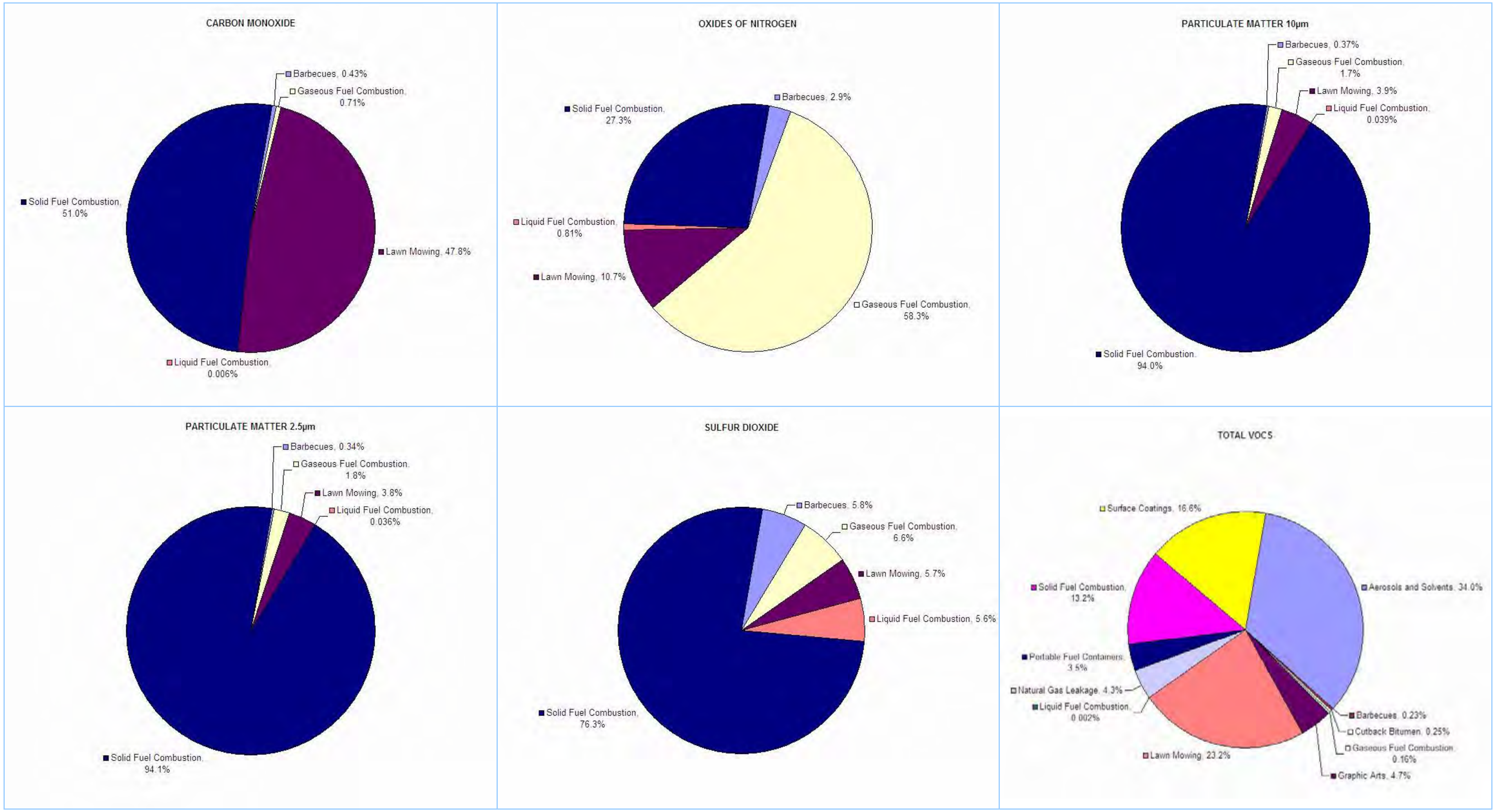

Figure ES-5: Proportions of total estimated annual emissions by domestic-commercial source type in the Newcastle region

Table ES-6: Total estimated annual emissions by domestic-commercial source type in the Wollongong region

Substance	Emissions (tonne/year)										
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	4.87×10^{-2}	-	-	-	1.76	-	-	-	3.00	-	4.81
ACETALDEHYDE	-	0.71	-	1.08×10^{-5}	-	1.08	2.93×10^{-4}	-	-	9.94	1.06×10^{-2}	12
BENZENE	4.21×10^{-4}	0.16	-	1.71×10^{-3}	-	16	1.26×10^{-5}	-	0.68	15	-	31
CARBON MONOXIDE	-	20	-	33	-	2,148	0.30	-	-	2,209	-	4,412
FORMALDEHYDE	0.43	0.49	-	6.10×10^{-2}	-	2.81	2.01×10^{-3}	-	-	25	3.53×10^{-3}	29
ISOMERS OF XYLENE	25	3.25×10^{-2}	0.66	-	2.97	46	6.09×10^{-6}	-	0.48	2.33	55	133
LEAD & COMPOUNDS	-	1.18×10^{-4}	-	4.07×10^{-4}	-	1.31×10^{-2}	7.54×10^{-5}	-	-	3.16×10^{-2}	-	4.53×10^{-2}
OXIDES OF NITROGEN	-	3.87	-	78	-	14	1.08	-	-	33	-	130
PARTICULATE MATTER ≤ 10 µm	-	1.33	-	6.19	-	14	0.14	-	-	313	-	334
PARTICULATE MATTER ≤ 2.5 µm	-	1.19	-	6.19	-	13	0.13	-	-	301	-	321
PERCHLOROETHYLENE	3.43	1.88×10^{-6}	-	-	-	-	-	-	-	-	3.70×10^{-3}	3.44
POLYCYCLIC AROMATIC HYDROCARBONS	3.39	1.83×10^{-2}	-	5.68×10^{-4}	0.27	0.14	7.15×10^{-5}	-	-	5.53	0.23	9.59
SULFUR DIOXIDE	-	0.44	-	0.50	-	0.41	0.42	-	-	5.29	-	7.07
TOLUENE	31	6.58×10^{-2}	0.34	2.77×10^{-3}	0.39	45	3.46×10^{-4}	-	1.66	4.20	48	131
TOTAL SUSPENDED PARTICULATE	-	1.77	-	6.19	-	14	0.20	-	-	335	-	357
TOTAL VOLATILE ORGANIC COMPOUNDS	940	6.29	5.35	4.48	129	595	4.27×10^{-2}	116	87	328	449	2,660
TRICHLOROETHYLENE	0.21	-	-	-	-	-	-	-	-	-	-	0.21

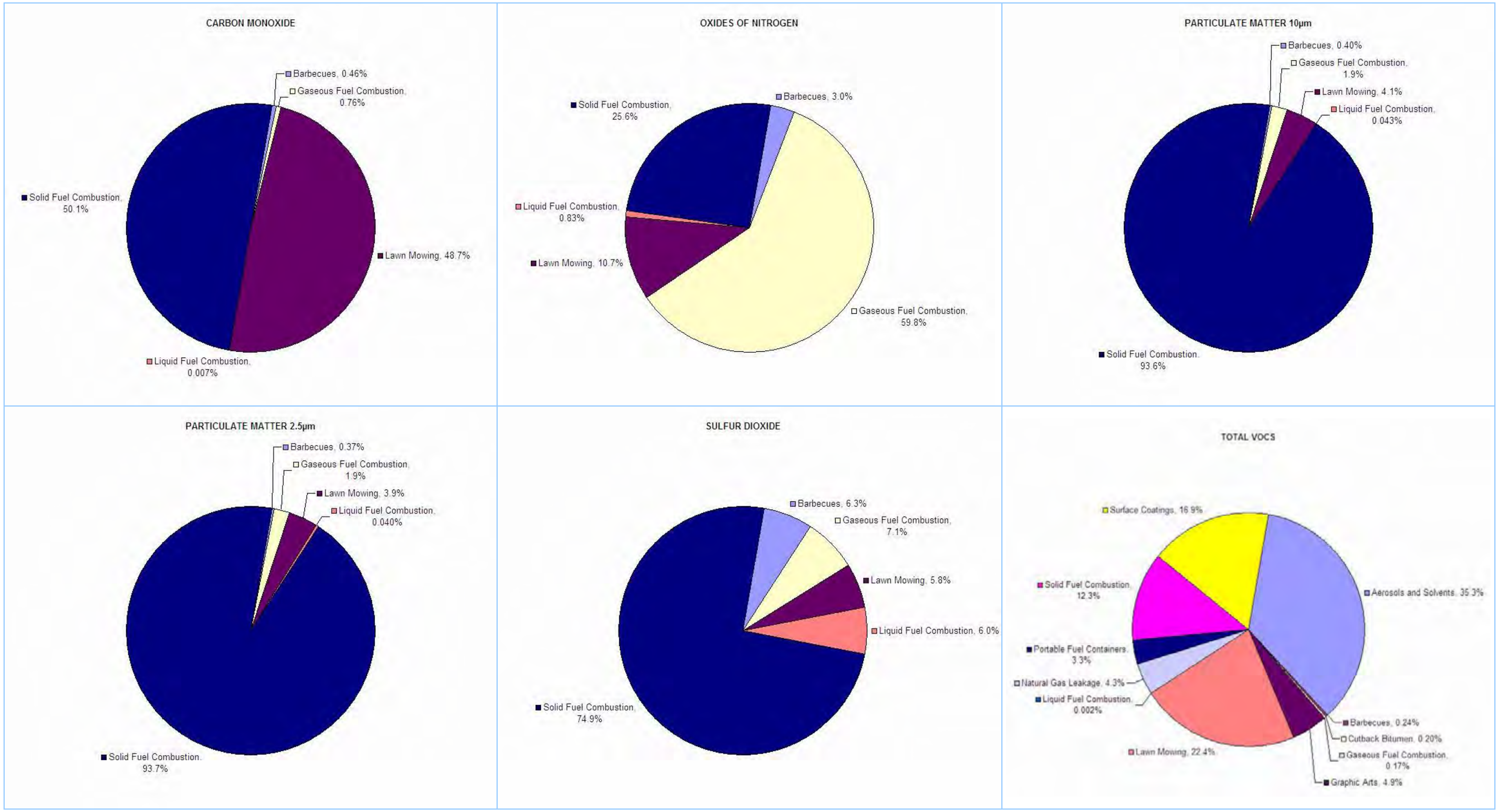

Figure ES-6: Proportions of total estimated annual emissions by domestic-commercial source type in the Wollongong region

Table ES-7: Total estimated annual emissions by domestic-commercial source type in the Non Urban region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	0.16	-	-	-	6.30	-	-	-	11	-	18
ACETALDEHYDE	-	2.33	-	3.56×10^{-5}	-	3.81	9.65×10^{-4}	-	-	38	3.48×10^{-2}	44
BENZENE	1.41×10^{-3}	0.52	-	5.62×10^{-3}	-	55	4.13×10^{-5}	-	2.56	57	-	116
CARBON MONOXIDE	-	67	-	110	-	7,652	0.98	-	-	8,396	-	16,226
FORMALDEHYDE	1.44	1.60	-	0.20	-	10	6.61×10^{-3}	-	-	95	1.16×10^{-2}	109
ISOMERS OF XYLENE	85	0.11	2.73	-	9.98	164	2.0×10^{-5}	-	1.81	8.86	180	453
LEAD & COMPOUNDS	-	3.88×10^{-4}	-	1.34×10^{-3}	-	4.72×10^{-2}	2.48×10^{-4}	-	-	0.12	-	0.17
OXIDES OF NITROGEN	-	13	-	255	-	47	3.54	-	-	126	-	445
PARTICULATE MATTER ≤ 10 µm	-	4.38	-	20	-	48	0.47	-	-	1,189	-	1,262
PARTICULATE MATTER ≤ 2.5 µm	-	3.93	-	20	-	45	0.42	-	-	1,145	-	1,214
PERCHLOROETHYLENE	12	6.18×10^{-6}	-	-	-	-	-	-	-	-	1.22×10^{-2}	12
POLYCYCLIC AROMATIC HYDROCARBONS	11	6.0×10^{-2}	-	1.87×10^{-3}	0.91	0.51	2.35×10^{-4}	-	-	21	0.75	35
SULFUR DIOXIDE	-	1.46	-	1.65	-	1.47	1.40	-	-	20	-	26
TOLUENE	106	0.22	1.43	9.10×10^{-3}	1.30	160	1.14×10^{-3}	-	6.24	16	158	449
TOTAL SUSPENDED PARTICULATE	-	5.84	-	20	-	50	0.65	-	-	1,272	-	1,348
TOTAL VOLATILE ORGANIC COMPOUNDS	3,154	21	22	15	434	2,133	0.14	380	329	1,248	1,478	9,213
TRICHLOROETHYLENE	0.69	-	-	-	-	-	-	-	-	-	-	0.69

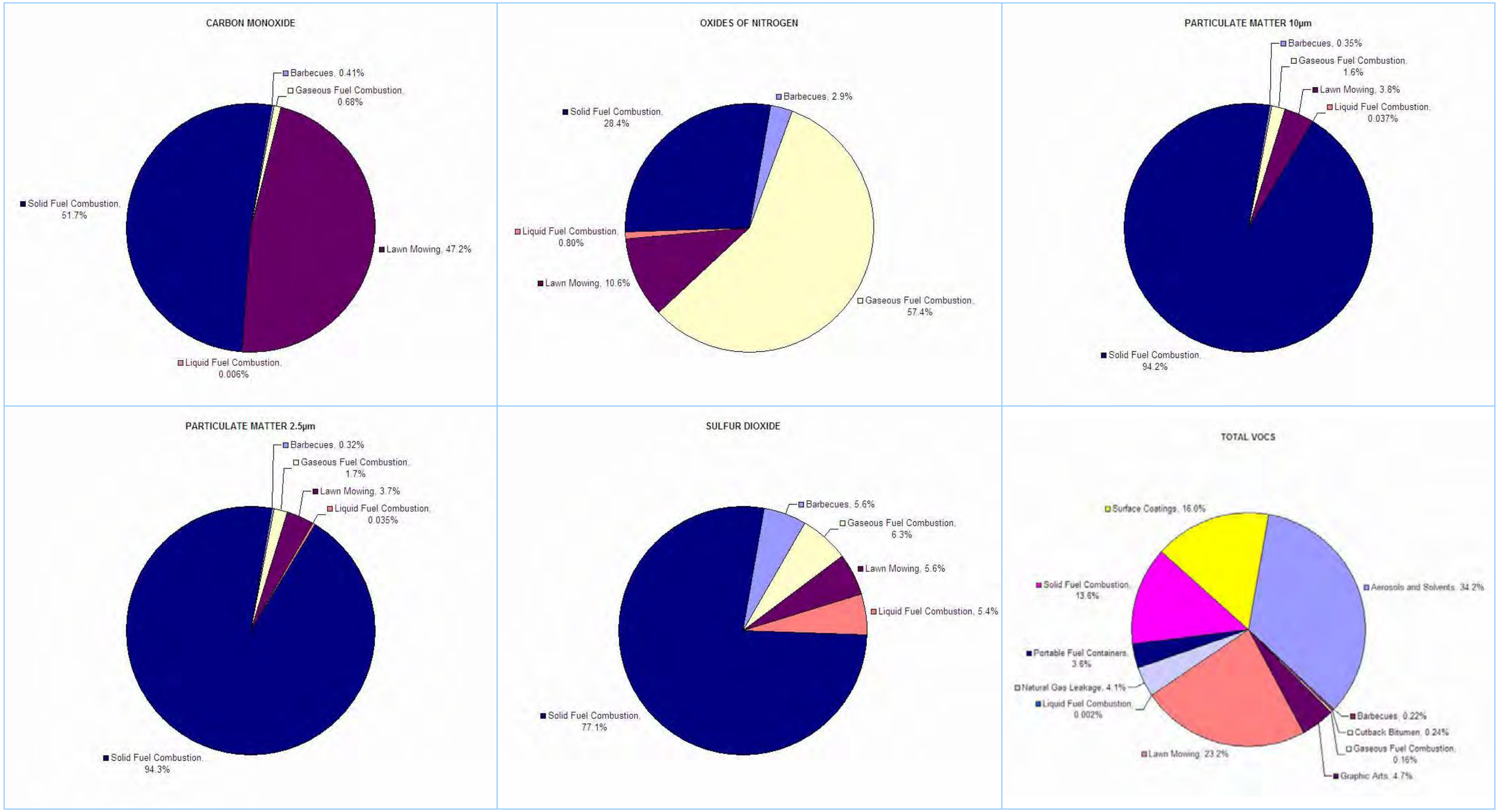

Figure ES-7: Proportions of total estimated annual emissions by domestic-commercial source type in the Non Urban region

Table ES-8 presents total estimated fuel consumption from all domestic-commercial sources in the GMR by volume and energy content.

Table ES-8: Total estimated annual fuel consumption from domestic-commercial sources by volume and energy content in the GMR

Fuel	Annual fuel consumption		
	Volume	Volume units	Energy content (TJ/year)
2-Stroke petrol	25,680	kL/year	878
4-Stroke petrol	39,736		1,359
Diesel	3,336		129
Heating oil	12,848		483
Kerosene	305		11
LPG	99,870		2,547
Natural gas	1,309	Mm^3/year	50,126
Charcoal	2,247	tonne/year	56
Wood	647,802		10,494

Figure ES-8 shows total estimated fuel consumption from all domestic-commercial sources in the GMR by energy content.

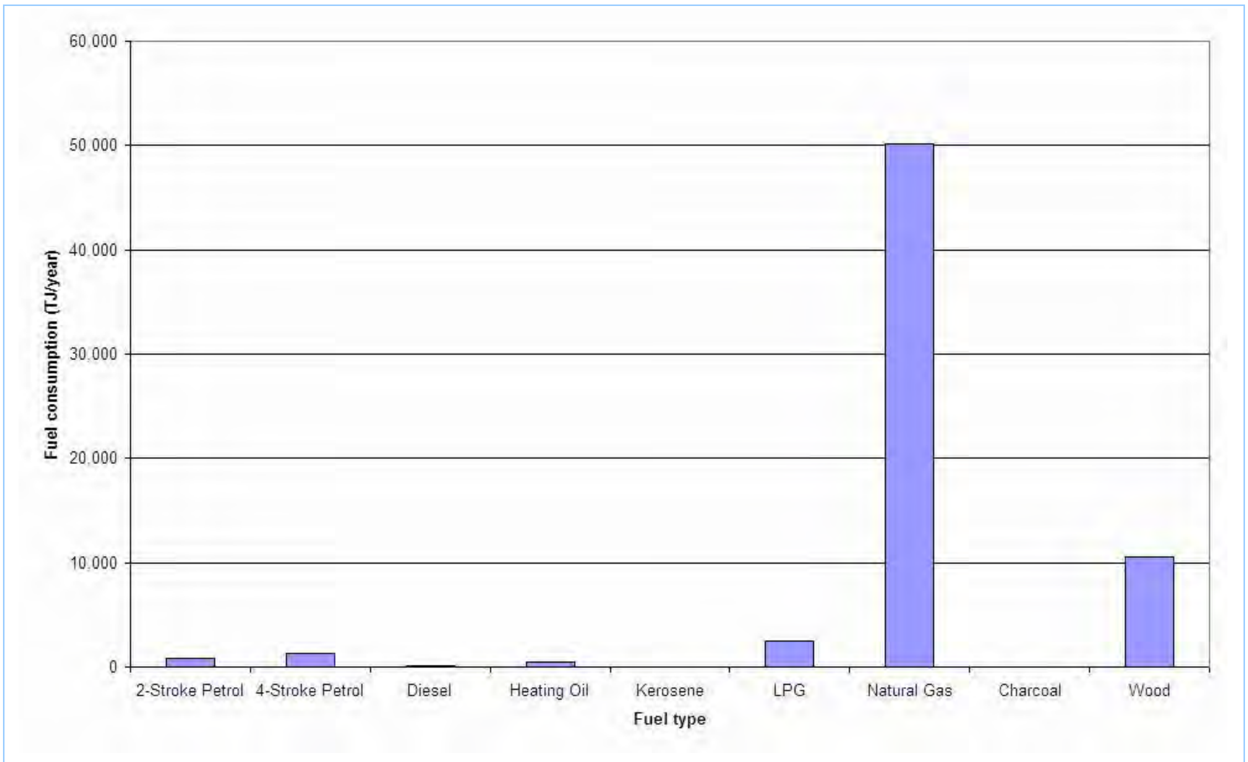

Figure ES-8: Total estimated annual fuel consumption from domestic-commercial sources by energy content in the GMR

Table ES-9 and Table ES-10 present total estimated fuel consumption by domestic-commercial source type in the GMR by volume and energy content, respectively. Figure ES-9 shows total estimated fuel consumption by domestic-commercial source type in the GMR by energy content.

Table ES-9: Total estimated annual fuel consumption by domestic-commercial source type and volume in the GMR

Source type	2-Stroke petrol	4-Stroke petrol	Diesel	Heating oil	Kerosene	LPG	Natural gas	Charcoal	Wood
	kL/year						Mm³/year	tonne/year	
Barbecues – briquettes	-	-	-	-	-	-	-	2,247	-
Barbecues – LPG and butane	-	-	-	-	-	49,885	-	-	-
Barbecues – natural gas	-	-	-	-	-	-	7	-	-
Barbecues – wood	-	-	-	-	-	-	-	-	1,285
Cutback bitumen	-	-	-	-	305	-	-	-	-
Lawn mowing (domestic) – petrol 2 stroke	15,665	-	-	-	-	-	-	-	-
Lawn mowing (domestic) – petrol 4 stroke	-	30,525	-	-	-	-	-	-	-
Lawn mowing (public open space) – diesel	-	-	3,336	-	-	-	-	-	-
Lawn mowing (public open space) – petrol 2 stroke	10,014	-	-	-	-	-	-	-	-
Lawn mowing (public open space) – petrol 4 stroke	-	9,212	-	-	-	-	-	-	-
Liquid fuel combustion (domestic)	-	-	-	12,848	-	-	-	-	-
LPG combustion (domestic)	-	-	-	-	-	49,984	-	-	-
Natural gas combustion (domestic)	-	-	-	-	-	-	508	-	-
Natural gas combustion (unaccounted commercial business equipment)	-	-	-	-	-	-	766	-	-
Natural gas leakage	-	-	-	-	-	-	28	-	-
Wood combustion – open fireplace	-	-	-	-	-	-	-	-	182,471
Wood combustion – pot belly stove	-	-	-	-	-	-	-	-	44,296
Wood combustion – slow combustion heater with AS[2]	-	-	-	-	-	-	-	-	292,435
Wood combustion – slow combustion heater without AS	-	-	-	-	-	-	-	-	127,314
Grand Total	25,680	39,736	3,336	12,848	305	99,870	1,309	2,247	647,802

[2] Appliances certified in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b).

Table ES-10: Total estimated annual fuel consumption by domestic-commercial source type and energy content in the GMR

Source type	Energy content (TJ/year)									
	2-Stroke petrol	4-Stroke petrol	Diesel	Heating oil	Kerosene	LPG	Natural gas	Charcoal	Wood	Grand Total
Barbecues – briquettes	-	-	-	-	-	-	-	56	-	56
Barbecues – LPG and butane	-	-	-	-	-	1,272	-	-	-	1,272
Barbecues - natural gas	-	-	-	-	-	-	252	-	-	252
Barbecues - wood	-	-	-	-	-	-	-	-	21	21
Cutback bitumen	-	-	-	-	11	-	-	-	-	11
Lawn mowing (domestic) - petrol 2 stroke	536	-	-	-	-	-	-	-	-	536
Lawn mowing (domestic) - petrol 4 stroke	-	1,044	-	-	-	-	-	-	-	1,044
Lawn mowing (public open space) - diesel	-	-	129	-	-	-	-	-	-	129
Lawn mowing (public open space) - petrol 2 stroke	342	-	-	-	-	-	-	-	-	342
Lawn mowing (public open space) - petrol 4 stroke	-	315	-	-	-	-	-	-	-	315
Liquid fuel combustion (domestic)	-	-	-	483	-	-	-	-	-	483
LPG combustion (domestic)	-	-	-	-	-	1,275	-	-	-	1,275
Natural gas combustion (domestic)	-	-	-	-	-	-	19,455	-	-	19,455
Natural gas combustion (unaccounted commercial business equipment)	-	-	-	-	-	-	29,332	-	-	29,332
Natural gas leakage	-	-	-	-	-	-	1,087	-	-	1,087
Wood combustion - open fire place	-	-	-	-	-	-	-	-	2,956	2,956
Wood combustion - pot belly stove	-	-	-	-	-	-	-	-	718	718
Wood combustion – slow combustion heater with AS[3]	-	-	-	-	-	-	-	-	4,737	4,737
Wood combustion – slow combustion heater without AS	-	-	-	-	-	-	-	-	2,062	2,062
Grand Total	878	1,359	129	483	11	2,547	50,126	56	10,494	66,084

[3] Appliances certified in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b).

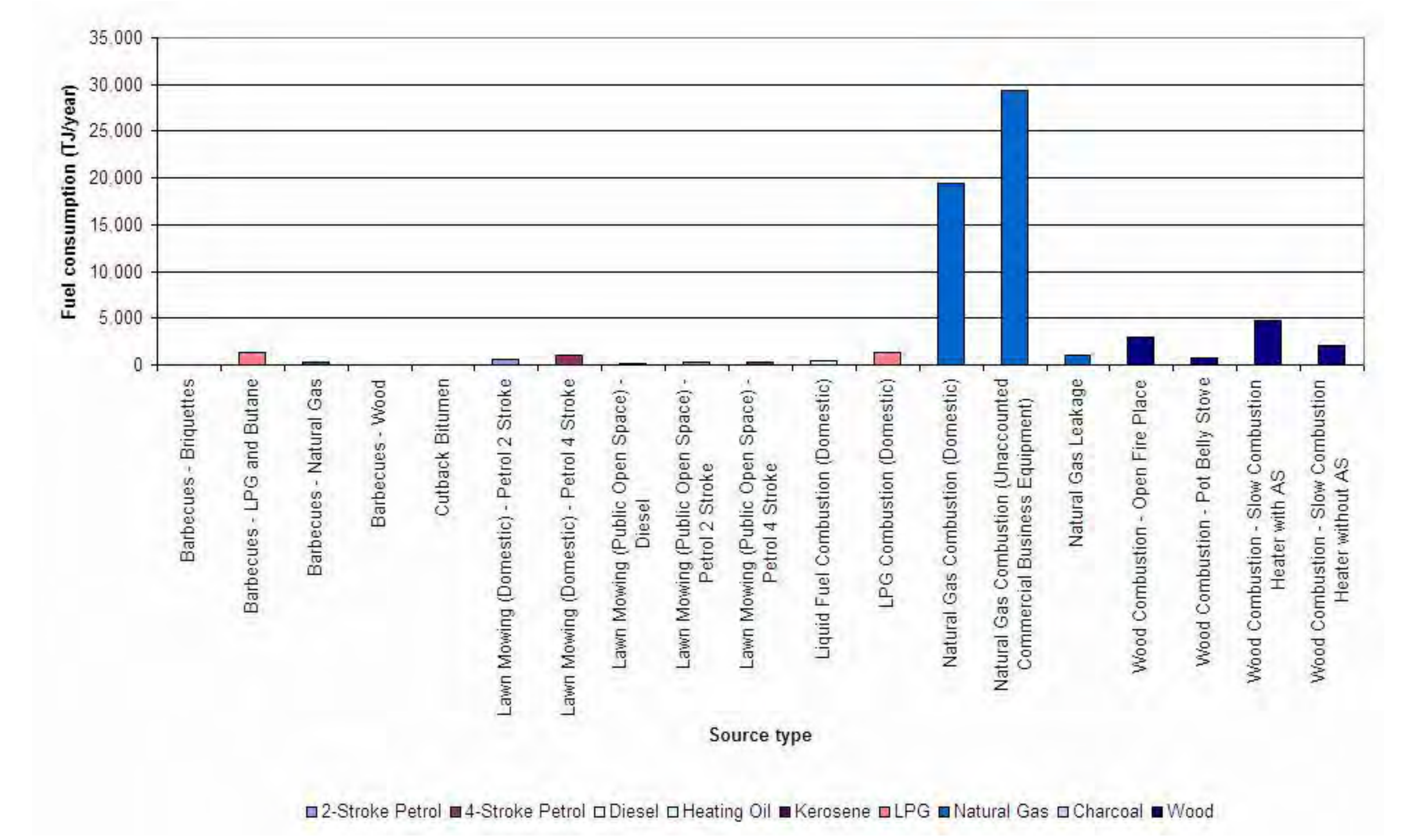

Figure ES-9: Total estimated annual fuel consumption by domestic-commercial source type and energy content in the GMR

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

An air emissions inventory project for domestic-commercial sources has taken over 2 years to complete. The base year of the domestic-commercial inventory represents activities that took place during the 2008 calendar year and is accompanied by emission projections in yearly increments up to the 2036 calendar year. The area included in the inventory covers the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The purpose of this document is to present the emission estimation methodologies and results of the domestic-commercial air emissions inventory. The information is structured as follows:

- A description of the domestic-commercial air emissions inventory specification (Section 2) including:
    - The inventory year (Section 2.1);
    - A description of the inventory region (Section 2.2);
    - A description of the grid coordinate system (Section 2.3);
    - A description of emission sources considered (Section 2.4);
    - A description of the pollutants evaluated (Section 2.5); and
    - A broad discussion of the methodology (Section 2.6).
- The emission estimation methodology; and activity, spatial, temporal and projection factor data presented by domestic-commercial source type (Section 3).
- An emission summary (for selected substances) presented by domestic-commercial source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions (Section 3).
- An emissions summary (for selected substances) presented for all domestic-commercial sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions (Section 4).
- A complete list of references (Section 5).
- Total domestic-commercial emissions of all substances emitted in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions (Appendix A: Estimated Annual Emissions of all Substances from Domestic-Commercial Sources).
- Domestic survey questionnaire form used to obtain activity data for barbecues, gaseous fuel combustion, domestic lawn mowing and garden equipment, liquid fuel combustion, domestic portable fuel containers and solid fuel combustion (Appendix B: Domestic Survey Form).

2 INVENTORY SPECIFICATIONS

2.1 The Inventory Year

The domestic-commercial air emissions inventory results presented in this report are based on activities that took place in the 2008 calendar year.

2.2 The Inventory Region

The inventory region defined as the GMR measures 210 km (east-west) by 273 km (north-south). The inventory region is presented in Table 2-1 and shown in Figure 2-1.

Table 2-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA[4] coordinates		North-east corner MGA coordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

[4] Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2006).

Figure 2-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

2.3 Grid Coordinate System

The grid coordinate system used for the domestic-commercial air emissions inventory uses 1 km by 1 km grid cells. The grid coordinates start from the bottom left corner having index number with

Easting (km) in the horizontal and Northing (km) in the vertical direction. The grid coordinate system is shown in Figure 2-2.

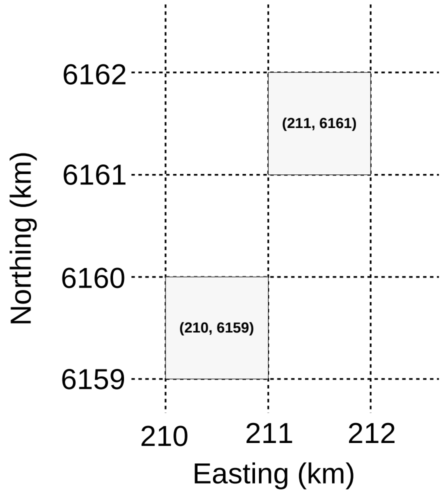

Figure 2-2: Grid coordinate system

2.4 Emission Sources Considered

The domestic-commercial air emissions inventory includes emissions from the following sources/activities:

- Aerosols and solvents (domestic and commercial);
- Barbecues (domestic);
- Cutback bitumen;
- Gaseous fuel combustion (domestic and unaccounted);
- Graphic arts (domestic and commercial);
- Lawn mowing and garden equipment (domestic and public open space);
- Liquid fuel combustion (domestic);
- Natural gas leakage;
- Portable fuel containers (domestic and public open space);
- Solid fuel combustion (domestic); and
- Surface coatings (domestic, commercial and industrial).

2.5 Pollutants Evaluated

The following pollutants have been considered:

- Substances included in the *National Environment Protection (National Pollutant Inventory) Measure* (NEPC, 2008);
- Pollutants included in the *National Environment Protection (Ambient Air Quality) Measure* (NEPC, 2003);
- Pollutants included in the *National Environment Protection (Air Toxics) Measure* (NEPC, 2004);
- Pollutants associated with the *Protection of the Environment Operations (Clean Air) Regulation 2010* (PCO, 2011);
- Air pollutants associated with the *Protection of the Environment Operations (General) Regulation 2009* (PCO, 2010b);
- Speciation of oxides of nitrogen (i.e. NO and NO_2) for photochemical modelling (USEPA, 2003)[5];
- Speciated organic compounds for photochemical modelling sourced from Carter (2010);
- Speciated particulate emissions (i.e. TSP (total suspended particulate), PM_{10} (particulate matter with an aerodynamic diameter ≤ 10 µm) and $PM_{2.5}$ (particulate matter with an aerodynamic diameter ≤ 2.5 µm));
- Environment Protection Authority of Victoria air toxic pollutants sourced from Hazardous Air Pollutants - A Review of Studies Performed in Australia and New Zealand (EPAV, 1999);
- Commonwealth Government Air Toxics Program Technical Advisory Group (13 March 2000) priority air pollutants (EA, 2001);
- U.S. Environmental Protection Agency list of 189 Hazardous Air Pollutants (USEPA, 2010a);
- Air pollutants included in the Office of Environmental Human Health Assessment (OEHHA)/Air Resources Board (ARB) 'hot spots' list (CARB, 2011);
- EPA regulated pollutants with design ground level concentrations (DEC, 2005);
- USEPA 16 priority polycyclic aromatic hydrocarbons (PAH) (Keith et. al., 1979);
- WHO97 polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF) and polychlorinated biphenyls (PCB) (Van den Berg et. al., 1998); and
- Greenhouse gases (i.e. carbon dioxide, methane and nitrous oxide) included in the National Greenhouse Accounts (NGA) Factors (DCCEE, 2010).

2.6 Methodology Overview

This section contains a broad overview of the methodology used to develop the domestic-commercial air emissions inventory, while specific details are provided in Section 3.

The methodology used to develop the domestic-commercial air emissions inventory involves the following steps:

[5] The default NO_x speciation profile used in the inventory is 95% NO and 5% NO_2.

2.6.1 *Identify Sources*

Domestic-commercial sources considered in this report include all sources defined in Section 2.4 with the potential for air emissions in the GMR.

Domestic-commercial air emission sources have been identified from a number of different sources including:

- *ARB's Emissions Inventory, Area-Wide Source Methodologies, Index of Methodologies by Major Category* (CARB, 2008a);
- *EMEP/EEA air pollutant emission inventory guidebook 2009* (EEA, 2009);
- *USEPA AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources* (USEPA, 1995a);
- *USEPA Emission Inventory Improvement Program, EIIP Technical Report Series, Volumes 1-10* (USEPA, 2007a);
- *USEPA 2008 National Emissions Inventory Data* (USEPA, 2011a); and
- *USEPA Nonroad Engines, Equipment, and Vehicles* (USEPA, 2011b).

2.6.2 *Select Emission Estimation Methodologies*

Emissions have been estimated by combining activity data with emission factors. The emissions have been allocated spatially to each 1 km by 1 km grid cell, and temporally to months, weekdays/weekend days and hours. Emissions have been estimated using estimation methodologies and emission factors sourced from references provided in Table 2-2.

Table 2-2: Domestic-commercial estimation methodologies and emission factor data

Source type	Methodology or substance	Estimation methodologies and emission factor source
Aerosols and solvents (domestic and commercial)	Methodology	- *Consumer and Commercial Solvent Use* (ERG, 1996a)
	Criteria pollutants: VOC	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c) - *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR Consulting, 2011)
	Speciated VOC	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Polycyclic aromatic hydrocarbons:	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Speciate 4.2 Database Development Documentation* (Pechan,

Source type	Methodology or substance	Estimation methodologies and emission factor source
	PAH	2009a)
Barbecues (domestic)	Methodology	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA, 1996a) - *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Criteria pollutants: TSP	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA, 1996a) - *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)

Source type	Methodology or substance	Estimation methodologies and emission factor source
		- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Metal air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Polycyclic aromatic hydrocarbons: PAH	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Ammonia	- *Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA,

Source type	Methodology or substance	Estimation methodologies and emission factor source
		1996a) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Cutback bitumen	Methodology	- *Asphalt Paving* (ERG, 2001) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Criteria pollutants: VOC	- *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Speciated VOC	- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Gaseous fuel combustion (domestic and unaccounted)	Methodology	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Criteria pollutants: TSP	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	Organic air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	Metal air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	Polycyclic aromatic hydrocarbons:	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and*

Source type	Methodology or substance	Estimation methodologies and emission factor source
	PAH	*Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Ammonia	- *Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
Graphic arts (domestic and commercial)	Methodology	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Solvent Usage – Other* (Pechan, 2009b)
	Criteria pollutants: VOC	- *Ink Manufacturing in Australia* (IBISWorld, 2008) - *Australian Demographic Statistics* (ABS, 2009) - *Graphic Arts* (ERG, 1996b) - *2008 Survey of EPA-Licensed Premises* (DECCW, 2009) - *2004 Survey of Commercial Businesses* (DECC, 2007a)
	Speciated VOC	- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Lawn mowing and garden equipment (domestic)	Methodology	- *Guidance for Estimating Lawn and Garden Equipment Activity Levels* (Environ, 1997)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009)
	Criteria pollutants: TSP	- *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)

Source type	Methodology or substance	Estimation methodologies and emission factor source
		- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Metal air toxics	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	Polycyclic aromatic hydrocarbons: PAH	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Ammonia	- *Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *NONROAD2008a Model* (USEPA, 2009) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)
Lawn mowing and garden equipment (public open space)	Methodology	- *Guidance for Estimating Lawn and Garden Equipment Activity Levels* (Environ, 1997)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009)
	Criteria pollutants: TSP	- *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Metal air toxics	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National*

Source type	Methodology or substance	Estimation methodologies and emission factor source
		Emissions Inventory, Volume I – Methodology (Pechan, 2005) - *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	Polycyclic aromatic hydrocarbons: PAH	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Ammonia	- *Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *NONROAD2008a Model* (USEPA, 2009) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)
Liquid fuel combustion (domestic)	Methodology	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Criteria pollutants: TSP	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Metal air toxics	- *Documentation for the Final 2002 NonPoint Sector (FEB 06*

Source type	Methodology or substance	Estimation methodologies and emission factor source
		version) National Emission Inventory for Criteria and Hazardous Air Pollutants (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Polycyclic aromatic hydrocarbons: PAH	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Ammonia	- *Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
Natural gas leakage	Methodology	- *National Greenhouse Accounts (NGA) Factors* (DCC, 2009a)
	Criteria pollutants: VOC	- *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b) - *NSW gas networks Performance report 2007-08* (DWE, 2009) - *NSW gas networks Performance report 2008-09* (II, 2009) - *National Greenhouse Accounts (NGA) Factors* (DCC, 2009a) - *National Greenhouse and Energy Reporting System Measurement, Technical Guidelines for the Estimation of Greenhouse Gas Emissions by Facilities in Australia* (DCC, 2009b)
	Speciated VOC	- *AGL Natural Gas, Chemwatch Material Safety Data Sheet* (AGL, 2008)
	Organic air toxics	- *Eastern Gas Pipeline Measurement Manual* (JEMENA, 2009c) - *Eastern Gas Pipeline Operations Manual* (JEMENA, 2009d)
Portable fuel containers (domestic)	Methodology	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b)
	Criteria pollutants: VOC	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b)

Source type	Methodology or substance	Estimation methodologies and emission factor source
		- *NONROAD2008a Model* (USEPA, 2009)
	Speciated VOC	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	Organic air toxics	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Portable fuel containers (public open space)	Methodology	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b)
	Criteria pollutants: VOC	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers* (PFCs) (USEPA, 2007b) - *NONROAD2008a Model* (USEPA, 2009)
	Speciated VOC	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	Organic air toxics	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Solid fuel combustion (domestic)	Methodology	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c)
	Criteria pollutants: CO, NO_x, PM_{10}, SO_2 and VOC	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c)
	Criteria pollutants: $PM_{2.5}$	- *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Criteria pollutants: TSP	- *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Speciated NOx	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000,*

Source type	Methodology or substance	Estimation methodologies and emission factor source
		Residential Wood Combustion and Wax Firelogs (Pechan, 2009c) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Metal air toxics	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b) - *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Polycyclic aromatic hydrocarbons: PAH	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Ammonia	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA, 1996a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b) - *Greenhouse Gases from Small-Scale Combustion Devices in Developing Countries: Phase IIA Household Stoves in India* (USEPA, 2000)
Surface coatings (domestic, commercial and industrial)	Methodology	- *Area-Wide Source Methodologies, Section 3.5, Coatings and Related Process Solvents Industrial Coatings* (CARB, 1997a) - *Area-Wide Source Methodologies, Section 3.6, Coatings and Related Process Solvents Thinning and Cleaning Solvents*

Source type	Methodology or substance	Estimation methodologies and emission factor source
		(CARB, 1997b) - *Area-Wide Source Methodologies, Section 6.3, Architectural Coatings* (CARB, 2003) - *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000)
	Criteria pollutants: VOC	- *Area-Wide Source Methodologies, Section 3.5, Coatings and Related Process Solvents Industrial Coatings* (CARB, 1997a) - *Area-Wide Source Methodologies, Section 3.6, Coatings and Related Process Solvents Thinning and Cleaning Solvents* (CARB, 1997b) - *Area-Wide Source Methodologies, Section 6.3, Architectural Coatings* (CARB, 2003) - *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000) - *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009)
	Speciated VOC	- *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *Speciate 4.2 Database Development Documentation* (Pechan, 2009a)

Detailed emission estimation methodologies for each domestic-commercial source are presented in Section 3.

2.6.3 *Acquire Activity, Spatial and Temporal Data*

Activity, spatial and temporal data have been acquired from a number of government departments and service providers. Emissions have been estimated using activity, spatial and temporal data sourced from the references provided in Table 2-3, Table 2-4 and Table 2-5.

Table 2-3: Domestic-commercial activity data

Source type	Activity data	Activity data source
Aerosols and solvents (domestic and commercial)	Gridded 1 km x 1 km population estimates required for per capita emission factors	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Barbecues (domestic)	Barbecue/outdoor stove/portable stove type, number and fuel consumption	- *Domestic Barbecue Pollution Survey* (TR, 2009)
	Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Cutback bitumen	Cutback bitumen and cutter consumption	- *Cutback Bitumen and Cutter Consumption in the NSW GMR*

Source type	Activity data	Activity data source
		(AAPA, 2009)
Gaseous fuel combustion (domestic and unaccounted)	Natural gas and LPG consumption	Domestic natural gas: - *Energy update 2009* (ABARE, 2009a) - *Australian Energy, National and State Projections to 2029-30* (ABARE, 2006) - *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b) Domestic LPG: - *Domestic Fuel Combustion Pollution Survey* (TR, 2009) Unaccounted natural gas: - *2008 Survey of EPA-Licensed Premises* (DECCW, 2009) - *2004 Survey of Commercial Businesses* (DECC, 2007a)
	Gridded 1 km x 1 km total dwelling estimates for domestic LPG required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Graphic arts (domestic and commercial)	Ink and solvent consumption	- *Ink Manufacturing in Australia* (IBISWorld, 2008) - *Australian Demographic Statistics* (ABS, 2009) - *Graphic Arts* (ERG, 1996b) - *2008 Survey of EPA-Licensed Premises* (DECCW, 2009) - *2004 Survey of Commercial Businesses* (DECC, 2007a)
	Gridded 1 km x 1 km population estimates required for per capita emission factors	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Lawn mowing and garden equipment (domestic)	Lawn mower and garden equipment type/number and monthly mowing frequency/duration	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)
	Gridded 1 km x 1 km dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
	Lawn mower and garden equipment fleet composition	- *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)
Lawn mowing and garden equipment (public open space)	Lawn mower and garden equipment type/number and monthly mowing frequency/duration	- *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b)
	Golf course locations required to scale-up golf course survey	- *Australian Course Directory* (Iseekgolf.com, 2011)
	Gridded 1 km x 1 km population estimates required to scale-up LGA survey	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
	Lawn mower and garden equipment fleet composition	- *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and*

Source type	Activity data	Activity data source
		Operating Life Data for 2000 to 2004 (AIA, 2005)
Liquid fuel combustion (domestic)	Liquid fuel consumption	- *Domestic Liquid Fuel Combustion Pollution Survey* (TR, 2009)
	Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Natural gas leakage	Unaccounted for natural gas	- *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b) - *NSW gas networks Performance report 2007-08* (DWE, 2009) - *NSW gas networks Performance report 2008-09* (II, 2009)
Portable fuel containers (domestic)	Petrol consumption	- *NONROAD2008a Model* (USEPA, 2009) using: *Domestic Lawn Mowing Pollution Survey* (TR, 2009); *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009); and *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)
	Portable fuel container survey data	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999)
Portable fuel containers (public open space)	Petrol consumption	- *NONROAD2008a Model* (USEPA, 2009) using: *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b); *Australian Course Directory* (Iseekgolf.com, 2011); *Forecasts for Population from 2006 to 2036* (TDC, 2009); and *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)
	Portable fuel container survey data	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999)
Solid fuel combustion (domestic)	Wood heater type, number and fuel consumption	- *Domestic Wood Heater Pollution Survey* (TR, 2009)
	Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Surface coatings	Surface coating consumption	- *Quarterly Industrial Sales Statistics Survey 2008* (APMF, 2009a to 2009d)

Source type	Activity data	Activity data source
(domestic, commercial and industrial)		- *Quarterly Automotive Refinish Statistics 2008* (APMF, 2009e to 2009h) - *Quarterly Architectural & Decorative Paints & Enamels Sales Quantity 2008* (Informark, 2009a to 2009d) - *Quarterly Woodcare Products Sales Quantity 2008* (Informark, 2009e to 2009h)
	NSW total and gridded 1 km x 1 km population estimates required to scale surface coating consumption from NSW to GMR	NSW: - *83101.0 - Australian Demographic Statistics, Dec 2008* (ABS, 2009) GMR: - *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Table 2-4: Domestic-commercial spatial data

Source type	Spatial data	Spatial data source
Aerosols and solvents (domestic and commercial)	Gridded 1 km x 1 km population estimates	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Barbecues (domestic)	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Cutback bitumen	Gridded 1 km x 1 km vehicle kilometres travelled (vkt) estimates	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009)
Gaseous fuel combustion (domestic and unaccounted)	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Graphic arts (domestic and commercial)	Gridded 1 km x 1 km population estimates	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Lawn mowing and garden equipment (domestic)	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)
Lawn mowing and garden equipment (public open space)	Gridded 1 km x 1 km population estimates (≥ 50 per grid cell)	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Liquid fuel combustion (domestic)	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Natural gas leakage	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Portable fuel containers (domestic)	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)
Portable fuel containers (public open space)	Gridded 1 km x 1 km population estimates (≥ 50 per grid cell)	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Solid fuel combustion (domestic)	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)
Surface coatings (domestic, commercial and industrial)	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Table 2-5: Domestic-commercial temporal data

Source type	Temporal data	Temporal data source
Aerosols and solvents (domestic and commercial)	Monthly, daily and hourly: Source type specific temporal allocation factors	- *CAIR Platform Temporal Allocation* (USEPA, 2005)
Barbecues (domestic)	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Barbecue Pollution Survey* (TR, 2009)
Cutback bitumen	Monthly: Cutback bitumen and cutter consumption combined with time varying emissions	- *Cutback Bitumen and Cutter Consumption in the NSW GMR* (AAPA, 2009) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Daily: VKT combined with time varying emissions	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, On-Road Mobile Emissions Module: Results* (DECC, 2007c) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Hourly: VKT combined with time varying emissions	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
Gaseous fuel combustion (domestic and unaccounted)	Monthly and daily: Daily natural gas flow	- *National Gas Market Bulletin Board, Daily Natural Gas Flow, 1 August 2008 to 31 July 2009* (AEMOL, 2009)
	Hourly: Source type specific temporal allocation factors	- *CAIR Platform Temporal Allocation* (USEPA, 2005)
Graphic arts (domestic and commercial)	Monthly, daily and hourly: Source type specific temporal allocation factors	- *CAIR Platform Temporal Allocation* (USEPA, 2005)
Lawn mowing and garden equipment (domestic)	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)
Lawn mowing and garden equipment (public open space)	Monthly: Derived from domestic survey	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)
	Daily and hourly: Derived from commercial survey	- *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b)
Liquid fuel combustion (domestic)	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Liquid Fuel Combustion Pollution Survey* (TR, 2009)
Natural gas leakage	Monthly and daily: Daily natural gas flow	- *National Gas Market Bulletin Board, Daily Natural Gas Flow, 1 August 2008 to 31 July 2009* (AEMOL, 2009)
	Hourly: Source type specific temporal allocation factors	- *CAIR Platform Temporal Allocation* (USEPA, 2005)

<table>
<tr><th>Source type</th><th>Temporal data</th><th>Temporal data source</th></tr>
<tr><td>Portable fuel containers (domestic)</td><td>Monthly, daily and hourly: Derived from domestic survey combined with hourly meteorological data (temperature (Kelvin) and monthly petrol Reid vapour pressure (RVP)</td><td>- Domestic Lawn Mowing Pollution Survey (TR, 2009)
- The Air Pollution Model (TAPM) Version 3 (Hurley, 2005)
- Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011)</td></tr>
<tr><td>Portable fuel containers (public open space)</td><td>Monthly, daily and hourly: Derived from commercial survey combined with hourly meteorological data (temperature (Kelvin) and monthly petrol Reid vapour pressure (RVP)</td><td>- Public Open Space Lawn Mowing Pollution Survey (DECC, 2007b)
- The Air Pollution Model (TAPM) Version 3 (Hurley, 2005)
- Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011)</td></tr>
<tr><td>Solid fuel combustion (domestic)</td><td>Monthly, daily and hourly: Derived from domestic survey</td><td>- Domestic Wood Heater Pollution Survey (TR, 2009)</td></tr>
<tr><td rowspan="2">Surface coatings (domestic, commercial and industrial)</td><td>Monthly: Surface coating consumption</td><td>- Quarterly Industrial Sales Statistics Survey 2008 (APMF, 2009a to 2009d)
- Quarterly Automotive Refinish Statistics 2008 (APMF, 2009e to 2009h)
- Quarterly Architectural & Decorative Paints & Enamels Sales Quantity 2008 (Informark, 2009a to 2009d)
- Quarterly Woodcare Products Sales Quantity 2008 (Informark, 2009e to 2009h)</td></tr>
<tr><td>Daily and hourly: Source type specific temporal allocation factors</td><td>- CAIR Platform Temporal Allocation (USEPA, 2005)</td></tr>
</table>

A detailed discussion of the activity, spatial and temporal data acquired for each domestic-commercial source is presented in Section 3.

2.6.4 *Design and Implement Emission Estimation Techniques*

All emissions have been calculated within the Domestic-Commercial Emissions Data Management System v1.0, which is a Microsoft® Access™ 2003 relational database that includes all the data necessary for estimating emissions to air from domestic-commercial sources, including: activity data; emission factors; particulate matter (PM) and volatile organic compound (VOC) speciation profiles; spatial allocation data; hourly, daily and monthly temporal variation data; and emission projection factors. The Domestic-Commercial Emissions Data Management System v1.0 start-up form is shown in Figure 2-3.

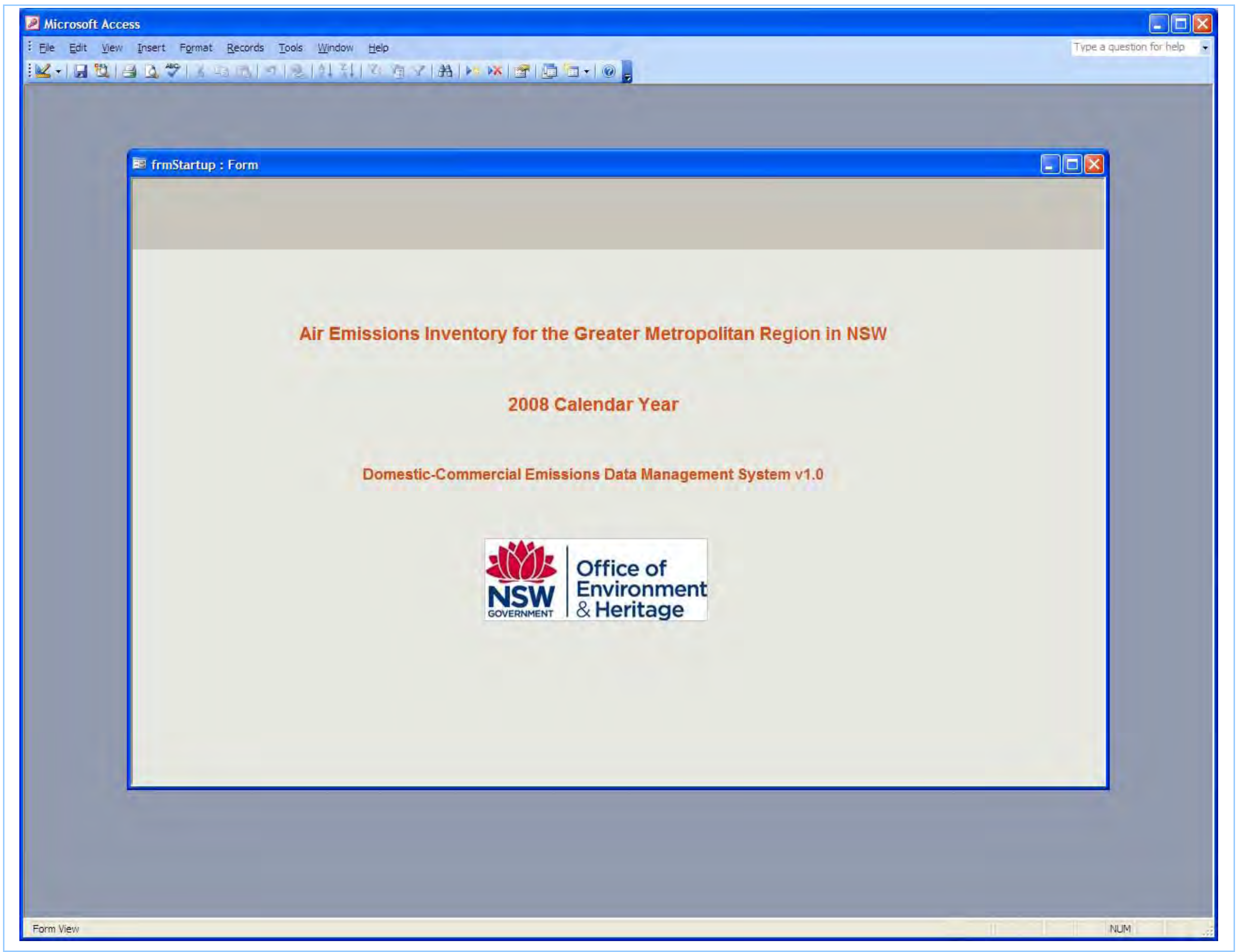

Figure 2-3: Domestic-commercial Emissions Data Management System v1.0 start-up form

In general, emissions have been estimated using Equation 1:

$$E_{i,j} = A_j \times EF_{i,j} \times (1 - ER_{i,j} / 100) \qquad \textbf{Equation 1}$$

where:

$E_{i,j}$	=	Emissions of substance i from source j	(kg/year)
A_j	=	Activity rate for source j	(activity unit/year)
$EF_{i,j}$	=	Emission factor for substance i from source j	(kg/activity unit)
$ER_{i,j}$	=	Emission reduction efficiency for substance i for source j	(%)

Detailed emission estimation techniques for each domestic-commercial source are presented in Section 3.

2.6.5 *Derive Source Type Specific Emission Projection Factors*

Emission projection factors have been derived based on either:

- Total final energy consumption by industry and fuel, New South Wales (ABARE, 2006);
- Total primary energy consumption by industry and fuel, New South Wales (ABARE, 2006);

- Free standing dwelling growth, Greater Metropolitan Region (TDC, 2009);
- Population growth, Greater Metropolitan Region (TDC, 2009);
- Total dwelling growth, Greater Metropolitan Region (TDC, 2009); and
- Vehicle kilometres travelled growth, Greater Metropolitan Region (TDC, 2009).

Projection factors have been developed for every year from 2009 to 2036 (emissions for the base year 2008 are based on activity data and emission estimation methodologies).

In general, future emissions have been estimated from base year 2008 emissions using Equation 2:

$$E_{i,j,n} = E_{i,j,2008} \times PF_{j,n}$$ **Equation 2**

where:			
$E_{i,j,n}$	=	Emission of substance i from source j for year n	(kg/year)
$E_{i,j,2008}$	=	Emission of substance i from source j for the base year, 2008	(kg/year)
$PF_{j,n}$	=	Projection factor for source j for year n (relative to the base year)	($tonne.year^{-1}$/ $tonne.year^{-1}$)

Projection factors have been sourced from references presented in Table 2-6.

Table 2-6: Domestic-commercial projection factors

Source type	Projection factor surrogate	Projection factor source
Aerosols and solvents (domestic and commercial)	Population growth	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Barbecues (domestic)	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Cutback bitumen	Vehicle kilometres travelled growth	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009)
Gaseous fuel combustion (domestic and unaccounted)	Final energy consumption for residential using liquid petroleum gas and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Graphic arts (domestic and commercial)	Population growth	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Lawn mowing and garden equipment (domestic)	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Lawn mowing and garden equipment (public open space)	Final energy consumption for commercial and services using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Liquid fuel combustion (domestic)	Final energy consumption for residential using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Natural gas leakage	Primary energy consumption for all sectors using natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Portable fuel containers	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to*

Source type	Projection factor surrogate	Projection factor source
(domestic)		*2036* (TDC, 2009)
Portable fuel containers (public open space)	Final energy consumption for commercial and services using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Solid fuel combustion (domestic)	Final energy consumption for residential using biomass	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Surface coatings (domestic, commercial and industrial)	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Detailed emission projection factors for each domestic-commercial source are presented in Section 3.

3 DATA SOURCES AND RESULTS

This section presents the: detailed emission estimation methodologies; activity, spatial, temporal and projection factor data sources used; and the associated emission estimates for the 2008 calendar year for the following domestic-commercial sources:

- Aerosols and solvents (domestic and commercial);
- Barbecues (domestic);
- Cutback bitumen;
- Gaseous fuel combustion (domestic and unaccounted);
- Graphic arts (domestic and commercial);
- Lawn mowing and garden equipment (domestic and public open space);
- Liquid fuel combustion (domestic);
- Natural gas leakage;
- Portable fuel containers (domestic and public open space);
- Solid fuel combustion (domestic); and
- Surface coatings (domestic, commercial and industrial).

For each domestic-commercial source type, the information in this section is structured as follows:

- Emission Source Description;
- Emission Estimation Methodology;
- Activity Data;
- Emission and Speciation Factors;
- Spatial Distribution of Emissions;
- Temporal Variation of Emissions;
- Emission Estimates; and
- Emission Projection Methodology.

Domestic-commercial emissions have been estimated by combining activity data with emission factors. The emissions have been allocated spatially to each 1 km by 1 km grid cell, and temporally to months, weekdays/weekend days and hours. Activity, spatial and temporal data have been acquired from a number of government departments and service providers. All emissions have been calculated within the Domestic-Commercial Emissions Data Management System v1.0, which is a Microsoft® Access™ 2003 relational database that includes all the data necessary for estimating emissions to air from domestic-commercial sources, including: activity data; emission factors; particulate matter (PM) and volatile organic compound (VOC) speciation profiles; spatial allocation data; hourly, daily and monthly temporal variation data; and emission projection factors.

Where reference is made to:

- *Combustion products*, this includes CO, NO_x, $PM_{2.5}$, PM_{10}, TSP, SO_2 and VOC (total and speciated); and

- *Particulate matter*, this includes $PM_{2.5}$, PM_{10} and TSP.

In this section total estimated emissions are presented for each domestic-commercial source type in the whole GMR and the Sydney, Newcastle and Wollongong regions. Total estimated emissions are also presented for the region defined as Non Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. Emissions are presented for the following pollutants only:

- 1,3-Butadiene
- Acetaldehyde
- Benzene
- Carbon monoxide (CO)
- Formaldehyde
- Isomers of xylene
- Lead & compounds
- Oxides of nitrogen (NO_x)
- Particulate matter ≤ 10 µm (PM_{10})
- Particulate matter ≤ 2.5 µm ($PM_{2.5}$)
- Perchloroethylene
- Polycyclic aromatic hydrocarbons (PAH)
- Sulfur dioxide (SO_2)
- Toluene
- Total suspended particulate (TSP)
- Total volatile organic compounds (VOC)
- Trichloroethylene

These substances were selected since they:

- Are the most common air pollutants found in airsheds according to the National Pollutant Inventory NEPM (NEPC, 2008);

- Are referred to in National Environment Protection Measures (NEPMs) for ambient air quality (NEPC, 2003) and air toxics (NEPC, 2004); and

- Have been classified as priority air pollutants (NEPC, 2006).

Total domestic-commercial emissions of all substances emitted in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions are presented in Appendix A: Estimated Annual Emissions of all Substances from Domestic-Commercial Sources.

3.1 Aerosols and Solvents

3.1.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from consumer and commercial aerosol and solvent products that serve as either: propellants; aid in product drying (through evaporation); act as co-solvents and cleaning agents; or are emitted during product use.

To estimate emissions from these sources, the following have been considered:

- *USEPA Report to Congress and Comprehensive Emissions Inventory*

The *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products* includes a *Report to Congress* (USEPA, 1995b), which is supported by a *Comprehensive Emissions Inventory* (USEPA, 1995c). The study presents per capita based emission factors by product group and category, which have been adopted for the GMR as they are representative of a developed economy in the absence of product regulations.

- *SLR Desktop Literature Review of Aerosols and Solvents Emission Source Category*

The *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR, 2011) presents revisions to the per capita based emission factors by product group and category (i.e. for coatings and related products; household cleaning products; pesticide and herbicide products; and personal care products) (USEPA, 1995c), which use Australian market volume and formulation data. The revised per capita based emission factors have been adopted for the GMR where relevant.

- *Product Groups*

Table 3-1 presents the consumer and commercial aerosols and solvents product groups and categories included in the inventory.

Table 3-1: Aerosols and solvents product groups and categories

Personal care products	Household products
Deodorants and antiperspirants Facial and body treatments Fragrance products Hair care products Health use products Miscellaneous personal care products Nail care products Oral care products Powders	Air fresheners Dishwashing products Fabric and carpet care products Hard surface cleaners Laundry products Miscellaneous household products Shoe and leather care products Waxes and polishes

Automotive aftermarket products - detailing products	Automotive aftermarket products - maintenance and repair products
Body cleaning compounds Bug and tar removers Car washing products Fibreglass polish Glass, plexiglass and plastic window cleaner/treatment Metal polish and chrome cleaner Polishes Rubber, vinyl and leather protectants and dressings, vinyl top cleaners and waxes Rust-proofing and other exterior treatment compounds Tyre coatings and paints Upholstery cleaners and interior cleaners Waxes Wheel, tyre and mat cleaners Antifreeze and coolant	Belt dressings Engine cleaners, degreasers and parts cleaners Engine starting fluids Fuel system antifreeze Lubricants Motor flush and crankcase cleaner Transmission sealer, conditioner, additive and leak-stop Tyre cement, sealant and inflators Windshield de-icer Windshield washer fluid
Adhesives and sealants	**Coatings and related products**
Consumer adhesives (e.g. cements, glues and pastes) Sealants	Aerosol spray paints Coating related products (e.g. paint removers)
Insecticide, fungicide, rodenticide and herbicide products	**Miscellaneous products (not otherwise covered)**
Antimicrobial agents Fungicides and nematicides Herbicides Insecticides Other products	Arts and crafts supplies Non-pesticidal veterinary and pet products Office supplies Pressurised food products

3.1.2 *Emission Estimation Methodology*

Table 3-2 summarises the emission estimation methodology used for consumer and commercial aerosols and solvents.

Table 3-2: Aerosols and solvents emission estimation methodology

Emission source	Emission estimation methodology source
Evaporative emissions from consumer and commercial aerosols and solvents	- *Consumer and Commercial Solvent Use* (ERG, 1996a)

Evaporative VOC emissions from consumer and commercial aerosols and solvents have been estimated using per capita based emission factors combined with population in the GMR (TDC, 2009). Emissions have been determined using Equation 3 (ERG, 1996a):

$$E_{VOC,i} = P \times EF_{VOC,i} \qquad \textbf{Equation 3}$$

where:			
$E_{VOC,i}$	=	Emissions of VOC from product group i	(kg/year)
P	=	Population	(capita)
$EF_{VOC,i}$	=	Emission factor for VOC from product group 1	(kg/capita/year)
i	=	Product group (either "adhesives and sealant products", "coatings and related products", "household cleaning products", "miscellaneous products", "motor vehicle aftermarket products", "personal care products" or "pesticide and herbicide products"	(-)

3.1.3 Activity Data

Table 3-3 summarises the activity data used for consumer and commercial aerosols and solvents.

Table 3-3: Aerosols and solvents activity data

Activity data	Activity data source
Gridded 1 km x 1 km population estimates required for per capita emission factors	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

The consumer and commercial aerosols and solvents VOC emissions in the GMR (i.e. 25,273,588 kg/year) have been estimated by multiplying the VOC emission factors by the GMR population (i.e. 5,284,560) (TDC, 2009).

3.1.4 Emission and Speciation Factors

Table 3-4 summarises the emission and speciation factors used for consumer and commercial aerosols and solvents.

Table 3-4: Aerosols and solvents emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: VOC	Adhesives and sealant products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c)
	Coatings and related products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c) - *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR Consulting, 2011)
	Household cleaning products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c) - *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR Consulting, 2011)
	Miscellaneous products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b)

Substance	Emission source	Emission and speciation factor source
		- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c)
	Motor vehicle aftermarket products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c)
	Personal care products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c) - *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR Consulting, 2011)
	Pesticide and herbicide products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c) - *Desktop Literature Review of Aerosols and Solvents Emission Source Category* (SLR Consulting, 2011)
Speciated VOC	Adhesives and sealant products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8523 Consumer and Commercial Products: Adhesives and Sealants: All Adhesives and Sealants -Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Coatings and related products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8532 Consumer and Commercial Products: Coatings and Related Products: All Coatings and Related Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Household cleaning products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8511 Consumer and Commercial Products: Household Products: All Household Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Miscellaneous products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8535 Consumer and Commercial Products: Miscellaneous Products: All Miscellaneous Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Motor vehicle aftermarket products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8520 Consumer and Commercial Products: Automotive Aftermarket Products: All Automotive Aftermarket Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Personal care products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8501 Consumer and Commercial Products: Personal Care Products: All Personal Care Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Pesticide and herbicide products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8526 Consumer and Commercial Products: Fifra Related Products: All Fifra Related Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Organic air toxics	Adhesives and sealant products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8523 Consumer and Commercial Products: Adhesives and Sealants: All Adhesives and Sealants -Speciate 4.2 Database Development Documentation* (Pechan, 2009a)

Substance	Emission source	Emission and speciation factor source
	Coatings and related products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8532 Consumer and Commercial Products: Coatings and Related Products: All Coatings and Related Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Household cleaning products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8511 Consumer and Commercial Products: Household Products: All Household Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Miscellaneous products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8535 Consumer and Commercial Products: Miscellaneous Products: All Miscellaneous Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Motor vehicle aftermarket products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8520 Consumer and Commercial Products: Automotive Aftermarket Products: All Automotive Aftermarket Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Personal care products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8501 Consumer and Commercial Products: Personal Care Products: All Personal Care Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Pesticide and herbicide products	- *Consumer and Commercial Solvent Use* (ERG, 1996a) - *Profile number 8526 Consumer and Commercial Products: Fifra Related Products: All Fifra Related Products - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Polycyclic aromatic hydrocarbons: PAH	Adhesives and sealant products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 2* (USEPA, 1995c)
	Coatings and related products	- *Consumer and Commercial Solvent Use* (ERG, 1996a)
	Household cleaning products	- *Consumer and Commercial Solvent Use* (ERG, 1996a)
	Motor vehicle aftermarket products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b) - *Consumer and Commercial Solvent Use* (ERG, 1996a)
	Pesticide and herbicide products	- *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products, Volume 1* (USEPA, 1995b)

Table 3-5 presents the VOC emission factors for consumer and commercial aerosols and solvents by product group and category. The consumer and commercial aerosols and solvents VOC emissions in the GMR (i.e. 25,273,588 kg/year) have been estimated by multiplying the VOC emission factors by the GMR population (i.e. 5,284,560) (TDC, 2009).

Table 3-5: Aerosols and solvents emission factors

Product group	Product category	VOC emission factor (kg/capita/year)
Adhesives and Sealant Products	Consumer Adhesives	0.28
	Sealants	3.39×10^{-2}
Adhesives and Sealant Products Total		0.31
Coatings and Related Products	Aerosol Spray Paints	0.43
	Coating-Related Products	0.29
Coatings and Related Products Total		0.72
Household Cleaning Products	Air Fresheners	0.15
	Dishwashing Products	7.05×10^{-3}
	Fabric and Carpet Care Products	2.34×10^{-2}
	Hard Surface Cleaners	0.10
	Laundry Products	3.44×10^{-2}
	Miscellaneous Household Products	6.19×10^{-2}
	Shoe and Leather Care Products	1.36×10^{-3}
	Waxes and Polishes	3.95×10^{-2}
Household Cleaning Products Total		0.42
Miscellaneous Products	Arts and Crafts Supplies	7.95×10^{-3}
	Non-Pesticidal Veterinary and Pet Products	3.30×10^{-3}
	Office Supplies	1.12×10^{-2}
	Pressurised Food Products	1.10×10^{-2}
Miscellaneous Products Total		3.34×10^{-2}
Motor Vehicle Aftermarket Products	Detailing Products	3.42×10^{-2}
	Maintenance and Repair Products	0.63
Motor Vehicle Aftermarket Products Total		0.67
Personal Care Products	Deodorants and Antiperspirants	0.18
	Facial and Body Treatments	4.21×10^{-2}
	Fragrance Products	0.11
	Hair Care Products	1.09
	Health Use Products	3.70×10^{-2}
	Miscellaneous Personal Care Products	0.17
	Nail Care Products	5.41×10^{-2}
	Oral Care Products	1.05×10^{-2}
	Powders	2.10×10^{-2}
Personal Care Products Total		1.72
Pesticide and Herbicide Products	Antimicrobial Agents	7.82×10^{-2}
	Fungicides & Nematicides	0.12
	Herbicides	0.28
	Insecticides	0.26
	Other Products	0.17
Pesticide and Herbicide Products Total		0.91
Grand Total		4.78

3.1.5 Spatial Distribution of Emissions

Table 3-6 summarises the data used for spatially allocating emissions from consumer and commercial aerosols and solvents.

Table 3-6: Aerosols and solvents spatial data

Emission source	Spatial data	Spatial data source
Evaporative emissions from consumer and commercial aerosols and solvents	Gridded 1 km x 1 km population estimates	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Emissions from consumer and commercial aerosols and solvents have been spatially distributed according to the proportion of population within each 1 km by 1 km grid cell (TDC, 2009). The proportion of population by LGA and region is presented in Table 3-7 and shown in Figure 3-1.

Table 3-7: Aerosols and solvents spatial distribution of population by LGA and region

LGA	2008 proportion of population (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.91	-	0.91
Auburn	-	-	1.32	-	1.32
Bankstown	-	-	3.30	-	3.30
Bathurst Regional	-	2.84×10^{-3}	-	-	2.84×10^{-3}
Baulkham Hills	-	2.44×10^{-3}	3.23	-	3.24
Blacktown	-	-	5.42	-	5.42
Blue Mountains	-	0.48	1.00	-	1.48
Botany Bay	-	-	0.63	-	0.63
Burwood	-	-	0.57	-	0.57
Camden	-	-	1.05	-	1.05
Campbelltown	-	-	2.85	-	2.85
Canada Bay	-	-	1.12	-	1.12
Canterbury	-	-	2.62	-	2.62
Cessnock	4.36×10^{-2}	0.88	-	-	0.92
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.58	-	3.58
Gosford	-	0.89	2.19	-	3.08
Goulburn Mulwaree	-	5.98×10^{-3}	-	-	5.98×10^{-3}
Great Lakes	-	7.21×10^{-2}	-	-	7.21×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.16	-	1.18
Holroyd	-	-	1.80	-	1.80
Hornsby	-	3.61×10^{-3}	3.04	-	3.04
Hunters Hill	-	-	0.18	-	0.18
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.28	-	-	0.28
Kogarah	-	-	1.09	-	1.09
Ku-ring-gai	-	-	2.03	-	2.03
Lake Macquarie	1.96	1.74	-	-	3.70
Lane Cove	-	-	0.54	-	0.54

LGA	2008 proportion of population (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Leichhardt	-	-	0.75	-	0.75
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	3.38	-	3.38
Maitland	0.10	1.16	-	-	1.26
Manly	-	-	0.64	-	0.64
Marrickville	-	-	1.65	-	1.65
Mid-western Regional	-	5.42×10^{-2}	-	-	5.42×10^{-2}
Mosman	-	-	0.59	-	0.59
Muswellbrook	-	0.27	-	-	0.27
N/A	2.48×10^{-2}	5.23×10^{-2}	0.35	6.03×10^{-2}	0.49
Newcastle	2.86	-	-	-	2.86
North Sydney	-	-	1.02	-	1.02
Oberon	-	3.10×10^{-2}	-	-	3.10×10^{-2}
Parramatta	-	-	2.89	-	2.89
Penrith	-	-	3.36	-	3.36
Pittwater	-	-	1.03	-	1.03
Port Stephens	6.56×10^{-2}	1.05	-	-	1.12
Randwick	-	-	2.48	-	2.48
Rockdale	-	-	1.70	-	1.70
Ryde	-	-	1.99	-	1.99
Shellharbour	-	0.94	-	0.29	1.23
Shoalhaven	-	1.45×10^{-3}	-	-	1.45×10^{-3}
Singleton	-	0.41	-	-	0.41
Strathfield	-	-	0.73	-	0.73
Sutherland	-	-	4.03	-	4.03
Sydney	-	-	3.17	-	3.17
Unincorporated	-	-	0.81	-	0.81
Upper Hunter	-	4.22×10^{-3}	-	-	4.22×10^{-3}
Upper Lachlan	-	5.94×10^{-3}	-	-	5.94×10^{-3}
Warringah	-	-	2.67	-	2.67
Waverley	-	-	1.08	-	1.08
Willoughby	-	-	1.32	-	1.32
Wingecarribee	-	0.85	5.04×10^{-3}	1.49×10^{-3}	0.86
Wollondilly	-	1.23×10^{-2}	0.80	4.13×10^{-4}	0.81
Wollongong	-	-	0.30	3.36	3.66
Woollahra	-	-	0.85	-	0.85
Wyong	-	2.75	-	-	2.75
Grand Total	5.05	12.48	78.76	3.72	100.00

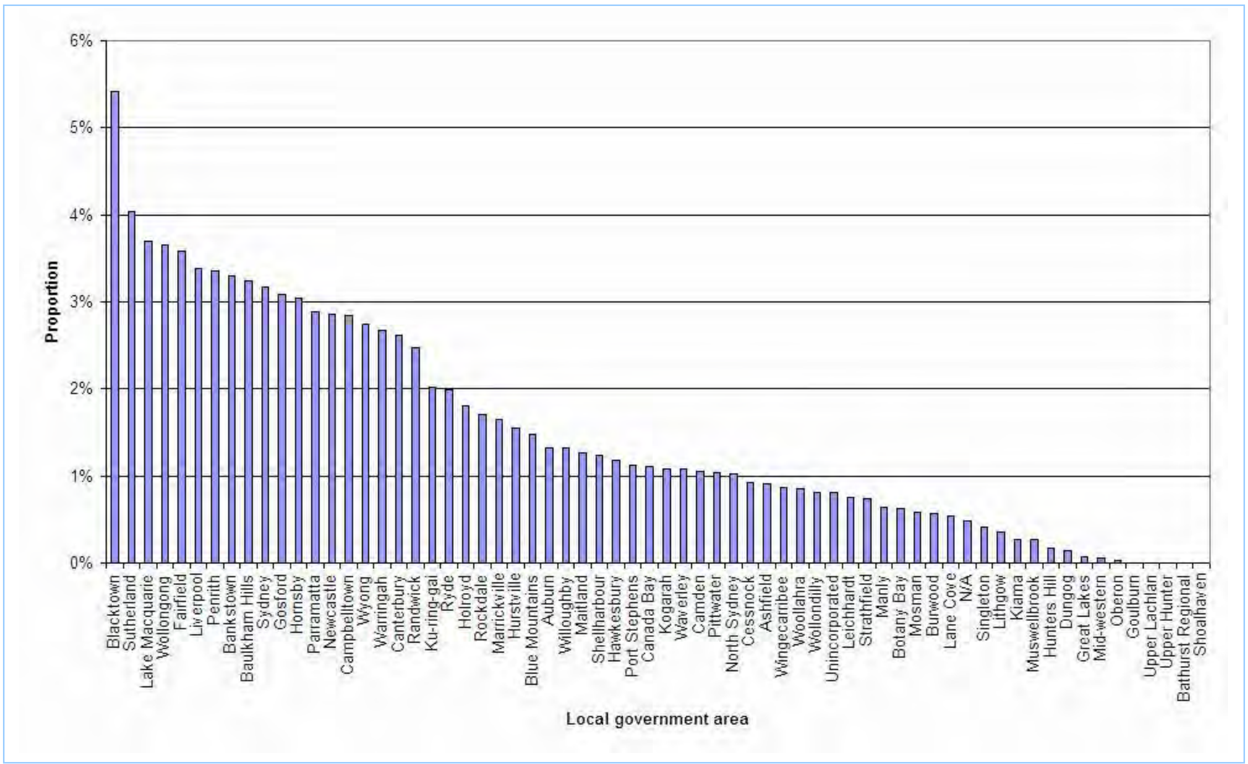

Figure 3-1: Aerosols and solvents spatial distribution of population by LGA

Figure 3-2 shows the spatial distribution of emissions from consumer and commercial aerosols and solvents.

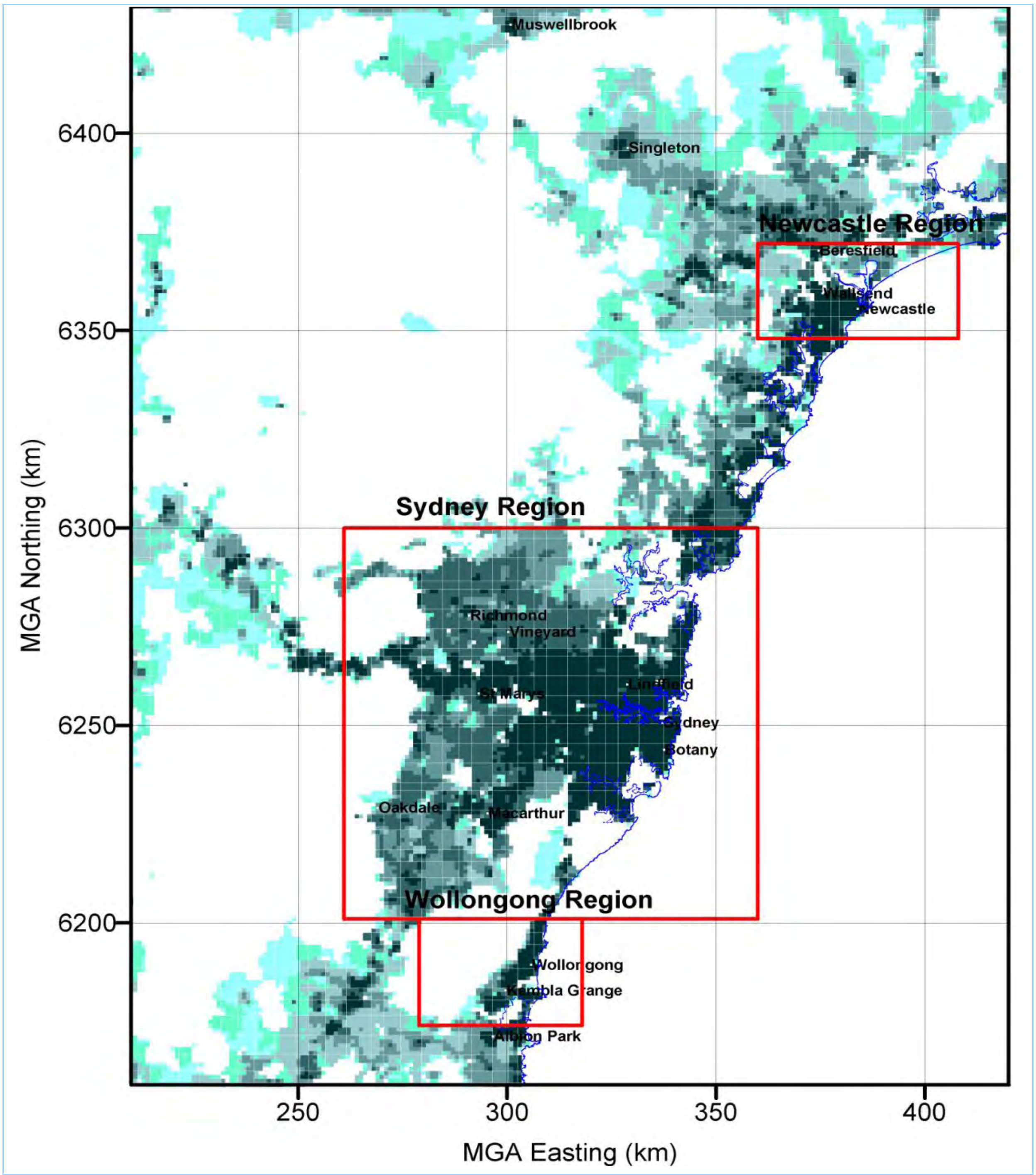

Figure 3-2: Aerosols and solvents spatial distribution of emissions

3.1.6 *Temporal Variation of Emissions*

Table 3-8 summarises the data used to estimate the temporal variation in emissions from consumer and commercial aerosols and solvents.

Table 3-8: Aerosols and solvents temporal data

Emission source	Temporal data	Temporal data source
Evaporative emissions from consumer and commercial aerosols and solvents	Monthly: Source type specific temporal allocation factors	- *Misc Non-indus: Consumer & Comm /All Processes /Total: All Solvent Types – Monthly profile number 260 - CAIR Platform Temporal Allocation* (USEPA, 2005)
	Daily: Source type specific temporal allocation factors	- *Misc Non-indus: Consumer & Comm /All Processes /Total: All Solvent Types – Weekly profile number 7 - CAIR Platform Temporal Allocation* (USEPA, 2005)
	Hourly: Source type specific temporal allocation factors	- *Misc Non-indus: Consumer & Comm /All Processes /Total: All Solvent Types – Weekday diurnal profile number 26 and Weekend diurnal profile number 26 - CAIR Platform Temporal Allocation* (USEPA, 2005)

The hourly, daily and monthly temporal variations in emissions from consumer and commercial aerosols and solvents have been estimated from generic temporal profiles (USEPA, 2005).

Hourly temporal variation profiles are presented in Table 3-9 and shown in Figure 3-3.

Table 3-9: Aerosols and solvents hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	1.98	13	6.20
2	1.86	14	6.31
3	1.82	15	6.35
4	1.87	16	6.24
5	2.10	17	5.94
6	2.50	18	5.48
7	3.11	19	5.31
8	3.88	20	5.09
9	4.67	21	4.25
10	5.28	22	3.27
11	5.71	23	2.57
12	6.04	24	2.18

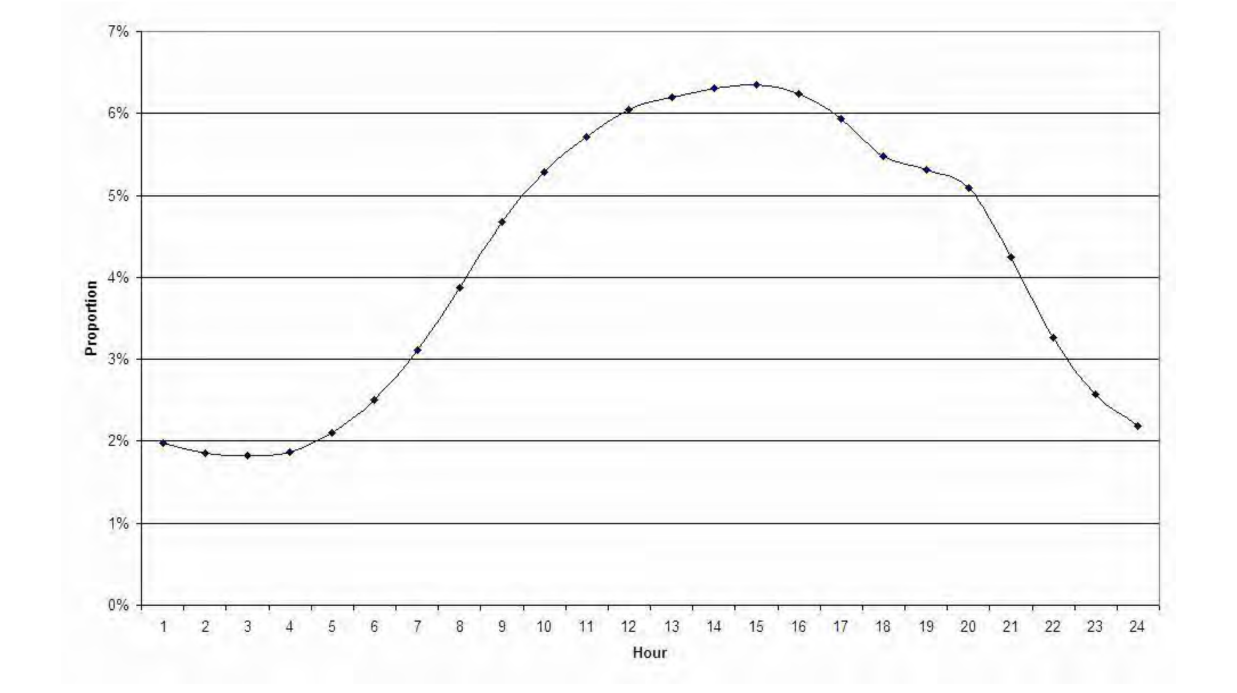

Figure 3-3: Aerosols and solvents hourly temporal profile

Daily temporal variation profiles are presented in Table 3-10 and shown in Figure 3-4.

Table 3-10: Aerosols and solvents daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.29	14.29	14.29	14.29	14.29	14.29	14.29

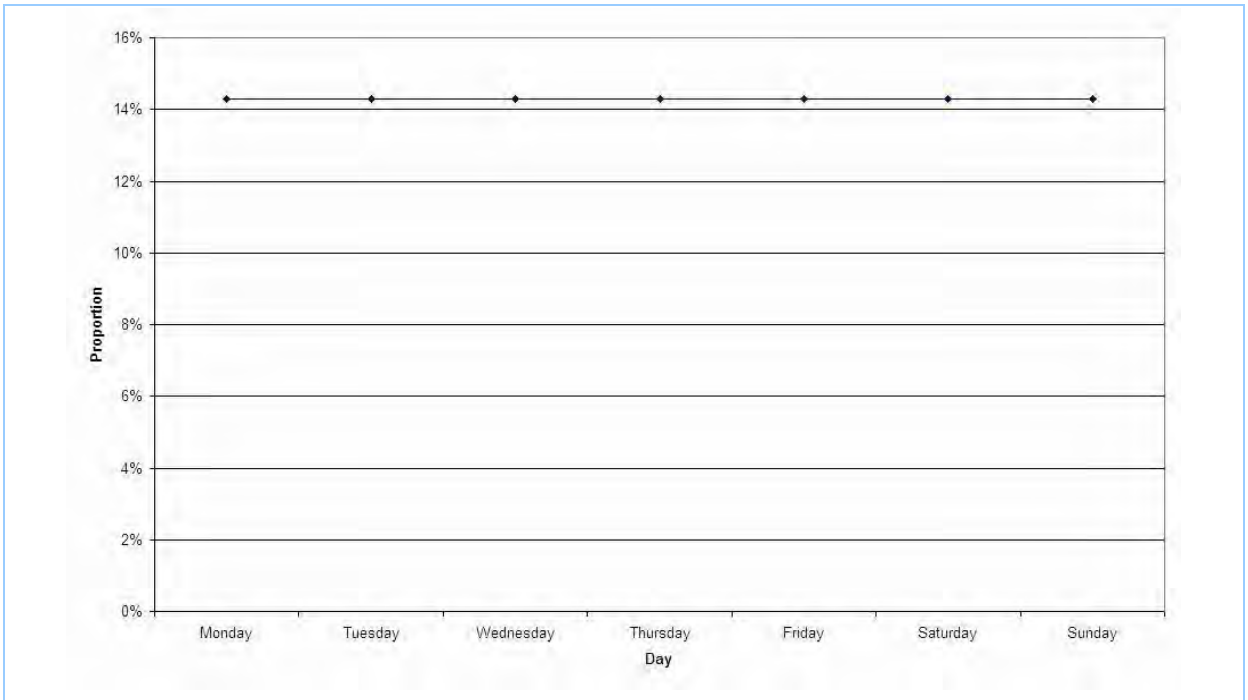

Figure 3-4: Aerosols and solvents daily temporal profile

Monthly temporal variation profiles are presented in Table 3-11 and shown in Figure 3-5.

Table 3-11: Aerosols and solvents monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.46	July	8.26
February	8.46	August	8.26
March	8.46	September	8.16
April	8.46	October	8.16
May	8.46	November	8.16
June	8.26	December	8.46

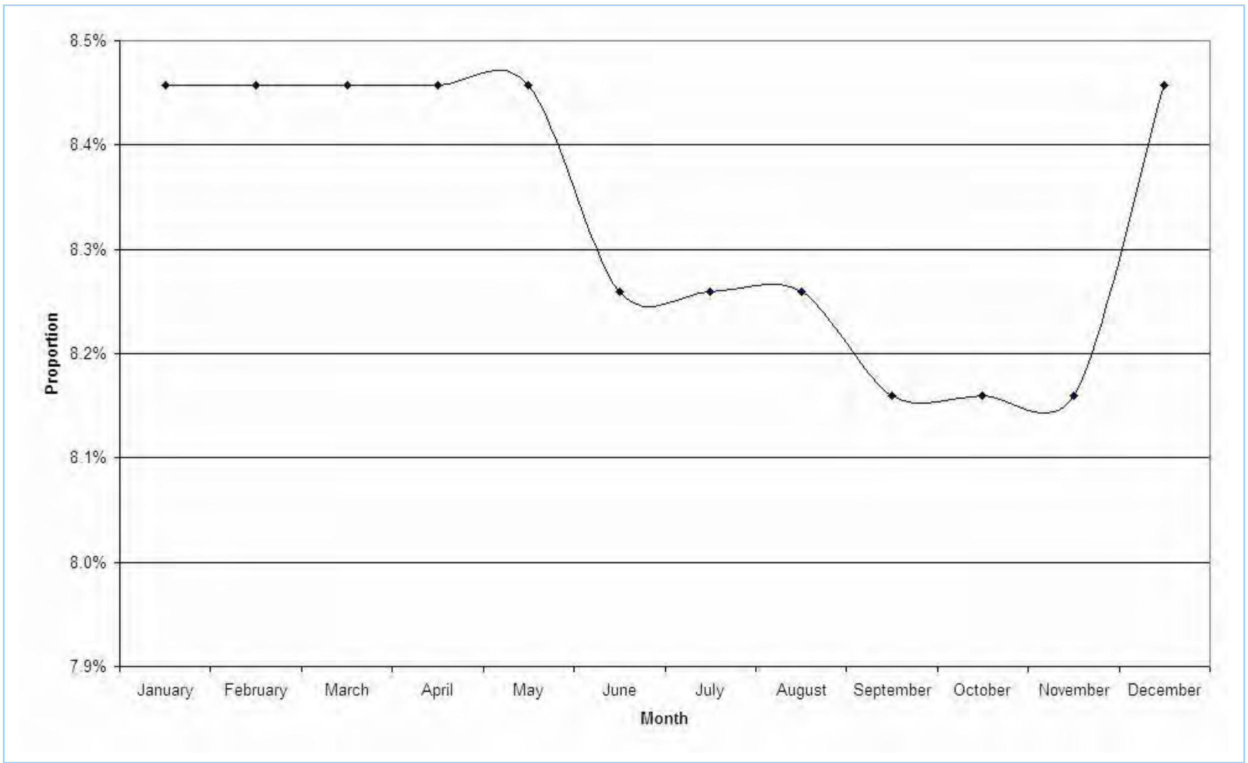

Figure 3-5: Aerosols and solvents monthly temporal profile

3.1.7 Emission Estimates

Table 3-12 presents annual emissions of selected substances from consumer and commercial aerosols and solvents by activity.

Table 3-12: Aerosols and solvents emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Consumer and Commercial Aerosols and Solvents	BENZENE	0.57	1.41	8.91	0.42	11
	FORMALDEHYDE	582	1,439	9,084	429	11,534
	ISOMERS OF XYLENE	34,384	84,993	536,438	25,322	681,138
	PERCHLOROETHYLENE	4,661	11,521	72,718	3,433	92,333
	POLYCYCLIC AROMATIC HYDROCARBONS	4,607	11,389	71,882	3,393	91,272
	TOLUENE	42,719	105,598	666,486	31,461	846,265
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,275,809	3,153,674	19,904,515	939,590	25,273,588
	TRICHLOROETHYLENE	281	693	4,377	207	5,558

Table 3-13 presents annual emissions of selected substances from consumer and commercial aerosols and solvents by source type.

Table 3-13: Aerosols and solvents emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Adhesives and Sealant Products	FORMALDEHYDE	3.04	7.51	47	2.24	60
	ISOMERS OF XYLENE	1,368	3,381	21,340	1,007	27,096
	PERCHLOROETHYLENE	92	228	1,440	68	1,829
	POLYCYCLIC AROMATIC HYDROCARBONS	84	207	1,309	62	1,662
	TOLUENE	11,756	29,061	183,418	8,658	232,894
	TOTAL VOLATILE ORGANIC COMPOUNDS	83,915	207,429	1,309,195	61,800	1,662,339
	TRICHLOROETHYLENE	8.39	21	131	6.18	166
Coatings and Related Products	FORMALDEHYDE	482	1,191	7,517	355	9,545
	ISOMERS OF XYLENE	13,626	33,681	212,582	10,035	269,924
	PERCHLOROETHYLENE	77	191	1,203	57	1,527
	POLYCYCLIC AROMATIC HYDROCARBONS	0.70	1.72	11	0.51	14
	TOLUENE	25,767	63,695	402,011	18,977	510,449
	TOTAL VOLATILE ORGANIC COMPOUNDS	192,726	476,399	3,006,810	141,936	3,817,872
	TRICHLOROETHYLENE	231	572	3,608	170	4,581
Household Cleaning Products	FORMALDEHYDE	0.82	2.02	13	0.60	16
	ISOMERS OF XYLENE	180	444	2,801	132	3,557
	PERCHLOROETHYLENE	954	2,358	14,882	703	18,897
	POLYCYCLIC AROMATIC	6.68×10^{-2}	0.17	1.04	4.92×10^{-2}	1.32

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	HYDROCARBONS					
	TOLUENE	56	139	875	41	1,112
	TOTAL VOLATILE ORGANIC COMPOUNDS	112,225	277,408	1,750,873	82,650	2,223,155
	TRICHLOROETHYLENE	5.25	13	82	3.87	104
Miscellaneous Products	ISOMERS OF XYLENE	21	53	334	16	424
	PERCHLOROETHYLENE	128	317	2,003	95	2,544
	TOLUENE	0.30	0.74	4.64	0.22	5.90
	TOTAL VOLATILE ORGANIC COMPOUNDS	8,918	22,044	139,132	6,568	176,661
Motor Vehicle Aftermarket Products	BENZENE	0.57	1.41	8.91	0.42	11
	ISOMERS OF XYLENE	2,334	5,769	36,413	1,719	46,235
	PERCHLOROETHYLENE	3,385	8,368	52,813	2,493	67,058
	POLYCYCLIC AROMATIC HYDROCARBONS	18	45	282	13	358
	TOLUENE	4,543	11,230	70,880	3,346	89,999
	TOTAL VOLATILE ORGANIC COMPOUNDS	178,163	440,402	2,779,614	131,211	3,529,391
	TRICHLOROETHYLENE	36	88	556	26	706
Personal Care Products	TOLUENE	596	1,473	9,297	439	11,805
	TOTAL VOLATILE ORGANIC COMPOUNDS	458,382	1,133,074	7,151,431	337,582	9,080,468
Pesticide and Herbicide Products	FORMALDEHYDE	97	239	1,507	71	1,913
	ISOMERS OF XYLENE	16,855	41,665	262,969	12,413	333,902
	PERCHLOROETHYLENE	24	60	377	18	478
	POLYCYCLIC AROMATIC HYDROCARBONS	4,505	11,135	70,279	3,318	89,236
	TOTAL VOLATILE ORGANIC COMPOUNDS	241,481	596,917	3,767,460	177,842	4,783,700

3.1.8 Emission Projection Methodology

Table 3-14 summarises the data used to estimate the emission projection factors for consumer and commercial aerosols and solvents, while Figure 3-6 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-14: Aerosols and solvents emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Evaporative emissions from consumer and commercial aerosols and solvents	Population growth	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

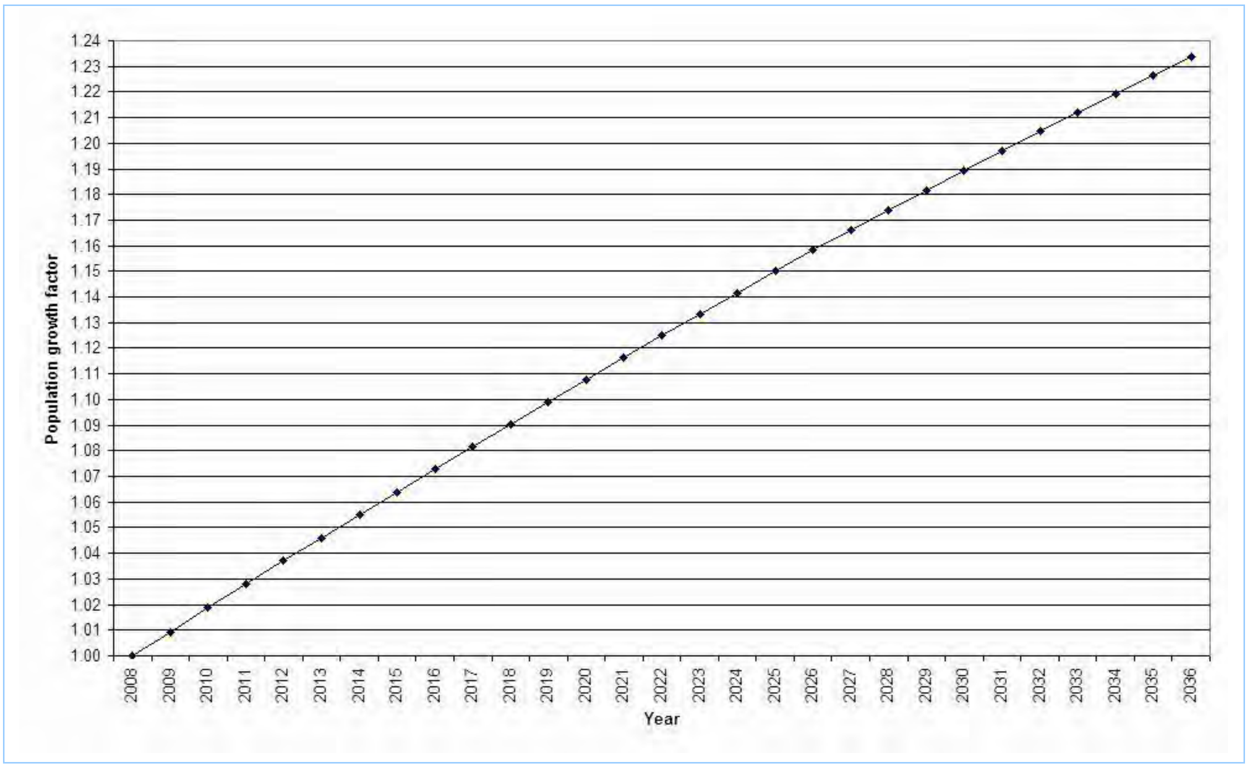

Figure 3-6: Aerosols and solvents emission projection factors

3.2 Barbecues

3.2.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes emissions of combustion products from gas, liquid and solid fuel fired barbecues, outdoor stoves and portable stoves.

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of gas, liquid and solid fuel fired barbecue, outdoor stove and portable stove ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[6] located in the GMR. The survey results include data about: barbecue/outdoor stove/portable stove number; fuel type; quantity of fuel used; and frequency and duration of barbecue/outdoor stove/portable stove use by hour, day and season (TR, 2009).

- *Barbecue type*

The inventory includes small outdoor cooking appliances used in residential applications as follows:

  - *Barbecue;*
  - *Outdoor stove; and*
  - *Portable stove.*

- *Fuel type*

The inventory includes residential barbecues, outdoor stoves and portable stoves that use natural gas, liquid petroleum gas (LPG), butane, briquettes[7] and wood.

Table 3-15 presents the barbecue, outdoor stove and portable stove fuel type and properties used in the inventory (ABARE, 2009b; AGL, 2008; Auschar, 2009; DPI, 2007; Kleenheat Gas, 2008; USEPA, 1998a; USEPA, 2000 and USEPA, 2008a).

Table 3-15: Barbecues fuel type and properties

Fuel type	Sulfur content		Density		Effective heating value		Carbon content (%)
Natural gas	3.36	ppm	0.753	kg/m^3	38.3	MJ/m^3	76
Liquid petroleum gas (LPG)	12.88	ppm	0.510	kg/L	25.5	MJ/L	82
Butane	12.88	ppm	0.568	kg/L	28.1	MJ/L	83

[6] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.
[7] Charcoal manufactured from brown coal (Auschar, 2009).

Fuel type	Sulfur content		Density		Effective heating value		Carbon content (%)
Briquettes	0.3	%	-		25.0	MJ/kg	66
Wood	-		769	kg/m^3	16.2	MJ/kg	45

3.2.2 *Emission Estimation Methodology*

Table 3-16 summarises the emission estimation methodology used for barbecues, outdoor stoves and portable stoves.

Table 3-16: Barbecues emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust emissions from gas, liquid and solid fuel combustion in barbecues, outdoor stoves and portable stoves	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)

Emissions of combustion products from barbecues, outdoor stoves and portable stoves have been estimated using fuel consumption based emission factors combined with activity rates. Activity rates include barbecue/outdoor stove/portable stove number, fuel type and quantity of fuel used (TR, 2009). Emissions have been determined using Equation 4 (Pechan, 2006):

$$\mathbf{E_{i,j} = C_j \times EF_{i,j}} \qquad \textbf{Equation 4}$$

where:			
$E_{i,j}$	=	Emissions of substance i from fuel type j	(kg/year)
C_j	=	Fuel consumption for fuel type j	
		natural gas	(Mm^3/year)
		LPG	(kL/year)
		butane	(kL/year)
		briquettes	(tonne/year)
		wood	(tonne/year)
$EF_{i,j}$	=	Emission factor for substance i and fuel type j	
		natural gas	(kg/Mm^3)
		LPG	(kg/kL)
		butane	(kg/kL)
		briquettes	(kg/tonne)
		wood	(kg/tonne)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)
j	=	Fuel type (either "natural gas", "LPG", "butane", "briquettes" or "wood")	(-)

3.2.3 *Activity Data*

Table 3-17 summarises the activity data used for barbecues, outdoor stoves and portable stoves.

Table 3-17: Barbecues activity data

Activity data	Activity data source
Barbecue/outdoor stove/portable stove type, number and fuel consumption	- *Domestic Barbecue Pollution Survey* (TR, 2009)
Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

A domestic survey of gas, liquid and solid fuel fired barbecue, outdoor stove and portable stove ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: barbecue/outdoor stove/portable stove number; fuel type; quantity of fuel used; and frequency and duration of barbecue/outdoor stove/portable stove use by hour, day and season (TR, 2009).

The key considerations in designing and conducting a domestic survey include:

Survey method - The domestic survey has been conducted using the computer assisted telephone interview (CATI) method for recruiting households to complete either an on-line or mail-out questionnaire.

Sample size - To provide a reasonable level of precision for estimating barbecue, outdoor stove and portable stove activity rates across all households in the GMR, the survey sample was sized accordingly. While a total of 832 households were recruited, 31 households were outside the GMR so they were excluded from the survey. Activity rates for barbecues, outdoor stoves and portable stoves have been based on survey responses from 801 households in the GMR.

Confidence interval and confidence level - The confidence interval quantifies the uncertainty or range in possible values. For example, for a confidence interval of 3.5% and where 47% percent of the sample picks a particular answer one can be "sure" that if the question has been asked of the entire relevant population, between 43.5% (47-3.5) and 50.5% (47+3.5) would have picked that answer.

The confidence level quantifies the level of certainty to which an estimate can be trusted. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means one can be 95% certain. Most researchers use the 95% confidence level.

When combining the confidence level and confidence interval together, one can be 95% sure that the true answer for the entire relevant population is between 43.5% and 50.5% for the example described above.

Table 3-18 presents the theoretical confidence intervals for samples of varied sizes for characteristics with a population incidence of 50% or 50%, 75% or 25% and 90% or 10%.

Table 3-18: Confidence intervals at 95% confidence level by sample size for barbecue survey

Sample size	Confidence interval at 95% confidence level		
	Endorsement rate of 50%/50%	Endorsement rate of 75%/25%	Endorsement rate of 90%/10%
100	9.8	8.5	5.9
150	8.0	6.9	4.8
200	6.9	6.0	4.2
300	5.7	4.9	3.4
400	4.9	4.2	2.9
500	4.4	3.8	2.6
600	4.0	3.5	2.4
800	3.5	3.0	2.1
1,000	3.1	2.7	1.9

The domestic survey of barbecues, outdoor stoves and portable stoves randomly sampled 801 households from a population of 5,284,560 in 1,901,680 households, so survey items with a true population incidence of 50% will produce estimates within ±3.5% of the true population value in 95% of the samples.

Random sampling and stratification - Households were selected at random across the GMR to limit bias. In practice, actual samples are not truly random since respondents always have the right to decline an interview and others cannot be reached for a variety of reasons. To reduce the standard error of estimated population values, samples were stratified on a geographic basis into the following subpopulations by location:

Sydney region, sub-grouped into

- *North East*
- *North West*
- *South East*
- *South West*

Newcastle region

Wollongong region

Development of survey questionnaires – Three survey questionnaires were developed including: initial recruitment using the computer assisted telephone interview (CATI) method to capture household details using pre-coded questions within OzQuest on-line software; self complete main survey using pre-coded questions within OzQuest on-line software; and self complete main survey using a traditional hard copy mail-out with a reply paid envelope. The questionnaires request information about: barbecue/outdoor stove/portable stove number; fuel type; quantity of fuel used; and frequency and duration of barbecue/outdoor stove/portable stove use by hour, day and season. The domestic survey questionnaire form is included at Appendix B: Domestic Survey Form (TR, 2009).

Recruitment and data collection - A random sample of phone numbers was selected from the 64 local government areas (LGA) located in the GMR, stratified into Sydney, Newcastle and Wollongong regions.

As part of the computer assisted telephone interview (CATI), households were phoned up to five times to make contact and the interviewer asked to speak to an "adult household member who is familiar with any devices the household uses that might burn solid fuel (like wood or coal heaters), liquid fuel (like kerosene heaters or petrol lawn mowers) or gas fuel (like natural gas cooktops or heaters)". If required, arrangements were made to call back at a more convenient time when an appropriate adult household member would be available.

When an adult household member was available for interview, respondents were asked what LGA they lived in. If not in the GMR they were thanked and the interview was terminated. If in the GMR, they were then asked about the number of residents in the household, the dwelling type and which of the fuel burning devices were used by the household. All were then asked for their postcode and age group. Respondents in households that had none of the fuel burning devices were thanked and the interview terminated. All other respondents were then asked if they would be willing to complete a further questionnaire either on-line or by mail. If willing, contact details were recorded, and the interview concluded. Those who initially declined were read material emphasizing the importance of obtaining data from all households, whether they make little use of fuel burning devices or not and asked again if they would be willing to take part.

Consenting respondents were then either e-mailed a link to a self complete on-line main survey or mailed a self complete hard copy main survey. The mailed questionnaires included an identifying serial number on the front page with a letter from DECCW encouraging completion of the survey.

Main survey completions on-line and mail-out were closely monitored and households were phoned on two occasions in order to remind them to complete. Some respondents indicated they preferred to go through the questions on the phone. Data for these were entered into the on-line version of the questionnaire.

Data capture – Data from the three survey questionnaires (i.e. CATI, on-line main survey and hard copy main survey) have all been entered into a database which captures pre-coded questions using OzQuest on-line software. All data was then checked, cleaned and saved in a Microsoft® Excel™ 2003 workbook.

Survey timeframe - The survey took approximately 15 weeks to complete, from the time that questionnaire development commenced to the date data analysis and report were completed. The key tasks and milestones for the domestic survey are presented in Table 3-19.

Table 3-19: Barbecue survey milestones

Task	Milestones
Questionnaire development commenced	11 August 2009
CATI recruitment commenced	18 September 2009
CATI recruitment completed	21 October 2009
Main survey completed	12 November 2009
Data analysis and report completed	26 November 2009

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the barbecue survey results (TR, 2009). Table 3-20 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-20: Population and dwelling by LGA used to scale-up barbecue survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[8]	Total dwelling
Ashfield	47,887	7,660	2,728	7,882	142	18,412
Auburn	69,555	7,358	2,326	11,421	284	21,390
Bankstown	174,326	7,781	8,028	41,407	287	57,503
Bathurst Regional	157	-	-	41	1	41
Baulkham Hills	170,925	2,345	5,004	46,441	137	53,928
Blacktown	286,162	3,915	9,712	77,217	700	91,544
Blue Mountains	78,427	777	1,030	27,952	63	29,822
Botany Bay	33,316	4,244	1,974	5,777	100	12,095
Burwood	30,277	3,332	1,108	5,770	65	10,275
Camden	55,287	258	499	16,910	161	17,828
Campbelltown	150,373	1,333	8,057	39,856	97	49,343
Canada Bay	58,880	6,445	2,342	13,157	137	22,080
Canterbury	138,343	16,795	4,851	25,673	328	47,647
Cessnock	48,845	562	339	16,615	150	17,667
Dungog	7,659	23	60	2,581	38	2,702
Fairfield	189,024	7,302	6,172	43,571	198	57,243
Gosford	162,826	5,481	8,288	49,407	676	63,852
Goulburn Mulwaree	341	-	1	79	-	80
Great Lakes	4,062	10	29	1,301	44	1,383
Hawkesbury	62,416	899	1,674	18,441	241	21,254
Holroyd	95,192	6,969	3,562	22,399	144	33,074
Hornsby	160,612	9,018	4,454	40,736	265	54,472
Hunters Hill	9,295	898	318	1,892	3	3,111
Hurstville	81,935	7,352	3,548	18,534	111	29,545
Kiama	14,586	580	338	4,433	75	5,426
Kogarah	57,349	6,558	1,565	11,945	81	20,148
Ku-ring-gai	106,943	3,805	1,253	30,103	73	35,235
Lake Macquarie	195,295	3,160	4,849	63,598	926	72,532
Lane Cove	28,511	4,473	652	5,687	92	10,904

[8] Caravan, cabin, houseboat, improvised home, tent, sleepers out, house or flat attached to a shop or office (TDC, 2009).

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[8]	Total dwelling
Leichhardt	39,692	4,537	6,175	5,998	278	16,988
Lithgow	19,595	227	341	6,350	59	6,977
Liverpool	178,554	6,938	5,352	42,517	317	55,125
Maitland	66,554	1,330	1,049	21,169	117	23,666
Manly	33,804	5,898	1,520	5,676	97	13,192
Marrickville	86,873	13,062	10,292	11,838	553	35,744
Mid-western Regional	3,412	25	14	1,149	17	1,205
Mosman	30,915	6,692	1,506	4,604	104	12,905
Muswellbrook	15,221	364	121	4,582	62	5,128
N/A	25,875	4,778	1,262	4,329	119	10,488
Newcastle	150,930	8,242	6,306	44,792	500	59,840
North Sydney	53,850	17,299	4,228	3,854	252	25,633
Oberon	1,803	4	5	438	5	452
Parramatta	152,570	16,729	6,975	29,743	348	53,796
Penrith	177,459	3,483	4,905	51,040	349	59,776
Pittwater	54,586	2,542	1,577	15,389	183	19,690
Port Stephens	59,017	756	1,587	18,809	482	21,634
Randwick	130,955	25,728	8,002	16,752	370	50,853
Rockdale	89,735	12,199	4,159	16,242	256	32,856
Ryde	105,073	11,196	5,519	22,448	111	39,275
Shellharbour	65,104	1,282	2,369	18,768	328	22,747
Shoalhaven	81	-	-	30	-	30
Singleton	22,222	405	275	6,357	132	7,169
Strathfield	38,732	5,612	806	6,543	45	13,006
Sutherland	212,924	16,252	8,522	52,450	274	77,498
Sydney	167,382	52,686	17,811	4,651	1,028	76,176
Unincorporated	42,682	9,672	2,028	5,866	146	17,713
Upper Hunter	350	-	-	66	-	66
Upper Lachlan	502	-	-	92	-	92
Warringah	141,123	16,643	3,029	32,008	175	51,854
Waverley	57,147	14,769	4,430	5,038	245	24,481
Willoughby	69,528	11,760	2,038	12,473	82	26,353
Wingecarribee	45,480	537	1,113	15,131	144	16,924
Wollondilly	42,871	168	292	13,634	133	14,227
Wollongong	193,292	11,210	7,296	52,219	992	71,717
Woollahra	44,773	12,138	3,128	4,232	71	19,569
Wyong	145,088	2,801	4,575	47,918	1,006	56,300
Grand Total	5,284,560	417,295	213,366	1,256,021	14,998	1,901,680

The total population of in-service barbecues, outdoor stoves and portable stoves have been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates

(TDC, 2009). In-service barbecue, outdoor stove and portable stove population by dwelling type for the GMR is presented in Table 3-21 and shown in Figure 3-7.

Table 3-21: Barbecues population by dwelling type in the GMR

Dwelling type	2008 statistics		
	Dwelling number	Barbecue number	Proportion of dwelling type with barbecue (%)
Flat, unit or apartment	417,295	142,155	34.07
Semi detached, terrace house or townhouse	213,366	162,737	76.27
Separate house	1,256,021	967,659	77.04
Other dwelling	14,998	-	-
Grand Total	1,901,680	1,272,551	66.92

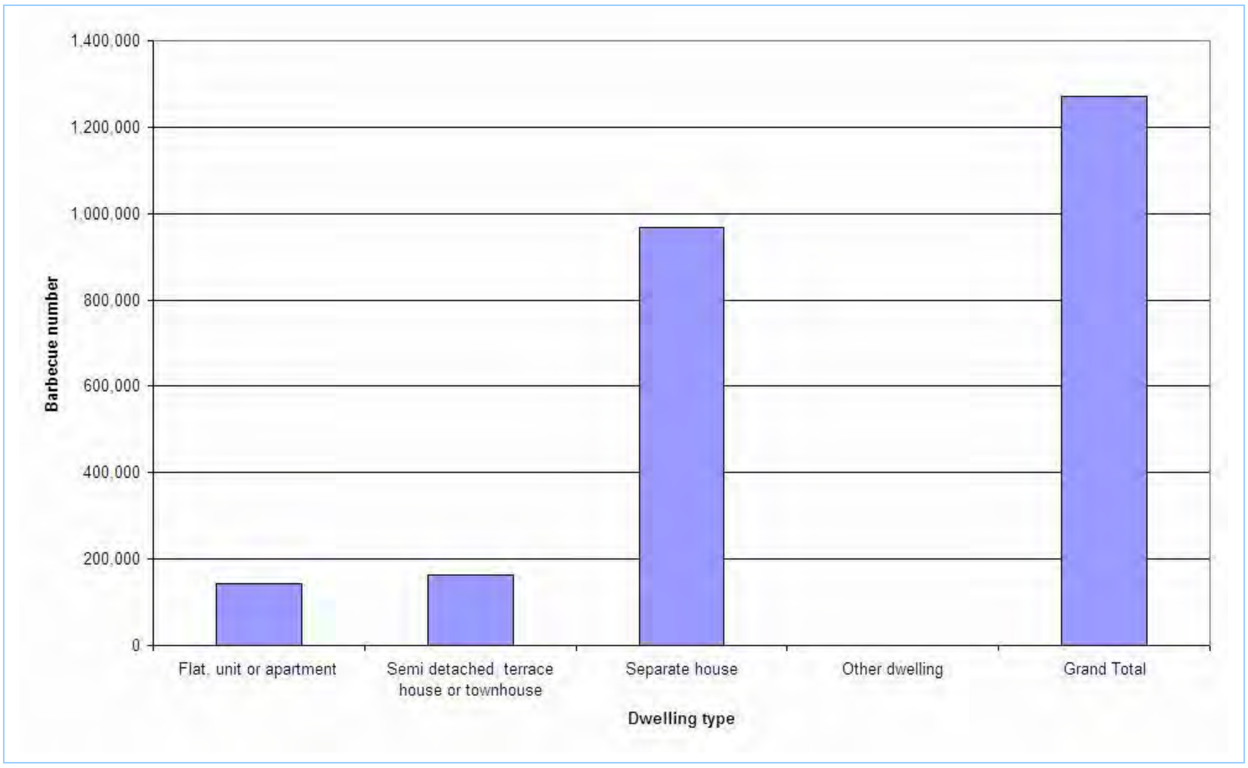

Figure 3-7: Barbecues population by dwelling type in the GMR

In-service barbecue, outdoor stove and portable stove population by fuel type for the GMR are presented in Table 3-22 and shown in Figure 3-8.

Table 3-22: Barbecues population by fuel type in the GMR

Barbecue type	2008 barbecue number
Natural gas	193,958
LPG	979,249
Butane	4,731
Briquettes	23,653
Wood	18,923
Other[9]	52,037
Grand Total	1,272,551

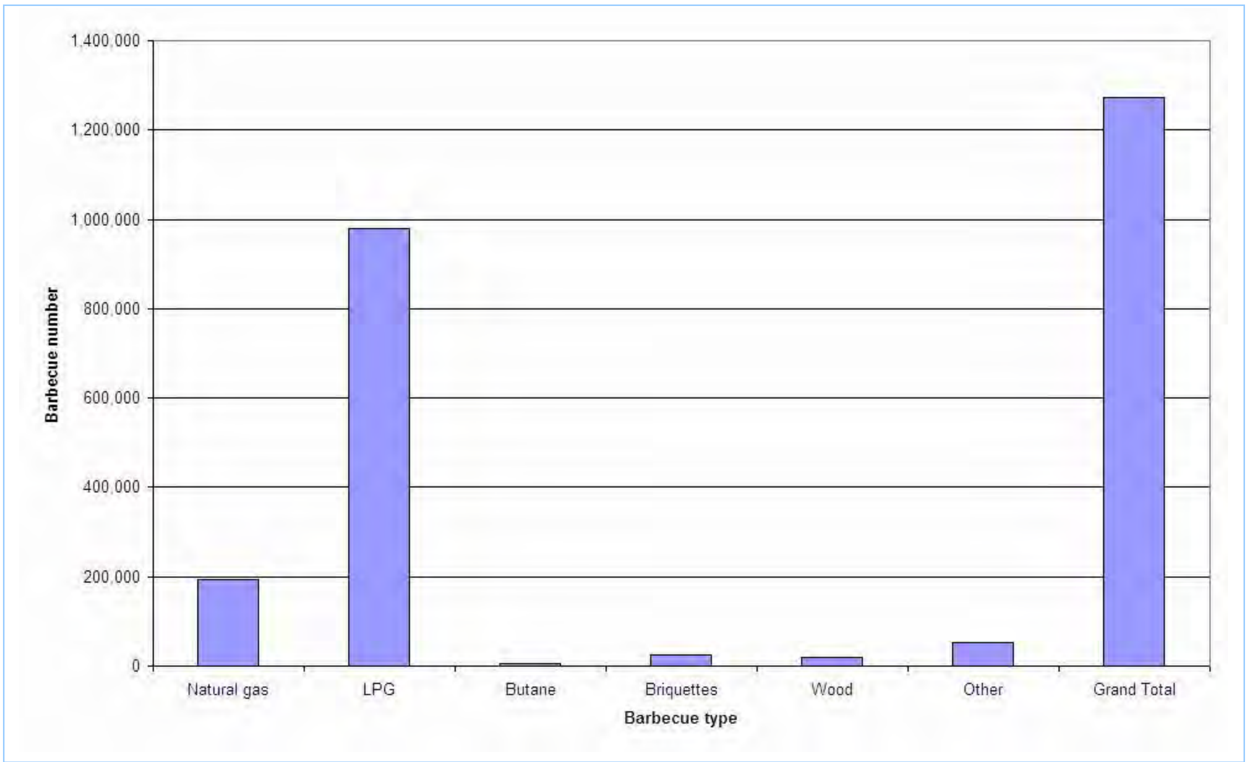

Figure 3-8: Barbecues population by fuel type in the GMR

The total consumption of natural gas, liquid petroleum gas (LPG), butane, briquettes and wood have been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). Table 3-23 presents the barbecue, outdoor stove and portable stove fuel consumption estimates.

[9] The barbecue type could not be determined from the domestic survey, so emissions from other barbecues have not been estimated (TR, 2009).

Table 3-23: Barbecues fuel consumption in the GMR

Dwelling type	2008 fuel consumption				
	Natural gas (Mm^3/year)	LPG (kL/year)	Butane (kL/year)	Briquettes (tonne/year)	Wood (tonne/year)
Flat, unit or apartment	0.7	5,568	4	251	144
Semi detached, terrace house or townhouse	0.8	6,374	5	287	164
Separate house	5.0	37,902	28	1,709	977
Other dwelling	-	-	-	-	-
Grand Total	6.6	49,845	37	2,247	1,285

3.2.4 *Emission and Speciation Factors*

Table 3-24 summarises the emission and speciation factors used for barbecues, outdoor stoves and portable stoves.

Table 3-24: Barbecues emission and speciation factors

Substance	Emission source	Emission and speciation factor source[10]
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	Natural gas combustion	- *Table 1.4-1 Residential furnaces and Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Butane combustion	- *Table 1.5-1 Butane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Briquettes combustion	- *Table 1.1-3 Hand-fed units - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Table 1.1-4 Hand-fed units - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Table 1.1-5 Spreader stoker, travelling grate, overfeed stoker and underfeed stoker - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Table 1.1-11 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And*

[10] Where references are marked with an asterisk (i.e. *), LPG fired barbecues and outdoor stoves use natural gas emission data, which have been adjusted to LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 38.3 MJ/m^3 for natural gas (ABARE, 2009b). Where references are marked with a hash (i.e. #), butane fired portable stoves use natural gas emission data, which have been adjusted to butane equivalent based on effective heating value of 28.1 MJ/L for butane and 38.3 MJ/m^3 for natural gas (ABARE, 2009b).

<table>
<tr><th>Substance</th><th>Emission source</th><th>Emission and speciation factor source[10]</th></tr>
<tr><td rowspan="2"></td><td></td><td>Subbituminous Coal Combustion (USEPA, 1998b)</td></tr>
<tr><td>Wood combustion</td><td>- Table 1.9-1 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces (USEPA, 1996a)
- PMPROF 424 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles (CARB, 2008b)</td></tr>
<tr><td rowspan="5">Criteria pollutants: TSP</td><td>Natural gas combustion</td><td>- Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion (USEPA, 1998a)</td></tr>
<tr><td>LPG combustion</td><td>- Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion (USEPA, 2008a)</td></tr>
<tr><td>Butane combustion</td><td>- Table 1.5-1 Butane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion (USEPA, 2008a)</td></tr>
<tr><td>Briquettes combustion</td><td>- Table 1.1-4 Hand-fed units - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion (USEPA, 1998b)
- Table 1.1-5 Spreader stoker, travelling grate, overfeed stoker and underfeed stoker - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion (USEPA, 1998b)</td></tr>
<tr><td>Wood combustion</td><td>- PMPROF 424 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles (CARB, 2008b)</td></tr>
<tr><td>Speciated NO_x</td><td>Natural gas, LPG, butane, briquettes and wood combustion</td><td>- Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors (USEPA, 2003)</td></tr>
<tr><td rowspan="5">Speciated VOC</td><td>Natural gas combustion</td><td>- Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion (USEPA, 1998a)</td></tr>
<tr><td>LPG combustion</td><td>- Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion (USEPA, 1998a)*</td></tr>
<tr><td>Butane combustion</td><td>- Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion (USEPA, 1998a)#</td></tr>
<tr><td>Briquettes combustion</td><td>- Table 1.1-14 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion (USEPA, 1998b)
- Profile number 1185 Coal fired boiler industrial - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td>Wood combustion</td><td>- Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td rowspan="2">Organic air toxics</td><td>Natural gas combustion</td><td>- Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion (USEPA, 1998a)</td></tr>
<tr><td>LPG combustion</td><td>- Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion</td></tr>
</table>

Substance	Emission source	Emission and speciation factor source[10]
		(USEPA, 1998a)*
	Butane combustion	- *Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)#
	Briquettes combustion	- *Table 1.1-14 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Profile number 1185 Coal fired boiler industrial - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Wood combustion	- *Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Metal air toxics	Natural gas combustion	- *Table 1.4-4 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-4 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
	Butane combustion	- *Table 1.4-4 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)#
	Briquettes combustion	- *Table 1.1-18 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b) - *Profile number 4320130 Residential space heating coal - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Wood combustion	- *Composite profile number 3831, 3832, 3833, 3835, 3846 and 3856 Residential wood burning - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Polycyclic aromatic hydrocarbons: PAH	Natural gas combustion	- *Table 1.4-3 – AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-3 – AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
	Butane combustion	- *Table 1.4-3 – AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)#
	Briquettes combustion	- *Table 1.1-13 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b)
	Wood combustion	- *Table 1.10-3 Conventional stove - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b)
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans:	Natural gas combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Natural gas - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	LPG combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Natural gas - Australian Inventory of Dioxin*

Substance	Emission source	Emission and speciation factor source[10]
PCDD and PCDF		*Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)*
	Butane combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Natural gas - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)#
	Briquettes combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Coal - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Wood combustion	- *Table 4.51 Emission Factors – Household Heating and Cooking (Biomass) - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
Ammonia	Natural gas combustion	- *Table III-1 Residential natural gas combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	LPG combustion	- *Table III-1 Residential natural gas combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)*
	Butane combustion	- *Table III-1 Residential natural gas combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)#
	Briquettes combustion	- *Table III-1 Residential coal combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Wood combustion	- *Table III-8 Stationary Source Fuel Combustion, Residential Wood, Fireplaces - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
Greenhouse gases: CH_4	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Butane combustion	- *Table 1.5-1 Butane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Briquettes combustion	- *Table 1.1-19 Hand-fed units - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b)
	Wood combustion	- *Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Greenhouse gases: CO_2	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)

Substance	Emission source	Emission and speciation factor source[10]
	Butane combustion	- *Table 1.5-1 Butane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Briquettes combustion	- *Table 1.1-20 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b)
	Wood combustion	- *Table 1.9-1 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA, 1996a)
Greenhouse gases: N_2O	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Butane combustion	- *Table 1.5-1 Butane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
	Briquettes combustion	- *Table 1.1-19 Hand-fed units - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.1 Bituminous And Subbituminous Coal Combustion* (USEPA, 1998b)
	Wood combustion	- *Table 1.9-1 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9 Residential Fireplaces* (USEPA, 1996a)

Table 3-25 presents emission factors for natural gas, liquid petroleum gas (LPG), butane, briquettes and wood fired residential barbecues, outdoor stoves and portable stoves.

Table 3-25: Barbecues emission factors

Emission source	Emission factors											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
Natural gas combustion (kg/Mm^3)	1,505.59	35.237	320.339	9.610	121.73	121.73	88.09	36.839	640.68	1,922,033.90	0.0112	4.98×10^{-8}
LPG and butane[11] combustion (kg/kL)	1.56	0.108	0.213	0.013	0.08	0.08	0.06	0.024	0.90	1,498.02	7.45×10^{-6}	3.32×10^{-11}
Briquettes combustion (kg/tonne)	4.55	0.020	1.000	4.650	3.12	1.92	5.00	2.500	137.50	2,401.20	1.04×10^{-5}	1.75×10^{-9}
Wood combustion (kg/tonne)	1.30	0.150	0.900	0.200	17.30	16.65	114.50	34.312	126.30	1,700.00	0.3650	4.10×10^{-9}

[11] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 28.1 MJ/L for butane (ABARE, 2009b).

3.2.5 Spatial Distribution of Emissions

Table 3-26 summarises the data used for spatially allocating emissions from barbecues, outdoor stoves and portable stoves.

Table 3-26: Barbecues spatial data

Emission source	Spatial data	Spatial data source
Exhaust emissions from gas, liquid and solid fuel combustion in barbecues, outdoor stoves and portable stoves	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from barbecues, outdoor stoves and portable stoves have been spatially distributed according to natural gas, liquid petroleum gas (LPG), butane, briquettes and wood consumption, which are proportional to total dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of natural gas, liquid petroleum gas (LPG), butane, briquettes and wood consumption by LGA and region are presented in Table 3-27 and shown in Figure 3-9.

Table 3-27: Barbecues spatial distribution of fuel consumption by LGA and region

LGA	2008 proportion of annual natural gas, liquid petroleum gas (LPG), butane, briquettes and wood consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.97	-	0.97
Auburn	-	-	1.13	-	1.13
Bankstown	-	-	3.03	-	3.03
Bathurst Regional	-	2.18×10^{-3}	-	-	2.18×10^{-3}
Baulkham Hills	-	2.39×10^{-3}	2.84	-	2.84
Blacktown	-	-	4.82	-	4.82
Blue Mountains	-	0.56	1.00	-	1.57
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.54	-	0.54
Camden	-	-	0.94	-	0.94
Campbelltown	-	-	2.60	-	2.60
Canada Bay	-	-	1.16	-	1.16
Canterbury	-	-	2.51	-	2.51
Cessnock	3.84×10^{-2}	0.89	-	-	0.93
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.01	-	3.01
Gosford	-	0.91	2.45	-	3.36
Goulburn Mulwaree	-	4.14×10^{-3}	-	-	4.14×10^{-3}
Great Lakes	-	6.80×10^{-2}	-	-	6.80×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.10	-	1.12
Holroyd	-	-	1.74	-	1.74
Hornsby	-	3.62×10^{-3}	2.86	-	2.87
Hunters Hill	-	-	0.16	-	0.16
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.29	-	-	0.29

LGA	2008 proportion of annual natural gas, liquid petroleum gas (LPG), butane, briquettes and wood consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Kogarah	-	-	1.06	-	1.06
Ku-ring-gai	-	-	1.85	-	1.85
Lake Macquarie	2.00	1.82	-	-	3.82
Lane Cove	-	-	0.57	-	0.57
Leichhardt	-	-	0.89	-	0.89
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	2.90	-	2.90
Maitland	9.39×10^{-2}	1.15	-	-	1.25
Manly	-	-	0.69	-	0.69
Marrickville	-	-	1.88	-	1.88
Mid-western Regional	-	5.16×10^{-2}	-	-	5.16×10^{-2}
Mosman	-	-	0.68	-	0.68
Muswellbrook	-	0.26	-	-	0.26
N/A	3.05×10^{-2}	5.58×10^{-2}	0.39	7.60×10^{-2}	0.55
Newcastle	3.15	-	-	-	3.15
North Sydney	-	-	1.35	-	1.35
Oberon	-	2.26×10^{-2}	-	-	2.26×10^{-2}
Parramatta	-	-	2.83	-	2.83
Penrith	-	-	3.15	-	3.15
Pittwater	-	-	1.04	-	1.04
Port Stephens	6.97×10^{-2}	1.07	-	-	1.14
Randwick	-	-	2.68	-	2.68
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.07	-	2.07
Shellharbour	-	0.89	-	0.31	1.20
Shoalhaven	-	1.50×10^{-3}	-	-	1.50×10^{-3}
Singleton	-	0.37	-	-	0.37
Strathfield	-	-	0.68	-	0.68
Sutherland	-	-	4.08	-	4.08
Sydney	-	-	4.01	-	4.01
Unincorporated	-	-	0.93	-	0.93
Upper Lachlan	-	6.05×10^{-4}	-	-	6.05×10^{-4}
Warringah	-	-	2.73	-	2.73
Waverley	-	-	1.29	-	1.29
Willoughby	-	-	1.39	-	1.39
Wingecarribee	-	0.88	4.72×10^{-3}	1.50×10^{-3}	0.89
Wollondilly	-	1.16×10^{-2}	0.74	3.91×10^{-4}	0.75
Wollongong	-	-	0.27	3.50	3.77
Woollahra	-	-	1.03	-	1.03
Wyong	-	2.96	-	-	2.96
Grand Total	5.38	12.78	77.95	3.89	100.00

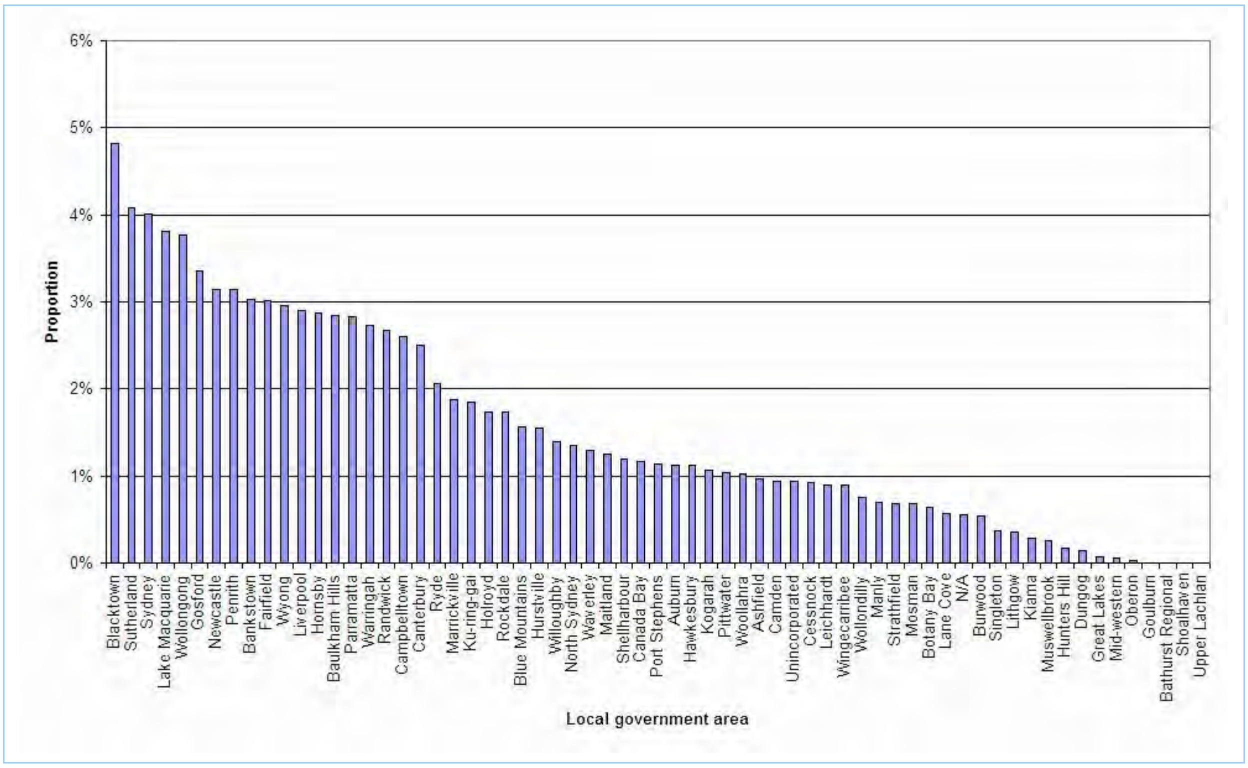

Figure 3-9: Barbecues spatial distribution of fuel consumption by LGA

Figure 3-10 shows the spatial distribution of barbecue, outdoor stove and portable stove emissions.

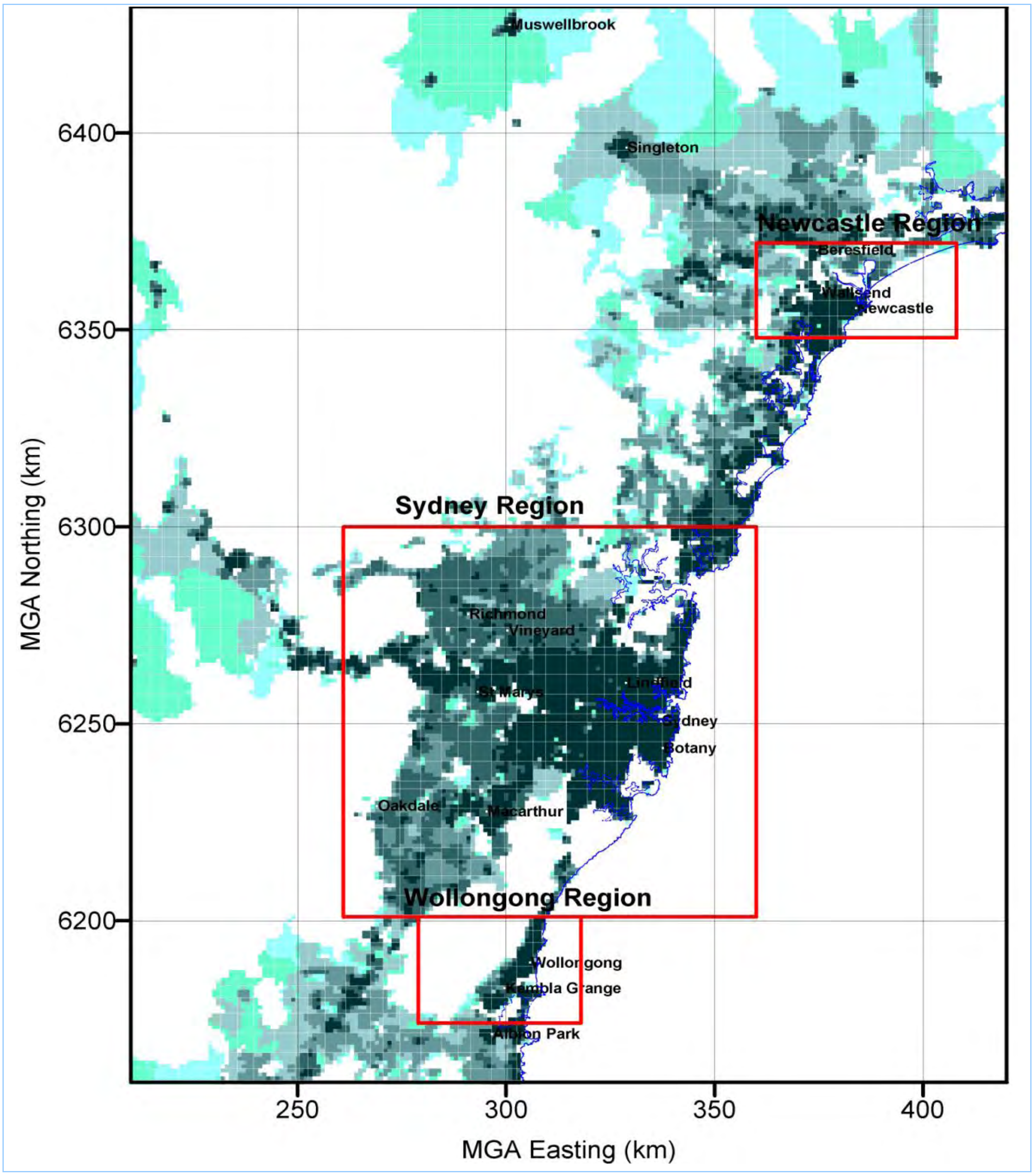

Figure 3-10: Barbecues spatial distribution of emissions

3.2.6 *Temporal Variation of Emissions*

Table 3-28 summarises the data used to estimate the temporal variation in emissions from barbecues, outdoor stoves and portable stoves.

Table 3-28: Barbecues temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from gas, liquid and solid fuel combustion in barbecues, outdoor stoves and portable stoves	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Barbecue Pollution Survey* (TR, 2009)

The temporal variation in emissions from barbecues, outdoor stoves and portable stoves have been estimated from barbecue/outdoor stove/portable stove number, fuel type, quantity of fuel used and frequency and duration of barbecue/outdoor stove/portable stove use by hour, day and season data (TR, 2009).

Hourly temporal variation profiles are presented in Table 3-29 and shown in Figure 3-11.

Table 3-29: Barbecues hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	0.16	13	10.39
2	0.16	14	3.25
3	0.16	15	1.79
4	0.16	16	4.55
5	0.16	17	15.75
6	0.49	18	25.81
7	0.81	19	13.15
8	1.30	20	2.44
9	1.79	21	0.32
10	1.62	22	0.16
11	0.65	23	0.16
12	1.95	24	10.39

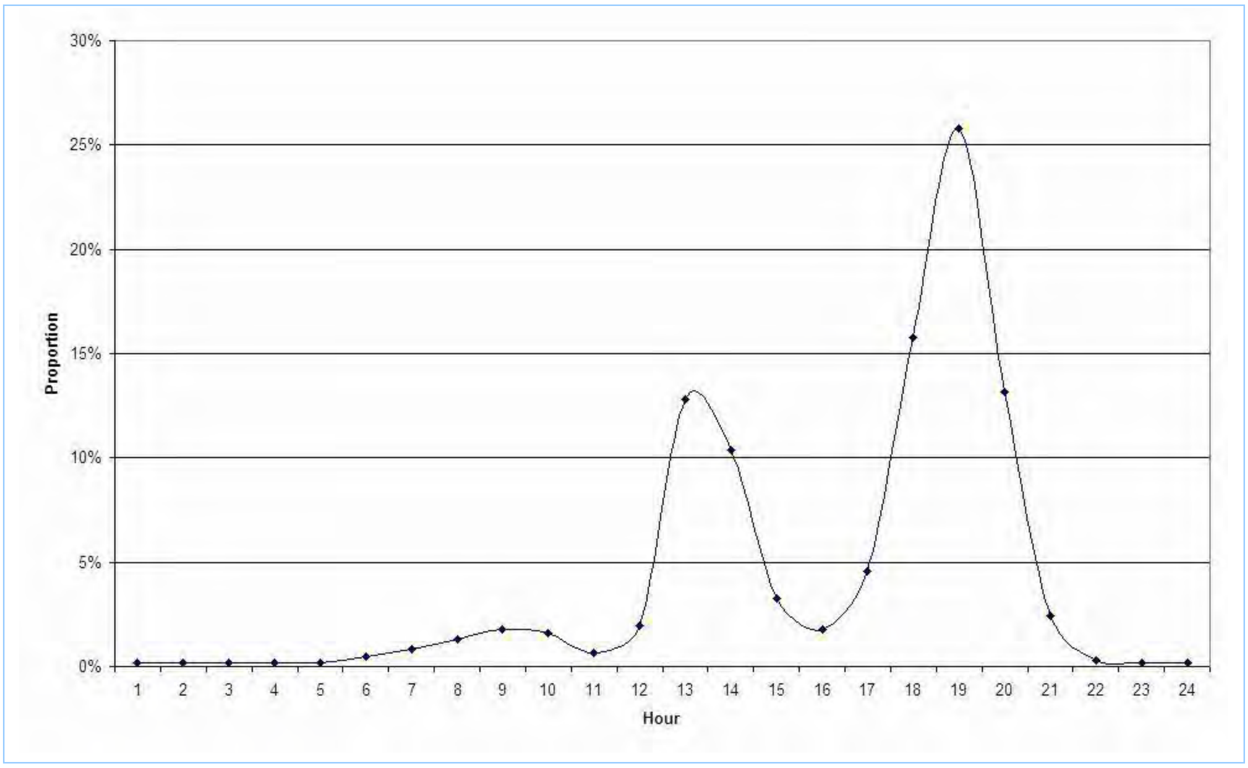

Figure 3-11: Barbecues hourly temporal profile

Daily temporal variation profiles are presented in Table 3-30 and shown in Figure 3-12.

Table 3-30: Barbecues daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	9.37	9.37	9.37	9.37	9.37	26.58	26.58

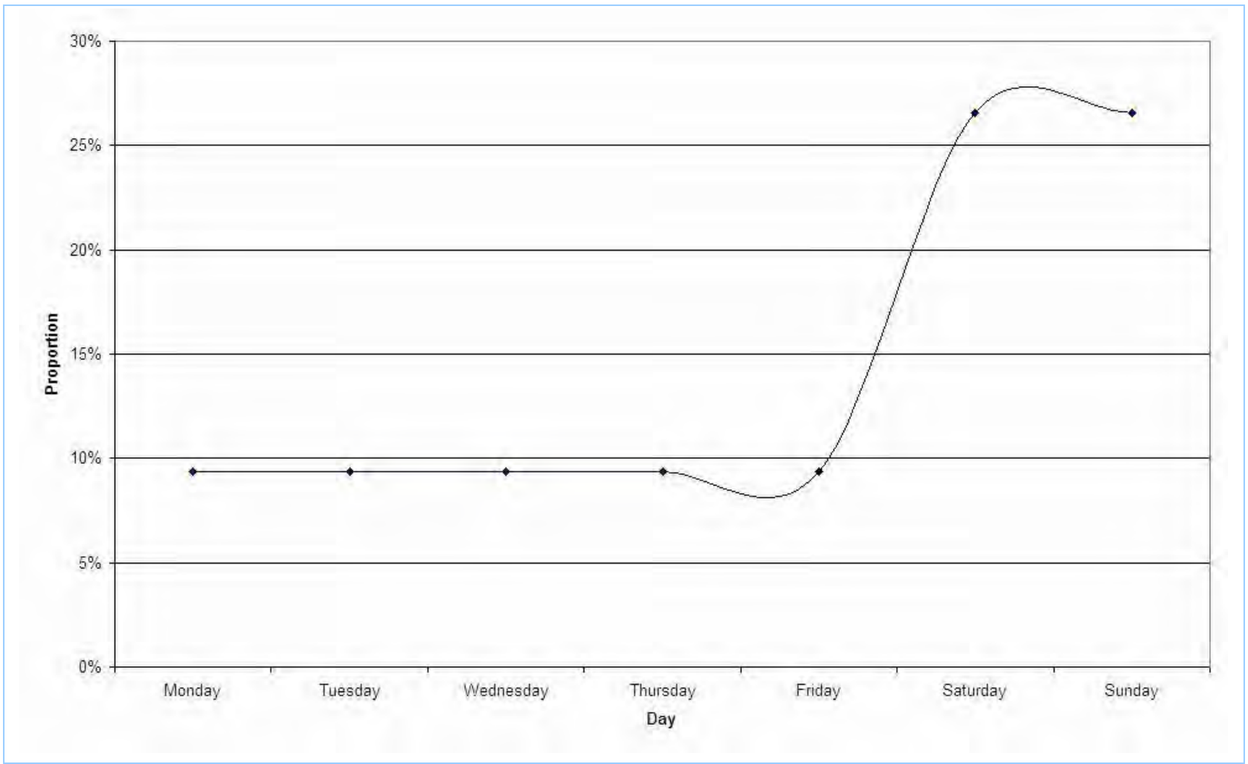

Figure 3-12: Barbecues daily temporal profile

Monthly temporal variation profiles are presented in Table 3-31 and shown in Figure 3-13.

Table 3-31: Barbecues monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	22.79	July	2.05
February	18.74	August	2.46
March	4.36	September	2.50
April	3.26	October	5.23
May	2.16	November	7.96
June	1.64	December	26.85

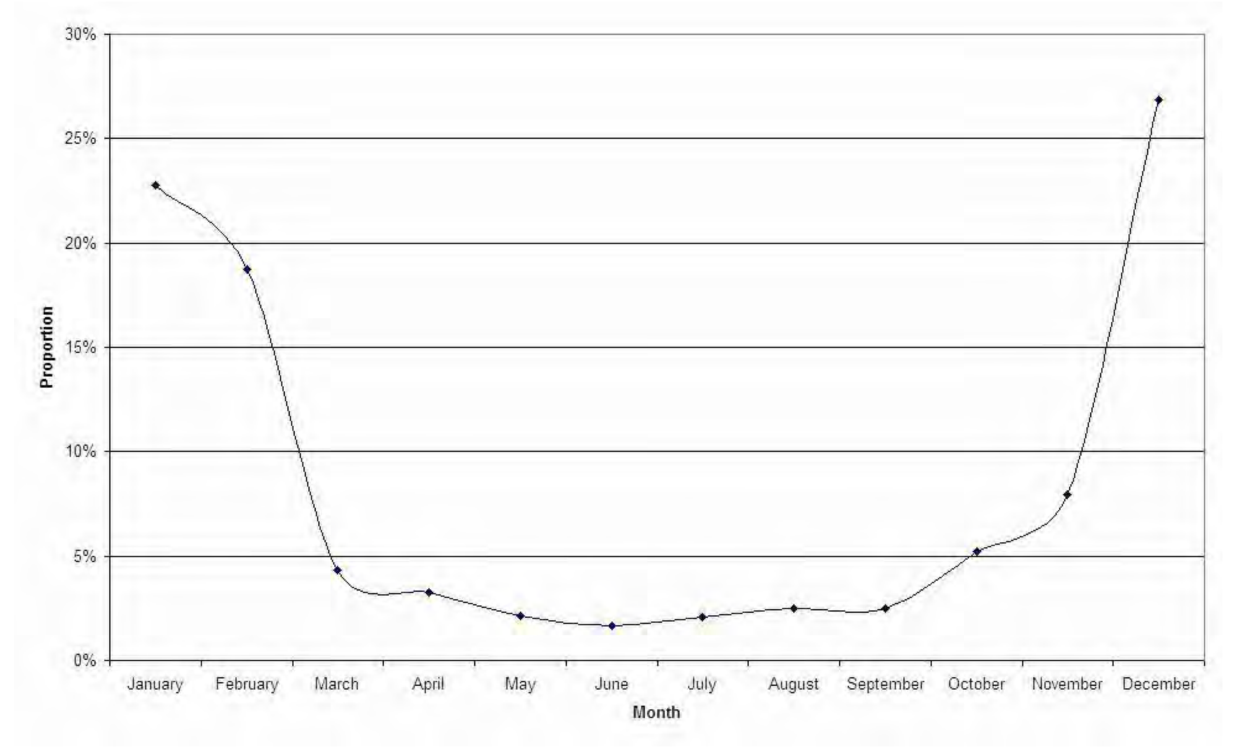

Figure 3-13: Barbecues monthly temporal profile

3.2.7 *Emission Estimates*

Table 3-32 presents annual emissions of selected substances from barbecues, outdoor stoves and portable stoves by activity.

Table 3-32: Barbecues emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Barbecues	1,3-BUTADIENE	67	160	976	49	1,252
	ACETALDEHYDE	981	2,332	14,219	709	18,241
	BENZENE	221	524	3,198	159	4,103
	CARBON MONOXIDE	27,988	66,525	405,620	20,224	520,357
	FORMALDEHYDE	673	1,600	9,758	487	12,519
	ISOMERS OF XYLENE	45	107	652	32	836
	LEAD & COMPOUNDS	0.16	0.39	2.37	0.12	3.04
	OXIDES OF NITROGEN	5,352	12,722	77,568	3,867	99,510
	PARTICULATE MATTER ≤ 10 µm	1,841	4,376	26,684	1,330	34,232
	PARTICULATE MATTER ≤ 2.5 µm	1,652	3,926	23,935	1,193	30,705
	PERCHLOROETHYLENE	2.60×10^{-3}	6.18×10^{-3}	3.77×10^{-2}	1.88×10^{-3}	4.83×10^{-2}
	POLYCYCLIC AROMATIC HYDROCARBONS	25	60	366	18	470
	SULFUR DIOXIDE	614	1,461	8,905	444	11,425

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOLUENE	91	217	1,320	66	1,694
	TOTAL SUSPENDED PARTICULATE	2,456	5,838	35,598	1,775	45,667
	TOTAL VOLATILE ORGANIC COMPOUNDS	8,708	20,699	126,209	6,293	161,910

Table 3-33 presents annual emissions of selected substances from barbecues, outdoor stoves and portable stoves by source type.

Table 3-33: Barbecues emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Briquettes	ACETALDEHYDE	3.44×10^{-2}	8.19×10^{-2}	0.50	2.49×10^{-2}	0.64
	BENZENE	7.86×10^{-2}	0.19	1.14	5.68×10^{-2}	1.46
	CARBON MONOXIDE	16,618	39,501	240,845	12,008	308,972
	FORMALDEHYDE	1.45×10^{-2}	3.45×10^{-2}	0.21	1.05×10^{-2}	0.27
	ISOMERS OF XYLENE	2.24×10^{-3}	5.31×10^{-3}	3.24×10^{-2}	1.62×10^{-3}	4.16×10^{-2}
	LEAD & COMPOUNDS	2.54×10^{-2}	6.03×10^{-2}	0.37	1.83×10^{-2}	0.47
	OXIDES OF NITROGEN	550	1,307	7,970	397	10,224
	PARTICULATE MATTER ≤ 10 µm	377	896	5,465	272	7,011
	PARTICULATE MATTER ≤ 2.5 µm	232	552	3,363	168	4,314
	PERCHLOROETHYLENE	2.60×10^{-3}	6.18×10^{-3}	3.77×10^{-2}	1.88×10^{-3}	4.83×10^{-2}
	POLYCYCLIC AROMATIC HYDROCARBONS	1.25×10^{-3}	2.98×10^{-3}	1.82×10^{-2}	9.06×10^{-4}	2.33×10^{-2}
	SULFUR DIOXIDE	562	1,336	8,145	406	10,449
	TOLUENE	1.45×10^{-2}	3.45×10^{-2}	0.21	1.05×10^{-2}	0.27
	TOTAL SUSPENDED PARTICULATE	909	2,160	13,172	657	16,898
	TOTAL VOLATILE ORGANIC COMPOUNDS	604	1,436	8,758	437	11,235
LPG and Butane	ACETALDEHYDE	3.81×10^{-4}	9.05×10^{-4}	5.52×10^{-3}	2.75×10^{-4}	7.08×10^{-3}
	BENZENE	6.01×10^{-2}	0.14	0.87	4.34×10^{-2}	1.12
	CARBON MONOXIDE	2,412	5,732	34,951	1,743	44,837
	FORMALDEHYDE	2.15	5.10	31	1.55	40
	LEAD & COMPOUNDS	1.43×10^{-2}	3.40×10^{-2}	0.21	1.03×10^{-2}	0.27
	OXIDES OF NITROGEN	4,180	9,936	60,581	3,021	77,718
	PARTICULATE MATTER ≤ 10 µm	225	535	3,262	163	4,185
	PARTICULATE MATTER ≤ 2.5 µm	225	535	3,262	163	4,185
	POLYCYCLIC AROMATIC	2.0×10^{-2}	4.75×10^{-2}	0.29	1.44×10^{-2}	0.37

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	HYDROCARBONS					
	SULFUR DIOXIDE	35	84	511	25	655
	TOLUENE	9.73×10^{-2}	0.23	1.41	7.03×10^{-2}	1.81
	TOTAL SUSPENDED PARTICULATE	225	535	3,262	163	4,185
	TOTAL VOLATILE ORGANIC COMPOUNDS	157	374	2,281	114	2,926
Natural Gas	ACETALDEHYDE	7.53×10^{-5}	1.79×10^{-4}	1.09×10^{-3}	5.44×10^{-5}	1.40×10^{-3}
	BENZENE	1.19×10^{-2}	2.83×10^{-2}	0.17	8.59×10^{-3}	0.22
	CARBON MONOXIDE	227	538	3,283	164	4,211
	FORMALDEHYDE	0.42	1.01	6.16	0.31	7.90
	LEAD & COMPOUNDS	2.83×10^{-3}	6.73×10^{-3}	4.10×10^{-2}	2.05×10^{-3}	5.26×10^{-2}
	OXIDES OF NITROGEN	532	1,265	7,714	385	9,897
	PARTICULATE MATTER ≤ 10 µm	43	102	624	31	800
	PARTICULATE MATTER ≤ 2.5 µm	43	102	624	31	800
	POLYCYCLIC AROMATIC HYDROCARBONS	3.95×10^{-3}	9.40×10^{-3}	5.73×10^{-2}	2.86×10^{-3}	7.35×10^{-2}
	SULFUR DIOXIDE	3.40	8.08	49	2.46	63
	TOLUENE	1.93×10^{-2}	4.58×10^{-2}	0.28	1.39×10^{-2}	0.36
	TOTAL SUSPENDED PARTICULATE	43	102	624	31	800
	TOTAL VOLATILE ORGANIC COMPOUNDS	31	74	451	23	579
Wood	1,3-BUTADIENE	67	160	976	49	1,252
	ACETALDEHYDE	981	2,332	14,218	709	18,240
	BENZENE	221	524	3,196	159	4,100
	CARBON MONOXIDE	8,731	20,754	126,542	6,309	162,336
	FORMALDEHYDE	671	1,594	9,721	485	12,471
	ISOMERS OF XYLENE	45	107	652	32	836
	LEAD & COMPOUNDS	0.12	0.29	1.75	8.74×10^{-2}	2.25
	OXIDES OF NITROGEN	90	214	1,302	65	1,671
	PARTICULATE MATTER ≤ 10 µm	1,196	2,843	17,333	864	22,236
	PARTICULATE MATTER ≤ 2.5 µm	1,151	2,737	16,686	832	21,406
	POLYCYCLIC AROMATIC HYDROCARBONS	25	60	366	18	469
	SULFUR DIOXIDE	14	33	200	9.99	257
	TOLUENE	91	216	1,318	66	1,691
	TOTAL SUSPENDED PARTICULATE	1,279	3,041	18,540	924	23,784
	TOTAL VOLATILE ORGANIC COMPOUNDS	7,916	18,815	114,719	5,720	147,170

3.2.8 Emission Projection Methodology

Table 3-34 summarises the data used to estimate the emission projection factors for barbecues, outdoor stoves and portable stoves, while Figure 3-14 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-34: Barbecues emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from gas, liquid and solid fuel combustion in barbecues, outdoor stoves and portable stoves	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

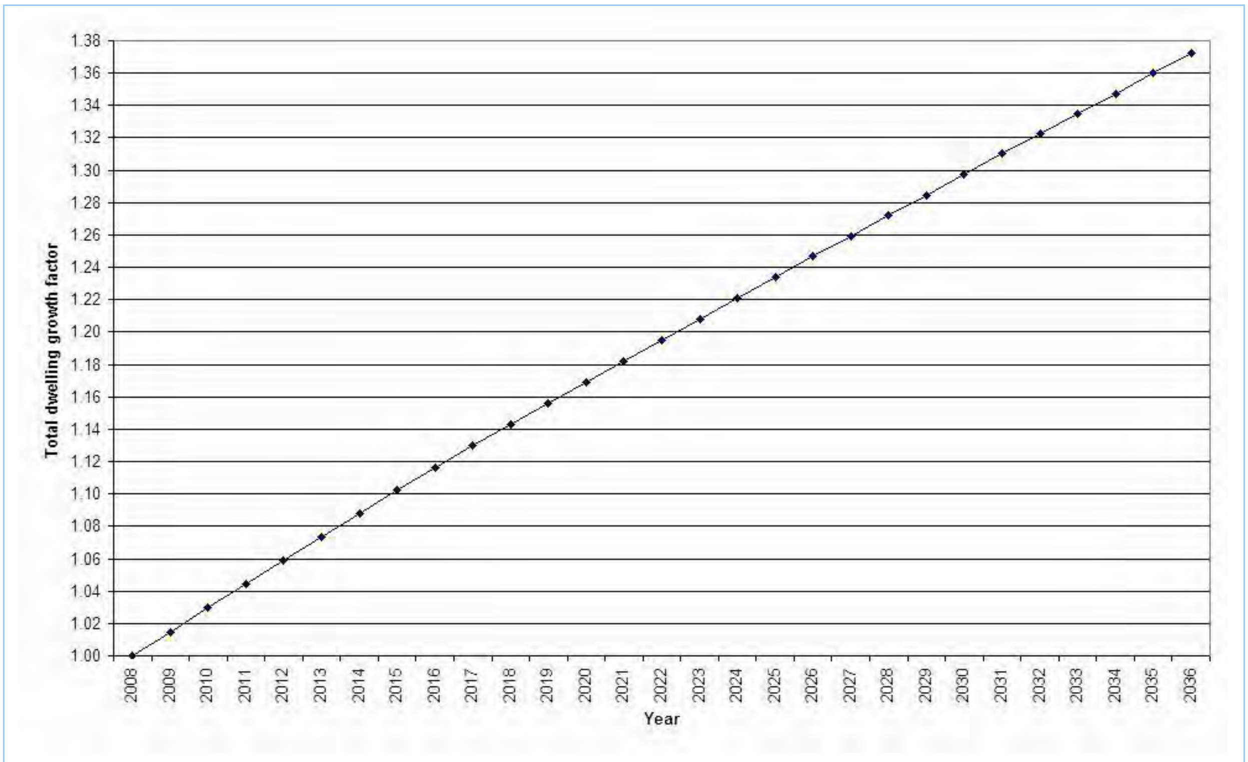

Figure 3-14: Barbecues emission projection factors

3.3 Cutback Bitumen

3.3.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from the construction of roads, which occur when cutter volatilises while bitumen cures.

To estimate emissions from these sources, the following have been considered:

- *Road construction survey*

A survey of the road construction industry has been undertaken by the Australian Asphalt Pavement Association (AAPA). The survey represents greater than 95% of cutback bitumen consumption in the GMR and includes the following organisations: Boral Asphalt; Downer EDI; Fulton Hogan; Pioneer Road Services; NSW Roads and Traffic Authority; SAMI Bitumen Technologies; and SRS Roads. The survey results include data about cutback bitumen and cutter consumption by month (AAPA, 2009).

- *Road construction type*

The NSW road network is largely constructed from petroleum bitumen. Bitumen acts as a thermo-plastic binder of the aggregate components to provide a durable and waterproof road surface.

The main bitumen surface types used in NSW include (Environ, 2010):

  - *Asphalt or bituminous concrete* consists of a mixture of coarse and fine aggregates held together with a bituminous binder. While hot, warm and cold mix asphalts are currently used, hot mix asphalt is more common in urban areas and has minimal VOC emissions; and

  - *Sprayed seal or spray and chip seal* is a layer of aggregate that is glued to the road surface using a bitumen binder. Cutback bitumen is widely used in sprayed seal surfacing, where solvent is used to reduce bitumen viscosity during application. The solvent is referred to as a cutter, while the bitumen and solvent together are known as cutback bitumen. Cutback bitumen is more common in rural areas and has relatively high VOC emissions since a significant amount of cutter is used. Cutter is typically kerosene.

- *Cutter type*

The inventory includes kerosene-like medium cure asphalt cutter.

Table 3-35 presents the cutback bitumen cutter type and properties used in the inventory (ABARE, 2009b; and USEPA, 2008b).

Table 3-35: Cutback bitumen cutter type and properties

Cutter type	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Power kerosene (Medium cure asphalt)	0.813	37.5	85

3.3.2 *Emission Estimation Methodology*

Table 3-36 summarises the emission estimation methodologies used for cutback bitumen

Table 3-36: Cutback bitumen emission estimation methodologies

Emission source	Emission estimation methodology source
Evaporative emissions from cutback bitumen	- *Asphalt Paving* (ERG, 2001) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)

The major factors influencing the quantity and period over which the VOC emissions occur, include the type and quantity of cutter. For medium cure cutback bitumen, a maximum of ~70% of the more volatile components of the cutter evaporate over a 4 month period, while ~30% of the less volatile components are retained in the road surface (USEPA, 1979). Evaporative VOC emissions from the application of cutback bitumen have been estimated using an emission factor combined with bitumen and cutter consumption data within Equation 5 (ERG, 2001):

$$E_{VOC,i} = EF_{VOC,i,t} \times V_i \times \rho_i \times 1000 \qquad \textbf{Equation 5}$$

where:			
$E_{VOC,i}$	=	Emissions of VOC from cutter type i	(kg/year)
$EF_{VOC,i,t}$	=	Cumulative VOC emission factor for cutter type i after time t (Equation 6)	(kg VOC/kg cutter)
V_i	=	Volume of cutter type i applied	(kL/year)
ρ_i	=	Density of cutter type i	(kg/L)
i	=	Cutter type (kerosene like "medium cure")	(-)
t	=	Time elapsed after single application of cutter	(month)
1000	=	Conversion factor	(L/kL)

The cumulative VOC emission factor for cutter evaporation has been estimated using Equation 6 by fitting an inverse second order polynomial to the data presented in *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (Figure 4.5-1. Percent of diluent evaporated from cutback asphalt over time; USEPA, 1979):

$$EF_{VOC,i,t} = \left\{ t \middle/ \left(5.3360 \times 10^{-4} + 1.6516 \times 10^{-2} \times t - 4.8412 \times 10^{-4} \times t^2\right)\right\} \text{ for } 0 \le t \le 4 \qquad \textbf{Equation 6}$$

where:			
$E_{VOC,i,t}$	=	Cumulative VOC emission factor for cutter type i after time t	(kg VOC/kg cutter)
i	=	Cutter type (kerosene like "medium cure")	(-)
t	=	Time elapsed after single application of cutter	(month)

The cumulative VOC emission factor for cutter evaporation is shown in Figure 3-15 as a function of elapsed hour, day and month after a single application of cutter.

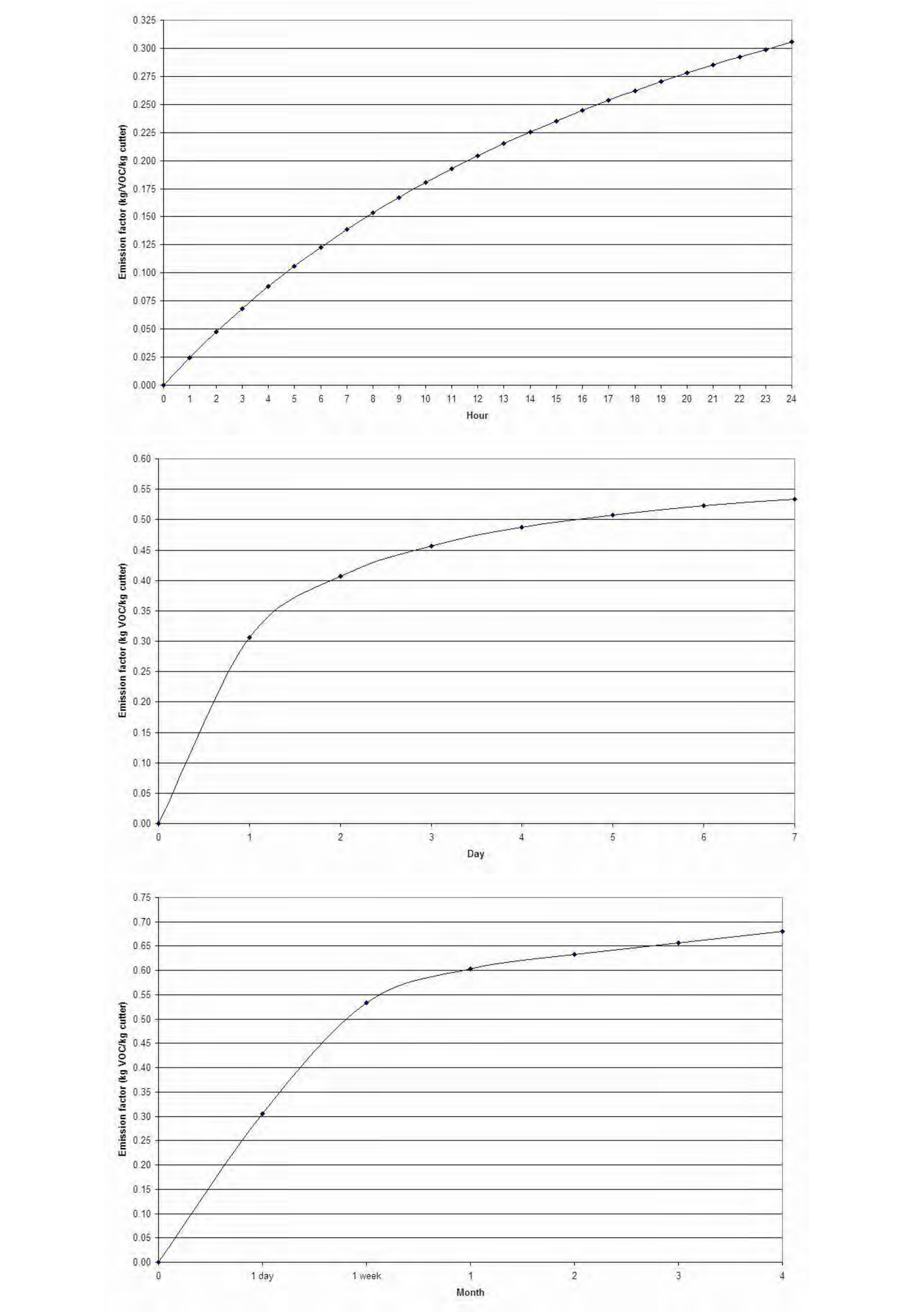

Figure 3-15: Cutback bitumen cumulative VOC evaporation of cutter as a function of elapsed time

3.3.3 *Activity Data*

Table 3-37 summarises the activity data used for cutback bitumen.

Table 3-37: Cutback bitumen activity data

Activity data	Activity data source
Cutback bitumen and cutter consumption	- *Cutback Bitumen and Cutter Consumption in the NSW GMR* (AAPA, 2009)

A survey of the road construction industry has been undertaken by AAPA, which represents greater than 95% of cutback bitumen consumption in the GMR (AAPA, 2009). Table 3-38 presents cutback bitumen and cutter consumption by month in the GMR.

Table 3-38: Cutback bitumen and cutter consumption in the GMR

Month	2008 product consumption (kL/year)	
	Cutback bitumen	Cutter
January	605.5	21.4
February	672.7	30.5
March	672.7	30.5
April	672.7	24.4
May	336.4	15.3
June	336.4	15.3
July	336.4	21.4
August	336.4	21.4
September	605.5	27.5
October	672.7	36.6
November	672.7	36.6
December	740.0	24.4
Total	6,660	305

3.3.4 *Emission and Speciation Factors*

Table 3-39 summarises the emission and speciation factors used for cutback bitumen.

Table 3-39: Cutback bitumen emission and speciation factors

Emission source	Substance	Emission and speciation factor source
Evaporative emissions from cutback bitumen	Criteria pollutants: VOC	- *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Speciated VOC	- *ORGPROF 716 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *ORGPROF 716 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)

The cumulative VOC emission factor for cutter evaporation is 552.57 kg VOC/kL medium cure cutter applied. The VOC emissions occur over a 4 month period and have been estimated using Equation 5 (ERG, 2001) and Equation 6 (USEPA, 1979).

3.3.5 Spatial Distribution of Emissions

Table 3-40 summarises the data used for spatially allocating emissions from cutback bitumen.

Table 3-40: Cutback bitumen spatial data

Emission source	Spatial data	Spatial data source
Evaporative emissions from cutback bitumen	Gridded 1 km x 1 km vehicle kilometres travelled (vkt) estimates	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009)

Emissions from cutback bitumen have been spatially distributed according to cutter consumption, which is proportional to annual vehicle kilometres travelled (VKT) in each 1 km by 1 km grid cell (TDC, 2009). The proportion of cutter consumption by LGA and region is presented in Table 3-41 and shown in Figure 3-16.

Table 3-41: Cutback bitumen cutter consumption by LGA and region

LGA	2008 proportion of annual cutter consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.70	-	0.70
Auburn	-	-	1.44	-	1.44
Bankstown	-	-	3.34	-	3.34
Bathurst Regional	-	3.02×10^{-3}	-	-	3.02×10^{-3}
Baulkham Hills	-	6.63×10^{-3}	3.54	-	3.55
Blacktown	-	-	6.67	-	6.67
Blue Mountains	-	0.27	0.92	-	1.18
Botany Bay	-	-	1.05	-	1.05
Burwood	-	-	0.51	-	0.51
Camden	-	-	1.28	-	1.28
Campbelltown	-	-	2.85	-	2.85
Canada Bay	-	-	0.98	-	0.98
Canterbury	-	-	2.05	-	2.05
Cessnock	0.18	0.84	-	-	1.02
Dungog	-	0.15	-	-	0.15
Fairfield	-	-	3.15	-	3.15
Gosford	-	1.31	1.91	-	3.22
Goulburn Mulwaree	-	6.69×10^{-3}	-	-	6.69×10^{-3}
Great Lakes	-	8.03×10^{-2}	-	-	8.03×10^{-2}
Hawkesbury	-	4.09×10^{-2}	1.51	-	1.55
Holroyd	-	-	2.04	-	2.04
Hornsby	-	1.75×10^{-3}	3.63	-	3.63
Hunters Hill	-	-	0.20	-	0.20
Hurstville	-	-	0.93	-	0.93
Kiama	-	0.19	-	-	0.19

LGA	2008 proportion of annual cutter consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Kogarah	-	-	0.84	-	0.84
Ku-ring-gai	-	-	2.13	-	2.13
Lake Macquarie	2.16	1.93	-	-	4.10
Lane Cove	-	-	0.49	-	0.49
Leichhardt	-	-	0.48	-	0.48
Lithgow	-	0.38	-	-	0.38
Liverpool	-	-	4.46	-	4.46
Maitland	7.26×10^{-2}	0.93	-	-	1.00
Manly	-	-	0.35	-	0.35
Marrickville	-	-	1.13	-	1.13
Mid-western Regional	-	5.90×10^{-2}	-	-	5.90×10^{-2}
Mosman	-	-	0.35	-	0.35
Muswellbrook	-	0.29	-	-	0.29
N/A	1.87×10^{-3}	4.68×10^{-2}	5.98×10^{-2}	4.16×10^{-3}	0.11
Newcastle	2.78	-	-	-	2.78
North Sydney	-	-	1.30	-	1.30
Oberon	-	3.34×10^{-2}	-	-	3.34×10^{-2}
Parramatta	-	-	3.30	-	3.30
Penrith	-	-	3.67	-	3.67
Pittwater	-	-	0.62	-	0.62
Port Stephens	0.40	0.83	-	-	1.23
Randwick	-	-	0.83	-	0.83
Rockdale	-	-	1.69	-	1.69
Ryde	-	-	2.27	-	2.27
Shellharbour	-	0.72	-	0.15	0.86
Shoalhaven	-	1.26×10^{-2}	-	-	1.26×10^{-2}
Singleton	-	0.43	-	-	0.43
Strathfield	-	-	0.94	-	0.94
Sutherland	-	-	3.42	-	3.42
Sydney	-	-	3.90	-	3.90
Unincorporated	-	-	0.78	-	0.78
Upper Hunter	-	4.61×10^{-3}	-	-	4.61×10^{-3}
Upper Lachlan	-	6.21×10^{-3}	-	-	6.21×10^{-3}
Warringah	-	-	1.90	-	1.90
Waverley	-	-	0.33	-	0.33
Willoughby	-	-	1.23	-	1.23
Wingecarribee	-	1.42	9.17×10^{-3}	4.57×10^{-3}	1.43
Wollondilly	-	5.12×10^{-2}	1.67	1.03×10^{-2}	1.73
Wollongong	-	-	0.81	3.01	3.82
Woollahra	-	-	0.36	-	0.36
Wyong	-	3.17	-	-	3.17
Grand Total	5.59	13.20	78.03	3.18	100.00

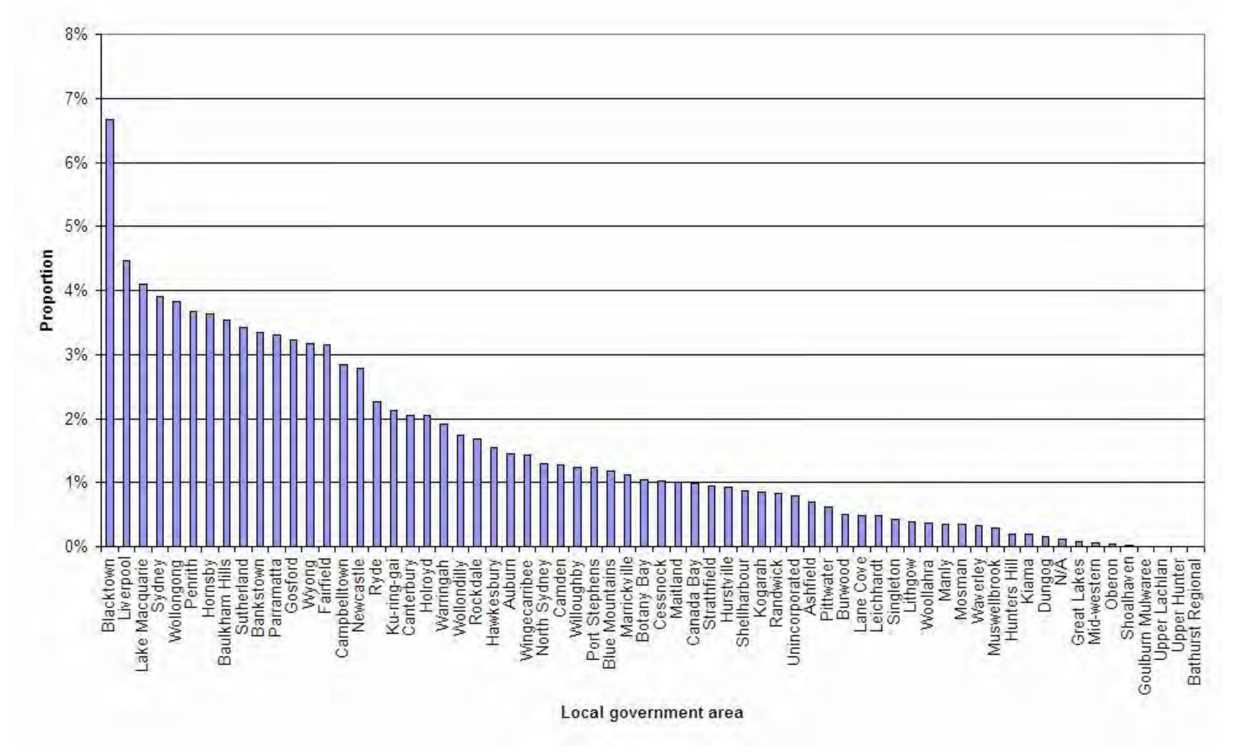

Figure 3-16: Cutback bitumen cutter consumption by LGA

Figure 3-17 shows the spatial distribution of cutback bitumen emissions.

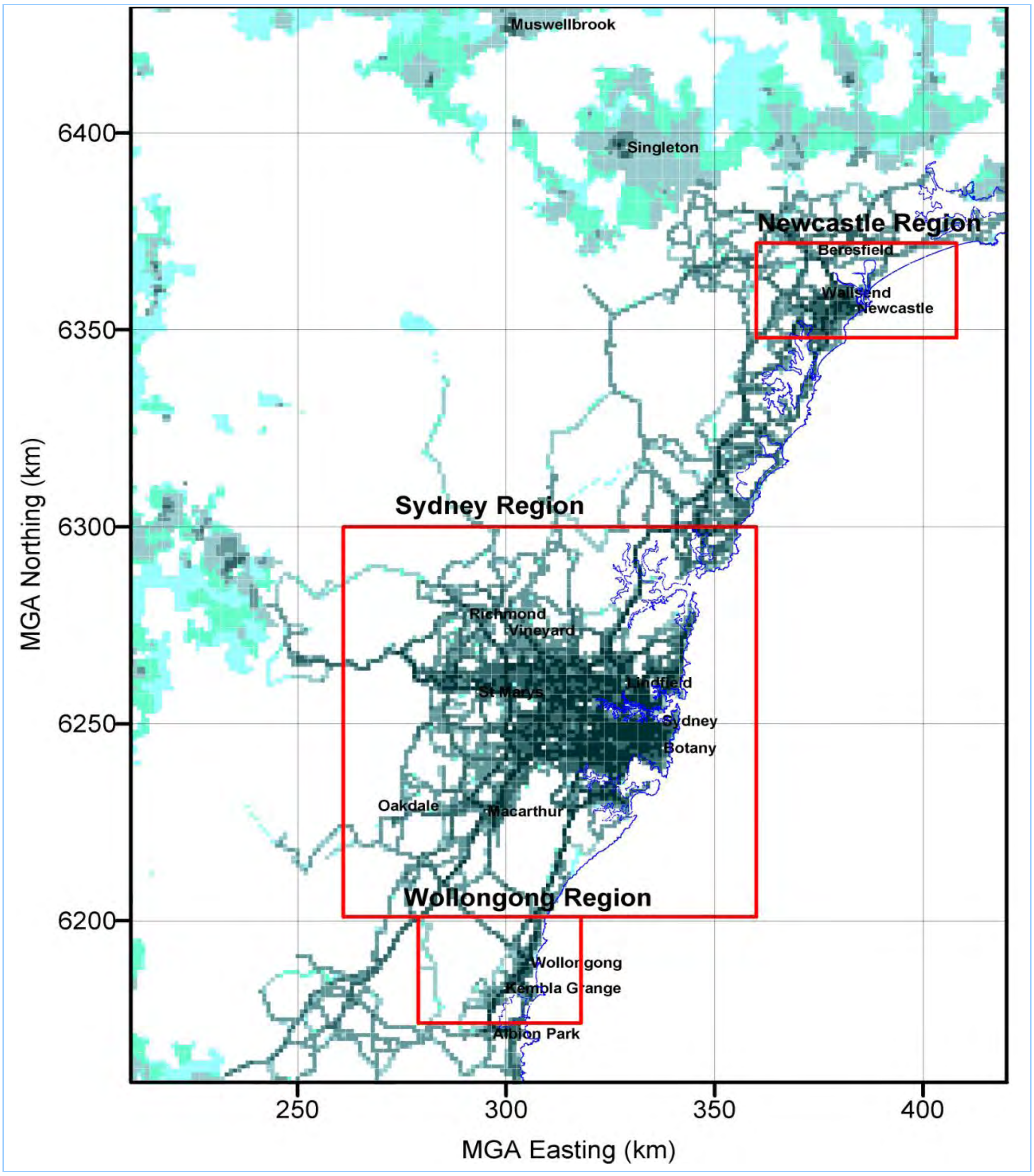

Figure 3-17: Cutback bitumen spatial distribution of emissions

3.3.6 Temporal Variation of Emissions

Table 3-42 summarises the data used to estimate the temporal variation in emissions from cutback bitumen.

Table 3-42: Cutback bitumen temporal data

Emission source	Temporal data	Temporal data source
Evaporative emissions from cutback bitumen	Monthly: Cutback bitumen and cutter consumption combined with time varying emissions	- *Cutback Bitumen and Cutter Consumption in the NSW GMR* (AAPA, 2009) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Daily: VKT combined with time varying emissions	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, On-Road Mobile Emissions Module: Results* (DECC, 2007c) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)
	Hourly: VKT combined with time varying emissions	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009) - *AP-42, Fifth Edition, Volume I, Chapter 4: Evaporation Loss Sources, 4.5 Asphalt Paving Operations* (USEPA, 1979)

Since road construction is less likely to occur during peak hours, the inverse of hourly VKT (TDC, 2009) has been used to estimate the hourly cutter application rate from monthly cutter consumption data (AAPA, 2009). The cumulative VOC emissions associated with each hourly cutter application have been estimated using Equation 5 (ERG, 2001) and Equation 6 (USEPA, 1979). The hourly cutter application rate and cumulative VOC emissions associated with each hourly cutter application are shown in Figure 3-18.

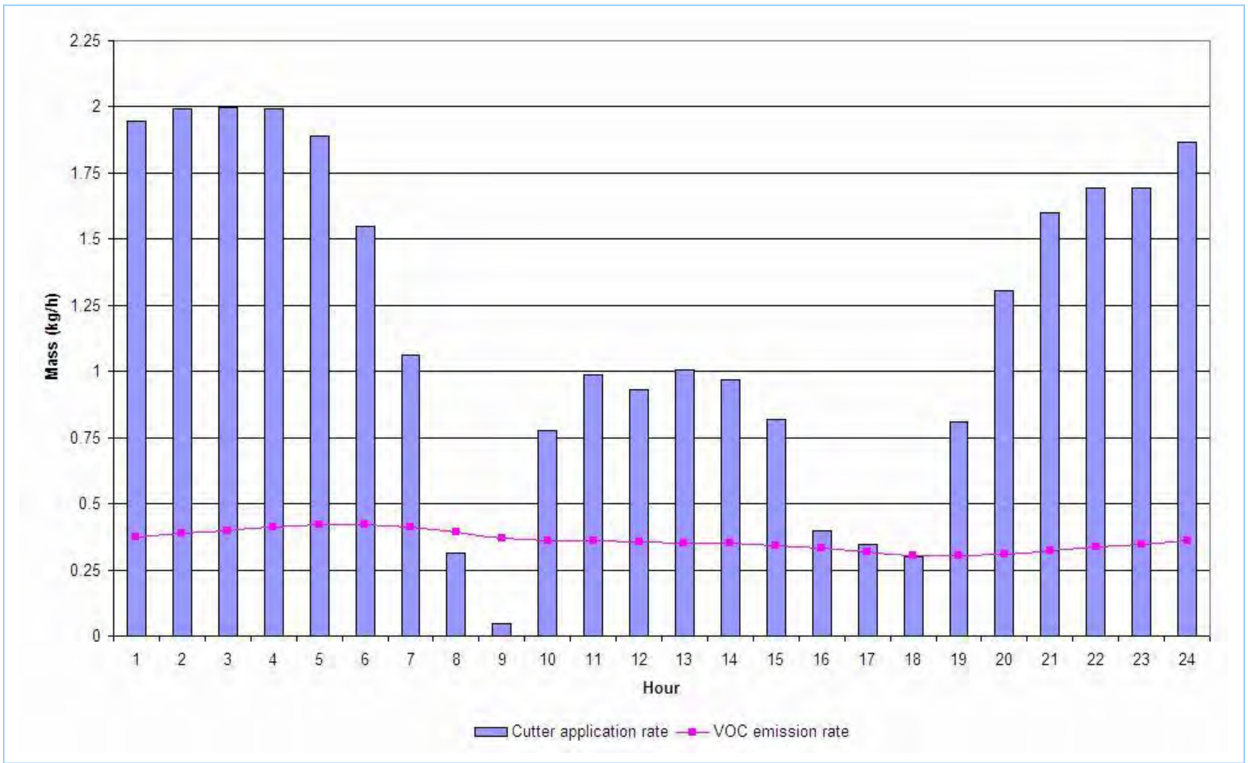

Figure 3-18: Cutback bitumen hourly cutter application rate and cumulative VOC emissions

Hourly temporal variation profiles are presented in Table 3-43 and shown in Figure 3-19.

Table 3-43: Cutback bitumen hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	4.33	13	4.07
2	4.48	14	4.04
3	4.62	15	3.98
4	4.75	16	3.83
5	4.85	17	3.68
6	4.87	18	3.54
7	4.78	19	3.52
8	4.55	20	3.60
9	4.28	21	3.74
10	4.19	22	3.88
11	4.15	23	4.01
12	4.10	24	4.17

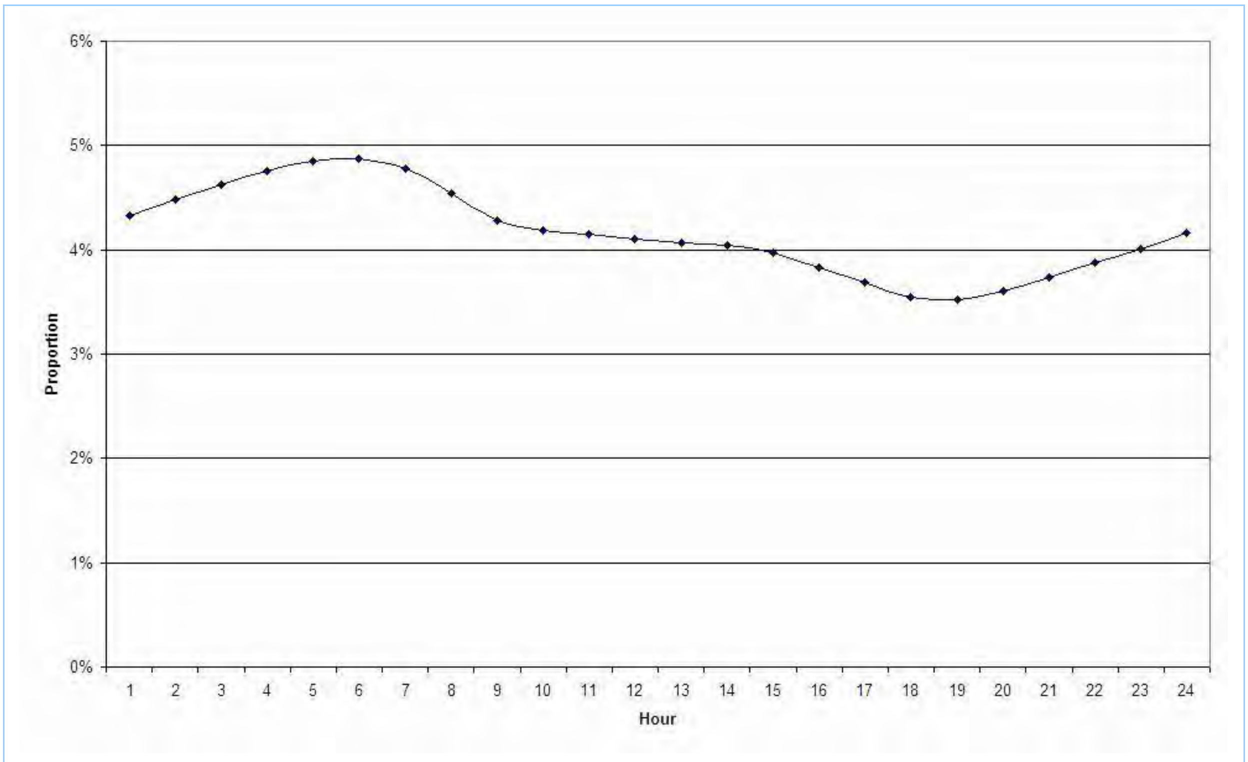

Figure 3-19: Cutback bitumen hourly temporal profile

Since road construction is less likely to occur during week days, the inverse of daily VKT (DECC, 2007c) has been used to estimate the daily cutter application rate from monthly cutter consumption data (AAPA, 2009). The cumulative VOC emissions associated with each daily cutter application have been estimated using Equation 5 (ERG, 2001) and Equation 6 (USEPA, 1979). The daily cutter application rate and cumulative VOC emissions associated with each daily cutter application are shown in Figure 3-20.

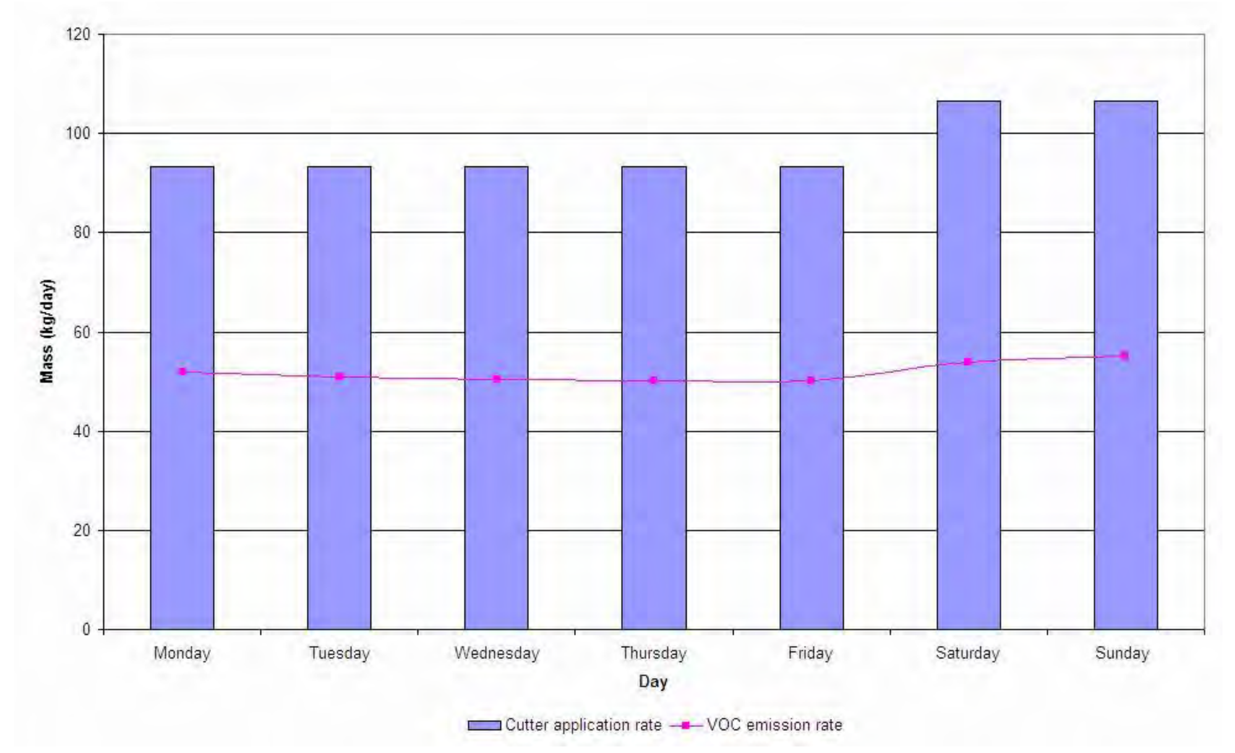

Figure 3-20: Cutback bitumen daily cutter application rate and cumulative VOC emissions

Daily temporal variation profiles are presented in Table 3-44 and shown in Figure 3-21.

Table 3-44: Cutback bitumen daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.28	14.02	13.91	13.86	13.82	14.89	15.22

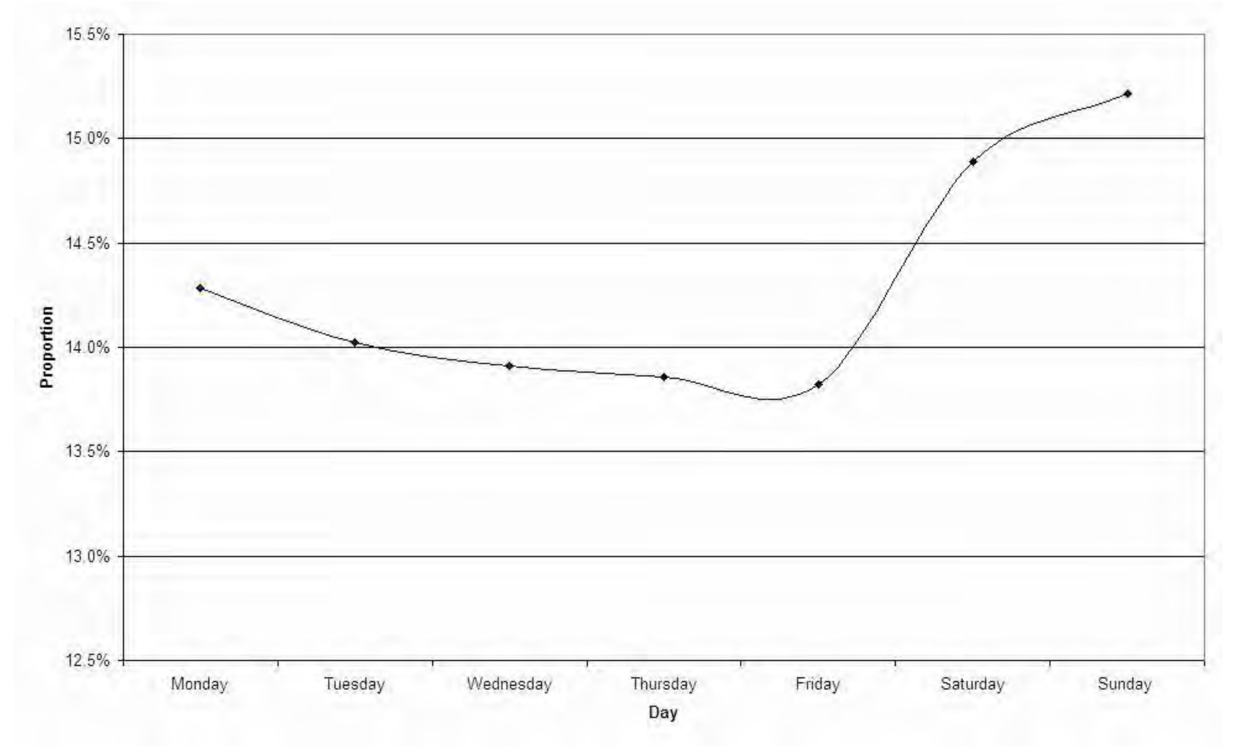

Figure 3-21: Cutback bitumen daily temporal profile

Monthly cutter consumption data (AAPA, 2009) has been used to estimate the monthly cutter application rate. The cumulative VOC emissions associated with each monthly cutter application have been estimated using Equation 5 (ERG, 2001) and Equation 6 (USEPA, 1979). The monthly cutter application rate and cumulative VOC emissions associated with each monthly cutter application are shown in Figure 3-22.

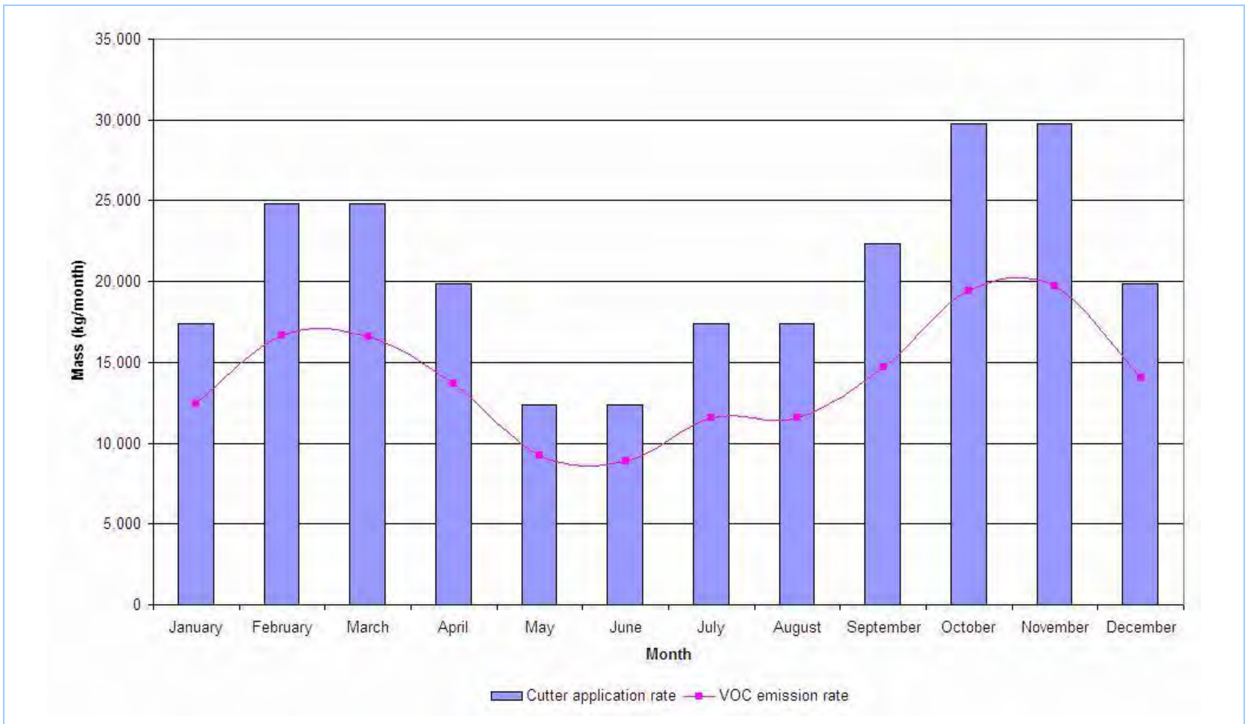

Figure 3-22: Cutback bitumen monthly cutter application rate and cumulative VOC emissions

Monthly temporal variation profiles are presented in Table 3-45 and shown in Figure 3-23.

Table 3-45: Cutback bitumen monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	7.39	July	6.88
February	9.87	August	6.86
March	9.83	September	8.71
April	8.12	October	11.53
May	5.47	November	11.72
June	5.28	December	8.34

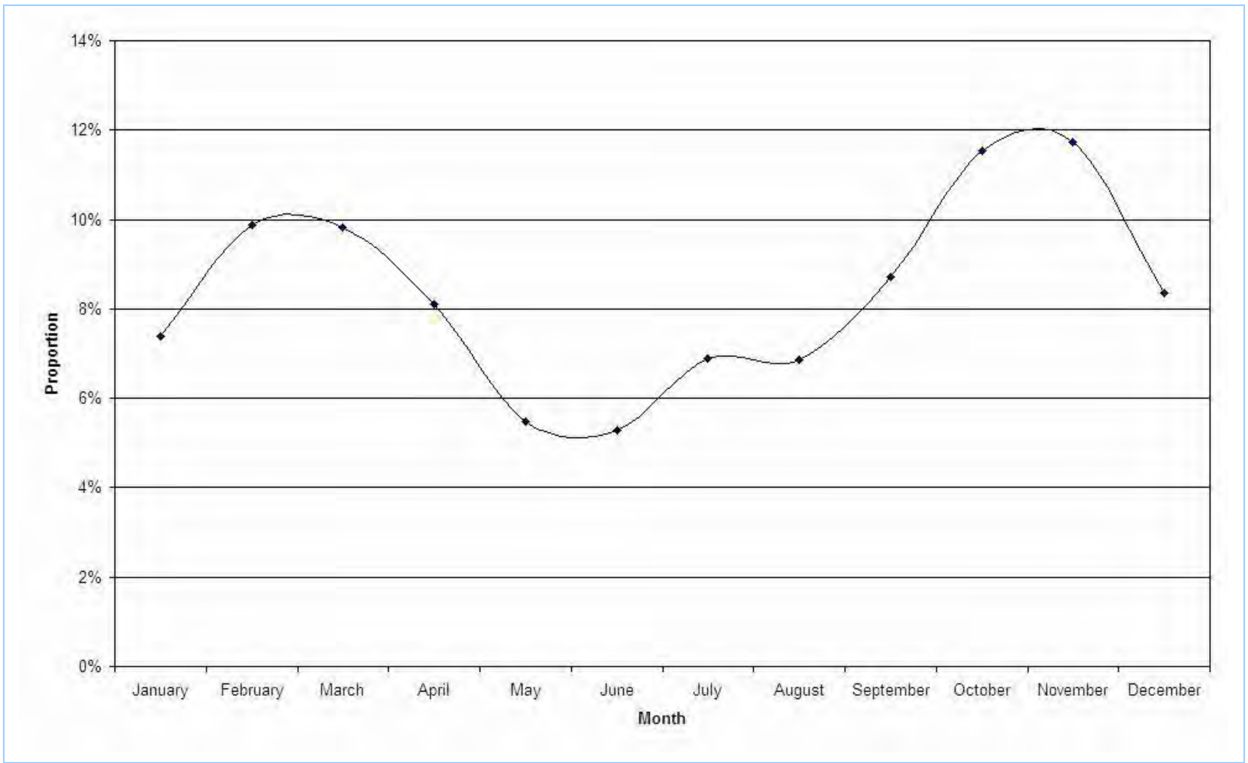

Figure 3-23: Cutback bitumen monthly temporal profile

3.3.7 *Emission Estimates*

Table 3-46 presents annual emissions of selected substances from cutback bitumen by activity.

Table 3-46: Cutback bitumen emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Cutback Bitumen	ISOMERS OF XYLENE	1,157	2,733	16,158	658	20,706
	TOLUENE	607	1,434	8,476	345	10,862
	TOTAL VOLATILE ORGANIC COMPOUNDS	9,419	22,248	131,514	5,352	168,534

3.3.8 Emission Projection Methodology

Table 3-47 summarises the data used to estimate the emission projection factors for cutback bitumen, while Figure 3-24 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-47: Cutback bitumen emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Evaporative emissions from cutback bitumen	Vehicle kilometres travelled growth	- *Forecasts for VKT from 2006 to 2036* (TDC, 2009)

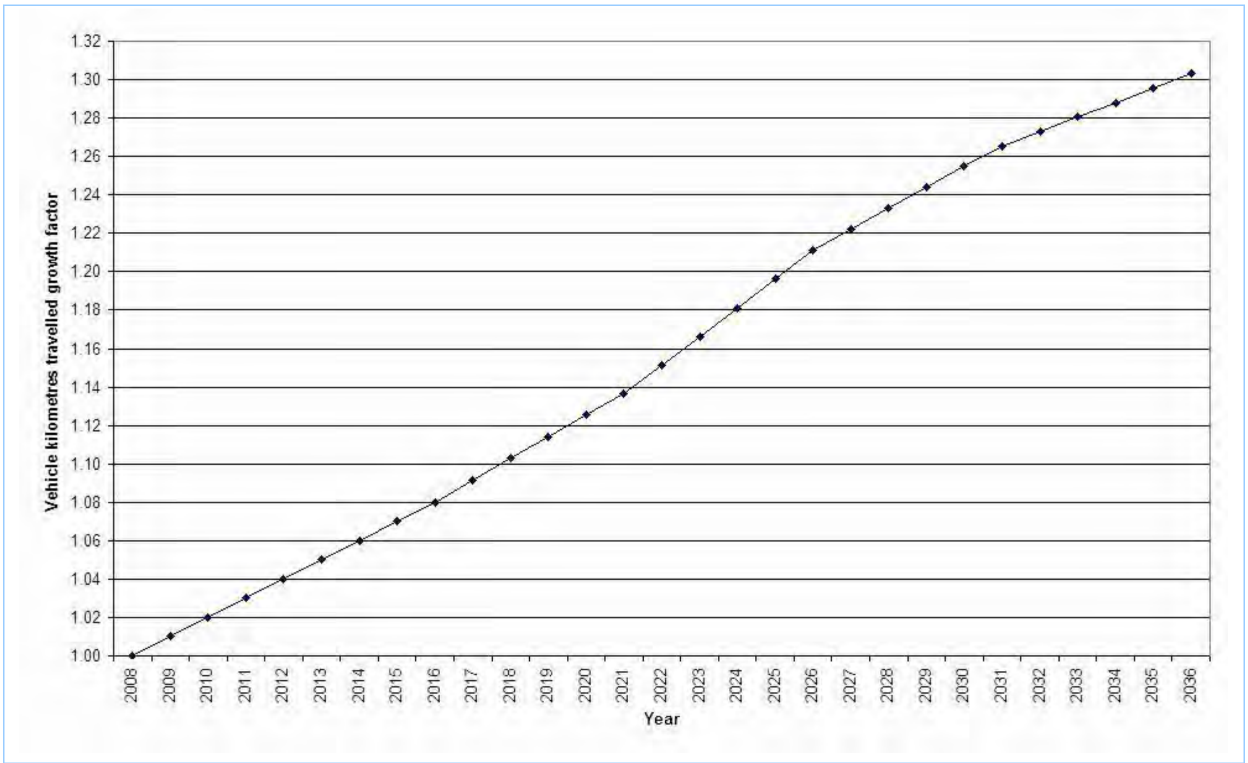

Figure 3-24: Cutback bitumen emission projection factors

3.4 Gaseous Fuel Combustion

3.4.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of combustion products from gaseous fuel fired:

- Residential cooktops, ovens, space heaters, stoves and water heaters; and
- Unaccounted commercial business equipment.

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of gaseous fuel fired residential appliance ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[12] located in the GMR. The survey results include data about: appliance number; fuel type; quantity of fuel used; and frequency and duration of appliance use by hour, day and season (TR, 2009).

- *Commercial survey*

A commercial survey of gaseous fuel fired commercial equipment ownership and usage has been conducted, which has provided activity data for commercial businesses (i.e. non-scheduled activity)[13]. The survey results include data about: equipment type, number and age; fuel used; and frequency and duration of equipment use by hour, day and month (DECC, 2007a). Emissions from gaseous fuel fired equipment used by commercial businesses are included in the commercial air emissions inventory.

- *Industrial survey*

An industrial survey of gaseous fuel fired industrial equipment ownership and usage has been conducted, which has provided activity data for EPA-licensed premises (i.e. scheduled activity)[14]. The survey results include data about: equipment type, number and age; fuel used; and frequency and duration of equipment use by hour, day and month (DECCW, 2009). Emissions from gaseous fuel fired equipment used by EPA-licensed premises are included in the industrial air emissions inventory.

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[12] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.

[13] Non-scheduled activity means an activity that is not a scheduled activity and is not scheduled development work as defined in the *Protection of the Environment (Operations) Act 1997* (PCO, 2010a).

[14] Scheduled activity means an activity listed in Schedule 1 of the *Protection of the Environment (Operations) Act 1997* (PCO, 2010a).

➢ *ABARE energy consumption by industry and fuel type*

Historical natural gas consumption for the period 1973-74 to 2007-08 in NSW (ABARE, 2009a) has been used in combination with energy projections for the period 2004-05 to 2029-30 (ABARE, 2006) and natural gas network access arrangement information (Jemena, 2009a; and Jemena, 2009b) to estimate total natural gas consumption in the GMR. The estimated residential, commercial and industrial natural gas consumption have been subtracted from total natural gas consumption in order to estimate unaccounted natural gas consumption by commercial business equipment.

➢ *Residential appliance type*

The inventory includes small indoor cooking appliances, boilers and heaters used in residential applications as follows:

- *Cooktop;*
- *Oven;*
- *Space heater;*
- *Stove; and*
- *Water heater.*

➢ *Fuel type*

The inventory includes:

- Residential cooktops, ovens, space heaters, stoves and water heaters that use natural gas and liquid petroleum gas (LPG); and
- Unaccounted commercial business equipment that use natural gas.

Table 3-48 presents the gaseous fuel type and properties used in the inventory (ABARE, 2009b; AGL, 2008; Kleenheat Gas, 2008; USEPA, 1998a; and USEPA, 2008a).

Table 3-48: Gaseous fuel type and properties

Fuel type	Sulfur content		Density		Effective heating value		Carbon content (%)
Natural gas	3.36	ppm	0.753	kg/m^3	38.3	MJ/m^3	76
Liquid petroleum gas (LPG)	12.88	ppm	0.510	kg/L	25.5	MJ/L	82

3.4.2 *Emission Estimation Methodology*

Table 3-49 summarises the emission estimation methodology used for gaseous fuel fired residential appliances and unaccounted commercial business equipment.

Table 3-49: Gaseous fuel combustion emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust emissions from gaseous fuel combustion in: Residential cooktops, ovens, space heaters, stoves and water heaters; and Unaccounted commercial business equipment	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)

Emissions of combustion products from gaseous fuel fired residential appliances and unaccounted commercial business equipment have been estimated using fuel consumption based emission factors combined with activity rates. Activity rates include fuel type and quantity of fuel used (ABARE, 2006; ABARE, 2009a; DECC, 2007a; DECCW, 2009; Jemena, 2009a; Jemena, 2009b; and TR, 2009). Emissions have been determined using Equation 7 (Pechan, 2006):

$$E_{i,j,k} = C_{j,k} \times EF_{i,j} \qquad \textbf{Equation 7}$$

where:

$E_{i,j,k}$	=	Emissions of substance i from gaseous fuel type j and source type k	(kg/year)
$C_{j,k}$	=	Fuel consumption for fuel type j and source type k	
		natural gas	(Mm^3/year)
		LPG	(kL/year)
$EF_{i,j}$	=	Emission factor for substance i and fuel type j	
		natural gas	(kg/Mm^3)
		LPG	(kg/kL)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)
j	=	Fuel type (either "natural gas" or "LPG")	(-)
k	=	Source type (either "residential" or "unaccounted")	(-)

3.4.3 *Activity Data*

Table 3-50 summarises the activity data used for gaseous fuel fired residential appliances and unaccounted commercial business equipment.

Table 3-50: Gaseous fuel combustion activity data

Activity data	Activity data source
Natural gas consumption in residential cooktops, ovens, space heaters, stoves and water heaters	- *Energy update 2009* (ABARE, 2009a) - *Australian Energy, National and State Projections to 2029-30* (ABARE, 2006) - *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b)

Activity data	Activity data source
LPG consumption in residential cooktops, ovens, space heaters, stoves and water heaters	- *Domestic Fuel Combustion Pollution Survey* (TR, 2009)
Natural gas consumption in unaccounted commercial business equipment	- *2008 Survey of EPA-Licensed Premises* (DECCW, 2009 - *2004 Survey of Commercial Businesses* (DECC, 2007a)
Gridded 1 km x 1 km total dwelling estimates for domestic LPG required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

A domestic survey of gas fired residential appliance ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: number of households that use gas fired appliances; fuel type; and quantity of fuel used (TR, 2009).

The key considerations in designing and conducting a domestic survey include:

Survey method - The domestic survey has been conducted using the computer assisted telephone interview (CATI) method for recruiting households to complete either an on-line or mail-out questionnaire.

Sample size - To provide a reasonable level of precision for estimating gas fired residential appliance activity rates across all households in the GMR, the survey sample was sized accordingly. While a total of 832 households were recruited, 31 households were outside the GMR so they were excluded from the survey. Activity rates for gas fired residential appliances have been based on survey responses from 801 households in the GMR.

Confidence interval and confidence level - The confidence interval quantifies the uncertainty or range in possible values. For example, for a confidence interval of 3.5% and where 47% percent of the sample picks a particular answer one can be "sure" that if the question has been asked of the entire relevant population, between 43.5% (47-3.5) and 50.5% (47+3.5) would have picked that answer.

The confidence level quantifies the level of certainty to which an estimate can be trusted. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means one can be 95% certain. Most researchers use the 95% confidence level.

When combining the confidence level and confidence interval together, one can be 95% sure that the true answer for the entire relevant population is between 43.5% and 50.5% for the example described above.

Table 3-51 presents the theoretical confidence intervals for samples of varied sizes for characteristics with a population incidence of 50% or 50%, 75% or 25% and 90% or 10%.

Table 3-51: Confidence intervals at 95% confidence level by sample size for gaseous fuel combustion survey

Sample size	Confidence interval at 95% confidence level		
	Endorsement rate of 50%/50%	Endorsement rate of 75%/25%	Endorsement rate of 90%/10%
100	9.8	8.5	5.9
150	8.0	6.9	4.8
200	6.9	6.0	4.2
300	5.7	4.9	3.4
400	4.9	4.2	2.9
500	4.4	3.8	2.6
600	4.0	3.5	2.4
800	3.5	3.0	2.1
1,000	3.1	2.7	1.9

The domestic survey of gas fired residential appliances randomly sampled 801 households from a population of 5,284,560 in 1,901,680 households, so survey items with a true population incidence of 50% will produce estimates within ±3.5% of the true population value in 95% of the samples.

Random sampling and stratification - Households were selected at random across the GMR to limit bias. In practice, actual samples are not truly random since respondents always have the right to decline an interview and others cannot be reached for a variety of reasons. To reduce the standard error of estimated population values, samples were stratified on a geographic basis into the following subpopulations by location:

Sydney region, sub-grouped into

- *North East*
- *North West*
- *South East*
- *South West*

Newcastle region

Wollongong region

Development of survey questionnaires – Three survey questionnaires were developed including: initial recruitment using the computer assisted telephone interview (CATI) method to capture household details using pre-coded questions within OzQuest on-line software; self complete main survey using pre-coded questions within OzQuest on-line software; and self complete main survey using a traditional hard copy mail-out with a reply paid envelope. The questionnaires request information about: number of households that use gas fired appliances; fuel type; and quantity of fuel used. The domestic survey questionnaire form is included at Appendix B: Domestic Survey Form (TR, 2009).

Recruitment and data collection - A random sample of phone numbers was selected from the 64 local government areas (LGA) located in the GMR, stratified into Sydney, Newcastle and Wollongong regions.

As part of the computer assisted telephone interview (CATI), households were phoned up to five times to make contact and the interviewer asked to speak to an "adult household member who is familiar with any devices the household uses that might burn solid fuel (like wood or coal heaters), liquid fuel (like kerosene heaters or petrol lawn mowers) or gas fuel (like natural gas cooktops or heaters)". If required, arrangements were made to call back at a more convenient time when an appropriate adult household member would be available.

When an adult household member was available for interview, respondents were asked what LGA they lived in. If not in the GMR they were thanked and the interview was terminated. If in the GMR, they were then asked about the number of residents in the household, the dwelling type and which of the fuel burning devices were used by the household. All were then asked for their postcode and age group. Respondents in households that had none of the fuel burning devices were thanked and the interview terminated. All other respondents were then asked if they would be willing to complete a further questionnaire either on-line or by mail. If willing, contact details were recorded, and the interview concluded. Those who initially declined were read material emphasizing the importance of obtaining data from all households, whether they make little use of fuel burning devices or not and asked again if they would be willing to take part.

Consenting respondents were then either e-mailed a link to a self complete on-line main survey or mailed a self complete hard copy main survey. The mailed questionnaires included an identifying serial number on the front page with a letter from DECCW encouraging completion of the survey.

Main survey completions on-line and mail-out were closely monitored and households were phoned on two occasions in order to remind them to complete. Some respondents indicated they preferred to go through the questions on the phone. Data for these were entered into the on-line version of the questionnaire.

Data capture – Data from the three survey questionnaires (i.e. CATI, on-line main survey and hard copy main survey) have all been entered into a database which captures pre-coded questions using OzQuest on-line software. All data was then checked, cleaned and saved in a Microsoft® Excel™ 2003 workbook.

Survey timeframe - The survey took approximately 15 weeks to complete, from the time that questionnaire development commenced to the date data analysis and report were completed. The key tasks and milestones for the domestic survey are presented in Table 3-52.

Table 3-52: Gaseous fuel combustion survey milestones

Task	Milestones
Questionnaire development commenced	11 August 2009
CATI recruitment commenced	18 September 2009
CATI recruitment completed	21 October 2009
Main survey completed	12 November 2009
Data analysis and report completed	26 November 2009

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the gaseous fuel combustion survey results (TR, 2009). Table 3-53 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-53: Population and dwelling by LGA used to scale-up gaseous fuel combustion survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[15]	Total dwelling
Ashfield	47,887	7,660	2,728	7,882	142	18,412
Auburn	69,555	7,358	2,326	11,421	284	21,390
Bankstown	174,326	7,781	8,028	41,407	287	57,503
Bathurst Regional	157	-	-	41	1	41
Baulkham Hills	170,925	2,345	5,004	46,441	137	53,928
Blacktown	286,162	3,915	9,712	77,217	700	91,544
Blue Mountains	78,427	777	1,030	27,952	63	29,822
Botany Bay	33,316	4,244	1,974	5,777	100	12,095
Burwood	30,277	3,332	1,108	5,770	65	10,275
Camden	55,287	258	499	16,910	161	17,828
Campbelltown	150,373	1,333	8,057	39,856	97	49,343
Canada Bay	58,880	6,445	2,342	13,157	137	22,080
Canterbury	138,343	16,795	4,851	25,673	328	47,647
Cessnock	48,845	562	339	16,615	150	17,667
Dungog	7,659	23	60	2,581	38	2,702
Fairfield	189,024	7,302	6,172	43,571	198	57,243
Gosford	162,826	5,481	8,288	49,407	676	63,852
Goulburn Mulwaree	341	-	1	79	-	80
Great Lakes	4,062	10	29	1,301	44	1,383
Hawkesbury	62,416	899	1,674	18,441	241	21,254
Holroyd	95,192	6,969	3,562	22,399	144	33,074
Hornsby	160,612	9,018	4,454	40,736	265	54,472
Hunters Hill	9,295	898	318	1,892	3	3,111
Hurstville	81,935	7,352	3,548	18,534	111	29,545
Kiama	14,586	580	338	4,433	75	5,426
Kogarah	57,349	6,558	1,565	11,945	81	20,148
Ku-ring-gai	106,943	3,805	1,253	30,103	73	35,235
Lake Macquarie	195,295	3,160	4,849	63,598	926	72,532
Lane Cove	28,511	4,473	652	5,687	92	10,904

[15] Caravan, cabin, houseboat, improvised home, tent, sleepers out, house or flat attached to a shop or office (TDC, 2009).

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[15]	Total dwelling
Leichhardt	39,692	4,537	6,175	5,998	278	16,988
Lithgow	19,595	227	341	6,350	59	6,977
Liverpool	178,554	6,938	5,352	42,517	317	55,125
Maitland	66,554	1,330	1,049	21,169	117	23,666
Manly	33,804	5,898	1,520	5,676	97	13,192
Marrickville	86,873	13,062	10,292	11,838	553	35,744
Mid-western Regional	3,412	25	14	1,149	17	1,205
Mosman	30,915	6,692	1,506	4,604	104	12,905
Muswellbrook	15,221	364	121	4,582	62	5,128
N/A	25,875	4,778	1,262	4,329	119	10,488
Newcastle	150,930	8,242	6,306	44,792	500	59,840
North Sydney	53,850	17,299	4,228	3,854	252	25,633
Oberon	1,803	4	5	438	5	452
Parramatta	152,570	16,729	6,975	29,743	348	53,796
Penrith	177,459	3,483	4,905	51,040	349	59,776
Pittwater	54,586	2,542	1,577	15,389	183	19,690
Port Stephens	59,017	756	1,587	18,809	482	21,634
Randwick	130,955	25,728	8,002	16,752	370	50,853
Rockdale	89,735	12,199	4,159	16,242	256	32,856
Ryde	105,073	11,196	5,519	22,448	111	39,275
Shellharbour	65,104	1,282	2,369	18,768	328	22,747
Shoalhaven	81	-	-	30	-	30
Singleton	22,222	405	275	6,357	132	7,169
Strathfield	38,732	5,612	806	6,543	45	13,006
Sutherland	212,924	16,252	8,522	52,450	274	77,498
Sydney	167,382	52,686	17,811	4,651	1,028	76,176
Unincorporated	42,682	9,672	2,028	5,866	146	17,713
Upper Hunter	350	-	-	66	-	66
Upper Lachlan	502	-	-	92	-	92
Warringah	141,123	16,643	3,029	32,008	175	51,854
Waverley	57,147	14,769	4,430	5,038	245	24,481
Willoughby	69,528	11,760	2,038	12,473	82	26,353
Wingecarribee	45,480	537	1,113	15,131	144	16,924
Wollondilly	42,871	168	292	13,634	133	14,227
Wollongong	193,292	11,210	7,296	52,219	992	71,717
Woollahra	44,773	12,138	3,128	4,232	71	19,569
Wyong	145,088	2,801	4,575	47,918	1,006	56,300
Grand Total	5,284,560	417,295	213,366	1,256,021	14,998	1,901,680

The total number of households that use gas fired appliances have been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009).

Households that use gas fired appliances by fuel type and dwelling type in the GMR are presented in Table 3-54 and shown in Figure 3-25.

Table 3-54: Gaseous fuel fired residential appliance usage in the GMR

Dwelling type	2008 statistics				
	Dwelling number	Households that use natural gas	Proportion of dwelling type with natural gas (%)	Households that use LPG	Proportion of dwelling type with LPG (%)
Flat, unit or apartment	417,295	206,355	49.45	13,757	3.30
Semi detached, terrace house or townhouse	213,366	130,190	61.02	10,849	5.08
Separate house	1,256,021	547,695	43.61	181,920	14.48
Other dwelling	14,998	-	-	7,499	50.00
Grand Total[16]	1,901,680	884,239	46.50	214,025	11.25

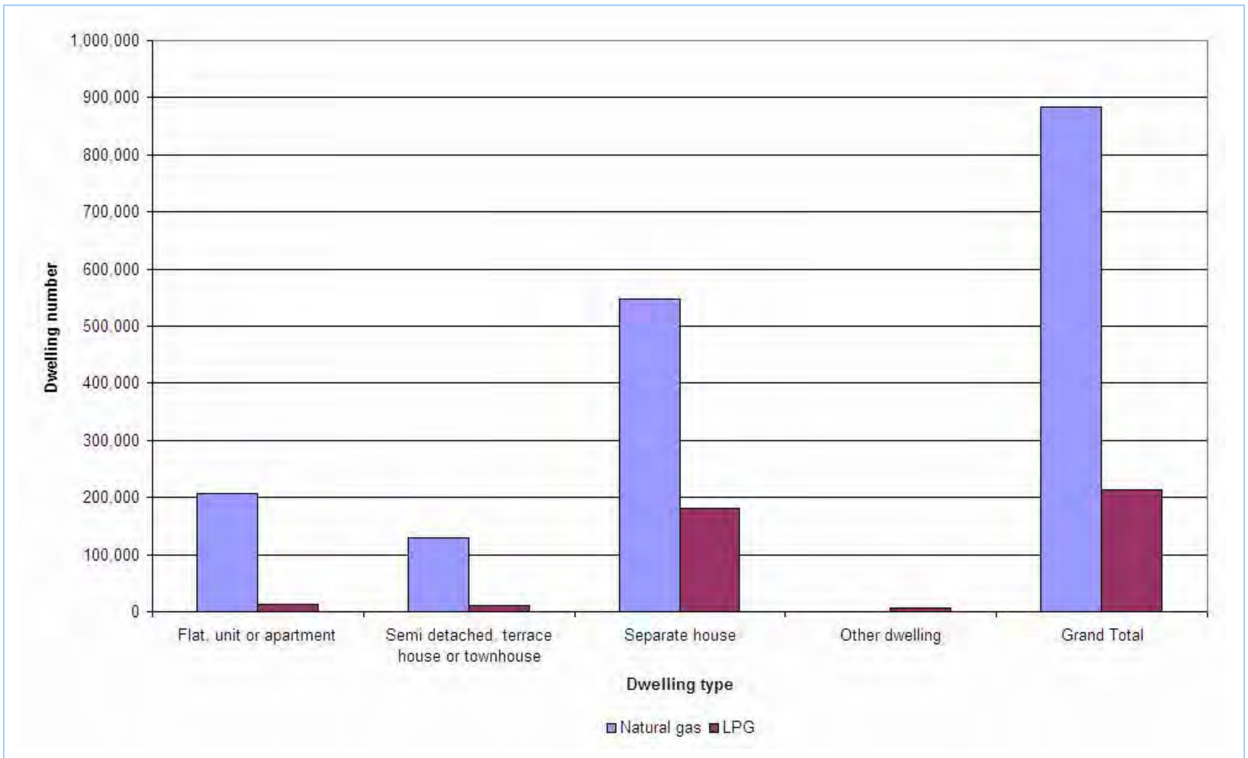

Figure 3-25: Gaseous fuel fired residential appliance usage in the GMR

The total consumption of LPG in households has been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). Table 3-55 presents residential LPG consumption in the GMR.

[16] Includes natural gas and LPG consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters.

Table 3-55: Residential LPG consumption in the GMR

Dwelling type	2008 LPG consumption (kL/year)
Flat, unit or apartment	3,213
Semi detached, terrace house or townhouse	2,534
Separate house	42,486
Other dwelling	1,751
Grand Total[17]	49,984

Historical energy consumption for the period 1973-74 to 2007-08 in NSW (ABARE, 2009a) has been used in combination with energy projections for the period 2004-05 to 2029-30 (ABARE, 2006) and natural gas network access arrangement information (Jemena, 2009a; and Jemena, 2009b) to estimate total natural gas consumption in households. Table 3-56 presents residential natural gas consumption in NSW and the GMR.

Table 3-56: Residential natural gas consumption in NSW and the GMR

Sector	Natural gas consumption in NSW				Natural gas consumption in the GMR[18]			
	2007-08 (PJ/year)	2008-09 (PJ/year)	2008 (PJ/year)	2008 (Mm³/year)	2007-08 (PJ/year)	2008-09 (PJ/year)	2008 (PJ/year)	2008 (Mm³/year)
Residential[19]	21.3	21.6	21.4	559.7	19.6	19.8	19.7	514.5

The estimated residential (ABARE, 2006; and ABARE, 2009a), commercial business (DECC, 2007a) and EPA-licensed premises (DECCW, 2009) natural gas consumption have been subtracted from total (ABARE, 2006; and ABARE, 2009a) natural gas consumption in order to estimate unaccounted natural gas consumption by commercial business equipment. Table 3-57 presents total natural gas consumption by sector in NSW, while Table 3-58 presents natural gas consumption by activity in the GMR.

Table 3-57: Total natural gas consumption in NSW

Sector	Natural gas consumption in NSW			
	2007-08 (PJ/year)	2008-09 (PJ/year)	2008 (PJ/year)	2008 (Mm³ /year)
Div. A Agriculture, forestry and fishing	-	-	-	-
Div. B Mining	2.6	2.7	2.6	68.8
Div. C Manufacturing	80.4	81.2	80.8	2,109.6
Div. D Electricity, gas and water	16.8	17.7	17.3	451.0

[17] Includes LPG consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters.
[18] Approximately 91.9% of natural gas for NSW is consumed in the GMR (Jemena, 2009a; and Jemena, 2009b).
[19] Includes natural gas consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters and outdoors in barbecues, outdoor stoves and portable stoves.

Sector	Natural gas consumption in NSW			
	2007-08 (PJ/year)	2008-09 (PJ/year)	2008 (PJ/year)	2008 (Mm³ /year)
Div. E Construction	0.2	0.2	0.2	5.2
Div. I Transport & storage	1.4	1.4	1.4	36.8
Commercial and services	9.0	9.2	9.1	237.3
Residential[20]	21.3	21.6	21.4	559.7
Grand Total	131.7	134.0	132.8	3,468.5

Table 3-58: Total natural gas consumption in the GMR

Activity	2008 natural gas consumption in the GMR[21] (Mm³/year)
EPA-licensed premises	1,760.0
Commercial businesses	148.3
Residential[22]	514.5
Unaccounted commercial business equipment	765.9
Grand Total	3,188.6

Table 3-151 presents the residential appliances and unaccounted commercial business equipment natural gas and LPG consumption estimates.

Table 3-59: Gaseous fuel fired residential appliances and commercial business equipment fuel consumption in the GMR

Activity	Dwelling/business type	2008 fuel consumption	
		Natural gas (Mm³/year)	LPG (kL/year)
Residential	Flat, unit or apartment	119	3,213
	Semi detached, terrace house or townhouse	75	2,534
	Separate house	315	42,486
	Other dwelling	-	1,751
	Residential Total[23]	508	49,984
Unaccounted	Commercial business equipment	766	-
Grand Total		1,274	49,984

[20] Includes natural gas consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters and outdoors in barbecues, outdoor stoves and portable stoves.
[21] Approximately 91.9% of natural gas for NSW is consumed in the GMR (Jemena, 2009a; and Jemena, 2009b).
[22] Includes natural gas consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters and outdoors in barbecues, outdoor stoves and portable stoves.
[23] Includes natural gas and LPG consumed indoors in residential cooktops, ovens, space heaters, stoves and water heaters.

3.4.4 *Emission and Speciation Factors*

Table 3-60 summarises the emission and speciation factors used for gaseous fuel fired residential appliances and unaccounted commercial business equipment.

Table 3-60: Gaseous fuel combustion emission and speciation factors

Substance	Emission source	Emission and speciation factor source[24]
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	Natural gas combustion	- *Table 1.4-1 Residential furnaces and Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
Criteria pollutants: TSP	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
Speciated NO_x	Natural gas and LPG combustion	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	Natural gas combustion	- *Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
Organic air toxics	Natural gas combustion	- *Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-3 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
Metal air toxics	Natural gas combustion	- *Table 1.4-4 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-4 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
Polycyclic aromatic hydrocarbons: PAH	Natural gas combustion	- *Table 1.4-3 – AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.4-3 – AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)*
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	Natural gas combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Natural gas - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	LPG combustion	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Natural gas - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)*

[24] Where references are marked with an asterisk (i.e. *), LPG fired residential appliances use natural gas emission data, which have been adjusted to LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 38.3 MJ/m³ for natural gas (ABARE, 2009b).

Substance	Emission source	Emission and speciation factor source[24]
Ammonia	Natural gas combustion	- *Table III-1 Residential natural gas combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	LPG combustion	- *Table III-1 Residential natural gas combustion - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)*
Greenhouse gases: CH_4	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
Greenhouse gases: CO_2	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)
Greenhouse gases: N_2O	Natural gas combustion	- *Table 1.4-2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998a)
	LPG combustion	- *Table 1.5-1 Propane - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.5 Liquified Petroleum Gas Combustion* (USEPA, 2008a)

Table 3-61 presents emission factors for natural gas and liquid petroleum gas (LPG) fired residential appliances and unaccounted commercial business equipment.

Table 3-61: Gaseous fuel combustion emission factors

Emission source	Emission factors											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
Natural gas combustion (kg/Mm^3)	1,505.59	35.237	320.339	9.610	121.73	121.73	88.09	36.839	640.68	1,922,033.90	0.0112	4.98×10^{-8}
LPG combustion (kg/kL)	1.56	0.108	0.213	0.013	0.08	0.08	0.06	0.024	0.90	1,498.02	7.45×10^{-6}	3.32×10^{-11}

3.4.5 Spatial Distribution of Emissions

Table 3-62 summarises the data used for spatially allocating emissions from gaseous fuel fired residential appliances and unaccounted commercial business equipment.

Table 3-62: Gaseous fuel combustion spatial data

Emission source	Spatial data	Spatial data source
Exhaust emissions from gaseous fuel combustion in: Residential cooktops, ovens, space heaters, stoves and water heaters; and Unaccounted commercial business equipment	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from gaseous fuel fired residential appliances and unaccounted commercial business equipment have been spatially distributed according to natural gas and liquid petroleum gas (LPG) consumption, which are proportional to total dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of natural gas and liquid petroleum gas (LPG) consumption by LGA and region are presented in Table 3-63 and shown in Figure 3-26.

Table 3-63: Gaseous fuel combustion spatial distribution of fuel consumption by LGA and region

LGA	2008 proportion of annual natural gas and liquid petroleum gas (LPG) consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.97	-	0.97
Auburn	-	-	1.13	-	1.13
Bankstown	-	-	3.03	-	3.03
Bathurst Regional	-	2.18×10^{-3}	-	-	2.18×10^{-3}
Baulkham Hills	-	2.39×10^{-3}	2.84	-	2.84
Blacktown	-	-	4.82	-	4.82
Blue Mountains	-	0.56	1.00	-	1.57
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.54	-	0.54
Camden	-	-	0.94	-	0.94
Campbelltown	-	-	2.60	-	2.60
Canada Bay	-	-	1.16	-	1.16
Canterbury	-	-	2.51	-	2.51
Cessnock	3.84×10^{-2}	0.89	-	-	0.93
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.01	-	3.01
Gosford	-	0.91	2.45	-	3.36
Goulburn Mulwaree	-	4.14×10^{-3}	-	-	4.14×10^{-3}
Great Lakes	-	6.80×10^{-2}	-	-	6.80×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.10	-	1.12
Holroyd	-	-	1.74	-	1.74
Hornsby	-	3.62×10^{-3}	2.86	-	2.87

LGA	2008 proportion of annual natural gas and liquid petroleum gas (LPG) consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Hunters Hill	-	-	0.16	-	0.16
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.29	-	-	0.29
Kogarah	-	-	1.06	-	1.06
Ku-ring-gai	-	-	1.85	-	1.85
Lake Macquarie	2.00	1.82	-	-	3.82
Lane Cove	-	-	0.57	-	0.57
Leichhardt	-	-	0.89	-	0.89
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	2.90	-	2.90
Maitland	9.39×10^{-2}	1.15	-	-	1.25
Manly	-	-	0.69	-	0.69
Marrickville	-	-	1.88	-	1.88
Mid-western Regional	-	5.16×10^{-2}	-	-	5.16×10^{-2}
Mosman	-	-	0.68	-	0.68
Muswellbrook	-	0.26	-	-	0.26
N/A	3.05×10^{-2}	5.58×10^{-2}	0.39	7.60×10^{-2}	0.55
Newcastle	3.15	-	-	-	3.15
North Sydney	-	-	1.35	-	1.35
Oberon	-	2.26×10^{-2}	-	-	2.26×10^{-2}
Parramatta	-	-	2.83	-	2.83
Penrith	-	-	3.15	-	3.15
Pittwater	-	-	1.04	-	1.04
Port Stephens	6.97×10^{-2}	1.07	-	-	1.14
Randwick	-	-	2.68	-	2.68
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.07	-	2.07
Shellharbour	-	0.89	-	0.31	1.20
Shoalhaven	-	1.50×10^{-3}	-	-	1.50×10^{-3}
Singleton	-	0.37	-	-	0.37
Strathfield	-	-	0.68	-	0.68
Sutherland	-	-	4.08	-	4.08
Sydney	-	-	4.01	-	4.01
Unincorporated	-	-	0.93	-	0.93
Upper Lachlan	-	6.05×10^{-4}	-	-	6.05×10^{-4}
Warringah	-	-	2.73	-	2.73
Waverley	-	-	1.29	-	1.29
Willoughby	-	-	1.39	-	1.39
Wingecarribee	-	0.88	4.72×10^{-3}	1.50×10^{-3}	0.89
Wollondilly	-	1.16×10^{-2}	0.74	3.91×10^{-4}	0.75
Wollongong	-	-	0.27	3.50	3.77
Woollahra	-	-	1.03	-	1.03
Wyong	-	2.96	-	-	2.96
Grand Total	5.38	12.78	77.95	3.89	100.00

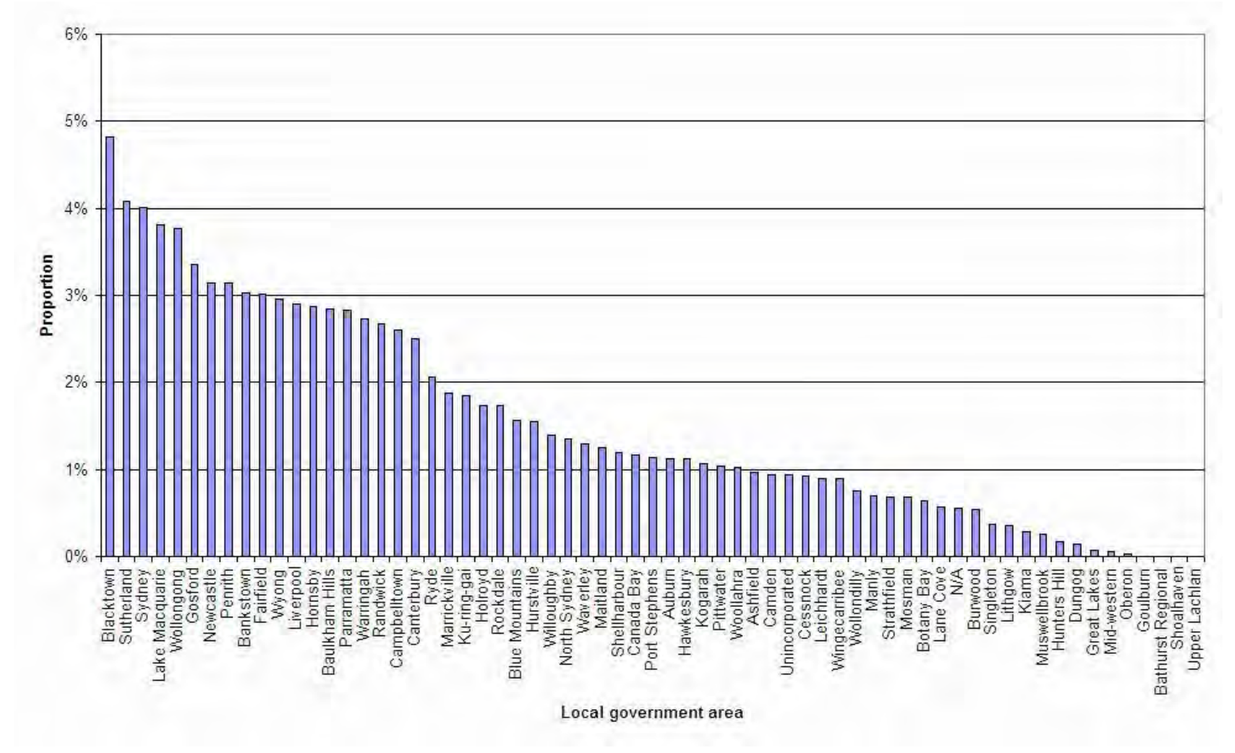

Figure 3-26: Gaseous fuel combustion spatial distribution of fuel consumption by LGA

Figure 3-27 shows the spatial distribution of gaseous fuel fired residential appliances and unaccounted commercial business equipment emissions.

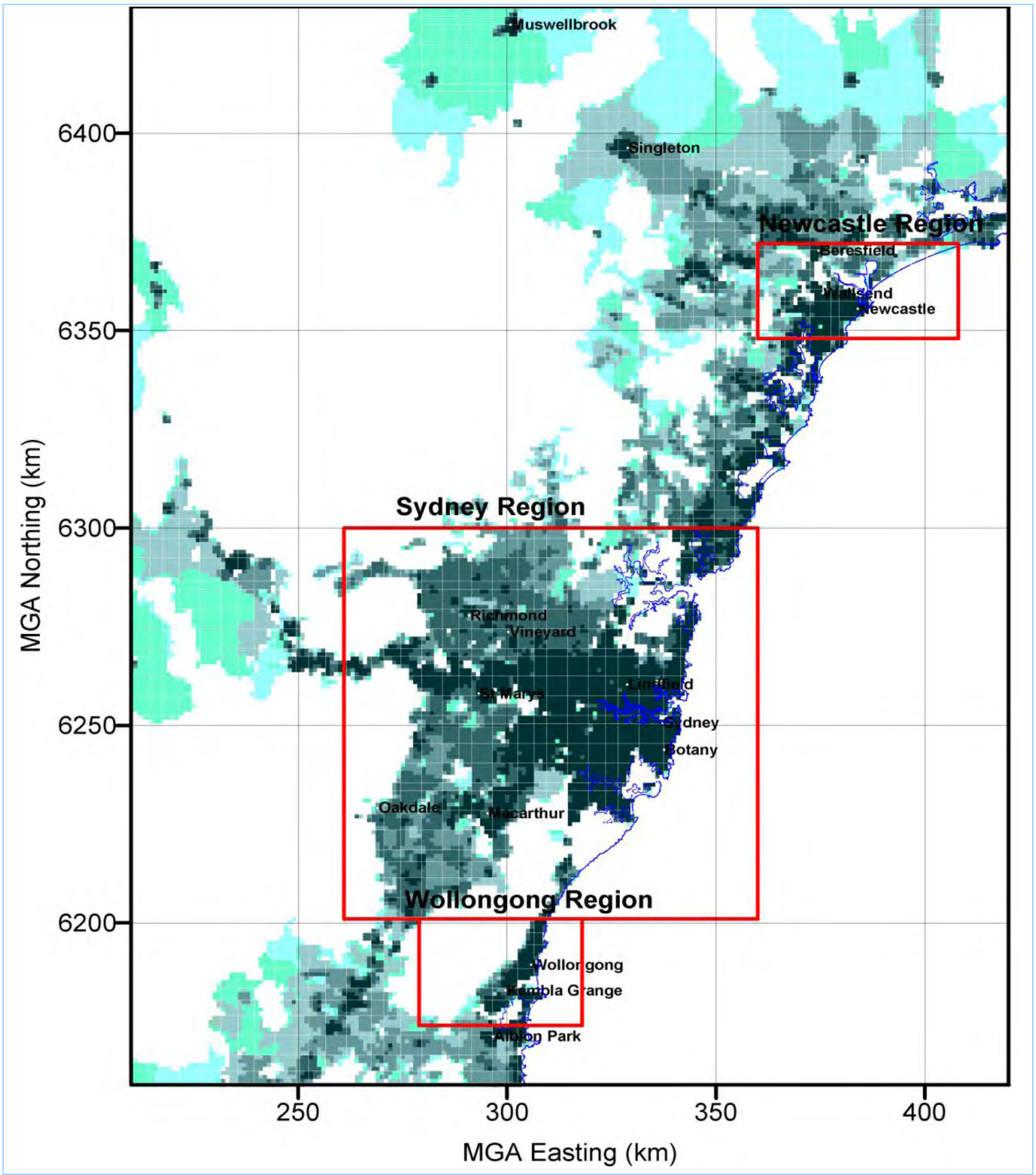

Figure 3-27: Gaseous fuel combustion spatial distribution of emissions

3.4.6 *Temporal Variation of Emissions*

Table 3-64 summarises the data used to estimate the temporal variation in emissions from gaseous fuel fired residential appliances and unaccounted commercial business equipment.

Table 3-64: Gaseous fuel combustion temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from gaseous fuel combustion in: Residential cooktops, ovens, space heaters, stoves and water heaters; and Unaccounted commercial business equipment	Monthly and daily: Daily natural gas flow	- *National Gas Market Bulletin Board, Daily Natural Gas Flow, 1 August 2008 to 31 July 2009* (AEMOL, 2009)
	Hourly: Source type specific temporal allocation factors	- *Stationary Fuel Comb /Residential /Natural Gas /Total: All Combustor Types - Weekday diurnal profile number 26 and Weekend diurnal profile number 26 - CAIR Platform Temporal Allocation* (USEPA, 2005)

The daily and monthly temporal variation in emissions from gaseous fuel fired residential appliances and unaccounted commercial business equipment have been estimated from daily natural gas flow data (AEMOL, 2009), while the hourly temporal variation in emissions have been estimated from generic temporal profiles (USEPA, 2005).

Hourly temporal variation profiles are presented in Table 3-65 and shown in Figure 3-28.

Table 3-65: Gaseous fuel combustion hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	1.98	13	6.20
2	1.86	14	6.31
3	1.82	15	6.35
4	1.87	16	6.24
5	2.10	17	5.94
6	2.50	18	5.48
7	3.11	19	5.31
8	3.88	20	5.09
9	4.67	21	4.25
10	5.28	22	3.27
11	5.71	23	2.57
12	6.04	24	2.18

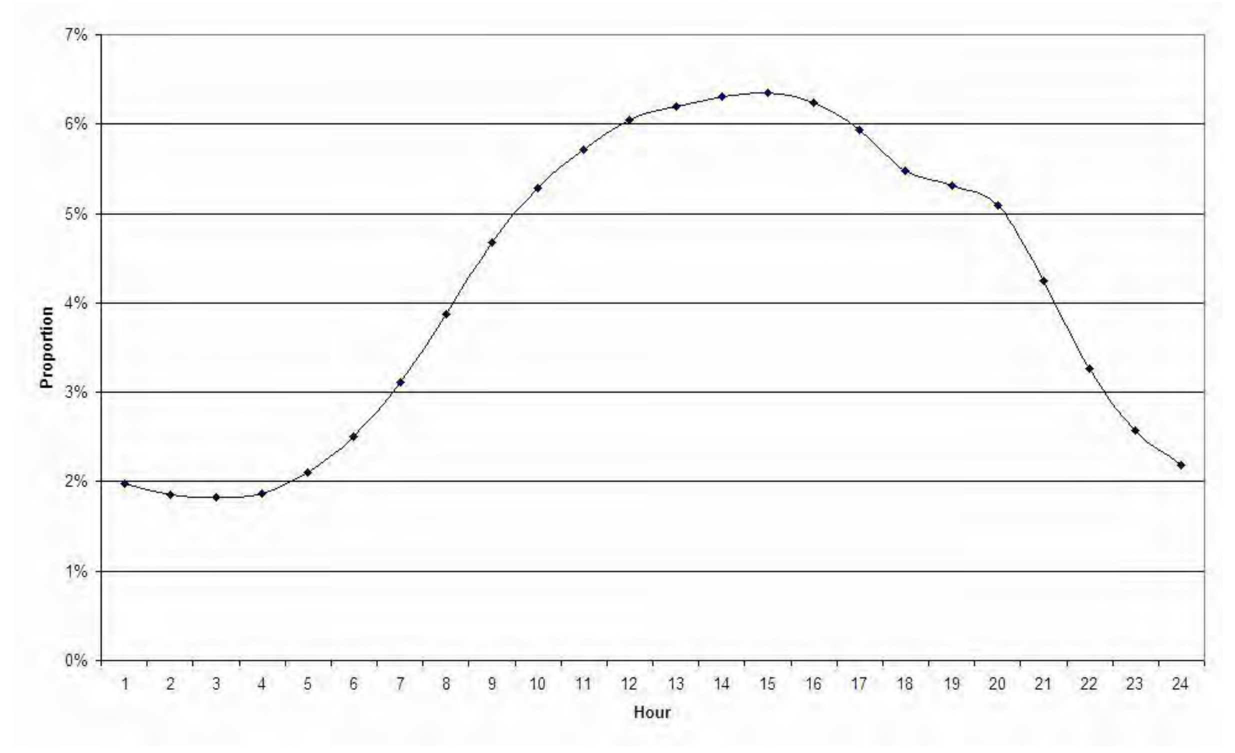

Figure 3-28: Gaseous fuel combustion hourly temporal profile

Daily temporal variation profiles are presented in Table 3-66 and shown in Figure 3-29.

Table 3-66: Gaseous fuel combustion daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.78	15.48	15.70	15.56	14.91	11.52	12.06

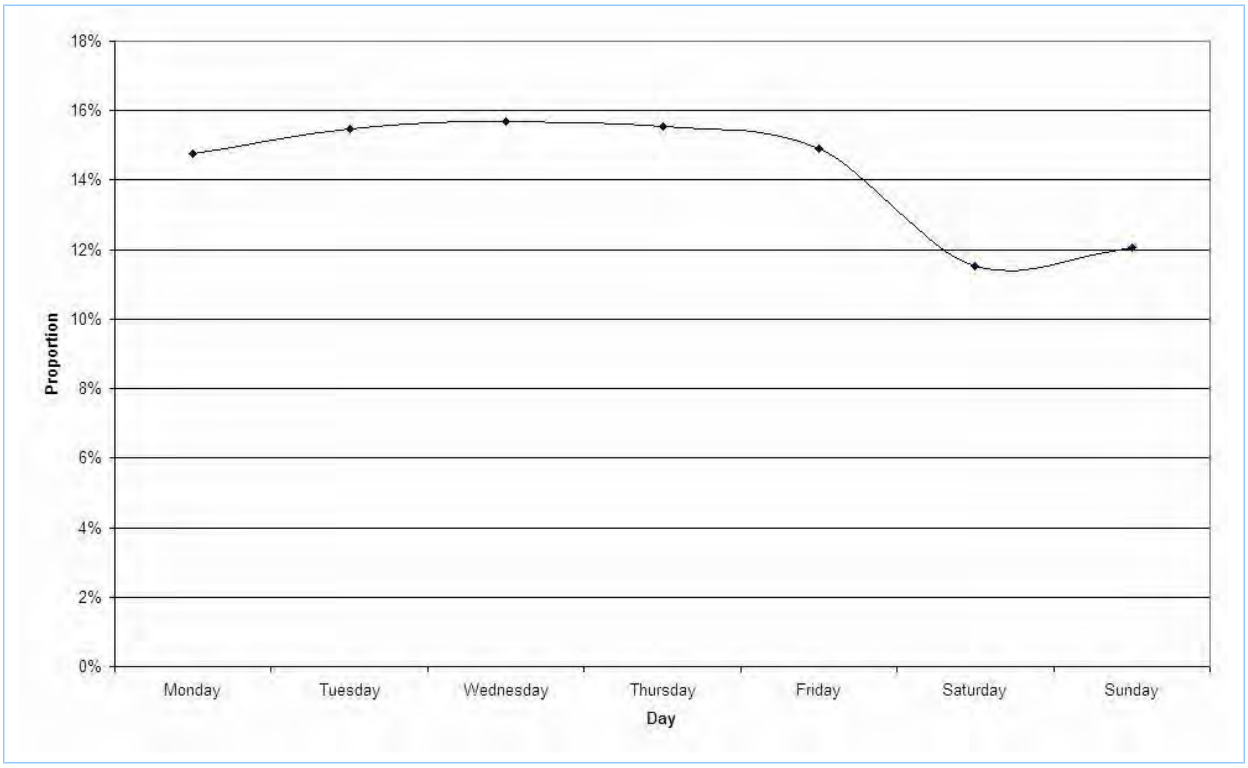

Figure 3-29: Gaseous fuel combustion daily temporal profile

Monthly temporal variation profiles are presented in Table 3-67 and shown in Figure 3-30.

Table 3-67: Gaseous fuel combustion monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	7.48	July	10.87
February	7.44	August	9.76
March	7.18	September	8.09
April	8.14	October	7.84
May	8.81	November	7.81
June	9.72	December	6.86

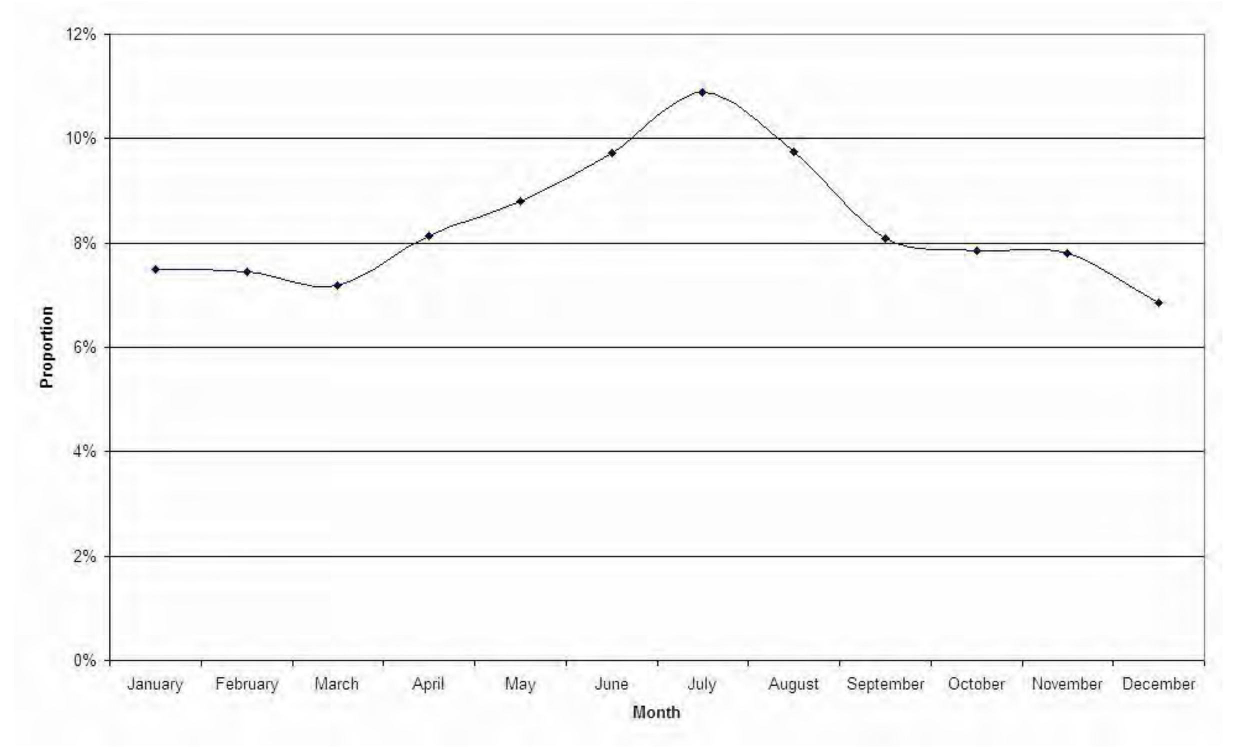

Figure 3-30: Gaseous fuel combustion monthly temporal profile

3.4.7 Emission Estimates

Table 3-68 presents annual emissions of selected substances from gaseous fuel fired residential appliances and unaccounted commercial business equipment by activity.

Table 3-68: Gaseous fuel combustion emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Gaseous Fuel Combustion	ACETALDEHYDE	1.50×10^{-2}	3.56×10^{-2}	0.22	1.08×10^{-2}	0.28
	BENZENE	2.36	5.62	34	1.71	44
	CARBON MONOXIDE	46,312	110,080	671,183	33,464	861,039
	FORMALDEHYDE	84	201	1,224	61	1,570
	LEAD & COMPOUNDS	0.56	1.34	8.16	0.41	10
	OXIDES OF NITROGEN	107,342	255,145	1,555,685	77,564	1,995,737
	PARTICULATE MATTER ≤ 10 µm	8,566	20,360	124,140	6,189	159,254
	PARTICULATE MATTER ≤ 2.5 µm	8,566	20,360	124,140	6,189	159,254
	POLYCYCLIC AROMATIC HYDROCARBONS	0.79	1.87	11	0.57	15
	SULFUR DIOXIDE	694	1,649	10,054	501	12,898
	TOLUENE	3.83	9.10	55	2.77	71
	TOTAL SUSPENDED PARTICULATE	8,566	20,360	124,140	6,189	159,254

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL VOLATILE ORGANIC COMPOUNDS	6,193	14,721	89,758	4,475	115,147

Table 3-69 presents annual emissions of selected substances from gaseous fuel fired residential appliances and unaccounted commercial business equipment by source type.

Table 3-69: Gaseous fuel combustion emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
LPG Combustion – Domestic	ACETALDEHYDE	3.81×10^{-4}	9.06×10^{-4}	5.53×10^{-3}	2.76×10^{-4}	7.09×10^{-3}
	BENZENE	6.02×10^{-2}	0.14	0.87	4.35×10^{-2}	1.12
	CARBON MONOXIDE	2,416	5,744	35,020	1,746	44,927
	FORMALDEHYDE	2.15	5.11	31	1.55	40
	LEAD & COMPOUNDS	1.43×10^{-2}	3.41×10^{-2}	0.21	1.04×10^{-2}	0.27
	OXIDES OF NITROGEN	4,188	9,956	60,702	3,027	77,873
	PARTICULATE MATTER ≤ 10 µm	226	536	3,269	163	4,193
	PARTICULATE MATTER ≤ 2.5 µm	226	536	3,269	163	4,193
	POLYCYCLIC AROMATIC HYDROCARBONS	2.0×10^{-2}	4.76×10^{-2}	0.29	1.45×10^{-2}	0.37
	SULFUR DIOXIDE	35	84	512	26	657
	TOLUENE	9.75×10^{-2}	0.23	1.41	7.04×10^{-2}	1.81
	TOTAL SUSPENDED PARTICULATE	226	536	3,269	163	4,193
	TOTAL VOLATILE ORGANIC COMPOUNDS	158	375	2,285	114	2,932
Natural Gas Combustion – Domestic	ACETALDEHYDE	5.82×10^{-3}	1.38×10^{-2}	8.44×10^{-2}	4.21×10^{-3}	0.11
	BENZENE	0.92	2.18	13	0.66	17
	CARBON MONOXIDE	17,504	41,607	253,688	12,649	325,448
	FORMALDEHYDE	33	78	476	24	610
	LEAD & COMPOUNDS	0.22	0.52	3.17	0.16	4.07
	OXIDES OF NITROGEN	41,135	97,776	596,166	29,724	764,802
	PARTICULATE MATTER ≤ 10 µm	3,326	7,905	48,201	2,403	61,835
	PARTICULATE MATTER ≤ 2.5 µm	3,326	7,905	48,201	2,403	61,835
	POLYCYCLIC	0.31	0.73	4.43	0.22	5.68

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	AROMATIC HYDROCARBONS					
	SULFUR DIOXIDE	263	624	3,805	190	4,882
	TOLUENE	1.49	3.54	22	1.08	28
	TOTAL SUSPENDED PARTICULATE	3,326	7,905	48,201	2,403	61,835
	TOTAL VOLATILE ORGANIC COMPOUNDS	2,407	5,721	34,882	1,739	44,749
Natural Gas Combustion – Unaccounted Commercial Business Equipment	ACETALDEHYDE	8.77×10^{-3}	2.09×10^{-2}	0.13	6.34×10^{-3}	0.16
	BENZENE	1.39	3.29	20	1.00	26
	CARBON MONOXIDE	26,391	62,729	382,475	19,070	490,665
	FORMALDEHYDE	49	118	717	36	920
	LEAD & COMPOUNDS	0.33	0.78	4.78	0.24	6.13
	OXIDES OF NITROGEN	62,018	147,413	898,817	44,814	1,153,062
	PARTICULATE MATTER ≤ 10 µm	5,014	11,919	72,670	3,623	93,226
	PARTICULATE MATTER ≤ 2.5 µm	5,014	11,919	72,670	3,623	93,226
	POLYCYCLIC AROMATIC HYDROCARBONS	0.46	1.09	6.68	0.33	8.56
	SULFUR DIOXIDE	396	941	5,737	286	7,360
	TOLUENE	2.24	5.33	33	1.62	42
	TOTAL SUSPENDED PARTICULATE	5,014	11,919	72,670	3,623	93,226
	TOTAL VOLATILE ORGANIC COMPOUNDS	3,629	8,625	52,590	2,622	67,466

3.4.8 *Emission Projection Methodology*

Table 3-70 summarises the data used to estimate the emission projection factors for gaseous fuel fired residential appliances and unaccounted commercial business equipment, while Figure 3-31 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-70: Gaseous fuel combustion emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from gaseous fuel combustion in: Residential cooktops, ovens, space heaters, stoves and water	Final energy consumption for residential using liquid petroleum gas and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

Emission source	Projection factor surrogate	Projection factor source
heaters; and Unaccounted commercial business equipment		

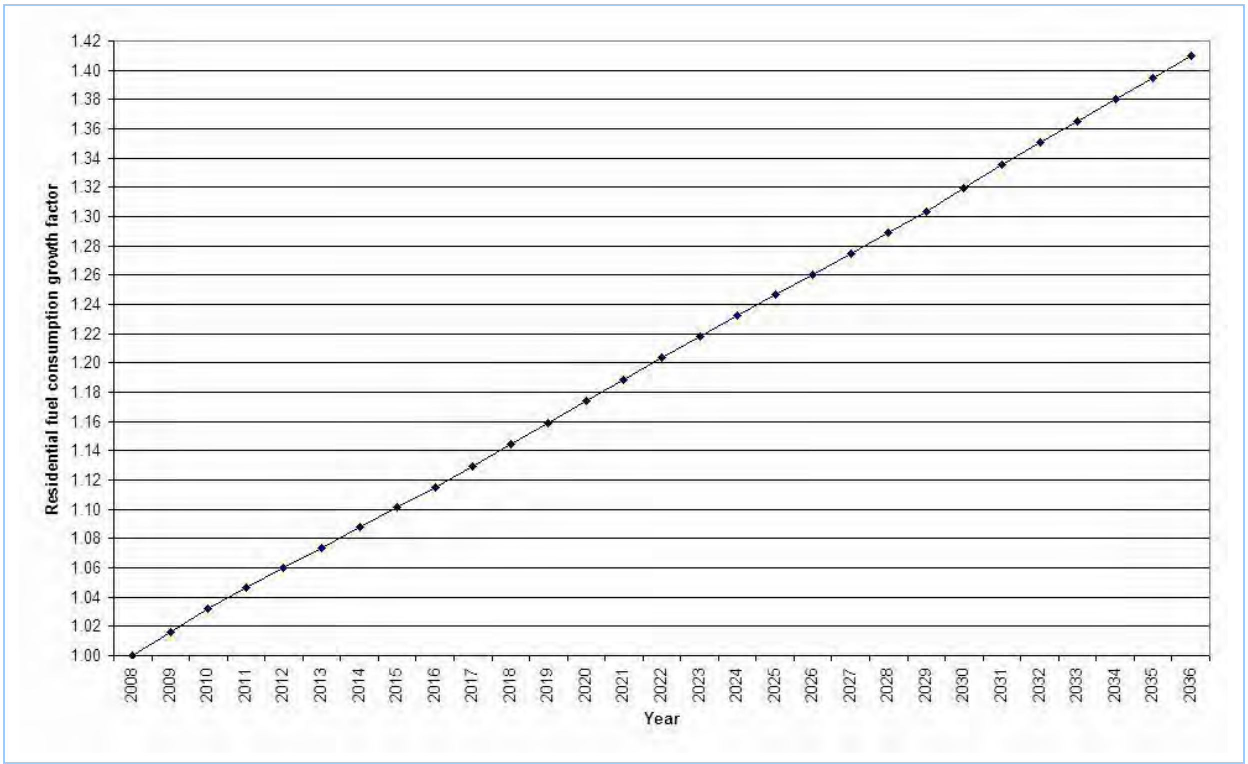

Figure 3-31: Gaseous fuel combustion emission projection factors

3.5 Graphic Arts

3.5.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from unaccounted commercial businesses involved in graphic arts, which arise from inks, fountain solutions and cleaning solutions.

To estimate emissions from these sources, the following have been considered:

- *IBISWorld industry report*

The consumption of ink by the paper, printing, publishing and packaging industry in Australia in 2008 (IBISWorld, 2008) has been used in combination with Australia, NSW and GMR demographic statistics (ABS, 2009; and TDC, 2009) to estimate total printing ink consumption in the GMR.

- *Commercial survey*

A commercial survey has been conducted, which has provided activity data for commercial printing businesses (i.e. non-scheduled activity)[25] (DECC, 2007a). Emissions of evaporative VOC from commercial businesses within the Printing Australian and New Zealand Standard Industrial Classification (ANZSIC) class (ABS, 1993) are included in the commercial air emissions inventory.

- *Industrial survey*

An industrial survey has been conducted, which has provided activity data for EPA-licensed printing premises (i.e. scheduled activity)[26] (DECCW, 2009). Emissions of evaporative VOC from EPA-licensed premises within the Printing, packaging and visual media production *Protection of the Environment (Operations) Act 1997* (POEO) scheduled activity (PCO, 2010a) are included in the industrial air emissions inventory.

- *Printing process*

The inventory includes unaccounted commercial businesses involved in graphic arts as follows (ERG, 1996b):

  - *Rotogravure* includes packaging, advertising, greeting cards, art books, catalogues and directories;
  - *Flexography* includes packaging, advertising newspapers, books, magazines, financial and legal document directories;

[25] Non-scheduled activity means an activity that is not a scheduled activity and is not scheduled development work as defined in the *Protection of the Environment (Operations) Act 1997* (PCO, 2010a).
[26] Scheduled activity means an activity listed in Schedule 1 of the *Protection of the Environment (Operations) Act 1997* (PCO, 2010a).

- *Offset Lithography* (i.e. heatset, nonheatset web, nonheatset sheet and newspaper) includes magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging and metal cans;

- *Letterpress* includes magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging and metal cans;

- *Screen* includes signs, electronics, wallpaper, greeting cards, ceramics, decals, banners and plastic bottles; and

- *Plateless* includes images printed on paper by laser printers, xerographic copiers, fax machines and ink jets.

3.5.2 *Emission Estimation Methodology*

Table 3-71 summarises the emission estimation methodology used for unaccounted commercial businesses involved in graphic arts.

Table 3-71: Graphic arts emission estimation methodology

Emission source	Emission estimation methodology source
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Solvent Usage – Other* (Pechan, 2009b)

Evaporative VOC emissions from unaccounted commercial businesses involved in graphic arts have been estimated using a per capita based emission factor combined with population in the GMR (TDC, 2009). Emissions have been determined using Equation 8 (Pechan, 2009b):

$$E_{VOC} = P \times EF_{VOC} \qquad \textbf{Equation 8}$$

where:			
E_{VOC}	=	Emissions of VOC	(kg/year)
P	=	Population	(capita)
EF_{VOC}	=	Emission factor for VOC	(kg/capita/year)

3.5.3 *Activity Data*

Table 3-72 summarises the activity data used for unaccounted commercial businesses involved in graphic arts.

Table 3-72: Graphic arts activity data

Activity data	Activity data source
Ink and solvent consumption	- *Ink Manufacturing in Australia* (IBISWorld, 2008) - *Australian Demographic Statistics* (ABS, 2009) - *Graphic Arts* (ERG, 1996b) - *2008 Survey of EPA-Licensed Premises* (DECCW, 2009) - *2004 Survey of Commercial Businesses* (DECC, 2007a)
Gridded 1 km x 1 km population estimates required for per capita emission factors	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Table 3-73 presents graphic arts ink solvent use and component VOC emission factors by printing process (ERG, 1996b). An ink solvent use weighted VOC emission factor for graphic arts of 0.6637 kg VOC/kg ink has been derived.

Table 3-73: Graphics arts component VOC emission factors

Printing process	Ink solvent use (%)	Component emission factor (kg VOC/kg ink)			
		Ink	Fountain solution	Cleaning solution	Grand Total
Rotogravure	22.00	0.70	-	0.03	0.73
Flexography	16.00	0.60	-	0.04	0.64
Heatset	8.75	0.32	0.90	0.03	1.25
Nonheatset Web	8.75	0.02	0.53	0.03	0.58
Nonheatset Sheet	8.75	0.02	1.25	1.10	2.37
Newspaper	8.75	0.02	0.07	0.07	0.16
Letterpress	8.00	0.24	-	-	0.24
Screen	9.50	-	-	-	-
Planographic	9.50	-	-	-	-
Grand Total[27]	100.00	0.3025	0.2406	0.1206	0.6637

Table 3-74 presents population (ABS, 2009), ink consumption (IBISWorld, 2008) and estimated VOC emissions in Australia by State. Ink consumption by State is assumed to be proportional to population, while VOC emissions by State have been estimated using an emission factor of 0.6637 kg VOC/kg ink (ERG, 1996b).

[27] $\{\Sigma(\text{Ink solvent use}_i \times \text{Component emission factor}_j)/100\}$. where: i = printing process (either "rotogravure", "flexography", "heatset", "nonheatset web", "nonheatset sheet", "newspaper", "letterpress", "screen" and "planographic") and j = emission source (either "ink", "fountain solution" and "cleaning solution").

Table 3-74: Graphic arts VOC emissions in Australia by State

Area	2008 statistics			
	Population	Proportion (%)	Ink consumption (tonne/year)	VOC emission (kg/year)
New South Wales	7,041,393	32.53	11,712	7,773,125
Victoria	5,364,796	24.79	8,923	5,922,298
Queensland	4,349,529	20.10	7,234	4,801,526
South Australia	1,612,002	7.45	2,681	1,779,519
Western Australia	2,204,040	10.18	3,666	2,433,081
Tasmania	500,278	2.31	832	552,266
Northern Territory	221,682	1.02	369	244,719
Australian Capital Territory	347,843	1.61	579	383,990
Australia	21,643,987	100.00	36,000	23,893,200

Table 3-75 presents graphic arts VOC emissions by activity in NSW and the GMR. The estimated commercial business (DECC, 2007a) and EPA-licensed premises (DECCW, 2009) VOC emissions have been subtracted from total (IBISWorld, 2008; ERG, 1996b; and ABS, 2009) VOC emissions in order to estimate unaccounted VOC emissions by commercial businesses in NSW. The unaccounted commercial business VOC emission factor of 0.6576 kg VOC/capita/year has been estimated from unaccounted commercial business VOC emissions in NSW (i.e. 4,630,323 kg/year) divided by the NSW population (i.e. 7,041,393). The unaccounted commercial business VOC emissions in the GMR (i.e. 3,475,054 kg/year) have been estimated by multiplying the unaccounted commercial business VOC emission factor of 0.6576 kg VOC/capita/year by the GMR population (i.e. 5,284,560) (TDC, 2009).

Table 3-75: Graphic arts VOC emissions in NSW and the GMR

Activity	2008 statistics	
	VOC in NSW (kg/year)	VOC in the GMR (kg/year)
EPA-licensed premises	1,827,598	1,827,598
Commercial businesses	1,315,203	1,315,203
Unaccounted commercial businesses	4,630,323	3,475,054
Grand Total	7,773,125	6,617,856

3.5.4 *Emission and Speciation Factors*

Table 3-76 summarises the emission and speciation factors used for unaccounted commercial businesses involved in graphic arts.

Table 3-76: Graphic arts emission and speciation factors

Emission source	Substance	Emission and speciation factor source
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	Criteria pollutants: VOC	- *Ink Manufacturing in Australia* (IBISWorld, 2008) - *Australian Demographic Statistics* (ABS, 2009) - *Graphic Arts* (ERG, 1996b) - *2008 Survey of EPA-Licensed Premises* (DECCW, 2009) - *2004 Survey of Commercial Businesses* (DECC, 2007a)
	Speciated VOC	- *ORGPROF 517 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *ORGPROF 517 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)

Table 3-77 presents the VOC emission factor for unaccounted commercial businesses involved in graphic arts. The unaccounted commercial business VOC emissions in the GMR (i.e. 3,475,054 kg/year) have been estimated by multiplying the unaccounted commercial business VOC emission factor of 0.6576 kg VOC/capita/year (DECC, 2007a; DECCW, 2009; IBISWorld, 2008; ERG, 1996b; and ABS, 2009) by the GMR population (i.e. 5,284,560) (TDC, 2009).

Table 3-77: Graphic arts emission factor

Emission source	2008 VOC in the GMR (kg/year)	2008 population in the GMR (capita)	VOC emission factor (kg/capita/year)
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	3,475,054	5,284,560	0.6576

3.5.5 *Spatial Distribution of Emissions*

Table 3-78 summarises the data used for spatially allocating emissions from unaccounted commercial businesses involved in graphic arts.

Table 3-78: Graphic arts spatial data

Emission source	Spatial data	Spatial data source
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	Gridded 1 km x 1 km population estimates	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Emissions from unaccounted commercial businesses involved in graphic arts have been spatially distributed according to the proportion of population within each 1 km by 1 km grid cell (TDC, 2009). The proportion of population by LGA and region is presented in Table 3-79 and shown in Figure 3-32.

Table 3-79: Graphic arts spatial distribution of population by LGA and region

LGA	2008 proportion of population (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.91	-	0.91
Auburn	-	-	1.32	-	1.32
Bankstown	-	-	3.30	-	3.30
Bathurst Regional	-	2.84×10^{-3}	-	-	2.84×10^{-3}
Baulkham Hills	-	2.44×10^{-3}	3.23	-	3.24
Blacktown	-	-	5.42	-	5.42
Blue Mountains	-	0.48	1.00	-	1.48
Botany Bay	-	-	0.63	-	0.63
Burwood	-	-	0.57	-	0.57
Camden	-	-	1.05	-	1.05
Campbelltown	-	-	2.85	-	2.85
Canada Bay	-	-	1.12	-	1.12
Canterbury	-	-	2.62	-	2.62
Cessnock	4.36×10^{-2}	0.88	-	-	0.92
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.58	-	3.58
Gosford	-	0.89	2.19	-	3.08
Goulburn Mulwaree	-	5.98×10^{-3}	-	-	5.98×10^{-3}
Great Lakes	-	7.21×10^{-2}	-	-	7.21×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.16	-	1.18
Holroyd	-	-	1.80	-	1.80
Hornsby	-	3.61×10^{-3}	3.04	-	3.04
Hunters Hill	-	-	0.18	-	0.18
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.28	-	-	0.28
Kogarah	-	-	1.09	-	1.09
Ku-ring-gai	-	-	2.03	-	2.03
Lake Macquarie	1.96	1.74	-	-	3.70
Lane Cove	-	-	0.54	-	0.54
Leichhardt	-	-	0.75	-	0.75
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	3.38	-	3.38
Maitland	0.10	1.16	-	-	1.26
Manly	-	-	0.64	-	0.64
Marrickville	-	-	1.65	-	1.65
Mid-western Regional	-	5.42×10^{-2}	-	-	5.42×10^{-2}
Mosman	-	-	0.59	-	0.59
Muswellbrook	-	0.27	-	-	0.27
N/A	2.48×10^{-2}	5.23×10^{-2}	0.35	6.03×10^{-2}	0.49
Newcastle	2.86	-	-	-	2.86
North Sydney	-	-	1.02	-	1.02
Oberon	-	3.10×10^{-2}	-	-	3.10×10^{-2}
Parramatta	-	-	2.89	-	2.89
Penrith	-	-	3.36	-	3.36
Pittwater	-	-	1.03	-	1.03

LGA	2008 proportion of population (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Port Stephens	6.56×10^{-2}	1.05	-	-	1.12
Randwick	-	-	2.48	-	2.48
Rockdale	-	-	1.70	-	1.70
Ryde	-	-	1.99	-	1.99
Shellharbour	-	0.94	-	0.29	1.23
Shoalhaven	-	1.45×10^{-3}	-	-	1.45×10^{-3}
Singleton	-	0.41	-	-	0.41
Strathfield	-	-	0.73	-	0.73
Sutherland	-	-	4.03	-	4.03
Sydney	-	-	3.17	-	3.17
Unincorporated	-	-	0.81	-	0.81
Upper Hunter	-	4.22×10^{-3}	-	-	4.22×10^{-3}
Upper Lachlan	-	5.94×10^{-3}	-	-	5.94×10^{-3}
Warringah	-	-	2.67	-	2.67
Waverley	-	-	1.08	-	1.08
Willoughby	-	-	1.32	-	1.32
Wingecarribee	-	0.85	5.04×10^{-3}	1.49×10^{-3}	0.86
Wollondilly	-	1.23×10^{-2}	0.80	4.13×10^{-4}	0.81
Wollongong	-	-	0.30	3.36	3.66
Woollahra	-	-	0.85	-	0.85
Wyong	-	2.75	-	-	2.75
Grand Total	5.05	12.48	78.76	3.72	100.00

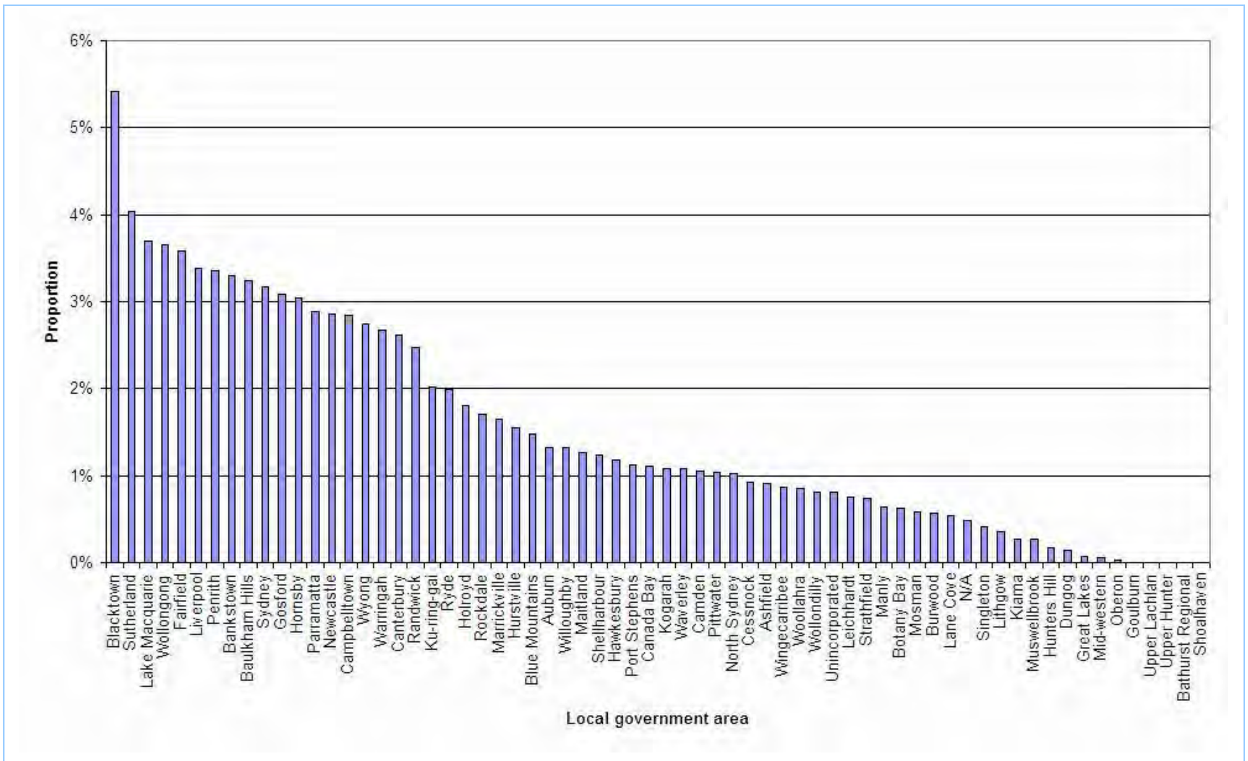

Figure 3-32: Graphic arts spatial distribution of population by LGA

Figure 3-33 shows the spatial distribution of emissions from unaccounted commercial businesses involved in graphic arts.

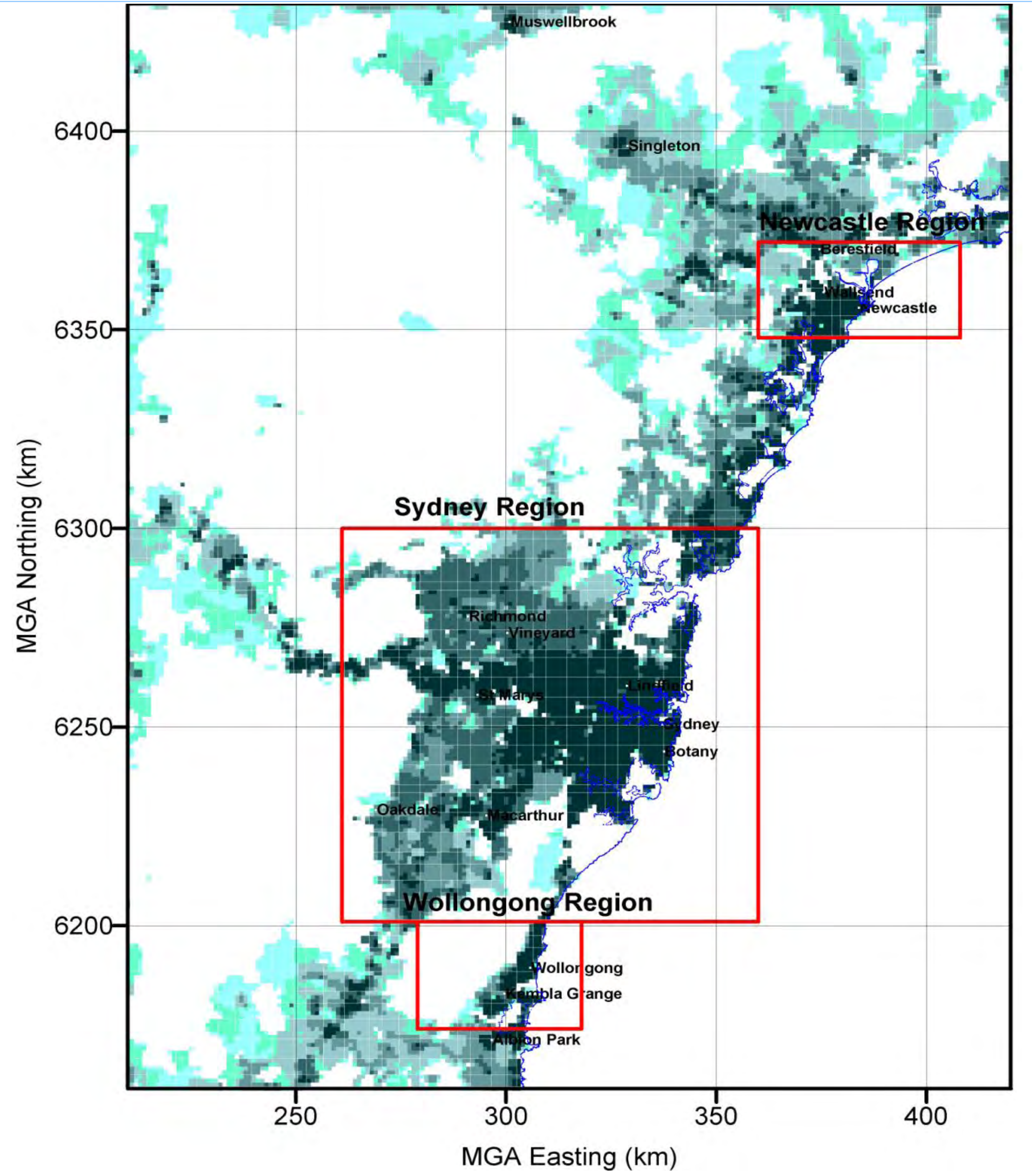

Figure 3-33: Graphic arts spatial distribution of emissions

3.5.6 *Temporal Variation of Emissions*

Table 3-80 summarises the data used to estimate the temporal variation in emissions from unaccounted commercial businesses involved in graphic arts.

Table 3-80: Graphic arts temporal data

Emission source	Temporal data	Temporal data source
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	Monthly: Source type specific temporal allocation factors	- *Graphic Arts /All Processes /Total: All Solvent Types – Monthly profile number 508 - CAIR Platform Temporal Allocation* (USEPA, 2005)
	Daily: Source type specific temporal allocation factors	- *Graphic Arts /All Processes /Total: All Solvent Types – Weekly profile number 107 - CAIR Platform Temporal Allocation* (USEPA, 2005)
	Hourly: Source type specific temporal allocation factors	- *Graphic Arts /All Processes /Total: All Solvent Types – Weekday diurnal profile number 109 and Weekend diurnal profile number 109 - CAIR Platform Temporal Allocation* (USEPA, 2005)

The hourly, daily and monthly temporal variation in emissions from unaccounted commercial businesses involved in graphic arts have been estimated from generic temporal profiles (USEPA, 2005).

Hourly temporal variation profiles are presented in Table 3-81 and shown in Figure 3-34.

Table 3-81: Graphic arts hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	-	13	7.00
2	-	14	7.00
3	-	15	7.00
4	-	16	6.00
5	-	17	7.00
6	-	18	6.00
7	7.00	19	3.00
8	7.00	20	3.00
9	7.00	21	3.00
10	7.00	22	3.00
11	7.00	23	3.00
12	7.00	24	3.00

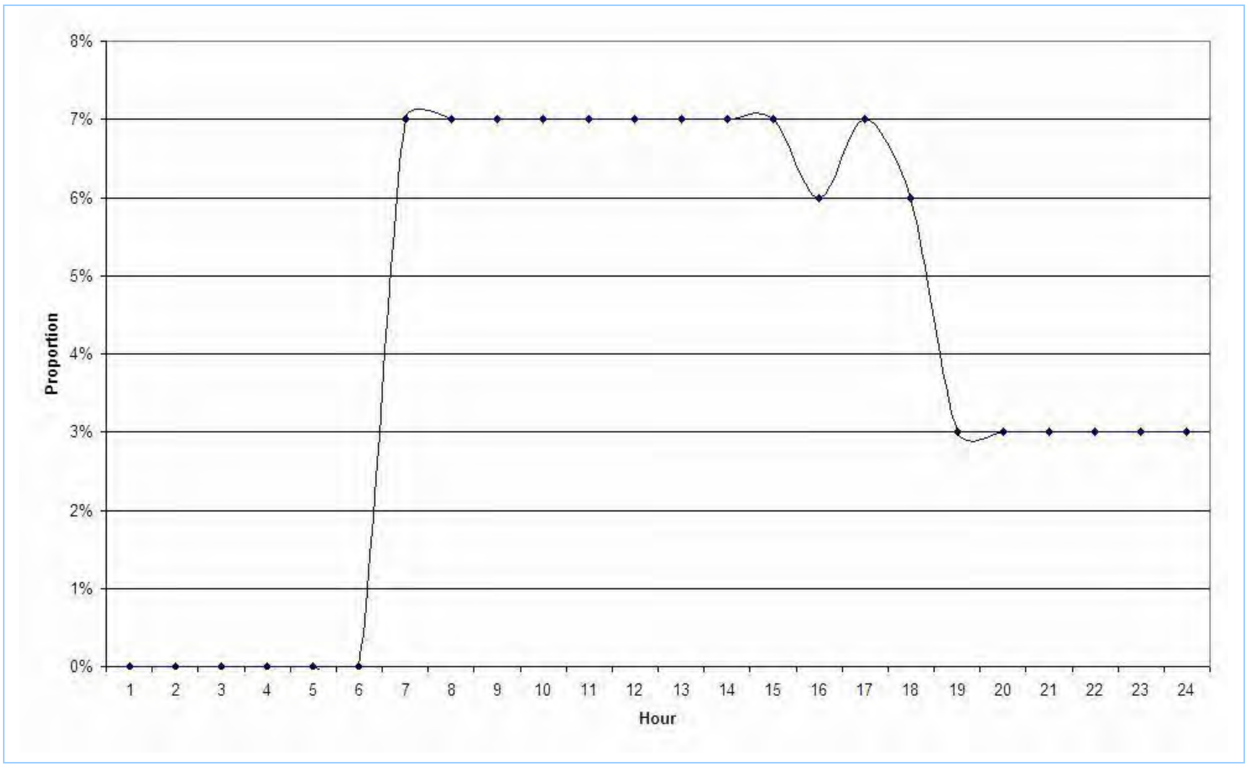

Figure 3-34: Graphic arts hourly temporal profile

Daily temporal variation profiles are presented in Table 3-82 and shown in Figure 3-35.

Table 3-82: Graphic arts daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	17.00	17.00	17.00	17.00	16.00	16.00	0.00

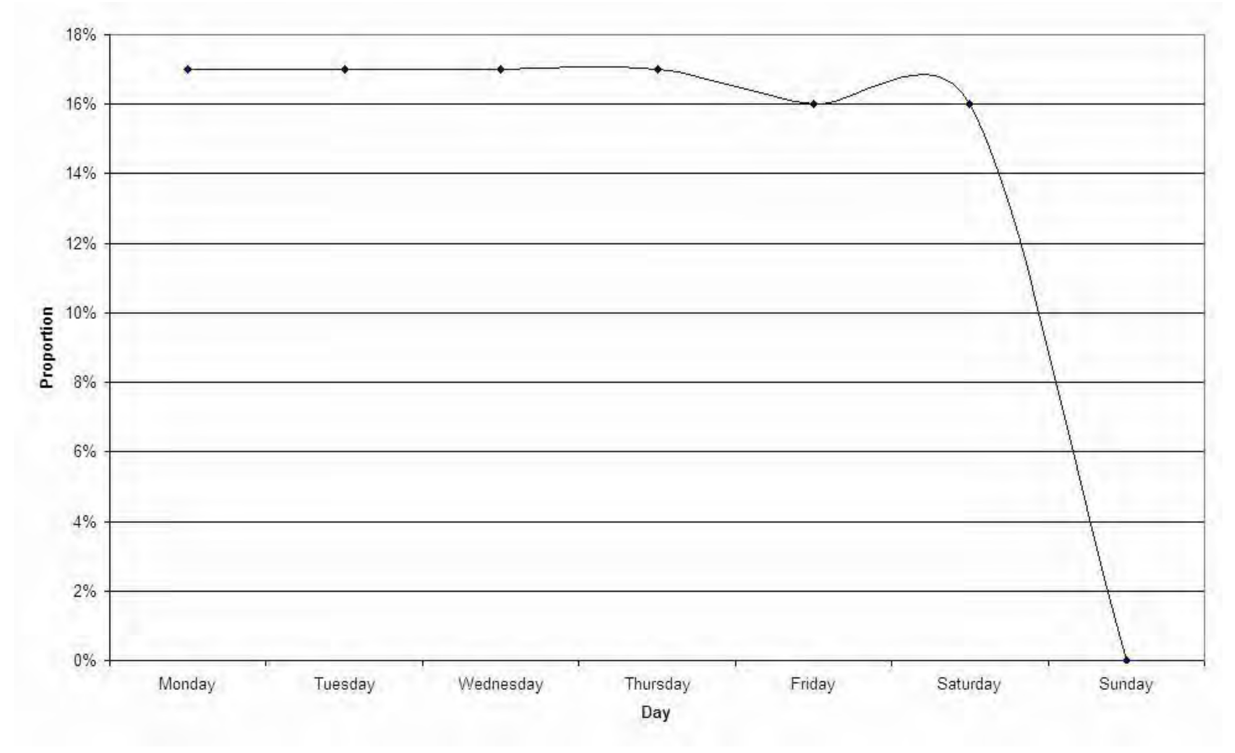

Figure 3-35: Graphic arts daily temporal profile

Monthly temporal variation profiles are presented in Table 3-83 and shown in Figure 3-36.

Table 3-83: Graphic arts monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	9.00	July	8.00
February	9.00	August	8.00
March	8.00	September	8.00
April	9.00	October	8.00
May	9.00	November	8.00
June	8.00	December	8.00

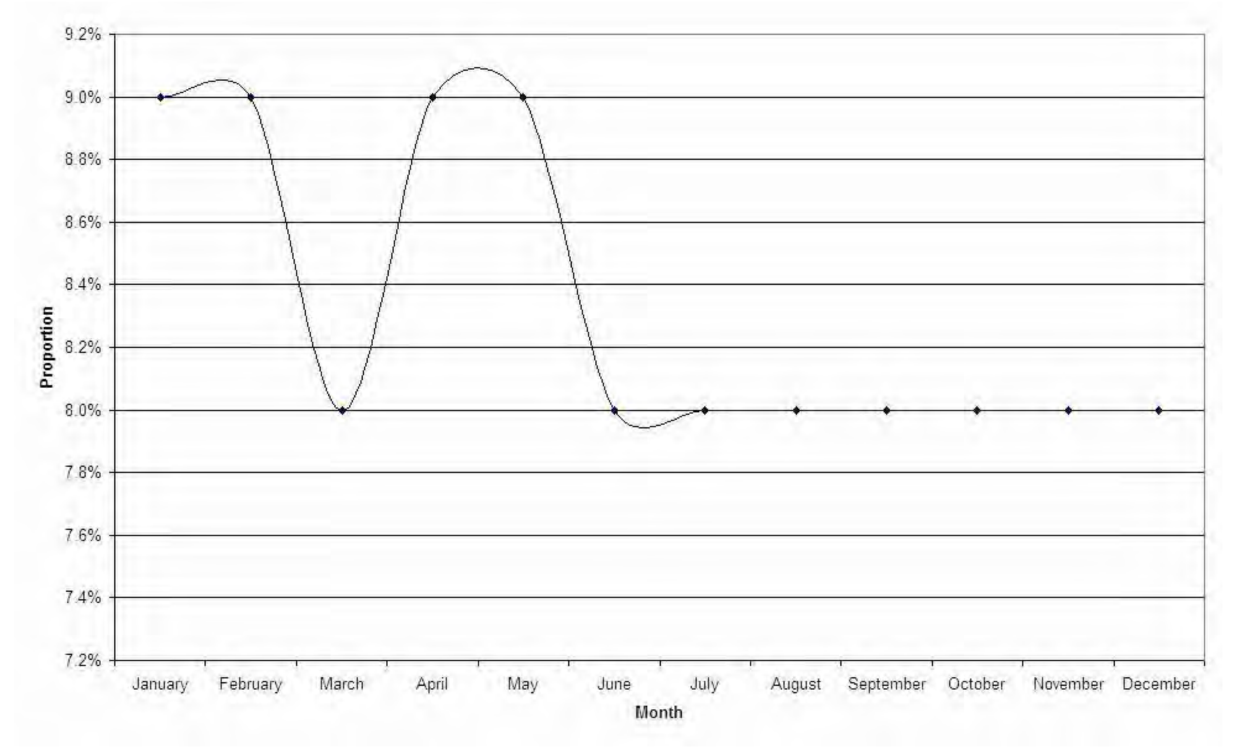

Figure 3-36: Graphic arts monthly temporal profile

3.5.7 *Emission Estimates*

Table 3-84 presents annual emissions of selected substances from unaccounted commercial businesses involved in graphic arts by activity.

Table 3-84: Graphic arts emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Graphic Arts	ISOMERS OF XYLENE	4,038	9,982	63,002	2,974	79,996
	POLYCYCLIC AROMATIC HYDROCARBONS	368	911	5,747	271	7,298
	TOLUENE	526	1,301	8,210	388	10,425
	TOTAL VOLATILE ORGANIC COMPOUNDS	175,421	433,622	2,736,820	129,191	3,475,054

3.5.8 *Emission Projection Methodology*

Table 3-85 summarises the data used to estimate the emission projection factors for unaccounted commercial businesses involved in graphic arts, while Figure 3-37 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-85: Graphic arts emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Evaporative emissions from unaccounted commercial businesses involved in graphic arts	Population growth	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

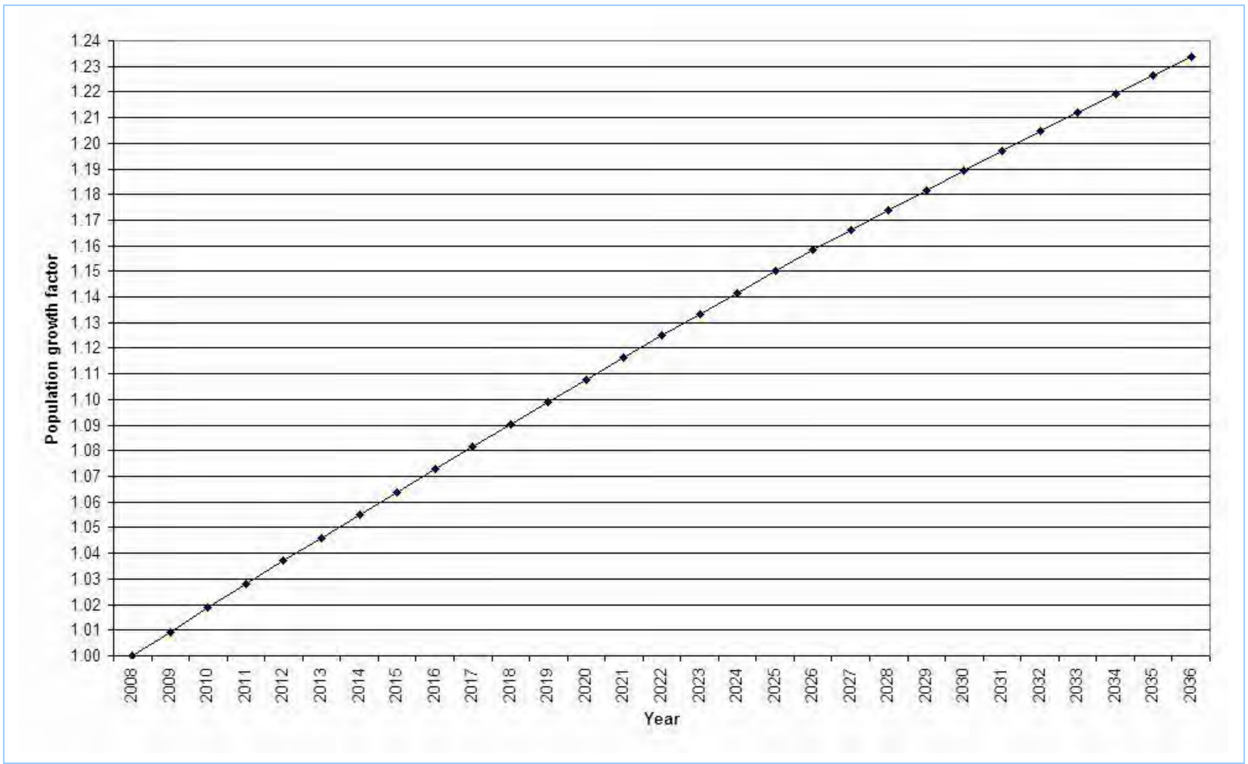

Figure 3-37: Graphic arts emission projection factors

3.6 Lawn Mowing and Garden Equipment (domestic)

3.6.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from lawn mowing and garden equipment engines; and
- Evaporative VOC:
    - Through the crankcase (i.e. combustion products and unburnt fuel);
    - From refuelling (i.e. vapour displacement and spillage);
    - Due to temperature changes (i.e. diurnal, hot soak and running loss); and
    - Via permeation (i.e. plastic fuel tanks and rubber hoses).

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[28] located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; frequency and duration of equipment use by hour, day and season; lawn area; and proportion of private and commercial usage (TR, 2009).

Figure 3-38 shows how the domestic survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009) to develop an inventory of lawn mowing and garden equipment emissions.

[28] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.

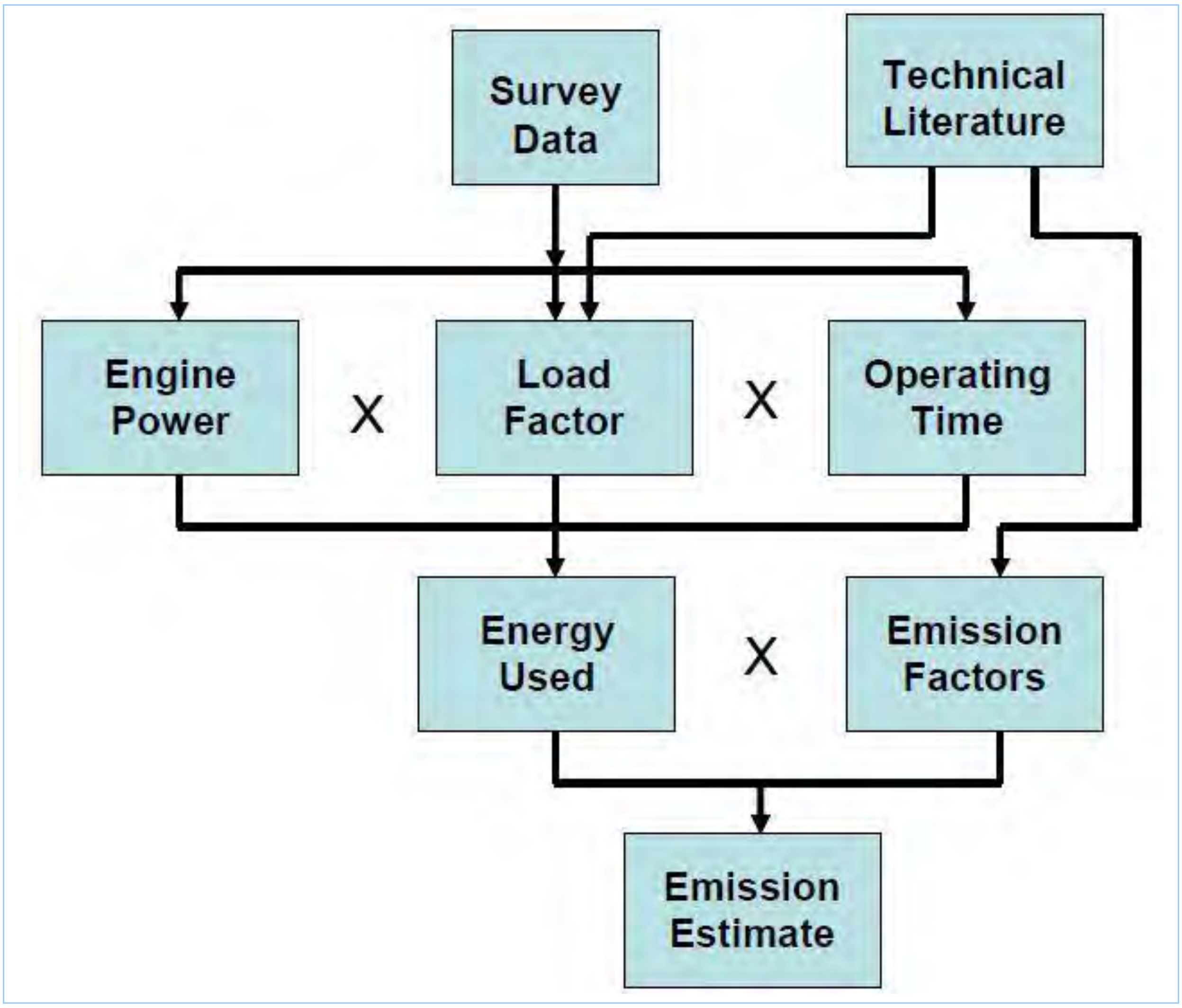

Figure 3-38: Lawn mowing and garden equipment (domestic) – use of survey data

- *Lawn mowing and garden equipment type*

The inventory includes small private-operated and commercial-operated lawn mowing and garden equipment for domestic use as follows:

- *Chainsaw;*
- *Chipper/Mulcher/Shredder;*
- *Leafblower/Vacuum;*
- *Pressure washer;*
- *Push lawnmower;*
- *Ride-on lawnmower; and*
- *Trimmer/Edger/Brush cutter.*

- *Engine type*

The inventory includes lawn mowing and garden equipment powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines, which are either handheld (e.g. chainsaw) or non-handheld (e.g. push lawnmower). Handheld equipment range from 1 to 6 horsepower (hp)[29], while non-handheld equipment range from 1 to 25 hp (AIA, 2005).

Since there are no NSW or Australian emission standards, the inventory considers all lawn mowing and garden equipment have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009).

- *Fuel type*

The inventory includes lawn mowing and garden equipment that use automotive gasoline (petrol).

Table 3-86 presents the lawn mowing and garden equipment fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009). The sulfur and oxygen contents are requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008), which are relevant for the 2008 calendar year. Weighted average sulfur and oxygen contents have been calculated from *Australian Petroleum Statistics 2008* (DRET, 2009) and the requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008).

Table 3-86: Lawn mowing and garden equipment (domestic) fuel type and properties

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive gasoline (petrol)	150 - All grades[30]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[31]	2.84 – Weighted average[32]			

Electric lawn mowing and garden equipment have not been included, since emissions from electricity generation have been separately estimated as part of the industrial air emissions inventory.

- *Source type*

The inventory includes emissions of combustion products and evaporation from lawn mowing and garden equipment engines.

[29] 1 horsepower (hp) is equivalent to 0.7457 kilowatts (kW) (USEPA, 1995a).
[30] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[31] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[32] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

Exhaust emissions are generated in the engine's combustion chamber and exit through the exhaust. Exhaust emissions mainly include CO, NO_x, $PM_{2.5}$, PM_{10}, TSP, SO_2 and VOC (total and speciated).

Evaporation occurs in a number of ways, including:

- *Crankcase emissions* originate from the combustion chamber then move past the piston rings and into the crankcase of 4-stroke petrol engines. Since gases flow freely from the crankcase to the combustion chamber in 2-stroke petrol engines, they are not an issue. They mainly include exhaust emissions plus some unburnt fuel;
- *Refuelling emissions* are the vapours displaced from the fuel tank when it is filled plus any spillage that may occur;
- *Diurnal emissions* arise with temperature changes that occur throughout the day. As the air temperature increases, the fuel temperature in the tank increases and begins to evaporate;
- *Hot soak emissions* are similar to diurnal emissions, except heating of the fuel is provided by the residual heat of the equipment, just after the engine is shut off;
- *Running loss emissions* are similar to diurnal emissions, except heating of the fuel is caused by engine operation; and
- *Permeation emissions* occur when fuel moves through the material used in the fuel system. Since the outer surfaces of the fuel system are exposed to air, petrol molecules permeate through them and are directly emitted. Permeation is most common through plastic fuel tanks and rubber hoses.

Evaporative emissions mainly include VOC (total and speciated).

3.6.2 *Emission Estimation Methodology*

Table 3-87 summarises the emission estimation methodology used for lawn mowing and garden equipment.

Table 3-87: Lawn mowing and garden equipment (domestic) emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from lawn mowing and garden equipment (domestic)	- *Guidance for Estimating Lawn and Garden Equipment Activity Levels* (Environ, 1997)

Exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population and activity data in combination with emission, load, transient adjustment and deterioration factors within the *NONROAD2008a Model* (USEPA, 2009).

Exhaust emission factors have been adjusted according to fuel sulfur and oxygen content for 2-stroke and 4-stroke petrol engines, while ambient temperature correction factors have been applied to 4-stroke petrol engine exhaust emission factors (USEPA, 2009).

An engine's rated power is the maximum power it is designed to produce at the rated speed. Since engines normally operate at a variety of speeds and loads, operation at rated power for extended periods is rare. To take into account the effect of operation over a wide range of conditions (e.g. idle, partial load and transient operation), a load factor (LF) has been used to determine the average proportion of rated power used (USEPA, 2009).

Transient adjustment factors (TAF) have been applied to 2-stroke and 4-stroke petrol engine emission factors to account for in-use (i.e. transient) operation and better represent the operational behaviour of the equipment (USEPA, 2009).

Deterioration factors (DF) have been applied to 2-stroke and 4-stroke petrol engine emission factors to account for deterioration of emission performance over time. Deterioration refers to the degradation of an engine's exhaust emissions performance over its lifetime due to either normal use and/or misuse (i.e. tampering or neglect). Engine deterioration increases exhaust emissions, which usually leads to a loss of combustion efficiency and can in some cases increase evaporative emissions. The amount of deterioration depends on an engine's design, production quality and technology type (i.e. 2-stroke and 4-stroke petrol spark ignition). Other factors may also affect deterioration, such as the equipment application, usage patterns and how it is stored and maintained (USEPA, 2009).

Evaporative emission factors for 2-stroke and 4-stroke petrol engines have been adjusted according to ambient temperature, Reid vapour pressure (RVP) and ethanol content of petrol (USEPA, 2009).

Equipment population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and seasonal basis. Equipment population and activity rates have been derived from a domestic survey (TR, 2009) and sales data (AIA, 2005). Emissions have been determined using Equation 9 within the *NONROAD2008a Model* (USEPA, 2009):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times TAF_{j,k,l} \times DF_{j,k,l} \times EF_{i,j,k,l,m} / 1000} \qquad \textbf{Equation 9}$$

where:			
$E_{i,j,k,l,m}$	=	Emissions of substance i from lawn mowing and garden equipment type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of lawn mowing and garden equipment type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of lawn mowing and garden equipment type j, engine type k and engine power range l	(h/year)
$HP_{j,k,l}$	=	Maximum rated power of lawn mowing and garden equipment type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for lawn mowing and garden equipment type j, engine type k and engine power range l	(hp/hp)
$TAF_{j,k,l}$	=	Fractional transient adjustment factor for lawn mowing and garden equipment type j, engine type k and engine power range l	$(g.(hp.h)^{-1}/ g.(hp.h)^{-1})$
$DF_{j,k,l}$	=	Fractional deterioration factor for lawn mowing and garden equipment type j, engine type k and engine power range l	$(g.(hp.h)^{-1}/ g.(hp.h)^{-1})$
$EF_{i,j,k,l,m}$	=	Emission factor for substance i from lawn mowing and garden equipment type j, engine type k, engine power range l and source type m	(g/hp.h)

where:			
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)
j	=	Lawn mowing and garden equipment type (either "Chainsaw", "Chipper/Mulcher/Shredder", "Leafblower/Vacuum", "Pressure washer", "Push lawnmower", "Ride-on lawnmower" or "Trimmer/Edger/Brush cutter")	(-)
k	=	Engine type (either "2-stroke petrol" or "4-stroke-petrol")	(-)
l	=	Engine power range	(hp)
m	=	Source type (either "exhaust", "crankcase", "refuelling", "diurnal", "hot soak", "running loss" or "permeation")	(-)
1000	=	Conversion factor	(g/kg)

3.6.3 Activity Data

Table 3-88 summarises the activity data used for lawn mowing and garden equipment.

Table 3-88: Lawn mowing and garden equipment (domestic) activity data

Activity data	Activity data source
Lawn mower and garden equipment type/number and monthly mowing frequency/duration	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)
Gridded 1 km x 1 km dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Lawn mower and garden equipment fleet composition	- *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)

A domestic survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; frequency and duration of equipment use by hour, day and season; lawn area; and proportion of private and commercial usage (TR, 2009).

The key considerations in designing and conducting a domestic survey include:

Survey method - The domestic survey has been conducted using the computer assisted telephone interview (CATI) method for recruiting households to complete either an on-line or mail-out questionnaire.

Sample size - To provide a reasonable level of precision for estimating lawn mowing and garden equipment activity rates across all households in the GMR, the survey sample was sized accordingly. While a total of 832 households were recruited, 31 households were outside the GMR so they were excluded from the survey. Activity rates for lawn mowing and garden equipment have been based on survey responses from 801 households in the GMR.

Confidence interval and confidence level - The confidence interval quantifies the uncertainty or range in possible values. For example, for a confidence interval of 3.5% and where 47% percent of the sample picks a particular answer one can be "sure" that if the question has been asked of the entire relevant population, between 43.5% (47-3.5) and 50.5% (47+3.5) would have picked that answer.

The confidence level quantifies the level of certainty to which an estimate can be trusted. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means one can be 95% certain. Most researchers use the 95% confidence level.

When combining the confidence level and confidence interval together, one can be 95% sure that the true answer for the entire relevant population is between 43.5% and 50.5% for the example described above.

Table 3-89 presents the theoretical confidence intervals for samples of varied sizes for characteristics with a population incidence of 50% or 50%, 75% or 25% and 90% or 10%.

Table 3-89: Confidence intervals at 95% confidence level by sample size for lawn mowing and garden equipment (domestic) survey

Sample size	Confidence interval at 95% confidence level		
	Endorsement rate of 50%/50%	Endorsement rate of 75%/25%	Endorsement rate of 90%/10%
100	9.8	8.5	5.9
150	8.0	6.9	4.8
200	6.9	6.0	4.2
300	5.7	4.9	3.4
400	4.9	4.2	2.9
500	4.4	3.8	2.6
600	4.0	3.5	2.4
800	3.5	3.0	2.1
1,000	3.1	2.7	1.9

The domestic survey of lawn mowing and garden equipment randomly sampled 801 households from a population of 5,284,560 in 1,901,680 households, so survey items with a true population incidence of 50% will produce estimates within ±3.5% of the true population value in 95% of the samples.

Random sampling and stratification - Households were selected at random across the GMR to limit bias. In practice, actual samples are not truly random since respondents always have the right to decline an interview and others cannot be reached for a variety of reasons. To reduce the standard error of estimated population values, samples were stratified on a geographic basis into the following subpopulations by location:

Sydney region, sub-grouped into

- *North East*
- *North West*

- *South East*
- *South West*

Newcastle region

Wollongong region

Development of survey questionnaires – Three survey questionnaires were developed including: initial recruitment using the computer assisted telephone interview (CATI) method to capture household details using pre-coded questions within OzQuest on-line software; self complete main survey using pre-coded questions within OzQuest on-line software; and self complete main survey using a traditional hard copy mail-out with a reply paid envelope. The questionnaires request information about: equipment type, number and age; engine type and fuel used; frequency and duration of equipment use by hour, day and season; lawn area; and proportion of private and commercial usage. The domestic survey questionnaire form is included at Appendix B: Domestic Survey Form (TR, 2009).

Recruitment and data collection - A random sample of phone numbers was selected from the 64 local government areas (LGA) located in the GMR, stratified into Sydney, Newcastle and Wollongong regions.

As part of the computer assisted telephone interview (CATI), households were phoned up to five times to make contact and the interviewer asked to speak to an "adult household member who is familiar with any devices the household uses that might burn solid fuel (like wood or coal heaters), liquid fuel (like kerosene heaters or petrol lawn mowers) or gas fuel (like natural gas cooktops or heaters)". If required, arrangements were made to call back at a more convenient time when an appropriate adult household member would be available.

When an adult household member was available for interview, respondents were asked what LGA they lived in. If not in the GMR they were thanked and the interview was terminated. If in the GMR, they were then asked about the number of residents in the household, the dwelling type and which of the fuel burning devices were used by the household. All were then asked for their postcode and age group. Respondents in households that had none of the fuel burning devices were thanked and the interview terminated. All other respondents were then asked if they would be willing to complete a further questionnaire either on-line or by mail. If willing, contact details were recorded, and the interview concluded. Those who initially declined were read material emphasizing the importance of obtaining data from all households, whether they make little use of fuel burning devices or not and asked again if they would be willing to take part.

Consenting respondents were then either e-mailed a link to a self complete on-line main survey or mailed a self complete hard copy main survey. The mailed questionnaires included an identifying serial number on the front page with a letter from DECCW encouraging completion of the survey.

Main survey completions on-line and mail-out were closely monitored and households were phoned on two occasions in order to remind them to complete. Some respondents indicated they preferred to go through the questions on the phone. Data for these were entered into the on-line version of the questionnaire.

Data capture – Data from the three survey questionnaires (i.e. CATI, on-line main survey and hard copy main survey) have all been entered into a database which captures pre-coded questions using OzQuest on-line software. All data was then checked, cleaned and saved in a Microsoft® Excel™ 2003 workbook.

Survey timeframe - The survey took approximately 15 weeks to complete, from the time that questionnaire development commenced to the date data analysis and report were completed. The key tasks and milestones for the domestic survey are presented in Table 3-90.

Table 3-90: Lawn mowing and garden equipment (domestic) survey milestones

Task	Milestones
Questionnaire development commenced	11 August 2009
CATI recruitment commenced	18 September 2009
CATI recruitment completed	21 October 2009
Main survey completed	12 November 2009
Data analysis and report completed	26 November 2009

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the lawn mowing and garden equipment survey results (TR, 2009). Table 3-91 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-91: Population and dwelling by LGA used to scale-up lawn mowing and garden equipment (domestic) survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[33]	Total dwelling
Ashfield	47,887	7,660	2,728	7,882	142	18,412
Auburn	69,555	7,358	2,326	11,421	284	21,390
Bankstown	174,326	7,781	8,028	41,407	287	57,503
Bathurst Regional	157	-	-	41	1	41
Baulkham Hills	170,925	2,345	5,004	46,441	137	53,928
Blacktown	286,162	3,915	9,712	77,217	700	91,544
Blue Mountains	78,427	777	1,030	27,952	63	29,822
Botany Bay	33,316	4,244	1,974	5,777	100	12,095
Burwood	30,277	3,332	1,108	5,770	65	10,275
Camden	55,287	258	499	16,910	161	17,828

33 Caravan, cabin, houseboat, improvised home, tent, sleepers out, house or flat attached to a shop or office (TDC, 2009).

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[33]	Total dwelling
Campbelltown	150,373	1,333	8,057	39,856	97	49,343
Canada Bay	58,880	6,445	2,342	13,157	137	22,080
Canterbury	138,343	16,795	4,851	25,673	328	47,647
Cessnock	48,845	562	339	16,615	150	17,667
Dungog	7,659	23	60	2,581	38	2,702
Fairfield	189,024	7,302	6,172	43,571	198	57,243
Gosford	162,826	5,481	8,288	49,407	676	63,852
Goulburn Mulwaree	341	-	1	79	-	80
Great Lakes	4,062	10	29	1,301	44	1,383
Hawkesbury	62,416	899	1,674	18,441	241	21,254
Holroyd	95,192	6,969	3,562	22,399	144	33,074
Hornsby	160,612	9,018	4,454	40,736	265	54,472
Hunters Hill	9,295	898	318	1,892	3	3,111
Hurstville	81,935	7,352	3,548	18,534	111	29,545
Kiama	14,586	580	338	4,433	75	5,426
Kogarah	57,349	6,558	1,565	11,945	81	20,148
Ku-ring-gai	106,943	3,805	1,253	30,103	73	35,235
Lake Macquarie	195,295	3,160	4,849	63,598	926	72,532
Lane Cove	28,511	4,473	652	5,687	92	10,904
Leichhardt	39,692	4,537	6,175	5,998	278	16,988
Lithgow	19,595	227	341	6,350	59	6,977
Liverpool	178,554	6,938	5,352	42,517	317	55,125
Maitland	66,554	1,330	1,049	21,169	117	23,666
Manly	33,804	5,898	1,520	5,676	97	13,192
Marrickville	86,873	13,062	10,292	11,838	553	35,744
Mid-western Regional	3,412	25	14	1,149	17	1,205
Mosman	30,915	6,692	1,506	4,604	104	12,905
Muswellbrook	15,221	364	121	4,582	62	5,128
N/A	25,875	4,778	1,262	4,329	119	10,488
Newcastle	150,930	8,242	6,306	44,792	500	59,840
North Sydney	53,850	17,299	4,228	3,854	252	25,633
Oberon	1,803	4	5	438	5	452
Parramatta	152,570	16,729	6,975	29,743	348	53,796
Penrith	177,459	3,483	4,905	51,040	349	59,776
Pittwater	54,586	2,542	1,577	15,389	183	19,690
Port Stephens	59,017	756	1,587	18,809	482	21,634
Randwick	130,955	25,728	8,002	16,752	370	50,853
Rockdale	89,735	12,199	4,159	16,242	256	32,856
Ryde	105,073	11,196	5,519	22,448	111	39,275
Shellharbour	65,104	1,282	2,369	18,768	328	22,747
Shoalhaven	81	-	-	30	-	30

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[33]	Total dwelling
Singleton	22,222	405	275	6,357	132	7,169
Strathfield	38,732	5,612	806	6,543	45	13,006
Sutherland	212,924	16,252	8,522	52,450	274	77,498
Sydney	167,382	52,686	17,811	4,651	1,028	76,176
Unincorporated	42,682	9,672	2,028	5,866	146	17,713
Upper Hunter	350	-	-	66	-	66
Upper Lachlan	502	-	-	92	-	92
Warringah	141,123	16,643	3,029	32,008	175	51,854
Waverley	57,147	14,769	4,430	5,038	245	24,481
Willoughby	69,528	11,760	2,038	12,473	82	26,353
Wingecarribee	45,480	537	1,113	15,131	144	16,924
Wollondilly	42,871	168	292	13,634	133	14,227
Wollongong	193,292	11,210	7,296	52,219	992	71,717
Woollahra	44,773	12,138	3,128	4,232	71	19,569
Wyong	145,088	2,801	4,575	47,918	1,006	56,300
Grand Total	5,284,560	417,295	213,366	1,256,021	14,998	1,901,680

Lawn mowing and garden equipment sales data for the 2003 and 2004 calendar years (AIA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and non-handheld/handheld equipment with a given maximum power rating, while the lawn mowing and garden equipment survey results (TR, 2009) have been used to estimate the total number of in-service equipment. Table 3-92 presents a summary of lawn mowing and garden equipment sales data for NSW.

Table 3-92: Lawn mowing and garden equipment sales data for NSW

Maximum rated power (hp)	2003 calendar year non-handheld		2004 calendar year non-handheld		2003 and 2004 calendar year non-handheld			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
1 to 3	18,960	10,790	43,070	12,380	62,030	23,170	46.02	7.81
3 to 6	31,550	75,140	41,220	111,530	72,770	186,670	53.98	62.91
6 to 16	-	36,630	-	35,750	-	72,380	-	24.39
16 to 25	-	6,860	-	7,650	-	14,510	-	4.89
Grand Total	50,510	129,420	84,290	167,310	134,800	296,730	100.00	100.00

Maximum rated power (hp)	2003 calendar year handheld		2004 calendar year handheld		2003 and 2004 calendar year handheld			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
1 to 3	126,730	7,150	208,430	10,130	335,160	17,280	95.48	100.00
3 to 6	10,410	-	5,450	-	15,860	-	4.52	-
Grand Total	137,140	7,150	213,880	10,130	351,020	17,280	100.00	100.00

The total population of in-service lawn mowing and garden equipment has been estimated by combining the domestic survey results (TR, 2009), gridded 1 km by 1 km dwelling estimates (TDC, 2009) and lawn mowing and garden equipment sales data (AIA, 2005). In-service lawn mowing and garden equipment population by equipment description and maximum rated power range data for the GMR is presented in Table 3-93 and shown in Figure 3-39.

Table 3-93: Lawn mowing and garden equipment (domestic) population in the GMR

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
2-Str Chain Saws < 6 HP (res)	230,138	10,890	-	-	-	241,028
2-Str Lawn mowers (com)	55,549	65,167	-	-	-	120,715
2-Str Lawn mowers (res)	151,801	178,084	-	-	-	329,885
2-Str Leafblowers/Vacuums (com)	46,534	2,202	-	-	-	48,736
2-Str Leafblowers/Vacuums (res)	144,139	6,821	-	-	-	150,960
2-Str Other Lawn & Garden Eqp. (com)	2,936	139	-	-	-	3,075
2-Str Other Lawn & Garden Eqp. (res)	47,778	2,261	-	-	-	50,039
2-Str Rear Engine Riding Mowers (com)	-	10,003	-	-	-	10,003
2-Str Rear Engine Riding Mowers (res)	-	19,353	-	-	-	19,353
2-Str Shredders < 6 HP (res)	1,669	1,958	-	-	-	3,628
2-Str Trimmers/Edgers/Brush Cutter (com)	263,894	12,488	-	-	-	276,382
2-Str Trimmers/Edgers/Brush Cutter (res)	535,541	25,342	-	-	-	560,883
4-Str Chain Saws < 6 HP (res)	47,260	-	-	-	-	47,260
4-Str Lawn mowers (com)	22,902	184,507	71,541	-	-	278,950
4-Str Lawn mowers (res)	64,262	517,725	200,744	-	-	782,731
4-Str Leafblowers/Vacuums (com)	28,569	-	-	-	-	28,569
4-Str Leafblowers/Vacuums (res)	76,645	-	-	-	-	76,645
4-Str Other Lawn & Garden Eqp. (com)	1,230	-	-	-	-	1,230
4-Str Other Lawn & Garden Eqp. (res)	20,016	-	-	-	-	20,016
4-Str Pressure Washers	2,189	17,636	-	-	-	19,825
4-Str Rear Engine Riding Mowers (com)	-	34,128	13,233	1,326	1,326	50,014
4-Str Rear Engine Riding Mowers (res)	-	66,030	25,603	2,566	2,566	96,766
4-Str Shredders < 6 HP (res)	2,003	16,135	-	-	-	18,138
4-Str Trimmers/Edgers/Brush Cutter (com)	80,240	-	-	-	-	80,240
4-Str Trimmers/Edgers/Brush Cutter (res)	250,716	-	-	-	-	250,716

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
Grand Total	2,076,009	1,170,870	311,122	3,893	3,893	3,565,786

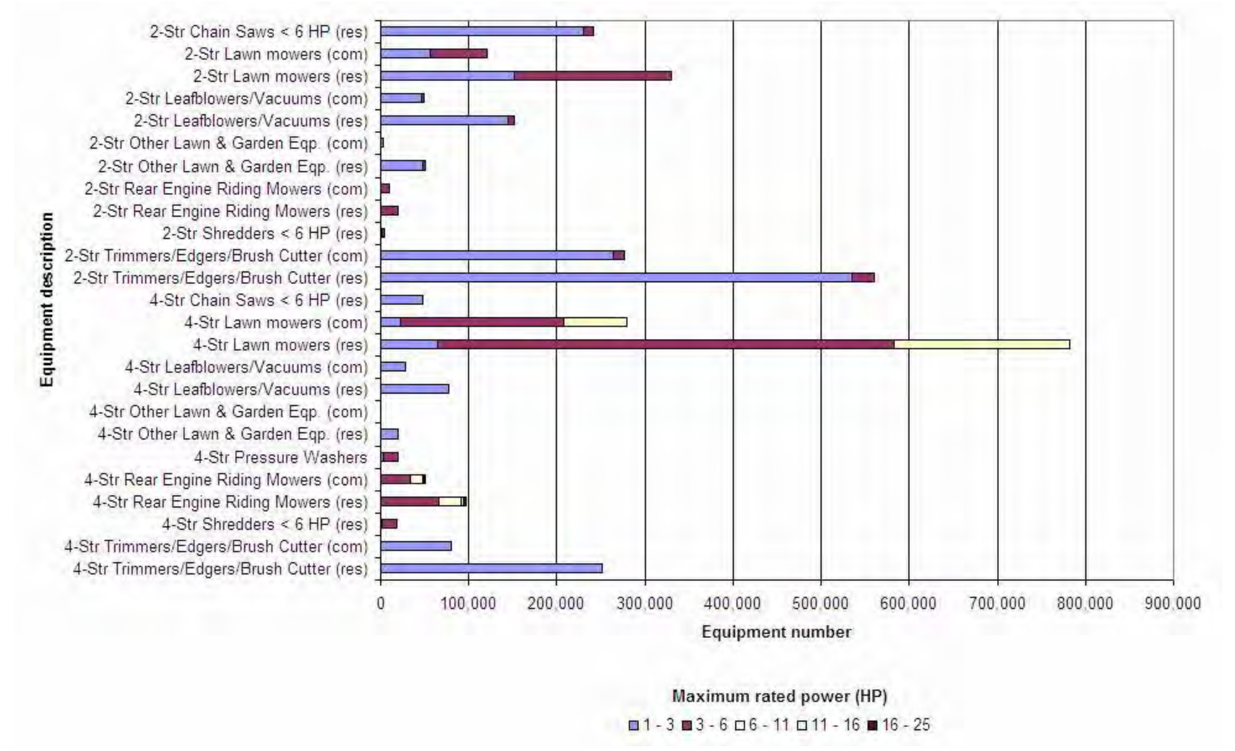

Figure 3-39: Lawn mowing and garden equipment (domestic) population in the GMR

The annual operating time of in-service lawn mowing and garden equipment has been estimated from the domestic survey results (TR, 2009). In-service lawn mowing and garden equipment annual operating time by equipment description for the GMR is presented in Table 3-94 and shown in Figure 3-40.

Table 3-94: Lawn mowing and garden equipment (domestic) annual operating time in the GMR

Equipment description	Annual operating time (h/year)
2-Stroke Chain Saws < 6 HP (res)	4.0
2-Stroke Lawn mowers (com)	16.4
2-Stroke Lawn mowers (res)	16.4
2-Stroke Leafblowers/Vacuums (com)	8.7
2-Stroke Leafblowers/Vacuums (res)	8.7
2-Stroke Other Lawn & Garden Equipment (com)	3.0
2-Stroke Other Lawn & Garden Equipment (res)	3.0
2-Stroke Rear Engine Riding Mowers (com)	29.6
2-Stroke Rear Engine Riding Mowers (res)	29.6
2-Stroke Shredders < 6 HP (res)	2.5

Equipment description	Annual operating time (h/year)
2-Stroke Trimmers/Edgers/Brush Cutters (com)	6.4
2-Stroke Trimmers/Edgers/Brush Cutters (res)	6.4
4-Stroke Chain Saws < 6 HP (res)	4.0
4-Stroke Lawn mowers (com)	16.4
4-Stroke Lawn mowers (res)	16.4
4-Stroke Leafblowers/Vacuums (com)	9.1
4-Stroke Leafblowers/Vacuums (res)	9.1
4-Stroke Other Lawn & Garden Equipment (com)	3.0
4-Stroke Other Lawn & Garden Equipment (res)	3.0
4-Stroke Pressure Washers	3.9
4-Stroke Rear Engine Riding Mowers (com)	29.6
4-Stroke Rear Engine Riding Mowers (res)	29.6
4-Stroke Shredders < 6 HP (res)	2.5
4-Stroke Trimmers/Edgers/Brush Cutters (com)	6.9
4-Stroke Trimmers/Edgers/Brush Cutters (res)	6.9

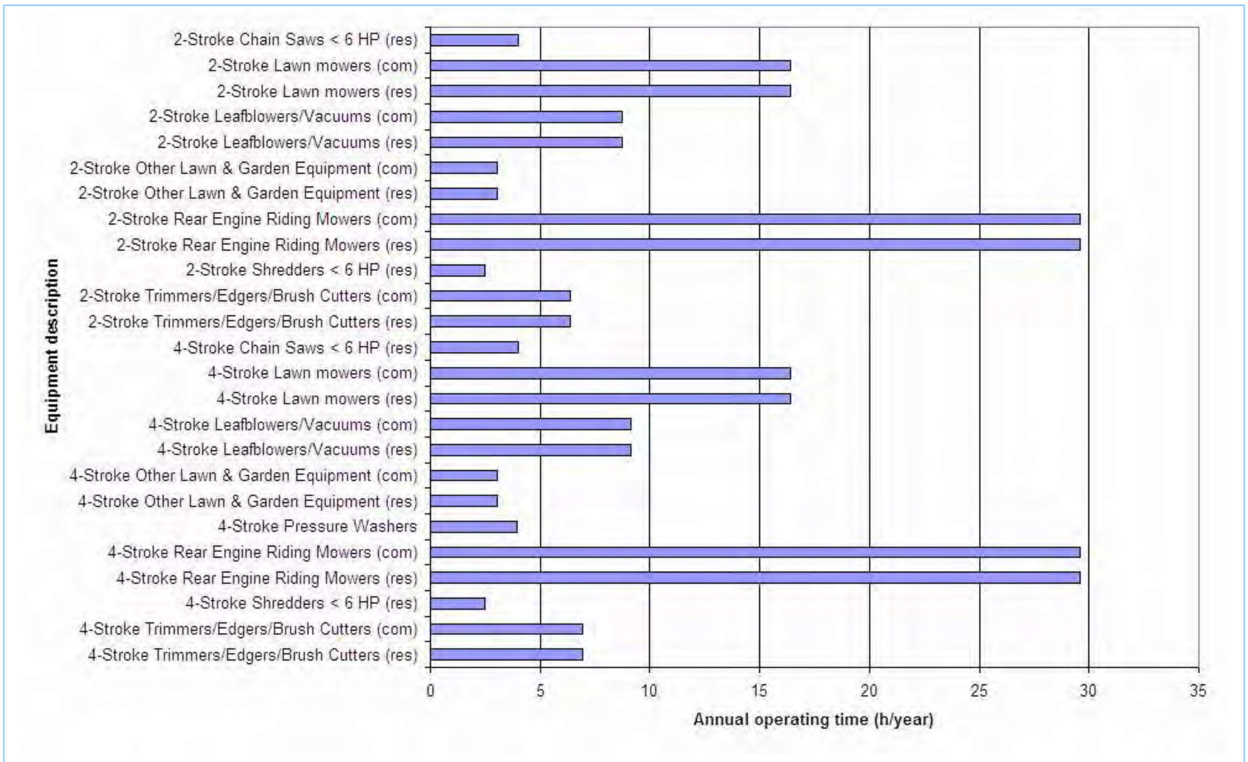

Figure 3-40: Lawn mowing and garden equipment (domestic) annual operating time in the GMR

Exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population (TR, 2009), annual operating time (TR, 2009), fuel properties (Attorney-General's Department, 2008; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009).

Figure 3-41 shows the NonRoad Model splash screen for the lawn mowing and garden equipment (domestic) emission estimation simulation.

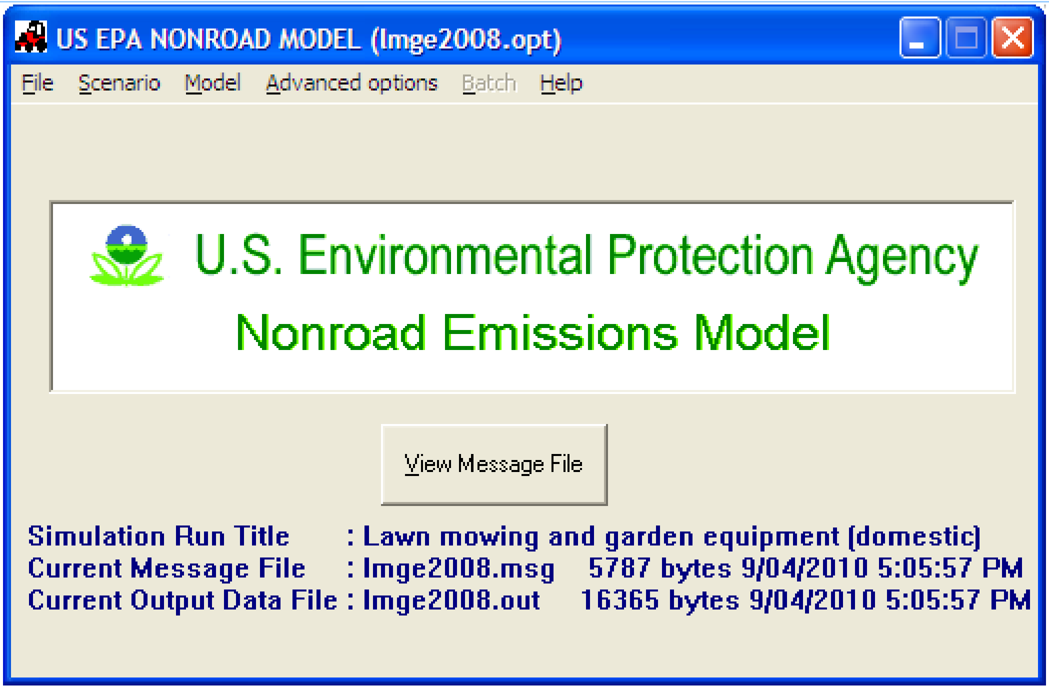

Figure 3-41: Lawn mowing and garden equipment (domestic) NonRoad Model splash screen

Figure 3-42 shows the NonRoad Model options screen for the lawn mowing and garden equipment (domestic) emission estimation simulation.

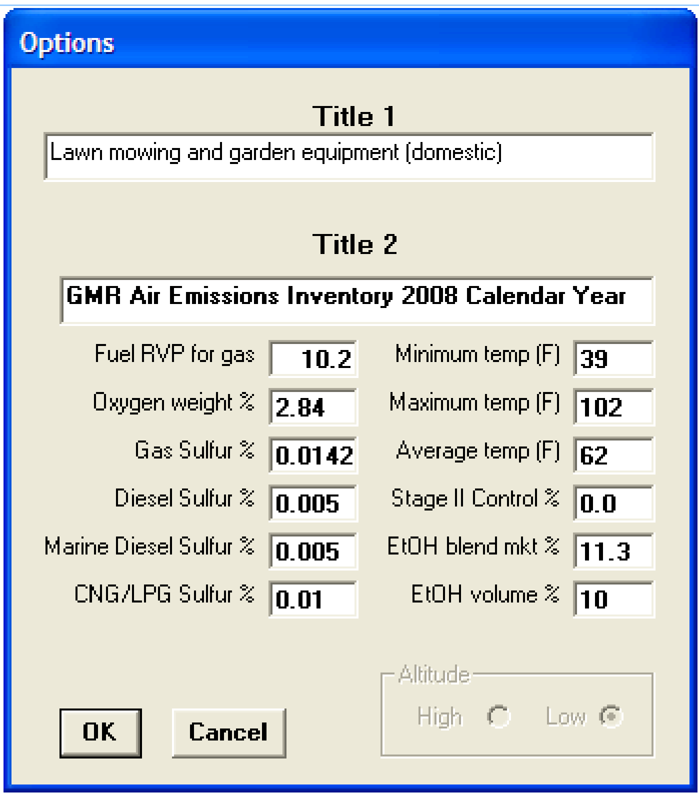

Figure 3-42: Lawn mowing and garden equipment (domestic) NonRoad Model options

In 2008, 677,384 kL and 6,009,999 kL of ethanol blended and total automotive gasoline, respectively was sold in NSW, so ethanol blended automotive gasoline has 11.3% share of the NSW market for all automotive gasoline (DRET, 2009) and contains 10% ethanol by volume (Attorney-General's Department, 2008).

The NonRoad Model has been run with the optional daily minimum, maximum and average ambient temperature and petrol RVP variation file. Table 3-95 presents the daily minimum, maximum and average ambient temperature (Hurley, 2005) and petrol RVP by month (PCO, 2011) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-95: Lawn mowing and garden equipment (domestic) NonRoad Model ambient temperature and petrol RVP by month

Month	RVP (psi)	T_{min} (°F)	T_{max} (°F)	T_{avg} (°F)
January	9.0	57.1	101.7	76.7
February	9.0	59.9	94.8	74.7
March	9.9	54.0	87.8	67.6
April	10.9	51.1	74.0	59.9
May	10.9	47.9	67.0	54.5
June	10.9	43.0	64.3	50.5
July	10.9	39.9	62.1	48.0
August	10.9	39.4	65.0	49.3
September	10.9	41.7	71.9	54.4
October	10.9	45.3	80.3	60.2
November	9.9	48.5	92.2	68.3
December	9.0	54.7	101.6	76.4

Table 3-96 presents the lawn mowing and garden equipment power rating (AIA, 2005), useful life (USEPA, 2009) and population (TR, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-96: Lawn mowing and garden equipment (domestic) NonRoad Model population

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2260004010	2-Str Lawn mowers (res)	1	3	2.55	47.9	151800.8
2260004010	2-Str Lawn mowers (res)	3	6	4.1	47.9	178083.9
2260004011	2-Str Lawn mowers (com)	1	3	2.55	268	55548.7
2260004011	2-Str Lawn mowers (com)	3	6	4.1	268	65166.6
2260004040	2-Str Rear Engine Riding Mowers (res)	3	6	5.105	79.3	19353.2
2260004041	2-Str Rear Engine Riding Mowers (com)	3	6	5.105	200	10002.9
2260004025	2-Str Trimmers/Edgers/Brush Cutter (res)	1	3	1.4	35.3	535540.8
2260004025	2-Str Trimmers/Edgers/Brush Cutter (res)	3	6	3.3	35.3	25342.2
2260004026	2-Str Trimmers/Edgers/Brush Cutter (com)	1	3	1.4	286.8	263894.0
2260004026	2-Str Trimmers/Edgers/Brush Cutter (com)	3	6	3.3	286.8	12487.6
2260004075	2-Str Other Lawn & Garden Eqp. (res)	1	3	2.34	200	47778.0
2260004075	2-Str Other Lawn & Garden Eqp. (res)	3	6	4.867	200	2260.9
2260004076	2-Str Other Lawn & Garden Eqp. (com)	1	3	2.34	200	2935.7
2260004076	2-Str Other Lawn & Garden Eqp. (com)	3	6	4.867	200	138.9
2260004050	2-Str Shredders < 6 HP (res)	1	3	2.986	200	1669.3

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2260004050	2-Str Shredders < 6 HP (res)	3	6	4.835	200	1958.3
2260004030	2-Str Leafblowers/Vacuums (res)	1	3	1.41	40.4	144139.0
2260004030	2-Str Leafblowers/Vacuums (res)	3	6	3.42	40.4	6820.8
2260004031	2-Str Leafblowers/Vacuums (com)	1	3	1.41	609.7	46533.9
2260004031	2-Str Leafblowers/Vacuums (com)	3	6	3.42	609.7	2202.0
2260004020	2-Str Chain Saws < 6 HP (res)	1	3	2.11	39.2	230138.2
2260004020	2-Str Chain Saws < 6 HP (res)	3	6	3.916	39.2	10890.3
2265004010	4-Str Lawn mowers (res)	1	3	2.55	47.9	64261.5
2265004010	4-Str Lawn mowers (res)	3	6	4.1	47.9	517725.4
2265004010	4-Str Lawn mowers (res)	6	11	6.24	400	200744.4
2265004011	4-Str Lawn mowers (com)	1	3	2.55	268	22901.6
2265004011	4-Str Lawn mowers (com)	3	6	4.1	268	184507.3
2265004011	4-Str Lawn mowers (com)	6	11	6.24	400	71541.4
2265004040	4-Str Rear Engine Riding Mowers (res)	3	6	5.105	79.3	66030.4
2265004040	4-Str Rear Engine Riding Mowers (res)	6	11	9.153	79.3	25602.8
2265004040	4-Str Rear Engine Riding Mowers (res)	11	16	12.61	79.3	2566.3
2265004040	4-Str Rear Engine Riding Mowers (res)	16	25	18.26	750	2566.3
2265004041	4-Str Rear Engine Riding Mowers (com)	3	6	5.105	200	34128.4
2265004041	4-Str Rear Engine Riding Mowers (com)	6	11	9.153	627	13233.1
2265004041	4-Str Rear Engine Riding Mowers (com)	11	16	12.61	627	1326.4
2265004041	4-Str Rear Engine Riding Mowers (com)	16	25	18.26	750	1326.4
2265004025	4-Str Trimmers/Edgers/Brush Cutter (res)	1	3	1.4	35.3	250716.1
2265004026	4-Str Trimmers/Edgers/Brush Cutter (com)	1	3	1.4	286.8	80239.8
2265004075	4-Str Other Lawn & Garden Eqp. (res)	1	3	2.34	200	20015.6
2265004076	4-Str Other Lawn & Garden Eqp. (com)	1	3	2.34	200	1229.8
2265004050	4-Str Shredders < 6 HP (res)	1	3	2.986	200	2002.7
2265004050	4-Str Shredders < 6 HP (res)	3	6	4.835	200	16135.1
2265006030	4-Str Pressure Washers	1	3	3	150	2189.0
2265006030	4-Str Pressure Washers	3	6	4.827	200	17635.7
2265004030	4-Str Leafblowers/Vacuums (res)	1	3	1.41	40.4	76645.0
2265004031	4-Str Leafblowers/Vacuums (com)	1	3	1.41	609.7	28569.3
2265004020	4-Str Chain Saws < 6 HP (res)	1	3	2.11	39.2	47260.5

Table 3-97 presents the lawn mowing and garden equipment load factor (USEPA, 2009) and annual operating time (TR, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-97: Lawn mowing and garden equipment (domestic) NonRoad Model load factor and annual operating time

SCC	Equipment description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2260004010	2-Stroke Lawn mowers (res)	0	9999	0.33	16.4
2260004011	2-Stroke Lawn mowers (com)	0	9999	0.33	16.4
2260004040	2-Stroke Rear Engine Riding Mowers (res)	0	9999	0.38	29.6
2260004041	2-Stroke Rear Engine Riding Mowers (com)	0	9999	0.38	29.6

SCC	Equipment description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2260004025	2-Stroke Trimmers/Edgers/Brush Cutters (res)	0	9999	0.91	6.4
2260004026	2-Stroke Trimmers/Edgers/Brush Cutters (com)	0	9999	0.91	6.4
2260004075	2-Stroke Other Lawn & Garden Equipment (res)	0	9999	0.58	3.0
2260004076	2-Stroke Other Lawn & Garden Equipment (com)	0	9999	0.58	3.0
2260004050	2-Stroke Shredders < 6 HP (res)	0	9999	0.80	2.5
2260004030	2-Stroke Leafblowers/Vacuums (res)	0	9999	0.94	8.7
2260004031	2-Stroke Leafblowers/Vacuums (com)	0	9999	0.94	8.7
2260004020	2-Stroke Chain Saws < 6 HP (res)	0	9999	0.70	4.0
2265004010	4-Stroke Lawn mowers (res)	0	9999	0.33	16.4
2265004011	4-Stroke Lawn mowers (com)	0	9999	0.33	16.4
2265004040	4-Stroke Rear Engine Riding Mowers (res)	0	9999	0.38	29.6
2265004041	4-Stroke Rear Engine Riding Mowers (com)	0	9999	0.38	29.6
2265004025	4-Stroke Trimmers/Edgers/Brush Cutters (res)	0	9999	0.91	6.9
2265004026	4-Stroke Trimmers/Edgers/Brush Cutters (com)	0	9999	0.91	6.9
2265004075	4-Stroke Other Lawn & Garden Equipment (res)	0	9999	0.58	3.0
2265004076	4-Stroke Other Lawn & Garden Equipment (com)	0	9999	0.58	3.0
2265004050	4-Stroke Shredders < 6 HP (res)	0	9999	0.80	2.5
2265006030	4-Stroke Pressure Washers	0	9999	0.85	3.9
2265004030	4-Stroke Leafblowers/Vacuums (res)	0	9999	0.94	9.1
2265004031	4-Stroke Leafblowers/Vacuums (com)	0	9999	0.94	9.1
2265004020	4-Stroke Chain Saws < 6 HP (res)	0	9999	0.70	4.0

The NonRoad Model has been run with the optional weekday/weekend and monthly temporal variation file. Section 3.6.6 provides further details about the temporal variation in exhaust and evaporative emissions from lawn mowing and garden equipment.

Table 3-98 presents the lawn mowing and garden equipment fuel consumption estimates from the *NONROAD2008a Model* (USEPA, 2009).

Table 3-98: Lawn mowing and garden equipment (domestic) NonRoad Model fuel consumption in the GMR

Classification	Equipment description	2008 fuel consumption (kL/year)		
		2-stroke petrol	4-stroke petrol	Grand Total
Commercial Equipment	Pressure Washers	-	233	233
Commercial Equipment Total		-	233	233
Lawn and Garden Equipment (com)	Lawn mowers	1,459	4,821	6,280
	Leafblowers/Vacuums	484	288	772
	Other Lawn & Garden Eqp.	11	4	15
	Rear Engine Riding Mowers	325	2,690	3,014
	Trimmers/Edgers/Brush Cutter	1,938	541	2,479
Lawn and Garden Equipment (com) Total		4,217	8,344	12,560
Lawn and Garden Equipment (res)	Chain Saws < 6 HP	1,206	214	1,421

Classification	Equipment description	2008 fuel consumption (kL/year)		
		2-stroke petrol	4-stroke petrol	Grand Total
	Lawn mowers	3,988	13,875	17,864
	Leafblowers/Vacuums	1,500	772	2,272
	Other Lawn & Garden Eqp.	174	63	236
	Rear Engine Riding Mowers	628	5,204	5,832
	Shredders < 6 HP	19	129	148
	Trimmers/Edgers/Brush Cutter	3,933	1,691	5,624
Lawn and Garden Equipment (res) Total		11,448	21,948	33,396
Grand Total		15,665	30,525	46,190

3.6.4 Emission and Speciation Factors

Table 3-99 summarises the emission and speciation factors used for lawn mowing and garden equipment.

Table 3-99: Lawn mowing and garden equipment (domestic) emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10} and SO_2	2-stroke and 4-stroke exhaust	- *NONROAD2008a Model* (USEPA, 2009)
Criteria pollutants: VOC	2-stroke and 4-stroke exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009)
Criteria pollutants: TSP	2-stroke and 4-stroke exhaust	- *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
Speciated NO_x	2-stroke and 4-stroke exhaust	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	2-stroke exhaust	- *Table D-1 (Default 2-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 815 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	4-stroke exhaust	- *Table D-1 (Default 4-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 816 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	evaporative	- *Petrol Vapour Speciation Profile - Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Organic air toxics	2-stroke exhaust	- *Table D-1 (Default 2-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume*

Substance	Emission source	Emission and speciation factor source
		I – Methodology (Pechan, 2005) - *ORGPROF 815 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	4-stroke exhaust	- *Table D-1 (Default 4-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 816 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	evaporative	- *Petrol Vapour Speciation Profile - Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Metal air toxics	2-stroke exhaust	- *Table D-3 (2-Stroke Metal/Fuel Fraction) Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	4-stroke exhaust	- *Table D-3 (4-Stroke Metal/Fuel Fraction) Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
Polycyclic aromatic hydrocarbons: PAH	2-stroke exhaust	- *Table D-2 (2-Stroke) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	4-stroke exhaust	- *Table D-2 (4-Stroke) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	2-stroke exhaust	- *Table D-1 (2-Stroke Dioxin/Furan/Fuel Fraction) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	4-stroke exhaust	- *Table D-1 (4-Stroke Dioxin/Furan/Fuel Fraction) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
Ammonia	2-stroke and 4-stroke exhaust	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
Greenhouse gases: CH_4 and CO_2	2-stroke and 4-stroke exhaust	- *NONROAD2008a Model* (USEPA, 2009)
Greenhouse gases: N_2O	2-stroke and 4-stroke exhaust	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)

Table 3-100 presents average activity weighted 2-stroke and 4-stroke exhaust and evaporative emission factors for lawn mowing and garden equipment.

Table 3-100: Lawn mowing and garden equipment (domestic) emission factors

Emission source	Emission factors (kg/kL)											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
2-stroke petrol exhaust	1.98	0.058	0.029	0.109	11.58	10.65	339.17	2.952	786.97	1,293.48	0.0167	3.29×10^{-12}
4-stroke petrol exhaust	3.92	0.058	0.029	0.182	0.68	0.63	64.50	6.914	742.55	2,111.08	0.0708	3.29×10^{-12}
2-stroke petrol evaporative	-	-	-	-	-	-	71.47	-	-	-	-	-
4-stroke petrol evaporative	-	-	-	-	-	-	57.51	0.445	-	-	-	-

3.6.5 Spatial Distribution of Emissions

Table 3-101 summarises the data used for spatially allocating emissions from lawn mowing and garden equipment.

Table 3-101: Lawn mowing and garden equipment (domestic) spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from lawn mowing and garden equipment (domestic)	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from lawn mowing and garden equipment have been spatially distributed according to petrol consumption, which is proportional to free standing dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of petrol consumption by LGA and region is presented in Table 3-102 and shown in Figure 3-43.

Table 3-102: Lawn mowing and garden equipment (domestic) spatial distribution of petrol consumption by LGA and region

LGA	2008 proportion of annual petrol consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.72	-	0.72
Auburn	-	-	0.94	-	0.94
Bankstown	-	-	3.37	-	3.37
Bathurst Regional	-	2.78×10^{-3}	-	-	2.78×10^{-3}
Baulkham Hills	-	2.50×10^{-3}	3.50	-	3.50
Blacktown	-	-	5.92	-	5.92
Blue Mountains	-	0.70	1.28	-	1.97
Botany Bay	-	-	0.53	-	0.53
Burwood	-	-	0.47	-	0.47
Camden	-	-	1.19	-	1.19
Campbelltown	-	-	3.26	-	3.26
Canada Bay	-	-	1.06	-	1.06
Canterbury	-	-	2.08	-	2.08
Cessnock	4.90×10^{-2}	1.11	-	-	1.15
Dungog	-	0.18	-	-	0.18
Fairfield	-	-	3.39	-	3.39
Gosford	-	1.06	2.87	-	3.93
Goulburn Mulwaree	-	5.41×10^{-3}	-	-	5.41×10^{-3}
Great Lakes	-	8.49×10^{-2}	-	-	8.49×10^{-2}
Hawkesbury	-	2.90×10^{-2}	1.34	-	1.37
Holroyd	-	-	1.77	-	1.77
Hornsby	-	4.26×10^{-3}	3.07	-	3.08
Hunters Hill	-	-	0.15	-	0.15
Hurstville	-	-	1.50	-	1.50
Kiama	-	0.32	-	-	0.32
Kogarah	-	-	0.92	-	0.92

LGA	2008 proportion of annual petrol consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ku-ring-gai	-	-	2.14	-	2.14
Lake Macquarie	2.46	2.21	-	-	4.66
Lane Cove	-	-	0.43	-	0.43
Leichhardt	-	-	0.83	-	0.83
Lithgow	-	0.45	-	-	0.45
Liverpool	-	-	3.26	-	3.26
Maitland	0.12	1.39	-	-	1.51
Manly	-	-	0.49	-	0.49
Marrickville	-	-	1.51	-	1.51
Mid-western Regional	-	6.41×10^{-2}	-	-	6.41×10^{-2}
Mosman	-	-	0.42	-	0.42
Muswellbrook	-	0.31	-	-	0.31
N/A	1.46×10^{-2}	6.58×10^{-2}	0.27	3.05×10^{-2}	0.38
Newcastle	3.48	-	-	-	3.48
North Sydney	-	-	0.55	-	0.55
Oberon	-	2.87×10^{-2}	-	-	2.87×10^{-2}
Parramatta	-	-	2.50	-	2.50
Penrith	-	-	3.81	-	3.81
Pittwater	-	-	1.16	-	1.16
Port Stephens	7.89×10^{-2}	1.31	-	-	1.39
Randwick	-	-	1.69	-	1.69
Rockdale	-	-	1.39	-	1.39
Ryde	-	-	1.90	-	1.90
Shellharbour	-	1.10	-	0.34	1.44
Shoalhaven	-	2.06×10^{-3}	-	-	2.06×10^{-3}
Singleton	-	0.44	-	-	0.44
Strathfield	-	-	0.50	-	0.50
Sutherland	-	-	4.15	-	4.15
Sydney	-	-	1.53	-	1.53
Unincorporated	-	-	0.54	-	0.54
Upper Lachlan	-	8.65×10^{-4}	-	-	8.65×10^{-4}
Warringah	-	-	2.39	-	2.39
Waverley	-	-	0.64	-	0.64
Willoughby	-	-	0.99	-	0.99
Wingecarribee	-	1.10	6.02×10^{-3}	1.94×10^{-3}	1.11
Wollondilly	-	1.49×10^{-2}	0.93	4.83×10^{-4}	0.95
Wollongong	-	-	0.33	3.72	4.05
Woollahra	-	-	0.50	-	0.50
Wyong	-	3.57	-	-	3.57
Grand Total	6.20	15.55	74.16	4.09	100.00

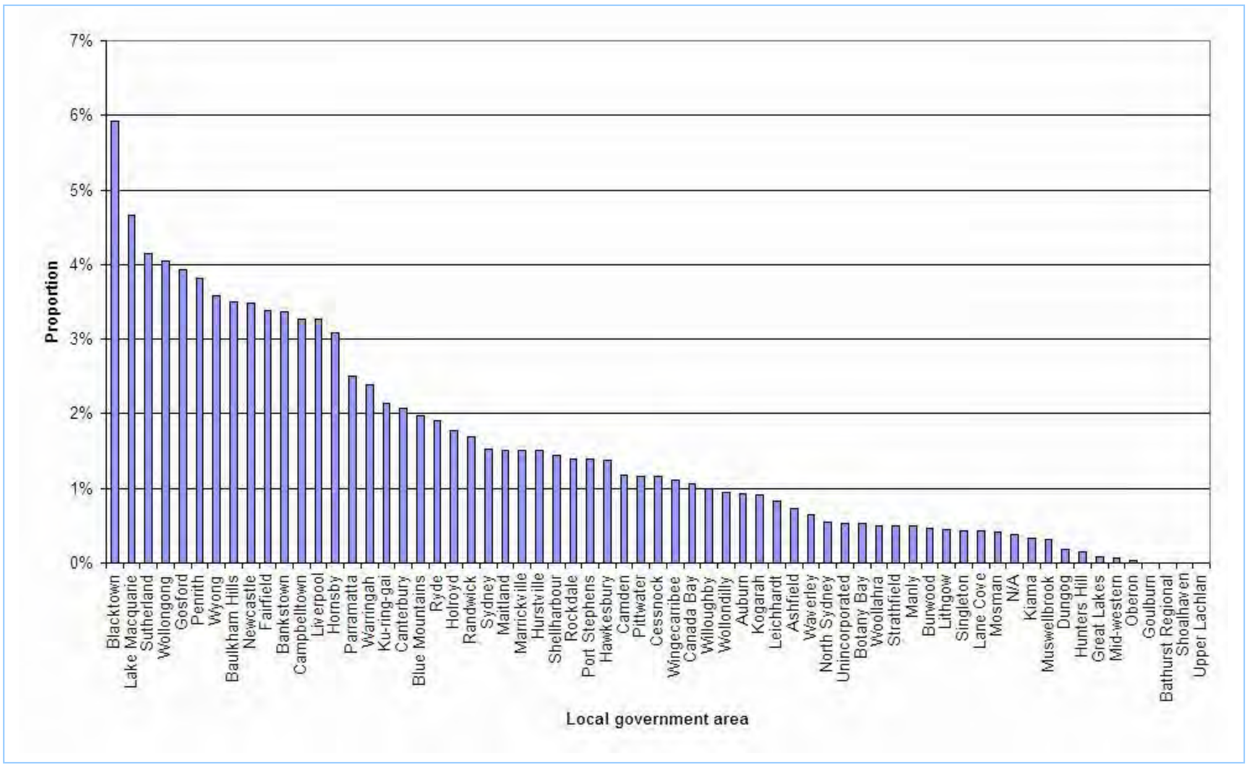

Figure 3-43: Lawn mowing and garden equipment (domestic) spatial distribution of petrol consumption by LGA

Figure 3-44 shows the spatial distribution of lawn mowing and garden equipment emissions.

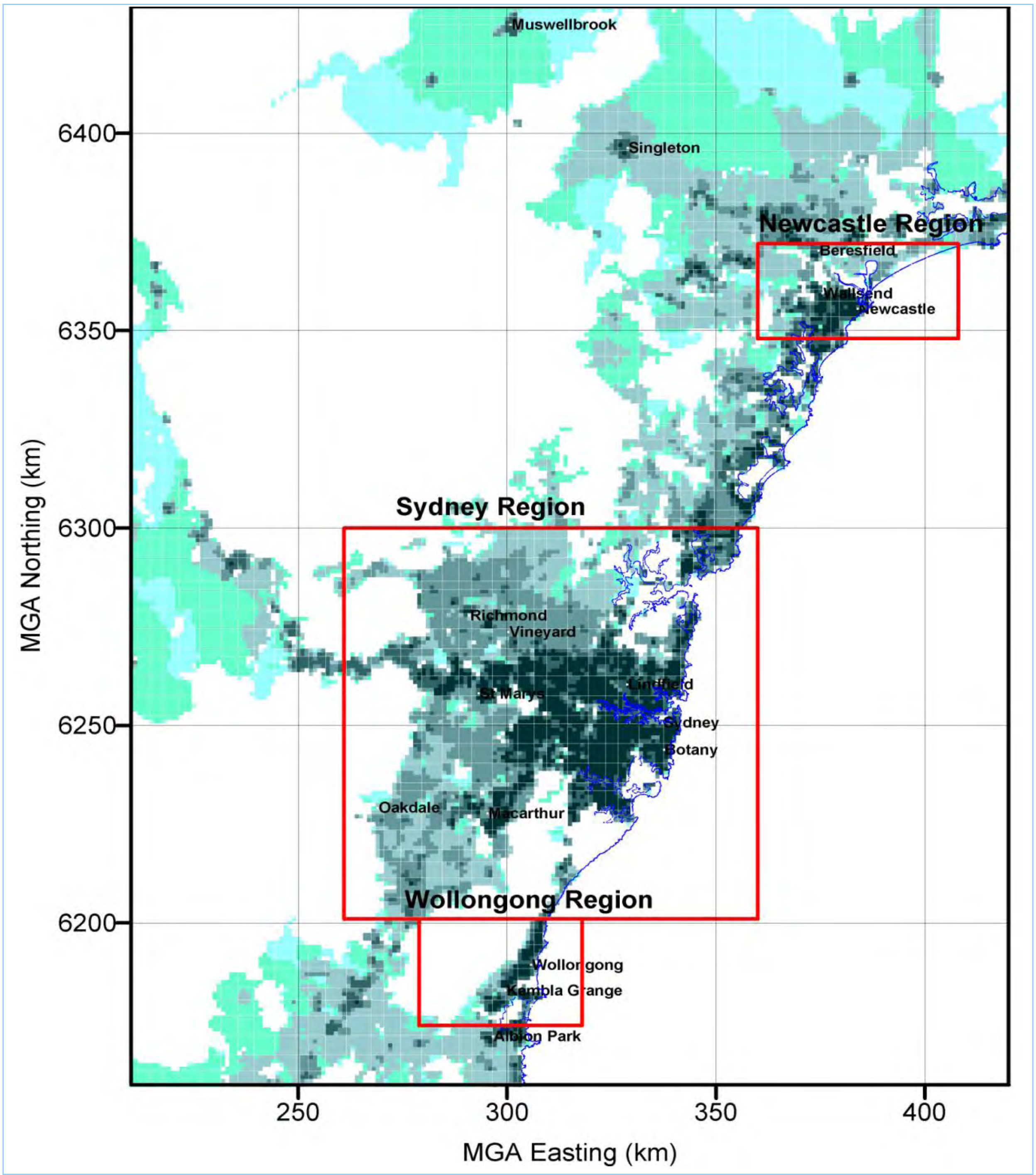

Figure 3-44: Lawn mowing and garden equipment (domestic) spatial distribution of emissions

3.6.6 *Temporal Variation of Emissions*

Table 3-103 summarises the data used to estimate the temporal variation in emissions from lawn mowing and garden equipment.

Table 3-103: Lawn mowing and garden equipment (domestic) temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from lawn mowing and garden equipment (domestic)	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)

The temporal variation in exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population (TR, 2009), annual operating time (TR, 2009), fuel properties (Attorney-General's Department, 2008; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009). Hourly temporal variation profiles for exhaust emissions are presented in Table 3-104 and shown in Figure 3-45.

Table 3-104: Lawn mowing and garden equipment (domestic) exhaust hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	-	13	8.05
2	-	14	7.66
3	-	15	9.20
4	-	16	10.98
5	-	17	11.62
6	-	18	5.87
7	0.26	19	1.40
8	0.77	20	0.26
9	2.94	21	-
10	10.09	22	-
11	18.90	23	-
12	12.01	24	-

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-105 (weighted hourly composite) and shown in Figure 3-46 (weighted hourly composite by source type).

Table 3-105: Lawn mowing and garden equipment (domestic) evaporative hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	2.41	1.56	13	6.61	7.13
2	2.38	1.53	14	6.46	6.89
3	2.35	1.52	15	6.58	7.52
4	2.34	1.51	16	6.65	8.18
5	2.32	1.50	17	6.34	8.20
6	2.36	1.52	18	4.58	5.03
7	2.67	1.81	19	3.22	2.57
8	3.27	2.38	20	2.73	1.85
9	4.34	3.84	21	2.56	1.65
10	6.39	7.70	22	2.51	1.62

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
11	8.65	12.30	23	2.47	1.59
12	7.39	9.04	24	2.44	1.57

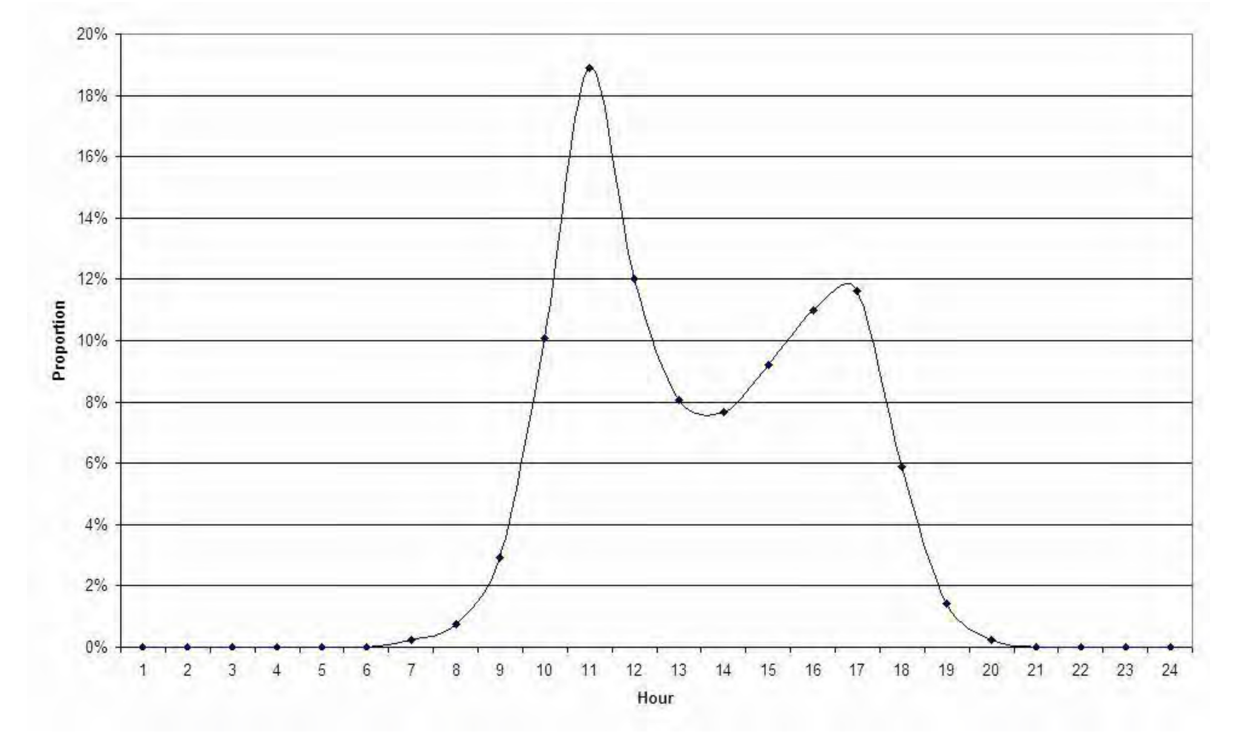

Figure 3-45: Lawn mowing and garden equipment (domestic) exhaust hourly temporal profile

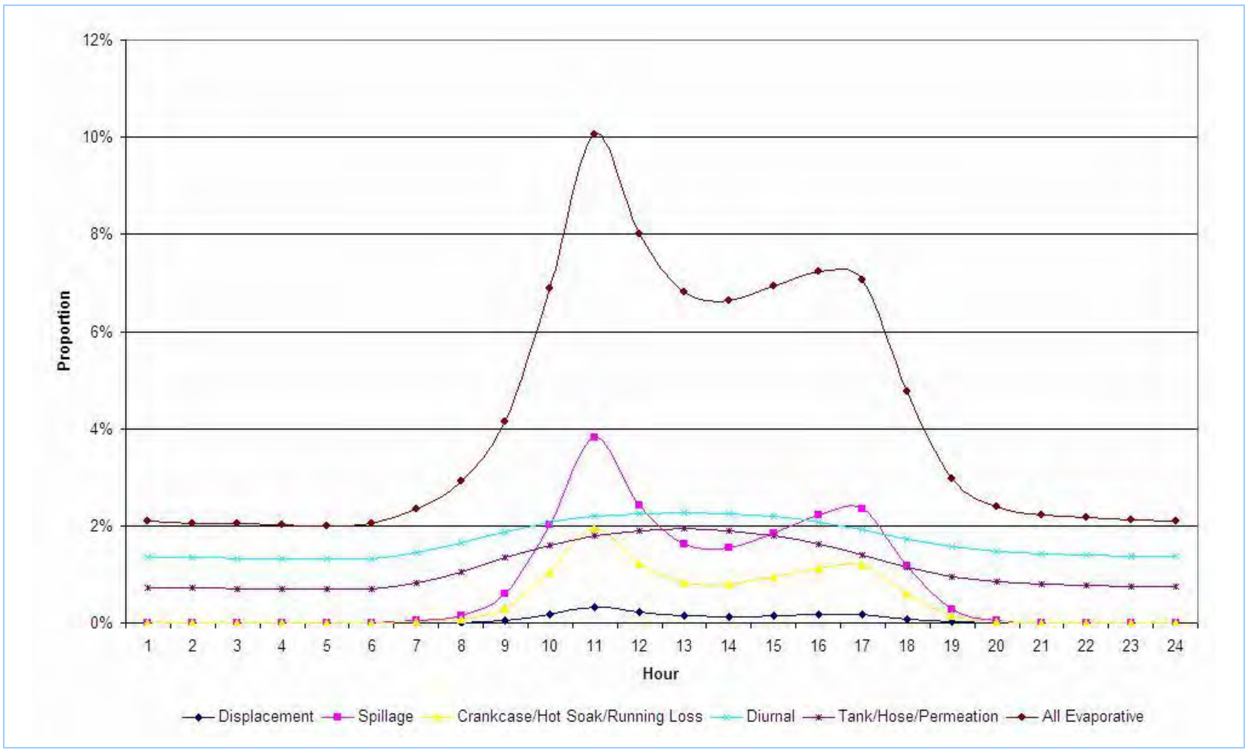

Figure 3-46: Lawn mowing and garden equipment (domestic) evaporative hourly temporal profile

Daily temporal variation profiles for exhaust emissions are presented in Table 3-106 and shown in Figure 3-47.

Table 3-106: Lawn mowing and garden equipment (domestic) exhaust daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	8.24	8.24	8.24	8.24	8.24	29.41	29.41

Daily temporal variation profiles for evaporative emissions are presented in Table 3-107 (weighted daily composite) and shown in Figure 3-48 (weighted daily composite by source type).

Table 3-107: Lawn mowing and garden equipment (domestic) evaporative daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	12.34	12.34	12.34	12.34	12.34	19.14	19.14

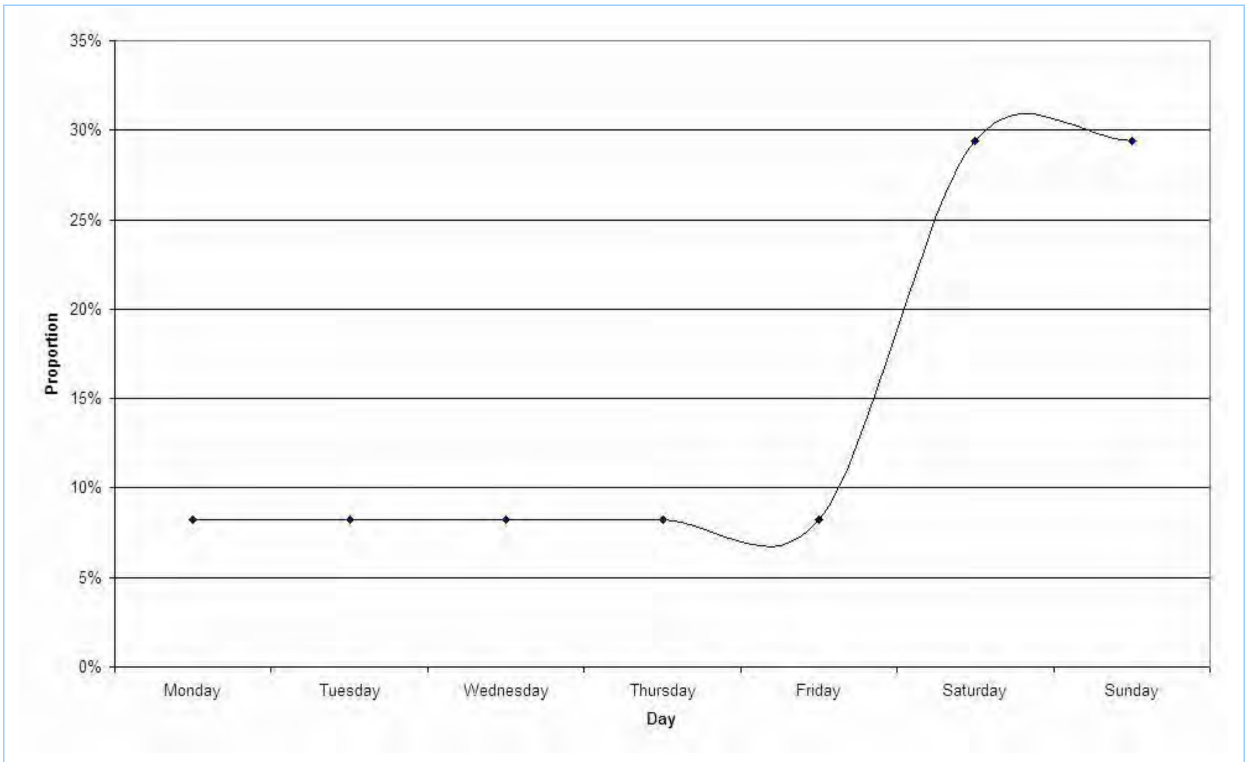

Figure 3-47: Lawn mowing and garden equipment (domestic) exhaust daily temporal profile

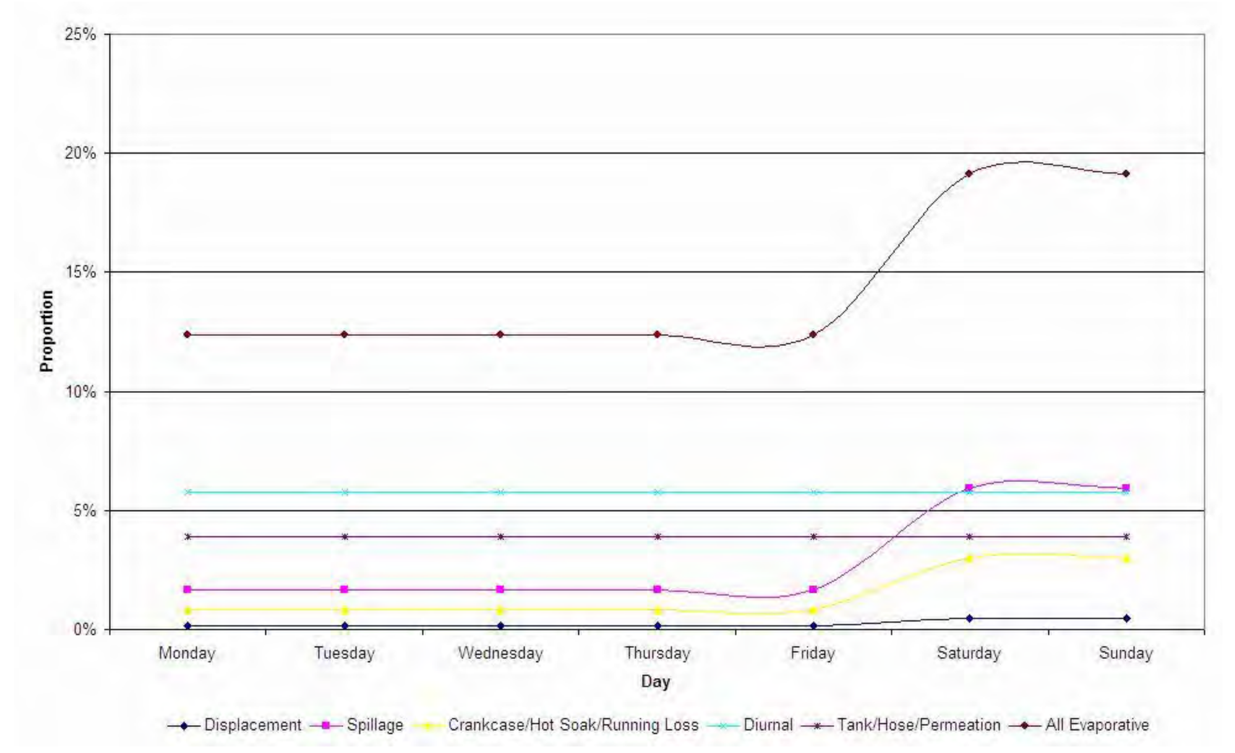

Figure 3-48: Lawn mowing and garden equipment (domestic) evaporative daily temporal profile

Monthly temporal variation profiles for exhaust emissions are presented in Table 3-108 and shown in Figure 3-49.

Table 3-108: Lawn mowing and garden equipment (domestic) exhaust monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	12.86	July	3.64
February	11.46	August	4.38
March	8.02	September	8.46
April	6.70	October	10.13
May	5.37	November	11.81
June	2.91	December	14.26

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-109 (weighted monthly composite) and shown in Figure 3-50 (weighted monthly composite by source type).

Table 3-109: Lawn mowing and garden equipment (domestic) evaporative monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	11.46	July	5.36
February	10.65	August	5.72
March	8.80	September	7.57
April	7.67	October	8.81
May	6.59	November	10.13
June	5.37	December	11.87

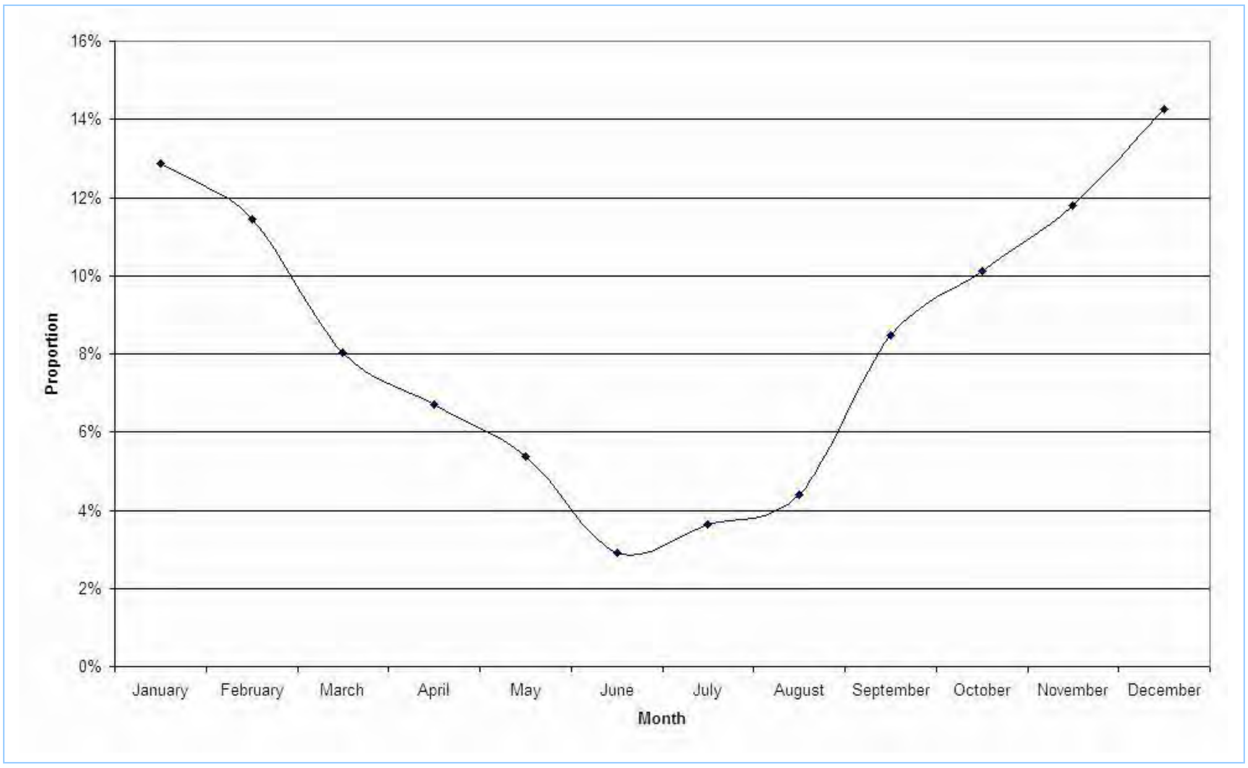

Figure 3-49: Lawn mowing and garden equipment (domestic) exhaust monthly temporal profile

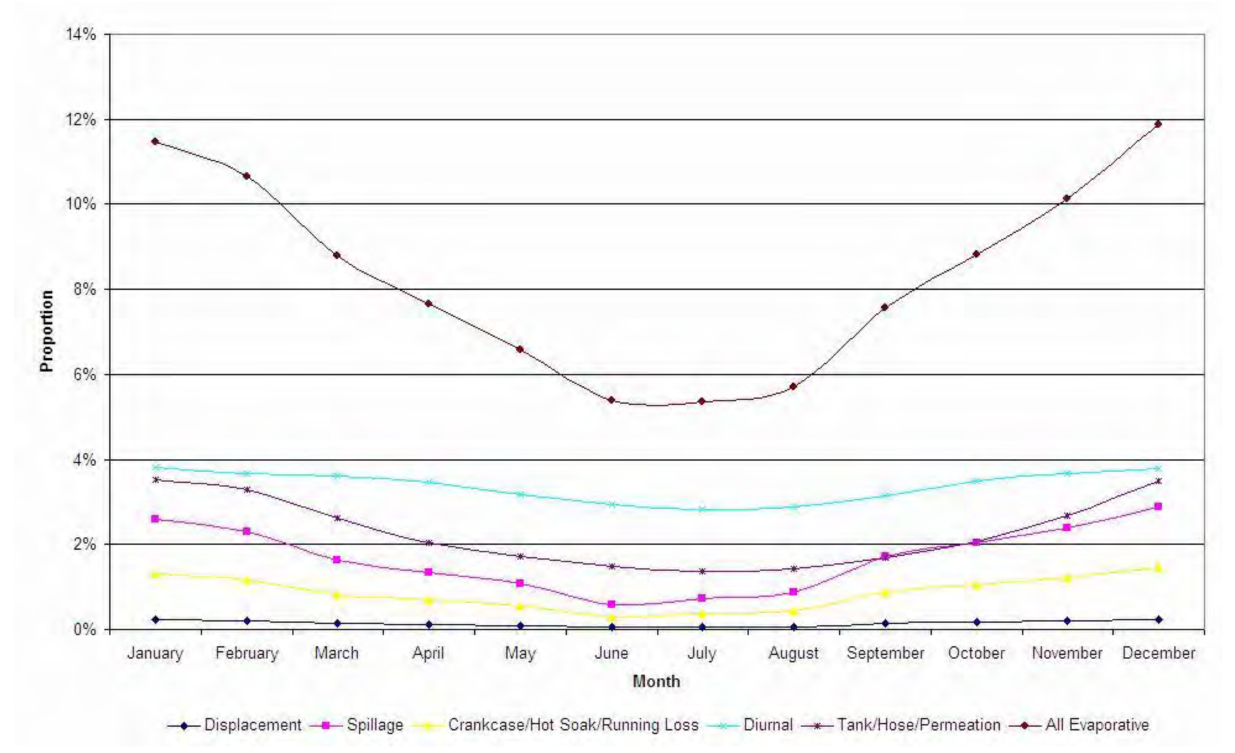

Figure 3-50: Lawn mowing and garden equipment (domestic) evaporative monthly temporal profile

3.6.7 Emission Estimates

Table 3-110 presents annual emissions of selected substances from lawn mowing and garden equipment by activity.

Table 3-110: Lawn mowing and garden equipment (domestic) emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Lawn Mowing and Garden Equipment Exhaust (Domestic)	1,3-BUTADIENE	1,868	4,689	22,356	1,234	30,146
	ACETALDEHYDE	1,048	2,631	12,544	692	16,915
	BENZENE	14,685	36,856	175,731	9,698	236,969
	CARBON MONOXIDE	2,168,539	5,442,703	25,950,733	1,432,068	34,994,042
	FORMALDEHYDE	2,928	7,349	35,041	1,934	47,252
	ISOMERS OF XYLENE	43,663	109,588	522,514	28,834	704,600
	LEAD & COMPOUNDS	14	36	171	9.45	231
	OXIDES OF NITROGEN	9,342	23,448	111,800	6,170	150,760
	PARTICULATE MATTER ≤ 10 µm	12,532	31,454	149,974	8,276	202,237
	PARTICULATE MATTER ≤ 2.5 µm	11,530	28,938	137,976	7,614	186,058
	POLYCYCLIC AROMATIC	150	377	1,798	99	2,424

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	HYDROCARBONS					
	SULFUR DIOXIDE	449	1,128	5,376	297	7,250
	TOLUENE	40,965	102,816	490,226	27,053	661,060
	TOTAL SUSPENDED PARTICULATE	12,920	32,427	154,612	8,532	208,492
	TOTAL VOLATILE ORGANIC COMPOUNDS	451,260	1,132,595	5,400,196	298,005	7,282,056
Lawn Mowing and Garden Equipment Evaporative (Domestic)	BENZENE	1,390	3,488	16,631	918	22,426
	ISOMERS OF XYLENE	980	2,459	11,727	647	15,813
	TOLUENE	3,385	8,496	40,510	2,236	54,627
	TOTAL VOLATILE ORGANIC COMPOUNDS	178,168	447,175	2,132,125	117,659	2,875,128

Table 3-111 presents annual emissions of selected substances from lawn mowing and garden equipment by source type.

Table 3-111: Lawn mowing and garden equipment (domestic) emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Exhaust - Petrol 2 Stroke	1,3-BUTADIENE	706	1,773	8,454	467	11,400
	ACETALDEHYDE	548	1,375	6,557	362	8,842
	BENZENE	8,283	20,790	99,125	5,470	133,668
	CARBON MONOXIDE	763,956	1,917,414	9,142,204	504,504	12,328,079
	FORMALDEHYDE	836	2,097	10,000	552	13,485
	ISOMERS OF XYLENE	35,391	88,826	423,520	23,372	571,108
	LEAD & COMPOUNDS	4.85	12	58	3.21	78
	OXIDES OF NITROGEN	1,925	4,833	23,042	1,272	31,072
	PARTICULATE MATTER ≤ 10 µm	11,238	28,206	134,487	7,422	181,352
	PARTICULATE MATTER ≤ 2.5 µm	10,339	25,950	123,728	6,828	166,844
	POLYCYCLIC AROMATIC HYDROCARBONS	16	41	194	11	262
	SULFUR DIOXIDE	106	265	1,265	70	1,705
	TOLUENE	32,199	80,816	385,329	21,264	519,608
	TOTAL SUSPENDED PARTICULATE	11,586	29,079	138,646	7,651	186,961
	TOTAL VOLATILE ORGANIC COMPOUNDS	329,248	826,363	3,940,089	217,430	5,313,130
Exhaust -	1,3-BUTADIENE	1,162	2,916	13,902	767	18,747

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Petrol 4 Stroke	ACETALDEHYDE	500	1,256	5,987	330	8,074
	BENZENE	6,401	16,067	76,606	4,227	103,302
	CARBON MONOXIDE	1,404,582	3,525,289	16,808,529	927,564	22,665,964
	FORMALDEHYDE	2,093	5,252	25,041	1,382	33,767
	ISOMERS OF XYLENE	8,272	20,762	98,994	5,463	133,491
	LEAD & COMPOUNDS	9.46	24	113	6.25	153
	OXIDES OF NITROGEN	7,417	18,615	88,758	4,898	119,688
	PARTICULATE MATTER ≤ 10 µm	1,294	3,248	15,487	855	20,884
	PARTICULATE MATTER ≤ 2.5 µm	1,191	2,988	14,248	786	19,214
	POLYCYCLIC AROMATIC HYDROCARBONS	134	336	1,603	88	2,162
	SULFUR DIOXIDE	344	862	4,112	227	5,545
	TOLUENE	8,766	22,000	104,897	5,789	141,452
	TOTAL SUSPENDED PARTICULATE	1,334	3,349	15,966	881	21,530
	TOTAL VOLATILE ORGANIC COMPOUNDS	122,012	306,232	1,460,108	80,575	1,968,926
Evaporative	BENZENE	1,390	3,488	16,631	918	22,426
	ISOMERS OF XYLENE	980	2,459	11,727	647	15,813
	TOLUENE	3,385	8,496	40,510	2,236	54,627
	TOTAL VOLATILE ORGANIC COMPOUNDS	178,168	447,175	2,132,125	117,659	2,875,128

3.6.8 *Emission Projection Methodology*

Table 3-112 summarises the data used to estimate the emission projection factors for lawn mowing and garden equipment, while Figure 3-51 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-112: Lawn mowing and garden equipment (domestic) emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from lawn mowing and garden equipment (domestic)	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

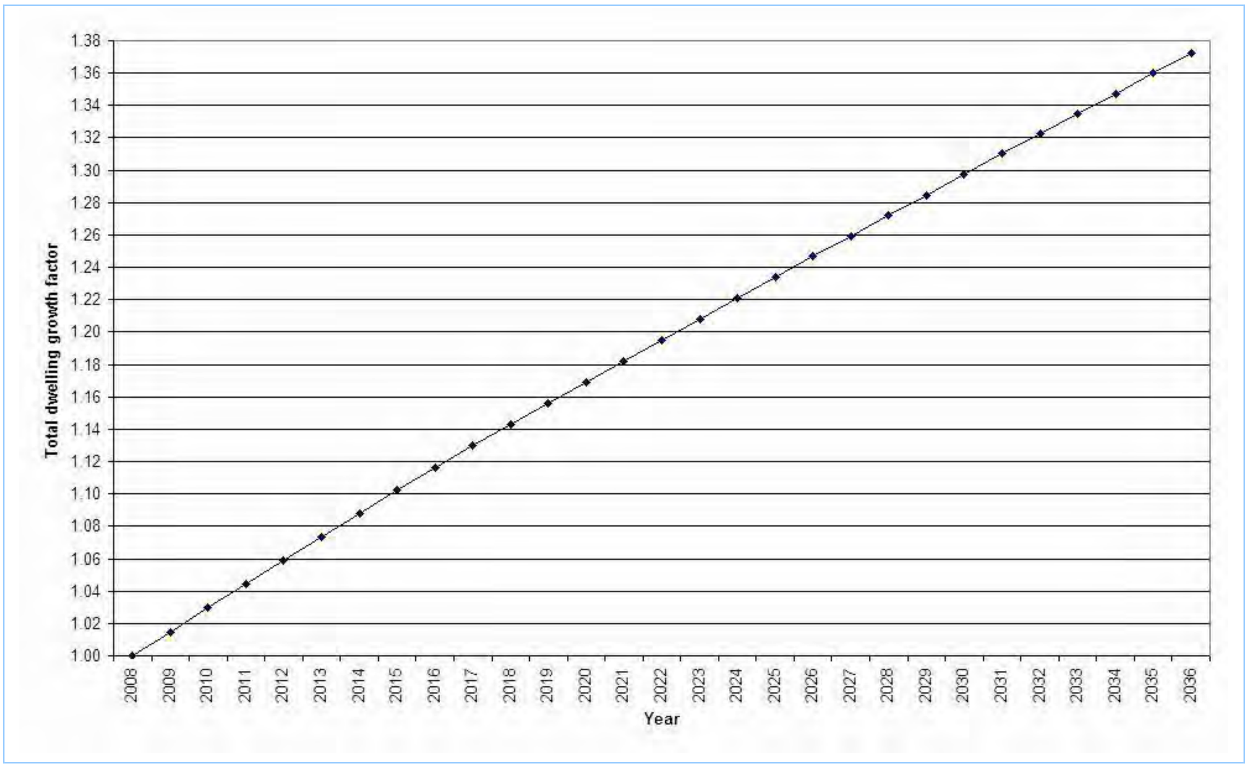

Figure 3-51: Lawn mowing and garden equipment (domestic) emission projection factors

3.7 Lawn Mowing and Garden Equipment (public open space)

3.7.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from lawn mowing and garden equipment engines; and
- Evaporative VOC:
    - Through the crankcase (i.e. combustion products and unburnt fuel);
    - From refuelling (i.e. vapour displacement and spillage);
    - Due to temperature changes (i.e. diurnal, hot soak and running loss); and
    - Via permeation (i.e. plastic fuel tanks and rubber hoses).

To estimate emissions from these sources, the following have been considered:

- *Commercial survey*

While commercial lawn mowing and garden equipment are typically used at airports, cemeteries, educational institutions (i.e. colleges, schools and universities), golf courses, hospitals, parks and sporting ovals etc., the inventory includes golf courses and local government areas (LGA) (e.g. parks and sporting ovals etc.). A commercial survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes 5 golf courses and 9 LGA[34] located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; and frequency and duration of equipment use by hour, day and season (DECC, 2007b).

Figure 3-52 shows how the commercial survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009) to develop an inventory of lawn mowing and garden equipment emissions.

[34] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 59 LGA plus the two areas designated N/A and unincorporated.

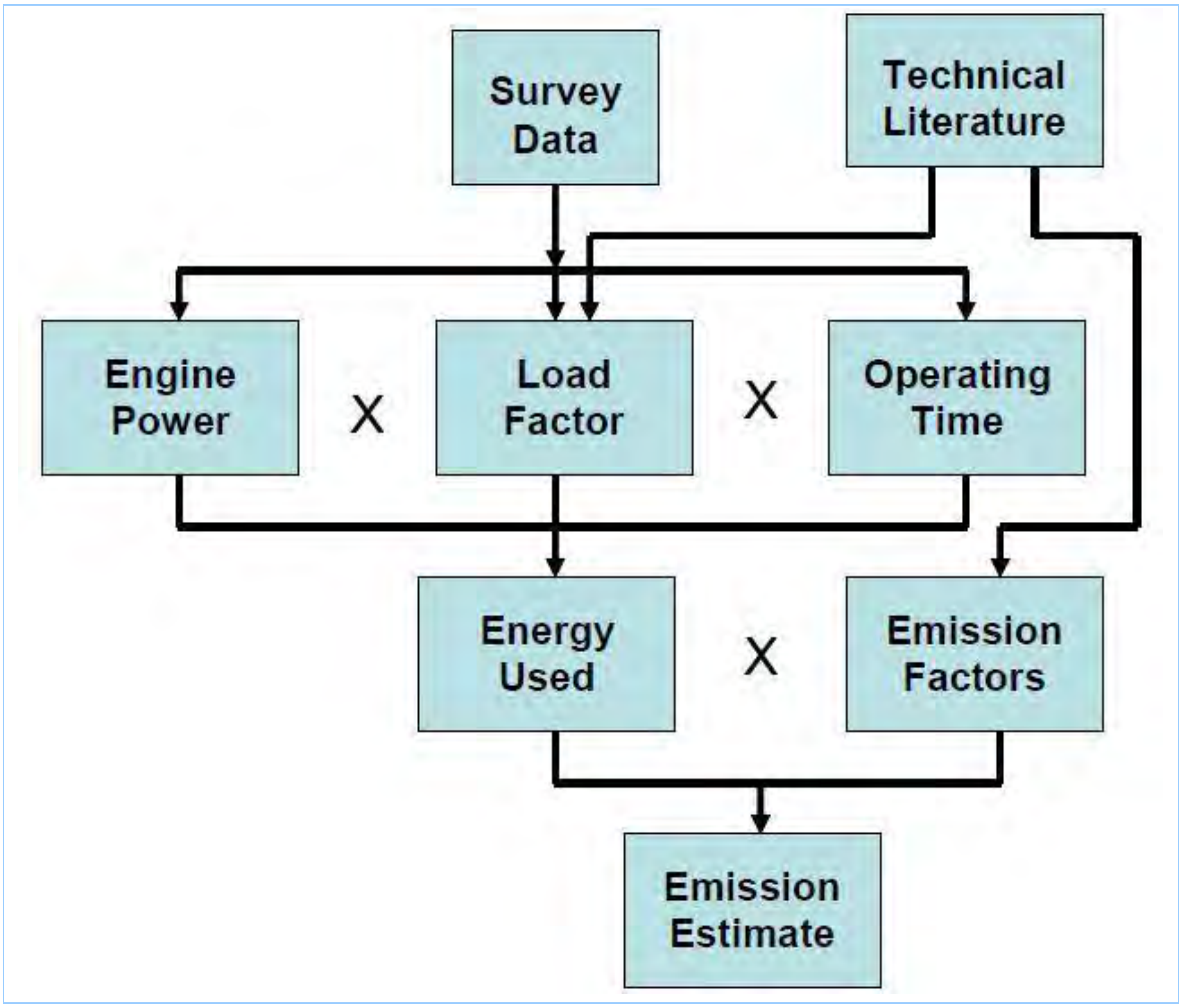

Figure 3-52: Lawn mowing and garden equipment (public open space) – use of survey data

- *Lawn mowing and garden equipment type*

The inventory includes commercial-operated lawn mowing and garden equipment for commercial use as follows:

- *Chainsaw;*
- *Chipper/Stump grinder;*
- *Commercial mower;*
- *Commercial turf equipment;*
- *Front mower;*
- *Golf cart;*
- *Lawn and garden tractor;*
- *Leafblower/Vacuum;*

- *Other lawn and garden equipment;*
- *Push lawnmower;*
- *Rear engine ride-on lawnmower;*
- *Rotary tiller;*
- *Shredder;*
- *Speciality vehicle cart; and*
- *Trimmer/Edger/Brush cutter.*

➢ *Engine type*

The inventory includes lawn mowing and garden equipment powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines, which are either handheld (e.g. chainsaw) or non-handheld (e.g. push lawnmower) and diesel compression ignition (CI) engines, which are all non-handheld. Handheld petrol powered equipment range from 1 to 6 horsepower (hp)[35], while non-handheld equipment range from 1 to 25 hp (AIA, 2005). Diesel powered equipment all range from 3 to 25 hp (DECC, 2007b).

Since there are no NSW or Australian emission standards, the inventory considers all lawn mowing and garden equipment have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009).

➢ *Fuel type*

The inventory includes lawn mowing and garden equipment that use automotive gasoline (petrol) and automotive diesel oil (ADO).

Table 3-113 presents the lawn mowing and garden equipment fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009). The sulfur and oxygen contents in petrol are requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008), which are relevant for the 2008 calendar year. Weighted average sulfur and oxygen contents have been calculated from *Australian Petroleum Statistics 2008* (DRET, 2009) and the requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008). The sulfur content in ADO is a requirement of the *Fuel Standard (Automotive Diesel) Determination 2001* (Attorney-General's Department, 2009), which is relevant for the 2008 calendar year.

[35] 1 horsepower (hp) is equivalent to 0.7457 kilowatts (kW) (USEPA, 1995a).

Table 3-113: Lawn mowing and garden equipment (public open space) fuel type and properties

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive gasoline (petrol)	150 - All grades[36]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[37]	2.84 – Weighted average[38]			
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

Electric lawn mowing and garden equipment have not been included, since emissions from electricity generation have been separately estimated as part of the industrial air emissions inventory.

- *Source type*

The inventory includes emissions of combustion products and evaporation from lawn mowing and garden equipment engines.

Exhaust emissions are generated in the engine's combustion chamber and exit through the exhaust. Exhaust emissions mainly include CO, NO_x, $PM_{2.5}$, PM_{10}, TSP, SO_2 and VOC (total and speciated).

Evaporation occurs in a number of ways, including:

- *Crankcase emissions* originate from the combustion chamber then move past the piston rings and into the crankcase of 4-stroke petrol and diesel engines. Since gases flow freely from the crankcase to the combustion chamber in 2-stroke petrol engines, they are not an issue. They mainly include exhaust emissions plus some unburnt fuel;
- *Refuelling emissions* are the vapours displaced from the fuel tank when it is filled plus any spillage that may occur. These occur from 2-stroke and 4-stroke petrol engines;
- *Diurnal emissions* arise with temperature changes that occur throughout the day. As the air temperature increases, the fuel temperature in the tank increases and begins to evaporate. These occur from 2-stroke and 4-stroke petrol engines;
- *Hot soak emissions* are similar to diurnal emissions, except heating of the fuel is provided by the residual heat of the equipment, just after the engine is shut off. These occur from 2-stroke and 4-stroke petrol engines;
- *Running loss emissions* are similar to diurnal emissions, except heating of the fuel is caused by engine operation. These occur from 2-stroke and 4-stroke petrol engines; and

[36] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[37] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[38] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

- *Permeation emissions* occur when fuel moves through the material used in the fuel system. Since the outer surfaces of the fuel system are exposed to air, petrol molecules permeate through them and are directly emitted. Permeation is most common through plastic fuel tanks and rubber hoses. These occur from 2-stroke and 4-stroke petrol engines

Evaporative emissions mainly include VOC (total and speciated).

3.7.2 Emission Estimation Methodology

Table 3-114 summarises the emission estimation methodology used for lawn mowing and garden equipment.

Table 3-114: Lawn mowing and garden equipment (public open space) emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from lawn mowing and garden equipment (public open space)	- *Guidance for Estimating Lawn and Garden Equipment Activity Levels* (Environ, 1997)

Exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population and activity data in combination with emission, load, transient adjustment and deterioration factors within the *NONROAD2008a Model* (USEPA, 2009).

Exhaust emission factors have been adjusted according to fuel sulfur content for 2-stroke/4-stroke petrol and diesel engines and oxygen content for 2-stroke/4-stroke petrol engines, while ambient temperature correction factors have been applied to 4-stroke petrol engine exhaust emission factors (USEPA, 2009).

An engine's rated power is the maximum power it is designed to produce at the rated speed. Since engines normally operate at a variety of speeds and loads, operation at rated power for extended periods is rare. To take into account the effect of operation over a wide range of conditions (e.g. idle, partial load and transient operation), a load factor (LF) has been used to determine the average proportion of rated power used (USEPA, 2009).

Transient adjustment factors (TAF) have been applied to 2-stroke/4-stroke petrol and diesel engine emission factors to account for in-use (i.e. transient) operation and better represent the operational behaviour of the equipment (USEPA, 2009).

Deterioration factors (DF) have been applied to 2-stroke/4-stroke petrol and diesel engine emission factors to account for deterioration of emission performance over time. Deterioration refers to the degradation of an engine's exhaust emissions performance over its lifetime due to either normal use and/or misuse (i.e. tampering or neglect). Engine deterioration increases exhaust emissions, which usually leads to a loss of combustion efficiency and can in some cases increase evaporative emissions. The amount of deterioration depends on an engine's design, production quality and technology type (i.e. 2-stroke and 4-stroke petrol spark ignition or diesel compression ignition). Other factors may also affect deterioration, such as the equipment application, usage patterns and how it is stored and maintained (USEPA, 2009).

Evaporative emission factors for 2-stroke and 4-stroke petrol engines have been adjusted according to ambient temperature, Reid vapour pressure (RVP) and ethanol content of petrol (USEPA, 2009).

Equipment population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and seasonal basis. Equipment population and activity rates have been derived from a commercial survey (DECC, 2007b) and sales data (AIA, 2005). Emissions have been determined using Equation 10 within the *NONROAD2008a Model* (USEPA, 2009):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times TAF_{j,k,l} \times DF_{j,k,l} \times EF_{i,j,k,l,m} / 1000} \qquad \textbf{Equation 10}$$

where:			
$E_{i,j,k,l,m}$	=	Emissions of substance i from lawn mowing and garden equipment type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of lawn mowing and garden equipment type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of lawn mowing and garden equipment type j, engine type k and engine power range l	(h/year)
$HP_{j,k,l}$	=	Maximum rated power of lawn mowing and garden equipment type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for lawn mowing and garden equipment type j, engine type k and engine power range l	(hp/hp)
$TAF_{j,k,l}$	=	Fractional transient adjustment factor for lawn mowing and garden equipment type j, engine type k and engine power range l	$(g.(hp.h)^{-1}/ g.(hp.h)^{-1})$
$DF_{j,k,l}$	=	Fractional deterioration factor for lawn mowing and garden equipment type j, engine type k and engine power range l	$(g.(hp.h)^{-1}/ g.(hp.h)^{-1})$
$EF_{i,j,k,l,m}$	=	Emission factor for substance i from lawn mowing and garden equipment type j, engine type k, engine power range l and source type m	(g/hp.h)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)
j	=	Lawn mowing and garden equipment type (either "Chainsaw", "Chipper/Stump grinder", "Commercial mower", "Commercial turf equipment", "Front mower", "Golf cart", "Lawn and garden tractor", "Leafblower/Vacuum", "Other lawn and garden equipment", "Push lawnmower", "Rear engine ride-on lawnmower", "Rotary tiller", "Shredder", "Speciality vehicle cart" or "Trimmer/Edger/Brush cutter")	(-)
k	=	Engine type (either "2-stroke petrol", "4-stroke-petrol" or "diesel")	(-)
l	=	Engine power range	(hp)
m	=	Source type (either "exhaust", "crankcase", "refuelling", "diurnal", "hot soak", "running loss" or "permeation")	(-)
1000	=	Conversion factor	(g/kg)

3.7.3 Activity Data

Table 3-115 summarises the activity data used for lawn mowing and garden equipment.

Table 3-115: Lawn mowing and garden equipment (public open space) activity data

Activity data	Activity data source
Lawn mower and garden equipment type/number and monthly mowing frequency/duration	- *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b)
Golf course locations required to scale-up golf course survey	- *Australian Course Directory* (Iseekgolf.com, 2011)
Gridded 1 km x 1 km population estimates required to scale-up LGA survey	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)
Lawn mower and garden equipment fleet composition	- *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)

A commercial survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes 5 golf courses and 9 LGA located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; and frequency and duration of equipment use by hour, day and season (DECC, 2007b).

The 5 golf courses surveyed include Castle Hill Country Club, Killara Golf Club, Manly Golf Club, Pennant Hills Golf Course and St Michaels Golf Club (DECC, 2007b). The golf course survey results (DECC, 2007b) have been used to scale-up activity data to the 162 golf courses in the GMR (Iseekgolf.com, 2011) using the average activity levels for each golf course. Table 3-116 presents the number of golf courses and equipment population by NSW region in the GMR.

Table 3-116: Golf course equipment population by NSW region in the GMR

NSW region	Number of golf courses	2008 equipment population
Blue Mountains	11	568
Central Coast	12	619
Hunter Valley	19	980
Illawarra	11	568
Southern Highlands	7	361
Sydney	102	5,263
Grand Total	162	8,359

The 9 LGA surveyed include Auburn, Bankstown, Canada Bay, Great Lakes, Kiama, Ku-ring-gai, Newcastle, Port Stephens and Strathfield (DECC, 2007b). While the GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated, the LGA survey results (DECC, 2007b) have been used to scale-up activity data to 59 LGA, plus the two areas designated N/A and unincorporated, using a linear regression of activity levels for each LGA. To scale-up LGA survey results, a number of linear regression models have been examined for each LGA, including:

- Equipment number versus population (TDC, 2009)[39];
- Equipment number versus area (TDC, 2009)[40]; and
- Equipment number versus area times population[41].

The Australian Classification of Local Governments (ACLG) provides a useful way of categorising LGA across Australia using population, population density and proportion of the population that is classified as urban or rural for the LGA. The ACLG defines a population density of more than 30 persons per km^2 as urban (DTRS, 2003) and this definition has been used as the basis of testing which linear regression models exhibit the best correlation.

Table 3-119 presents the coefficients of determination (R^2) for the three linear regression models evaluated.

Table 3-117: Evaluation of LGA lawn mowing and garden equipment linear regression models

Linear regression model	Coefficient of determination (R^2)				
	≥ 0 persons per km^2	≥ 30 persons per km^2	≥ 50 persons per km^2	≥ 70 persons per km^2	≥ 90 persons per km^2
Equipment number versus population	0.54	0.54	0.54	0.54	0.54
Equipment number versus area	0.16	0.38	0.47	0.50	0.52
Equipment number versus area times population	0.33	0.63	0.66	0.65	0.66

In summary, the three linear regression models exhibit the following:

- The equipment number versus population model yields consistent R^2 values of 0.54 for all population densities;
- The equipment number versus area model yields increasing R^2 values for all population densities, with a maximum R^2 value of 0.52 for a population density ≥ 90 persons per km^2; and
- The equipment number versus area times population model yields the highest R^2 value of 0.66 for a population density ≥ 50 persons per km^2, so this has been used to scale-up the LGA survey results.

[39] The sum of population for 1 km by 1 km grid cells with persons per km^2 ≥ 0, 30, 50, 70 and 90.
[40] The sum of area for 1 km by 1 km grid cells with persons per km^2 ≥ 0, 30, 50, 70 and 90.
[41] The product of sum of population and sum of area for 1 km by 1 km grid cells with persons per km^2 ≥ 0, 30, 50, 70 and 90.

For the equipment number versus area times population model, the F-statistic, p-value and t-statistic values have been calculated at the 95% confidence level. The F-statistic value is 15.59, while the F-critical value is 5.32. This implies the regression and correlation are indeed true and not the consequence of chance. The p-value is 0.42%, while the p-critical value is 5%. This implies the probability of the relationship being produced by random chance is 0.42% and it is significant, since the p-value is less than 5%. The t-statistic value is 3.95, while the t-critical value is 2.31. This implies the regression has established a significant relationship.

Figure 3-53 shows the preferred linear regression model used the scale-up LGA survey results to 59 LGA, plus the two areas designated N/A and unincorporated.

Table 3-118 presents the linear regression variables, including population more than 50 persons per km², area more than 50 persons per km², population times area and equipment population by LGA in the GMR.

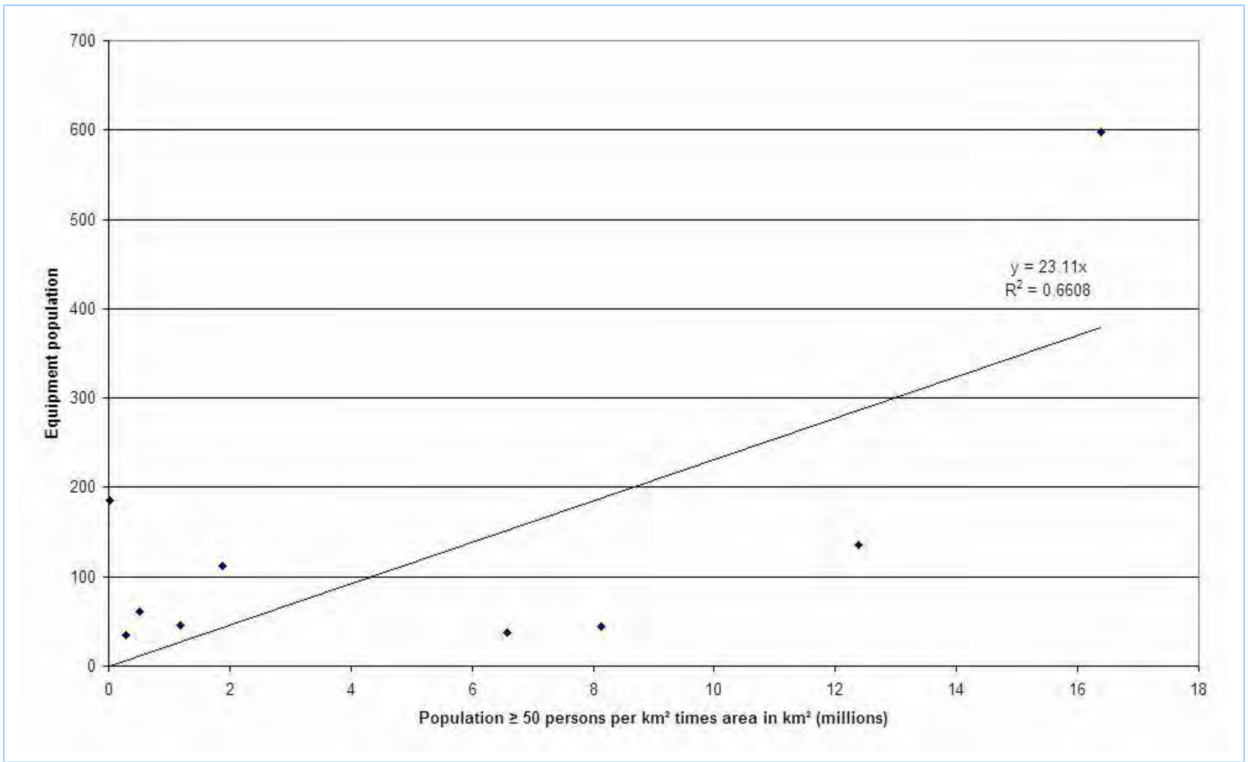

Figure 3-53: Preferred LGA lawn mowing and garden equipment linear regression model

Table 3-118: LGA equipment population by LGA in the GMR

LGA	Population ≥ 50 persons/km² (persons)	Area ≥ 50 persons/km² (km²)	Population times area (persons.km²) x million	2008 equipment population
Ashfield	47,887	10	0.5	11
Auburn	69,526	27	1.9	43
Bankstown	174,266	71	12.4	286
Baulkham Hills	167,629	176	29.5	682
Blacktown	285,424	173	49.4	1,141
Blue Mountains	76,763	174	13.4	309

LGA	Population ≥ 50 persons/km² (persons)	Area ≥ 50 persons/km² (km²)	Population times area (persons.km²) x million	2008 equipment population
Botany Bay	33,282	15	0.5	12
Burwood	30,277	7	0.2	5
Camden	54,008	93	5.0	116
Campbelltown	149,140	119	17.7	410
Canada Bay	58,880	20	1.2	27
Canterbury	138,343	34	4.7	109
Cessnock	42,796	94	4.0	93
Dungog	3,435	19	0.1	2
Fairfield	188,885	85	16.1	371
Gosford	158,858	214	34.0	786
Great Lakes	1,631	15	2.45×10^{-02}	1
Hawkesbury	53,982	235	12.7	293
Holroyd	95,192	37	3.5	81
Hornsby	158,865	156	24.8	573
Hunters Hill	9,295	4	3.72×10^{-02}	1
Hurstville	81,935	27	2.2	51
Kiama	13,416	22	0.3	7
Kogarah	57,349	19	1.1	25
Ku-ring-gai	106,943	76	8.1	188
Lake Macquarie	191,673	268	51.4	1,187
Lane Cove	28,511	11	0.3	7
Leichhardt	39,692	8	0.3	7
Lithgow	15,287	48	0.7	17
Liverpool	176,096	162	28.5	659
Maitland	62,895	102	6.4	148
Manly	33,804	12	0.4	9
Marrickville	86,873	18	1.6	36
Mid-western Regional	1,900	7	1.33×10^{-02}	0
Mosman	30,867	9	0.3	6
Muswellbrook	11,868	24	0.3	7
N/A	25,522	46	1.2	27
Newcastle	150,409	109	16.4	379
North Sydney	53,850	11	0.6	14
Oberon	852	4	3.41×10^{-03}	0
Parramatta	152,556	56	8.5	197
Penrith	174,190	211	36.8	849
Pittwater	54,354	52	2.8	65
Port Stephens	52,626	125	6.6	152
Randwick	130,952	31	4.1	94
Rockdale	89,713	25	2.2	52
Ryde	105,073	43	4.5	104
Shellharbour	64,307	52	3.3	77
Singleton	15,505	37	0.6	13
Strathfield	38,732	13	0.5	12

LGA	Population ≥ 50 persons/km² (persons)	Area ≥ 50 persons/km² (km²)	Population times area (persons.km²) x million	2008 equipment population
Sutherland	212,595	132	28.1	649
Sydney	167,382	28	4.7	108
Unincorporated	42,638	44	1.9	43
Warringah	140,805	87	12.3	283
Waverley	57,147	8	0.5	11
Willoughby	69,528	22	1.5	35
Wingecarribee	37,718	110	4.1	96
Wollondilly	31,472	119	3.7	87
Wollongong	191,956	166	31.9	736
Woollahra	44,773	10	0.4	10
Wyong	141,212	196	27.7	640
Grand Total	5,183,337	4,328	538.3	12,441

Lawn mowing and garden equipment sales data for the 2003 and 2004 calendar years (AIA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and non-handheld/handheld equipment with a given maximum power rating, while the lawn mowing and garden equipment survey results (DECC, 2007b) have been used to estimate the total number of in-service equipment. Since sales data for diesel equipment is not available, the proportion of 4-stroke petrol non-handheld equipment with a given maximum power rating has been assumed for diesel non-handheld equipment. Table 3-119 presents a summary of lawn mowing and garden equipment sales data for NSW.

Table 3-119: Lawn mowing and garden equipment sales data for NSW

Maximum rated power (hp)	2003 calendar year non-handheld		2004 calendar year non-handheld		2003 and 2004 calendar year non-handheld			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
1 to 3	18,960	10,790	43,070	12,380	62,030	23,170	46.02	7.81
3 to 6	31,550	75,140	41,220	111,530	72,770	186,670	53.98	62.91
6 to 16	-	36,630	-	35,750	-	72,380	-	24.39
16 to 25	-	6,860	-	7,650	-	14,510	-	4.89
Grand Total	50,510	129,420	84,290	167,310	134,800	296,730	100.00	100.00
Maximum rated power (hp)	2003 calendar year handheld		2004 calendar year handheld		2003 and 2004 calendar year handheld			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
1 to 3	126,730	7,150	208,430	10,130	335,160	17,280	95.48	100.00
3 to 6	10,410	-	5,450	-	15,860	-	4.52	-
Grand Total	137,140	7,150	213,880	10,130	351,020	17,280	100.00	100.00

The total population of in-service lawn mowing and garden equipment have been estimated by combining the commercial survey results (DECC, 2007b), the number of golf courses (Iseekgolf.com, 2011), the LGA population linear regression model and lawn mowing and garden equipment sales data (AIA, 2005).

In-service golf course equipment population by equipment description and maximum rated power range data for the GMR is presented in Table 3-120.

Table 3-120: Golf course equipment population in the GMR

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
2-Str Chain Saws < 6 HP (com)	495	23	-	-	-	518
2-Str Commercial Turf Equipment (com)	130	-	-	-	-	130
2-Str Lawn mowers (com)	253	297	-	-	-	551
2-Str Leafblowers/Vacuums (com)	480	23	-	-	-	502
2-Str Trimmers/Edgers/Brush Cutter (com)	681	32	-	-	-	713
4-Str Commercial Turf Equipment (com)	-	663	257	26	26	972
4-Str Front Mowers (com)	-	-	270	27	27	324
4-Str Golf Carts	-	-	778	-	-	778
4-Str Lawn mowers (com)	72	579	224	-	-	875
4-Str Leafblowers/Vacuums (com)	-	113	-	-	-	113
4-Str Other Lawn & Garden Eqp. (com)	20	163	63	6	6	259
4-Str Rear Engine Riding Mowers (com)	-	44	17	2	2	65
Dsl - Chippers/Stump Grinders (com)	-	-	-		97	97
Dsl - Commercial Mowers (com)	-	752	291	29	29	1,102
Dsl - Front Mowers (com)	-	111	43	4	4	162
Dsl - Lawn & Garden Tractors (com)	-	-	756	76	76	907
Dsl - Other Lawn & Garden Eqp. (com)	-	-	-	81	81	162
Dsl - Specialty Vehicle Carts	-	-	-	65	65	130
Grand Total	2,130	2,800	2,699	316	413	8,359

The annual operating time of in-service golf course equipment have been estimated from the golf course survey results (DECC, 2007b). In-service golf course equipment annual operating time by equipment description for the GMR is presented in Table 3-121.

Table 3-121: Golf course equipment annual operating time in the GMR

Equipment description	Annual operating time (h/year)
2-Stroke Chain Saws < 6 HP	93.4
2-Stroke Commercial Turf Equipment	286.0
2-Stroke Lawn mowers	425.2
2-Stroke Leafblowers/Vacuums	597.2
2-Stroke Trimmers/Edgers/Brush Cutter	622.8
4-Stroke Commercial Turf Equipment	222.7

Equipment description	Annual operating time (h/year)
4-Stroke Front Mowers	928.2
4-Stroke Golf Carts	1,135.3
4-Stroke Lawn mowers	505.0
4-Stroke Leafblowers/Vacuums	612.9
4-Stroke Other Lawn & Garden Equipment	2,879.5
4-Stroke Rear Engine Riding Mowers	861.3
Diesel Chippers/Stump Grinders	205.8
Diesel Commercial Mowers	840.4
Diesel Front Mowers	738.4
Diesel Lawn & Garden Tractors	360.8
Diesel Other Lawn & Garden Equipment	1,976.0
Diesel Specialty Vehicle Carts	1,007.5

In-service LGA equipment population by equipment description and maximum rated power range data for the GMR is presented in Table 3-122.

Table 3-122: LGA equipment population in the GMR

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
2-Str Chain Saws < 6 HP (com)	1,544	73	-	-	-	1,617
2-Str Lawn mowers (com)	590	693	-	-	-	1,283
2-Str Leafblowers/Vacuums (com)	1,847	87	-	-	-	1,935
2-Str Other Lawn & Garden Eqp. (com)	64	75	-	-	-	139
2-Str Trimmers/Edgers/Brush Cutter (com)	3,183	151	-	-	-	3,333
4-Str Chippers/Stump Grinders (com)	-	54	21	2	2	79
4-Str Commercial Turf Equipment (com)	-	54	21	2	2	79
4-Str Front Mowers (com)	-	-	99	10	10	119
4-Str Lawn & Garden Tractors (com)	-	257	100	10	10	377
4-Str Lawn mowers (com)	139	1,120	434	-	-	1,693
4-Str Other Lawn & Garden Eqp. (com)	10	81	31	3	3	129
4-Str Rotary Tillers < 6 HP (com)	-	129	-	-	-	129
4-Str Shredders < 6 HP (com)	2	18	-	-	-	20
Dsl - Chippers/Stump Grinders (com)	-	-	-	-	40	40
Dsl - Commercial Turf Equipment (com)	-	-	165	17	17	198
Dsl - Front Mowers (com)	-	332	129	13	13	486
Dsl - Lawn & Garden Tractors (com)	-	-	314	31	31	377
Dsl - Other Lawn & Garden Eqp. (com)	-	-		15	15	30
Dsl - Rear Engine Riding Mowers (com)	-	250	97	10	10	367
Dsl - Rotary Tillers < 6 HP (com)	-	10	-	-	-	10
Grand Total	7,379	3,384	1,412	113	153	12,441

The annual operating time of in-service LGA equipment have been estimated from the LGA survey results (DECC, 2007b). In-service LGA equipment annual operating time by equipment description for the GMR is presented in Table 3-123.

Table 3-123: LGA equipment annual operating time in the GMR

Equipment description	Annual operating time (h/year)
2-Stroke Chain Saws < 6 HP	792.0
2-Stroke Lawn mowers	1,101.1
2-Stroke Leafblowers/Vacuums	976.5
2-Stroke Other Lawn & Garden Equipment	1,597.1
2-Stroke Trimmers/Edgers/Brush Cutter	1,037.1
4-Stroke Chippers/Stump Grinders	851.5
4-Stroke Commercial Turf Equipment	383.5
4-Stroke Front Mowers	1,820.0
4-Stroke Lawn & Garden Tractors	114.3
4-Stroke Lawn mowers	669.4
4-Stroke Other Lawn & Garden Equipment	1,750.0
4-Stroke Rotary Tillers	296.0
4-Stroke Shredders < 6 HP	104.0
Diesel Chippers/Stump Grinders	1,482.0
Diesel Commercial Turf Equipment	949.0
Diesel Front Mowers	1,638.1
Diesel Lawn & Garden Tractors	1,337.5
Diesel Other Lawn & Garden Equipment	1,906.7
Diesel Rear Engine Riding Mowers	904.4
Diesel Rotary Tillers	1,820.0

In-service lawn mowing and garden equipment (i.e. golf course plus LGA) population by equipment description and maximum rated power range data for the GMR is presented in Table 3-124 and shown in Figure 3-54.

Table 3-124: Lawn mowing and garden equipment (public open space) population in the GMR

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
2-Str Chain Saws < 6 HP (com)	2,039	96	-	-	-	2,135
2-Str Commercial Turf Equipment (com)	130	-	-	-	-	130
2-Str Lawn mowers (com)	844	990	-	-	-	1,834
2-Str Leafblowers/Vacuums (com)	2,327	110	-	-	-	2,437
2-Str Other Lawn & Garden Eqp. (com)	64	75	-	-	-	139
2-Str Trimmers/Edgers/Brush Cutter (com)	3,863	183	-	-	-	4,046
4-Str Chippers/Stump Grinders (com)	-	54	21	2	2	79
4-Str Commercial Turf Equipment (com)	-	717	278	28	28	1,051
4-Str Front Mowers (com)	-	-	369	37	37	443

Equipment description	2008 equipment population					
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	Grand Total
4-Str Golf Carts	-	-	778	-	-	778
4-Str Lawn & Garden Tractors (com)	-	257	100	10	10	377
4-Str Lawn mowers (com)	211	1,698	659	-	-	2,568
4-Str Leafblowers/Vacuums (com)	-	113	-	-	-	113
4-Str Other Lawn & Garden Eqp. (com)	30	244	95	9	9	388
4-Str Rear Engine Riding Mowers (com)	-	44	17	2	2	65
4-Str Rotary Tillers < 6 HP (com)	-	129	-	-	-	129
4-Str Shredders < 6 HP (com)	2	18	-	-	-	20
Dsl - Chippers/Stump Grinders (com)	-	-	-	-	137	137
Dsl - Commercial Mowers (com)	-	752	291	29	29	1,102
Dsl - Commercial Turf Equipment (com)	-	-	165	17	17	198
Dsl - Front Mowers (com)	-	442	171	17	17	648
Dsl - Lawn & Garden Tractors (com)	-	-	1,070	107	107	1,284
Dsl - Other Lawn & Garden Eqp. (com)	-	-	-	96	96	192
Dsl - Rear Engine Riding Mowers (com)	-	250	97	10	10	367
Dsl - Rotary Tillers < 6 HP (com)	-	10	-	-	-	10
Dsl - Specialty Vehicle Carts	-	-	-	65	65	130
Grand Total	9,510	6,184	4,111	429	566	20,800

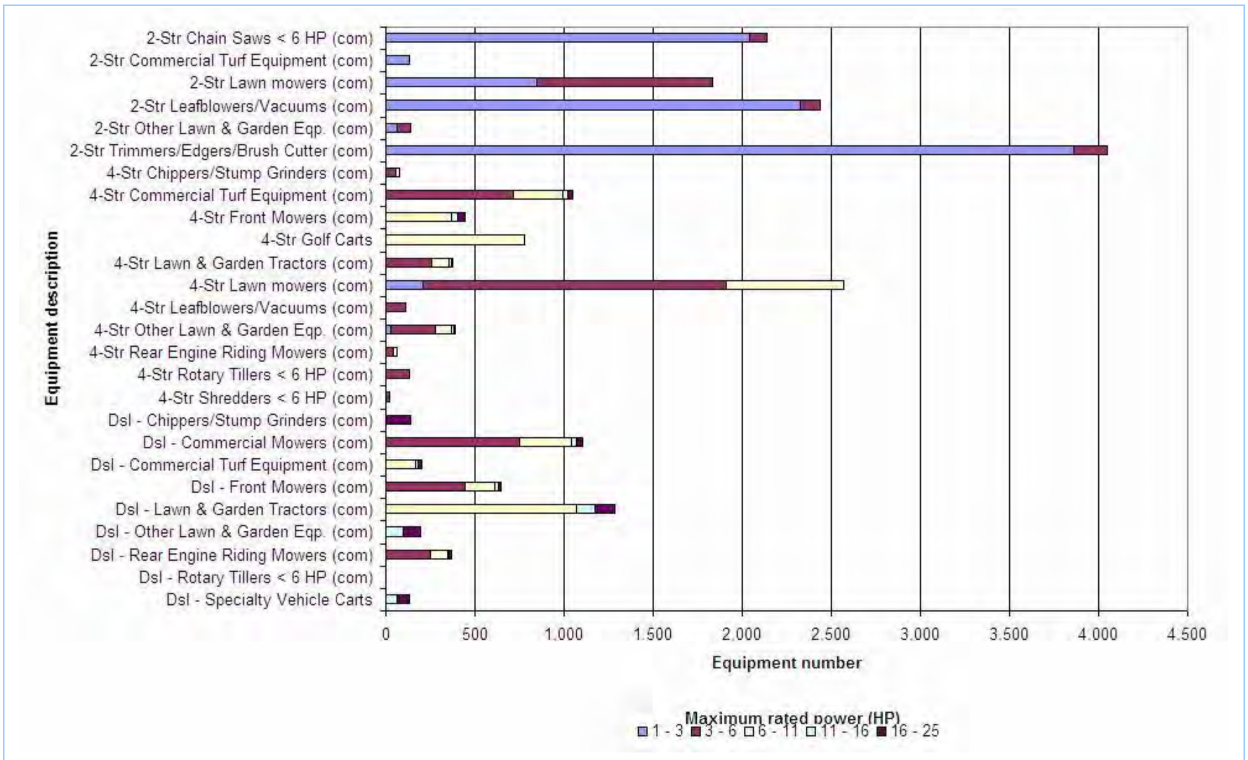

Figure 3-54: Lawn mowing and garden equipment (public open space) population in the GMR

The annual operating time of in-service lawn mowing and garden equipment (i.e. golf course plus LGA) have been estimated from the commercial survey results (DECC, 2007b). In-service lawn mowing equipment annual operating time by equipment description for the GMR is presented in Table 3-125 and shown in Figure 3-55.

Table 3-125: Lawn mowing and garden equipment (public open space) annual operating time in the GMR

Equipment description	Annual operating time (h/year)
2-Stroke Chain Saws < 6 HP (com)	622.5
2-Stroke Commercial Turf Equipment (com)	286.0
2-Stroke Lawn mowers (com)	898.1
2-Stroke Leafblowers/Vacuums (com)	898.3
2-Stroke Other Lawn & Garden Equipment (com)	1,597.1
2-Stroke Trimmers/Edgers/Brush Cutters (com)	964.1
4-Stroke Chippers/Stump Grinders (com)	851.5
4-Stroke Commercial Turf Equipment (com)	234.9
4-Stroke Front Mowers (com)	1,167.8
4-Stroke Golf Carts	1,135.3
4-Stroke Lawn & Garden Tractors (com)	114.3
4-Stroke Lawn mowers (com)	613.4
4-Stroke Leafblowers/Vacuums (com)	612.9
4-Stroke Other Lawn & Garden Equipment (com)	2,504.2
4-Stroke Rear Engine Riding Mowers (com)	861.3
4-Stroke Rotary Tillers < 6 HP (com)	296.0
4-Stroke Shredders < 6 HP (com)	104.0
Diesel Chippers/Stump Grinders (com)	575.8
Diesel Commercial Turf Equipment (com)	949.0
Diesel Front Mowers (com)	1,413.2
Diesel Lawn & Garden Tractors (com)	647.5
Diesel Lawn mowers (com)	840.4
Diesel Other Lawn & Garden Equipment (com)	1,965.2
Diesel Rear Engine Riding Mowers (com)	904.4
Diesel Rotary Tillers < 6 HP (com)	1,820.0
Diesel Specialty Vehicle Carts	1,007.5

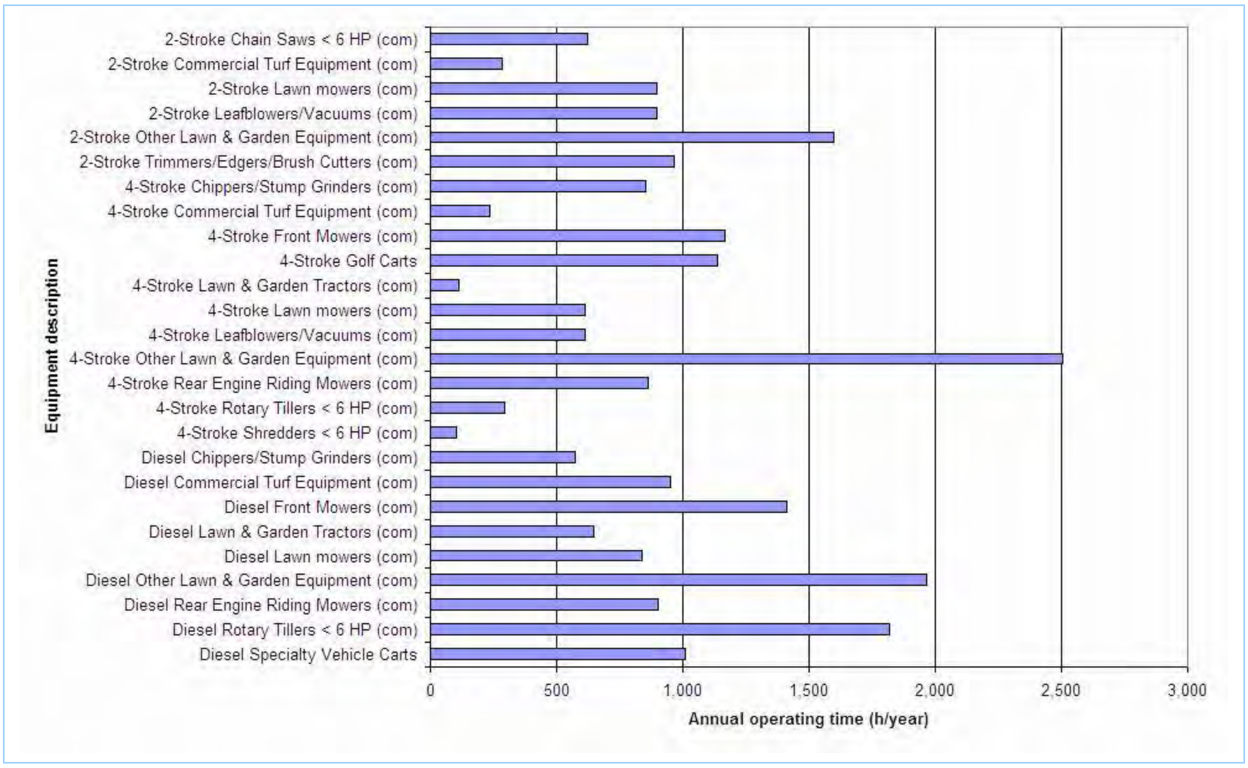

Figure 3-55: Lawn mowing and garden equipment (public open space) annual operating time in the GMR

Exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population (DECC, 2007b), annual operating time (DECC, 2007b), fuel properties (Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECC, 2007b; and TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009).

Figure 3-56 shows the NonRoad Model splash screen for the lawn mowing and garden equipment (public open space) emission estimation simulation.

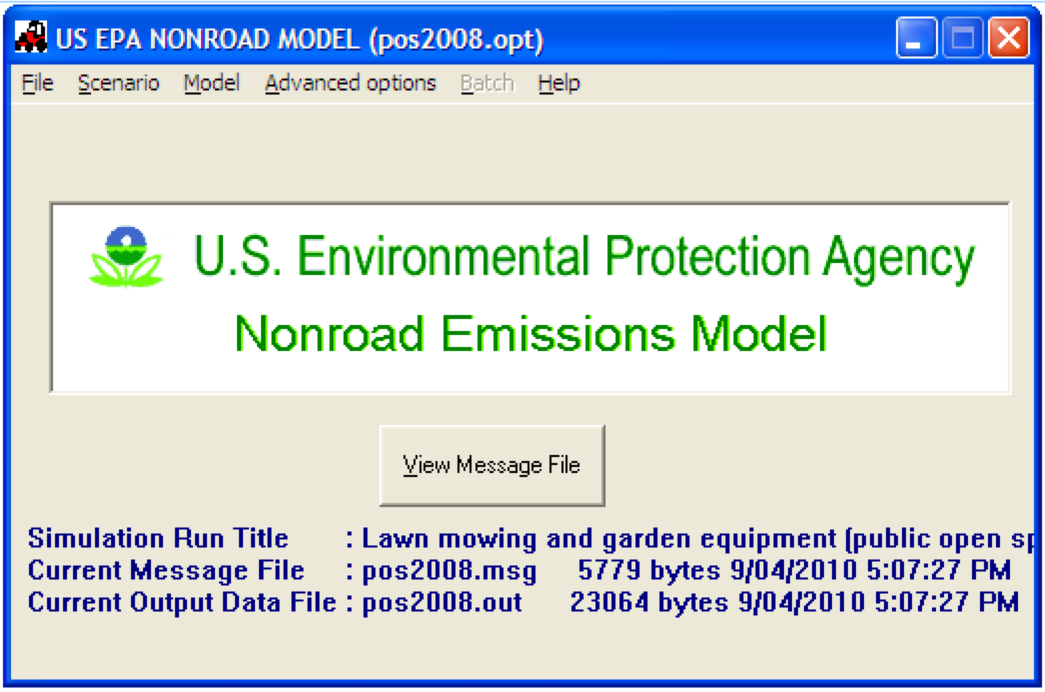

Figure 3-56: Lawn mowing and garden equipment (public open space) NonRoad Model splash screen

Figure 3-57 shows the NonRoad Model options screen for the lawn mowing and garden equipment (public open space) emission estimation simulation.

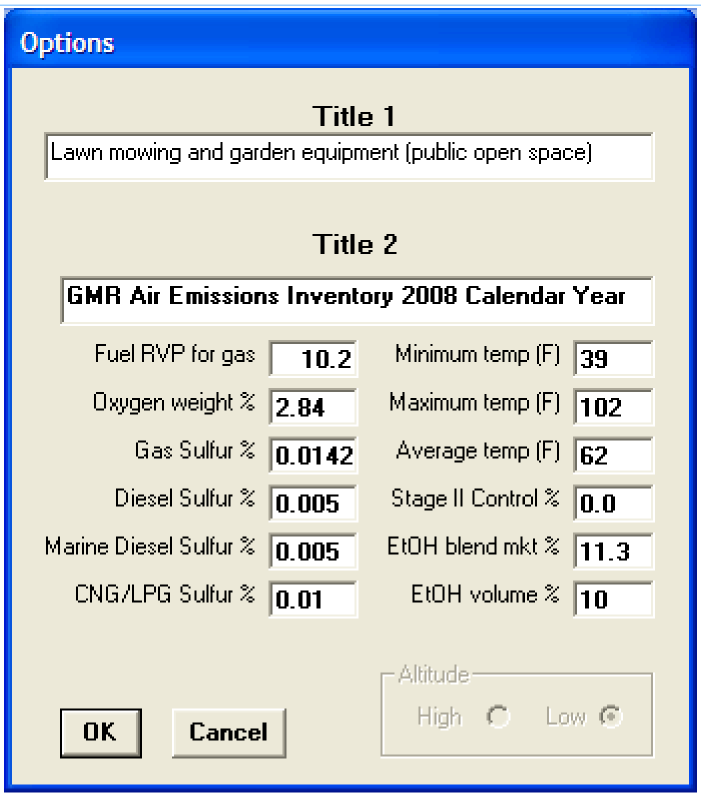

Figure 3-57: Lawn mowing and garden equipment (public open space) NonRoad Model options

In 2008, 677,384 kL and 6,009,999 kL of ethanol blended and total automotive gasoline, respectively was sold in NSW, so ethanol blended automotive gasoline has 11.3% share of the NSW market for all automotive gasoline (DRET, 2009) and contains 10% ethanol by volume (Attorney-General's Department, 2008).

The NonRoad Model has been run with the optional daily minimum, maximum and average ambient temperature and petrol RVP variation file. Table 3-126 presents the daily minimum, maximum and average ambient temperature (Hurley, 2005) and petrol RVP by month (PCO, 2011) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-126: Lawn mowing and garden equipment (public open space) NonRoad Model ambient temperature and petrol RVP by month

Month	RVP (psi)	T_{min} (°F)	T_{max} (°F)	T_{avg} (°F)
January	9.0	57.1	101.7	76.7
February	9.0	59.9	94.8	74.7
March	9.9	54.0	87.8	67.6
April	10.9	51.1	74.0	59.9
May	10.9	47.9	67.0	54.5
June	10.9	43.0	64.3	50.5
July	10.9	39.9	62.1	48.0
August	10.9	39.4	65.0	49.3
September	10.9	41.7	71.9	54.4
October	10.9	45.3	80.3	60.2
November	9.9	48.5	92.2	68.3
December	9.0	54.7	101.6	76.4

Table 3-127 presents the lawn mowing and garden equipment power rating (AIA, 2005), useful life (USEPA, 2009) and population (DECC, 2007b) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-127: Lawn mowing and garden equipment (public open space) NonRoad Model population

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2260004011	2-Str Lawn mowers (com)	1	3	2.55	268	843.9
2260004011	2-Str Lawn mowers (com)	3	6	4.1	268	990.0
2260004021	2-Str Chain Saws < 6 HP (com)	1	3	2.11	191	2039.0
2260004021	2-Str Chain Saws < 6 HP (com)	3	6	3.916	191	96.5
2260004026	2-Str Trimmers/Edgers/Brush Cutter (com)	1	3	1.4	286.8	3863.3
2260004026	2-Str Trimmers/Edgers/Brush Cutter (com)	3	6	3.3	286.8	182.8
2260004031	2-Str Leafblowers/Vacuums (com)	1	3	1.41	609.7	2326.6
2260004031	2-Str Leafblowers/Vacuums (com)	3	6	3.42	609.7	110.1
2260004071	2-Str Commercial Turf Equipment (com)	1	3	3	988.9	129.6
2260004076	2-Str Other Lawn & Garden Eqp. (com)	1	3	2.34	200	63.9

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2260004076	2-Str Other Lawn & Garden Eqp. (com)	3	6	4.867	200	75.0
2265001050	4-Str Golf Carts	6	11	9.15	400	777.6
2265004011	4-Str Lawn mowers (com)	1	3	2.55	268	210.8
2265004011	4-Str Lawn mowers (com)	3	6	4.1	268	1698.5
2265004011	4-Str Lawn mowers (com)	6	11	6.24	400	658.6
2265004016	4-Str Rotary Tillers < 6 HP (com)	3	6	4.712	830.7	129.0
2265004031	4-Str Leafblowers/Vacuums (com)	3	6	3.4	609.7	113.4
2265004041	4-Str Rear Engine Riding Mowers (com)	3	6	5.105	200	44.2
2265004041	4-Str Rear Engine Riding Mowers (com)	6	11	9.153	627	17.1
2265004041	4-Str Rear Engine Riding Mowers (com)	11	16	12.61	627	1.7
2265004041	4-Str Rear Engine Riding Mowers (com)	16	25	18.26	750	1.7
2265004046	4-Str Front Mowers (com)	6	11	8	400	369.1
2265004046	4-Str Front Mowers (com)	11	16	13.47	400	37.0
2265004046	4-Str Front Mowers (com)	16	25	17	750	37.0
2265004051	4-Str Shredders < 6 HP (com)	1	3	2.986	200	2.2
2265004051	4-Str Shredders < 6 HP (com)	3	6	4.835	200	17.7
2265004056	4-Str Lawn & Garden Tractors (com)	3	6	5.002	200	257.2
2265004056	4-Str Lawn & Garden Tractors (com)	6	11	9.735	920	99.7
2265004056	4-Str Lawn & Garden Tractors (com)	11	16	13.61	920	10.0
2265004056	4-Str Lawn & Garden Tractors (com)	16	25	18.41	920	10.0
2265004066	4-Str Chippers/Stump Grinders (com)	3	6	3.5	200	54.2
2265004066	4-Str Chippers/Stump Grinders (com)	6	11	9.791	400	21.0
2265004066	4-Str Chippers/Stump Grinders (com)	11	16	15.32	400	2.1
2265004066	4-Str Chippers/Stump Grinders (com)	16	25	20.05	750	2.1
2265004071	4-Str Commercial Turf Equipment (com)	3	6	5.217	988.9	717.4
2265004071	4-Str Commercial Turf Equipment (com)	6	11	8.771	988.9	278.2
2265004071	4-Str Commercial Turf Equipment (com)	11	16	13.99	988.9	27.9
2265004071	4-Str Commercial Turf Equipment (com)	16	25	19.33	988.9	27.9
2265004076	4-Str Other Lawn & Garden Eqp. (com)	1	3	2.34	200	30.3
2265004076	4-Str Other Lawn & Garden Eqp. (com)	3	6	4.867	200	244.2
2265004076	4-Str Other Lawn & Garden Eqp. (com)	6	11	8.208	400	94.7
2265004076	4-Str Other Lawn & Garden Eqp. (com)	11	16	15.54	400	9.5
2265004076	4-Str Other Lawn & Garden Eqp. (com)	16	25	20.04	750	9.5
2270001060	Dsl - Specialty Vehicle Carts	11	16	15	2500	64.8
2270001060	Dsl - Specialty Vehicle Carts	16	25	21.27	2500	64.8
2270004011	Dsl - Commercial Mowers (com)	3	6	5	2500	751.7
2270004011	Dsl - Commercial Mowers (com)	6	11	7.35	2500	291.5
2270004011	Dsl - Commercial Mowers (com)	11	16	14.12	2500	29.2
2270004011	Dsl - Commercial Mowers (com)	16	25	20.87	2500	29.2
2270004016	Dsl - Rotary Tillers < 6 HP (com)	3	6	4.712	830.7	9.9
2270004041	Dsl - Rear Engine Riding Mowers (com)	3	6	5	2500	250.5
2270004041	Dsl - Rear Engine Riding Mowers (com)	6	11	7.35	2500	97.1
2270004041	Dsl - Rear Engine Riding Mowers (com)	11	16	14.12	2500	9.7
2270004041	Dsl - Rear Engine Riding Mowers (com)	16	25	20.87	2500	9.7
2270004046	Dsl - Front Mowers (com)	3	6	5	2500	442.3

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270004046	Dsl - Front Mowers (com)	6	11	7.35	2500	171.5
2270004046	Dsl - Front Mowers (com)	11	16	14.12	2500	17.2
2270004046	Dsl - Front Mowers (com)	16	25	20.87	2500	17.2
2270004056	Dsl - Lawn & Garden Tractors (com)	6	11	10.5	2500	1069.7
2270004056	Dsl - Lawn & Garden Tractors (com)	11	16	14.62	2500	107.2
2270004056	Dsl - Lawn & Garden Tractors (com)	16	25	20.03	2500	107.2
2270004066	Dsl - Chippers/Stump Grinders (com)	16	25	25	2500	136.9
2270004071	Dsl - Commercial Turf Equipment (com)	6	11	7.75	2500	165.3
2270004071	Dsl - Commercial Turf Equipment (com)	11	16	13.56	2500	16.6
2270004071	Dsl - Commercial Turf Equipment (com)	16	25	21.15	2500	16.6
2270004076	Dsl - Other Lawn & Garden Eqp. (com)	11	16	15	2500	95.9
2270004076	Dsl - Other Lawn & Garden Eqp. (com)	16	25	22.9	2500	95.9

Table 3-128 presents the lawn mowing and garden equipment load factor (USEPA, 2009) and annual operating time (DECC, 2007b) data used within the *NONROAD2008a Model* (USEPA, 2009).

Table 3-128: Lawn mowing and garden equipment (public open space) NonRoad Model load factor and annual operating time

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2260004011	2-Stroke Lawn mowers (com)	0	9999	0.33	898.1
2260004021	2-Stroke Chain Saws < 6 HP (com)	0	9999	0.70	622.5
2260004026	2-Stroke Trimmers/Edgers/Brush Cutters (com)	0	9999	0.91	964.1
2260004031	2-Stroke Leafblowers/Vacuums (com)	0	9999	0.94	898.3
2260004071	2-Stroke Commercial Turf Equipment (com)	0	9999	0.60	286.0
2260004076	2-Stroke Other Lawn & Garden Equipment (com)	0	9999	0.58	1597.1
2265001050	4-Stroke Golf Carts	0	9999	0.46	1135.3
2265004011	4-Stroke Lawn mowers (com)	0	9999	0.33	613.4
2265004016	4-Stroke Rotary Tillers < 6 HP (com)	0	9999	0.40	296.0
2265004031	4-Stroke Leafblowers/Vacuums (com)	0	9999	0.94	612.9
2265004041	4-Stroke Rear Engine Riding Mowers (com)	0	9999	0.38	861.3
2265004046	4-Stroke Front Mowers (com)	0	9999	0.65	1167.8
2265004051	4-Stroke Shredders < 6 HP (com)	0	9999	0.80	104.0
2265004056	4-Stroke Lawn & Garden Tractors (com)	0	9999	0.44	114.3
2265004066	4-Stroke Chippers/Stump Grinders (com)	0	9999	0.78	851.5
2265004071	4-Stroke Commercial Turf Equipment (com)	0	9999	0.60	234.9
2265004076	4-Stroke Other Lawn & Garden Equipment (com)	0	9999	0.58	2504.2
2270001060	Diesel Specialty Vehicle Carts	0	9999	0.21	1007.5
2270004011	Diesel Lawn mowers (com)	0	9999	0.43	840.4
2270004016	Diesel Rotary Tillers < 6 HP (com)	0	9999	0.43	1820.0
2270004041	Diesel Rear Engine Riding Mowers (com)	0	9999	0.43	904.4

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2270004046	Diesel Front Mowers (com)	0	9999	0.43	1413.2
2270004056	Diesel Lawn & Garden Tractors (com)	0	9999	0.43	647.5
2270004066	Diesel Chippers/Stump Grinders (com)	0	9999	0.43	575.8
2270004071	Diesel Commercial Turf Equipment (com)	0	9999	0.43	949.0
2270004076	Diesel Other Lawn & Garden Equipment (com)	0	9999	0.43	1965.2

The NonRoad Model has been run with the optional weekday/weekend and monthly temporal variation file. Section 3.7.6 provides further details about the temporal variation in exhaust and evaporative emissions from lawn mowing and garden equipment.

Table 3-129 presents the lawn mowing and garden equipment fuel consumption estimates from the *NONROAD2008a Model* (USEPA, 2009).

Table 3-129: Lawn mowing and garden equipment (public open space) NonRoad Model fuel consumption in the GMR

Classification	Equipment description	2008 fuel consumption (kL/year)			
		2-stroke petrol	4-stroke petrol	Diesel	Grand Total
Lawn and Garden Equipment (com)	Chain Saws < 6 HP	1,663	-	-	1,663
	Chippers/Stump Grinders	-	204	184	388
	Commercial Turf Equipment	56	659	165	880
	Front Mowers	-	1,780	539	2,319
	Lawn & Garden Tractors	-	91	905	997
	Lawn mowers	1,214	1,660	544	3,418
	Leafblowers/Vacuums	2,500	186	-	2,686
	Other Lawn & Garden Eqp.	307	2,334	668	3,310
	Rear Engine Riding Mowers	-	101	195	296
	Rotary Tillers < 6 HP	-	55	8	63
	Shredders < 6 HP	-	6	-	6
	Trimmers/Edgers/Brush Cutter	4,274	-	-	4,274
Lawn and Garden Equipment (com) Total		10,014	7,076	3,209	20,299
Recreational Equipment	Golf Carts	-	2,136	-	2,136
	Speciality Vehicle Carts	-	-	128	128
Recreational Equipment Total		-	2,136	128	2,263
Grand Total		10,014	9,212	3,336	22,562

3.7.4 Emission and Speciation Factors

Table 3-130 summarises the emission and speciation factors used for lawn mowing and garden equipment.

Table 3-130: Lawn mowing and garden equipment (public open space) emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10} and SO_2	2-stroke /4-stroke petrol and diesel exhaust	- *NONROAD2008a Model* (USEPA, 2009)
Criteria pollutants: VOC	2-stroke /4-stroke petrol and diesel exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009)
Criteria pollutants: TSP	2-stroke and 4-stroke petrol exhaust	- *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	diesel exhaust	- *PMPROF 116 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
Speciated NO_x	2-stroke /4-stroke petrol and diesel exhaust	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	2-stroke petrol exhaust	- *Table D-1 (Default 2-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 815 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	4-stroke petrol exhaust	- *Table D-1 (Default 4-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 816 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust	- *Table D-1 (Diesel) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 818 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	evaporative	- *Petrol Vapour Speciation Profile - Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Organic air toxics	2-stroke petrol exhaust	- *Table D-1 (Default 2-stroke Exhaust Baseline) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 815 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	4-stroke petrol	- *Table D-1 (Default 4-stroke Exhaust Baseline) - Documentation*

Substance	Emission source	Emission and speciation factor source
	exhaust	*for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 816 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust	- *Table D-1 (Diesel) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *ORGPROF 818 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	evaporative	- *Petrol Vapour Speciation Profile - Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
Metal air toxics	2-stroke petrol exhaust	- *Table D-3 (2-Stroke Metal/Fuel Fraction) Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	4-stroke petrol exhaust	- *Table D-3 (4-Stroke Metal/Fuel Fraction) Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	diesel exhaust	- *Table D-3 (Diesel Metal/Activity Fraction) Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005) - *PMPROF 425 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
Polycyclic aromatic hydrocarbons: PAH	2-stroke petrol exhaust	- *Table D-2 (2-Stroke) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	4-stroke petrol exhaust	- *Table D-2 (4-Stroke) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	diesel exhaust	- *Table D-2 (Diesel) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
Polychlorinated dibenzo-p-dioxins	2-stroke petrol exhaust	- *Table D-1 (2-Stroke Dioxin/Furan/Fuel Fraction) - Documentation for Aircraft, Commercial Marine Vessel,*

Substance	Emission source	Emission and speciation factor source
and Polychlorinated dibenzofurans: PCDD and PCDF		*Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	4-stroke petrol exhaust	- *Table D-1 (4-Stroke Dioxin/Furan/Fuel Fraction) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	diesel exhaust	- *Table D-1 (Diesel Dioxin/Furan/Fuel Fraction) - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
Ammonia	2-stroke /4-stroke petrol and diesel exhaust	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
Greenhouse gases: CH_4 and CO_2	2-stroke /4-stroke petrol and diesel exhaust	- *NONROAD2008a Model* (USEPA, 2009)
Greenhouse gases: N_2O	2-stroke /4-stroke petrol and diesel exhaust	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)

Table 3-131 presents average activity weighted 2-stroke/4-stroke petrol and diesel exhaust and evaporative emission factors for lawn mowing and garden equipment.

Table 3-131: Lawn mowing and garden equipment (public open space) emission factors

Emission source	Emission factors (kg/kL)											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
2-stroke petrol exhaust	1.85	0.058	0.029	0.099	11.79	10.85	374.76	3.262	847.95	1,181.76	0.0171	3.29×10^{-12}
4-stroke petrol exhaust	4.53	0.058	0.029	0.181	0.96	0.89	65.78	7.050	1,132.04	2,106.19	0.0999	3.29×10^{-12}
Diesel exhaust	43.51	0.069	0.022	0.082	5.37	5.21	8.21	0.125	26.73	2,688.54	0.0056	4.57×10^{-9}
2-stroke petrol evaporative	-	-	-	-	-	-	23.91	-	-	-	-	-
4-stroke petrol evaporative	-	-	-	-	-	-	14.38	0.65	-	-	-	-
Diesel evaporative	-	-	-	-	-	-	0.16	2.49×10^{-3}	-	-	-	-

3.7.5 Spatial Distribution of Emissions

Table 3-132 summarises the data used for spatially allocating emissions from lawn mowing and garden equipment.

Table 3-132: Lawn mowing and garden equipment (public open space) spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from lawn mowing and garden equipment (public open space)	Gridded 1 km x 1 km population estimates (≥ 50 persons per grid cell)	- *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Emissions from lawn mowing and garden equipment have been spatially distributed according to petrol and diesel consumption, which is proportional to population ≥ 50 persons in each 1 km by 1 km grid cell (TDC, 2009). The proportion of petrol and diesel consumption by LGA and region is presented in Table 3-133 and shown in Figure 3-58.

Table 3-133: Lawn mowing and garden equipment (public open space) spatial distribution of petrol and diesel consumption by LGA and region

LGA	2008 proportion of annual petrol and diesel consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.92	-	0.92
Auburn	-	-	1.34	-	1.34
Bankstown	-	-	3.36	-	3.36
Baulkham Hills	-	-	3.23	-	3.23
Blacktown	-	-	5.51	-	5.51
Blue Mountains	-	0.48	1.00	-	1.48
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.58	-	0.58
Camden	-	-	1.04	-	1.04
Campbelltown	-	-	2.88	-	2.88
Canada Bay	-	-	1.14	-	1.14
Canterbury	-	-	2.67	-	2.67
Cessnock	3.36×10^{-2}	0.79	-	-	0.83
Dungog	-	6.63×10^{-2}	-	-	6.63×10^{-2}
Fairfield	-	-	3.64	-	3.64
Gosford	-	0.85	2.22	-	3.06
Great Lakes	-	3.15×10^{-2}	-	-	3.15×10^{-2}
Hawkesbury	-	5.14×10^{-3}	1.04	-	1.04
Holroyd	-	-	1.84	-	1.84
Hornsby	-	-	3.06	-	3.06
Hunters Hill	-	-	0.18	-	0.18
Hurstville	-	-	1.58	-	1.58
Kiama	-	0.26	-	-	0.26
Kogarah	-	-	1.11	-	1.11
Ku-ring-gai	-	-	2.06	-	2.06
Lake Macquarie	1.98	1.72	-	-	3.70

LGA	2008 proportion of annual petrol and diesel consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Lane Cove	-	-	0.55	-	0.55
Leichhardt	-	-	0.77	-	0.77
Lithgow	-	0.29	-	-	0.29
Liverpool	-	-	3.40	-	3.40
Maitland	0.10	1.11	-	-	1.21
Manly	-	-	0.65	-	0.65
Marrickville	-	-	1.68	-	1.68
Mid-western Regional	-	3.67×10^{-2}	-	-	3.67×10^{-2}
Mosman	-	-	0.60	-	0.60
Muswellbrook	-	0.23	-	-	0.23
N/A	2.48×10^{-2}	5.06×10^{-2}	0.36	6.08×10^{-2}	0.49
Newcastle	2.90	-	-	-	2.90
North Sydney	-	-	1.04	-	1.04
Oberon	-	1.64×10^{-2}	-	-	1.64×10^{-2}
Parramatta	-	-	2.94	-	2.94
Penrith	-	-	3.36	-	3.36
Pittwater	-	-	1.05	-	1.05
Port Stephens	3.70×10^{-2}	0.98	-	-	1.02
Randwick	-	-	2.53	-	2.53
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.03	-	2.03
Shellharbour	-	0.94	-	0.30	1.24
Singleton	-	0.30	-	-	0.30
Strathfield	-	-	0.75	-	0.75
Sutherland	-	-	4.10	-	4.10
Sydney	-	-	3.23	-	3.23
Unincorporated	-	-	0.82	-	0.82
Warringah	-	-	2.72	-	2.72
Waverley	-	-	1.10	-	1.10
Willoughby	-	-	1.34	-	1.34
Wingecarribee	-	0.73	1.48×10^{-3}	-	0.73
Wollondilly	-	1.10×10^{-2}	0.60	-	0.61
Wollongong	-	-	0.29	3.41	3.70
Woollahra	-	-	0.86	-	0.86
Wyong	-	2.72	-	-	2.72
Grand Total	5.08	11.62	79.53	3.77	100.00

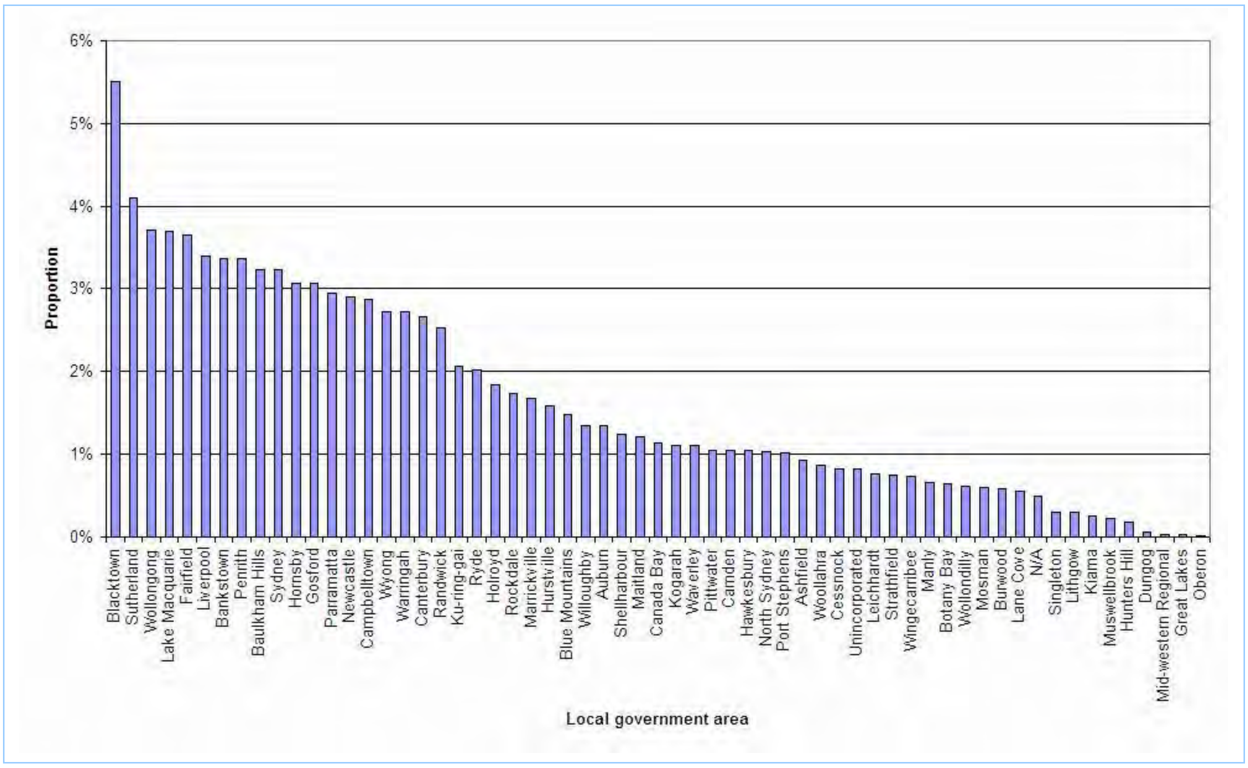

Figure 3-58: Lawn mowing and garden equipment (public open space) spatial distribution of petrol and diesel consumption by LGA

Figure 3-59 shows the spatial distribution of lawn mowing and garden equipment emissions.

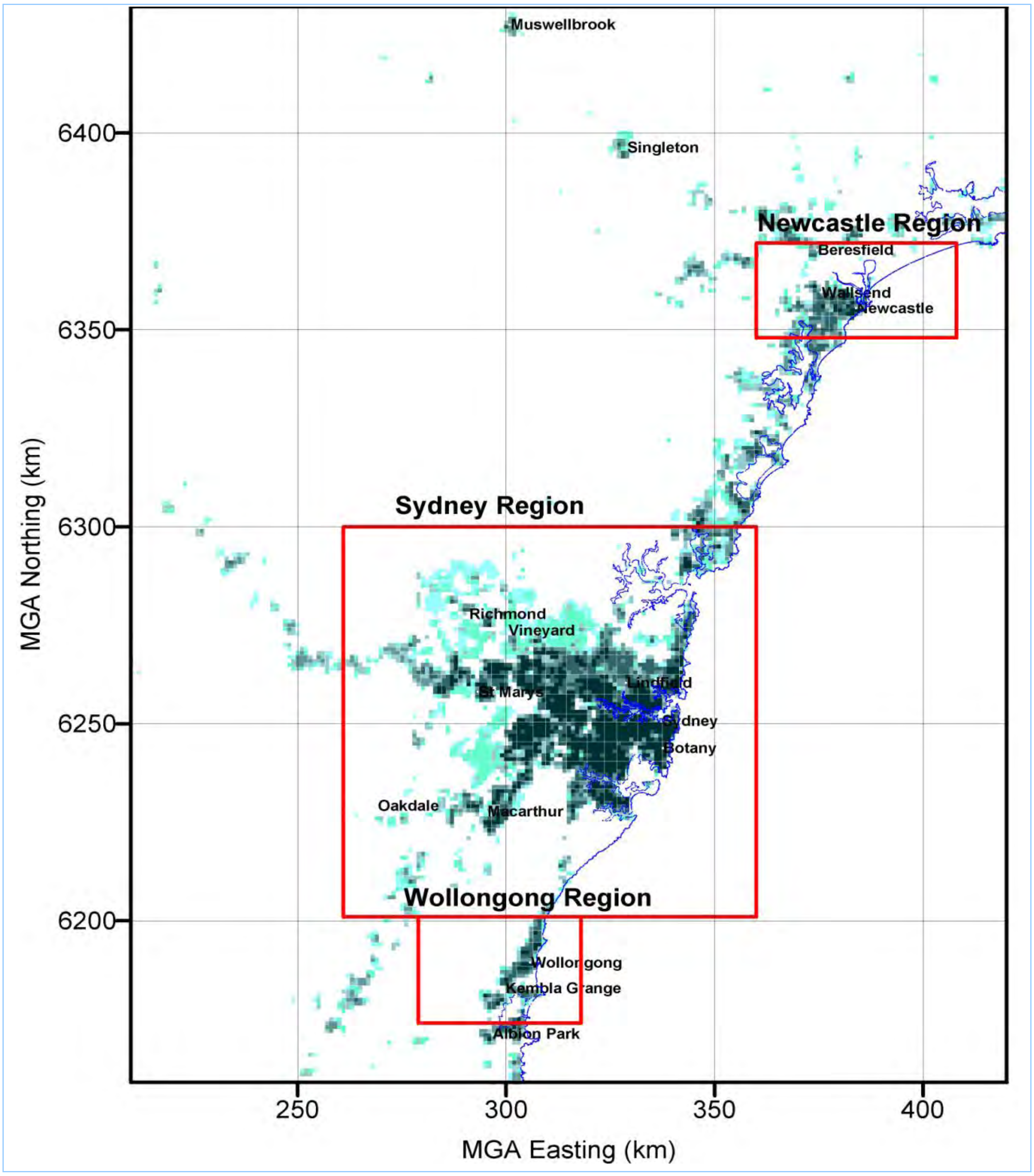

Figure 3-59: Lawn mowing and garden equipment (public open space) spatial distribution of emissions

3.7.6 *Temporal Variation of Emissions*

Table 3-134 summarises the data used to estimate the temporal variation in emissions from lawn mowing and garden equipment.

Table 3-134: Lawn mowing and garden equipment (public open space) temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from lawn mowing and garden equipment (public open space)	Monthly: Derived from domestic survey	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009)
	Daily and hourly: Derived from commercial survey	- *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b)

The temporal variation in exhaust and evaporative emissions from lawn mowing and garden equipment have been estimated using equipment population (DECC, 2007b), annual operating time (DECC, 2007b), fuel properties (Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECC, 2007b; and TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009). Hourly temporal variation profiles for exhaust emissions are presented in Table 3-135 and shown in Figure 3-60.

Table 3-135: Lawn mowing and garden equipment (public open space) exhaust hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	-	13	10.71
2	-	14	10.71
3	-	15	10.71
4	-	16	7.84
5	0.15	17	1.22
6	0.57	18	-
7	4.61	19	-
8	10.67	20	-
9	10.71	21	-
10	10.71	22	-
11	10.71	23	-
12	10.71	24	-

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-136 (weighted hourly composite) and shown in Figure 3-61 (weighted hourly composite by source type).

Table 3-136: Lawn mowing and garden equipment (public open space) evaporative hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	0.11	0.79	13	10.60	9.59
2	0.11	0.78	14	10.59	9.56
3	0.11	0.77	15	10.57	9.49
4	0.10	0.76	16	7.76	7.23
5	0.25	0.87	17	1.35	2.13

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
6	0.64	1.19	18	0.15	1.06
7	4.51	4.26	19	0.13	0.94
8	10.34	8.91	20	0.12	0.87
9	10.46	9.17	21	0.11	0.83
10	10.52	9.36	22	0.11	0.81
11	10.57	9.49	23	0.11	0.80
12	10.59	9.56	24	0.11	0.79

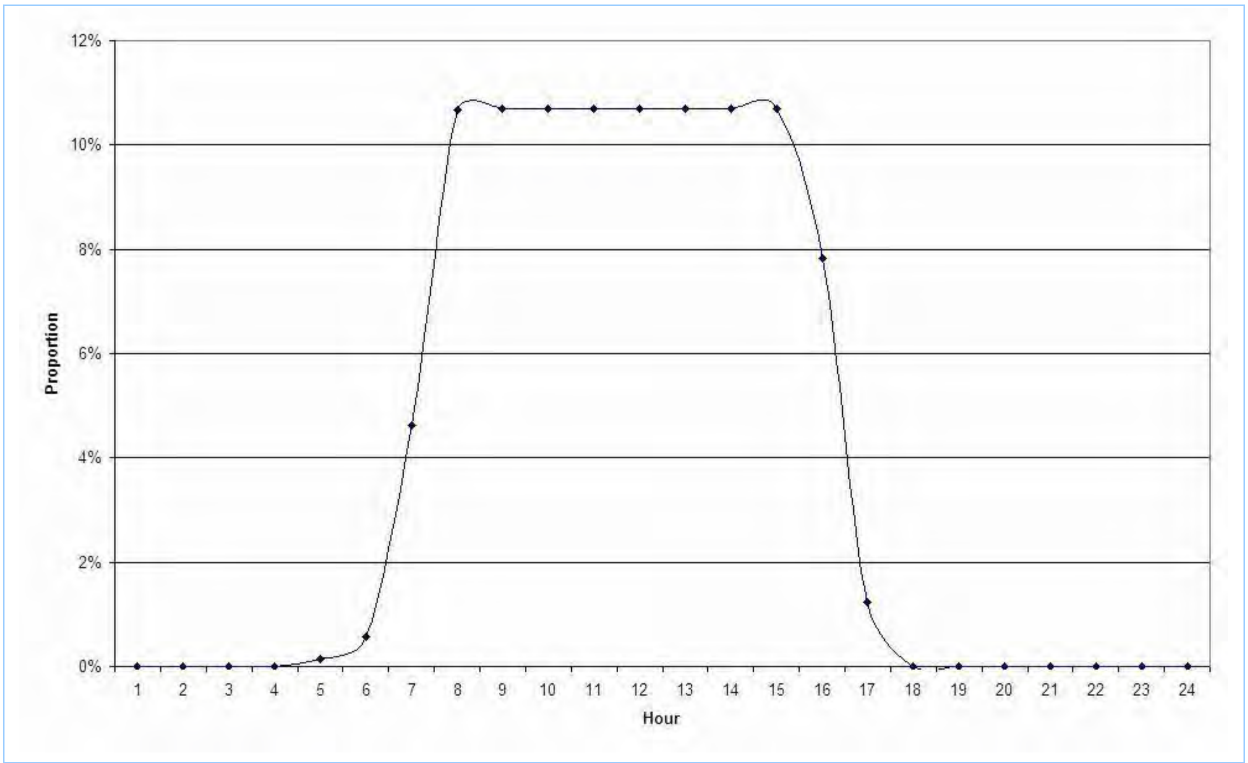

Figure 3-60: Lawn mowing and garden equipment (public open space) exhaust hourly temporal profile

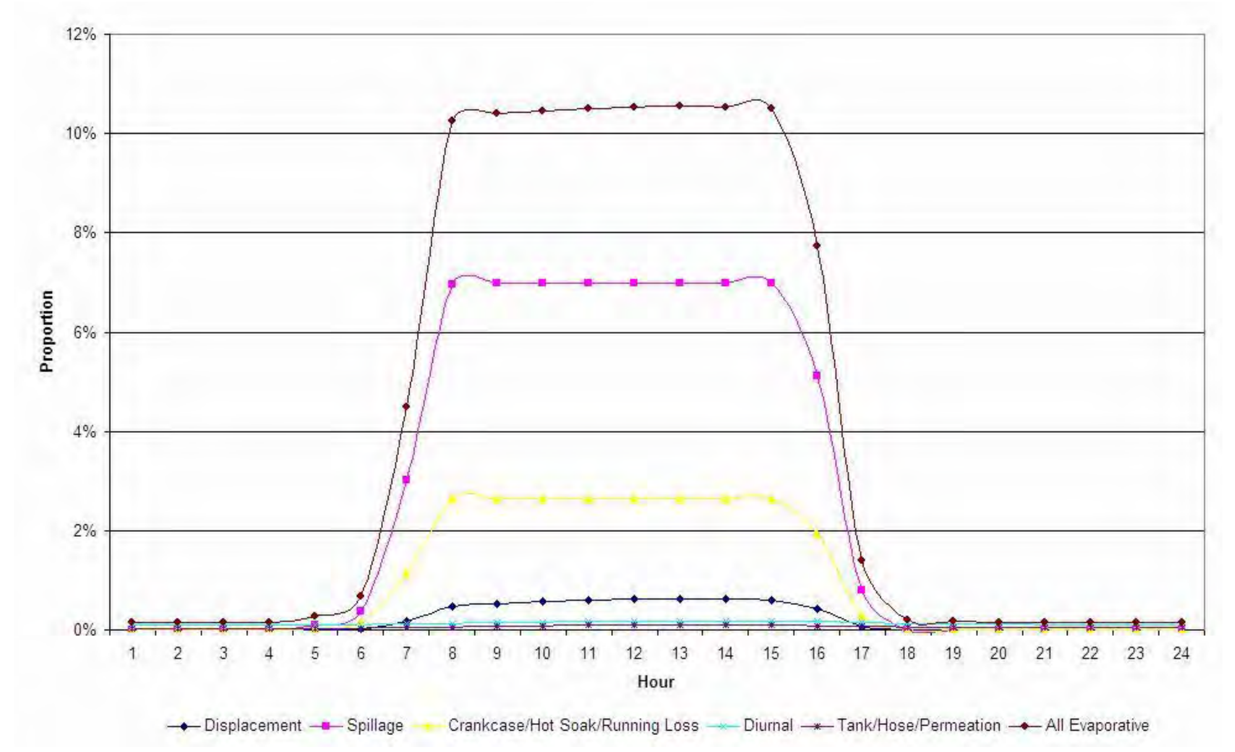

Figure 3-61: Lawn mowing and garden equipment (public open space) evaporative hourly temporal profile

Daily temporal variation profiles for exhaust emissions are presented in Table 3-137 and shown in Figure 3-62.

Table 3-137: Lawn mowing and garden equipment (public open space) exhaust daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	19.18	19.18	19.18	19.18	19.18	2.32	1.76

Daily temporal variation profiles for evaporative emissions are presented in Table 3-138 (weighted daily composite) and shown in Figure 3-63 (weighted daily composite by source type).

Table 3-138: Lawn mowing and garden equipment (public open space) evaporative daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	18.96	18.96	18.96	18.96	18.96	2.96	2.25

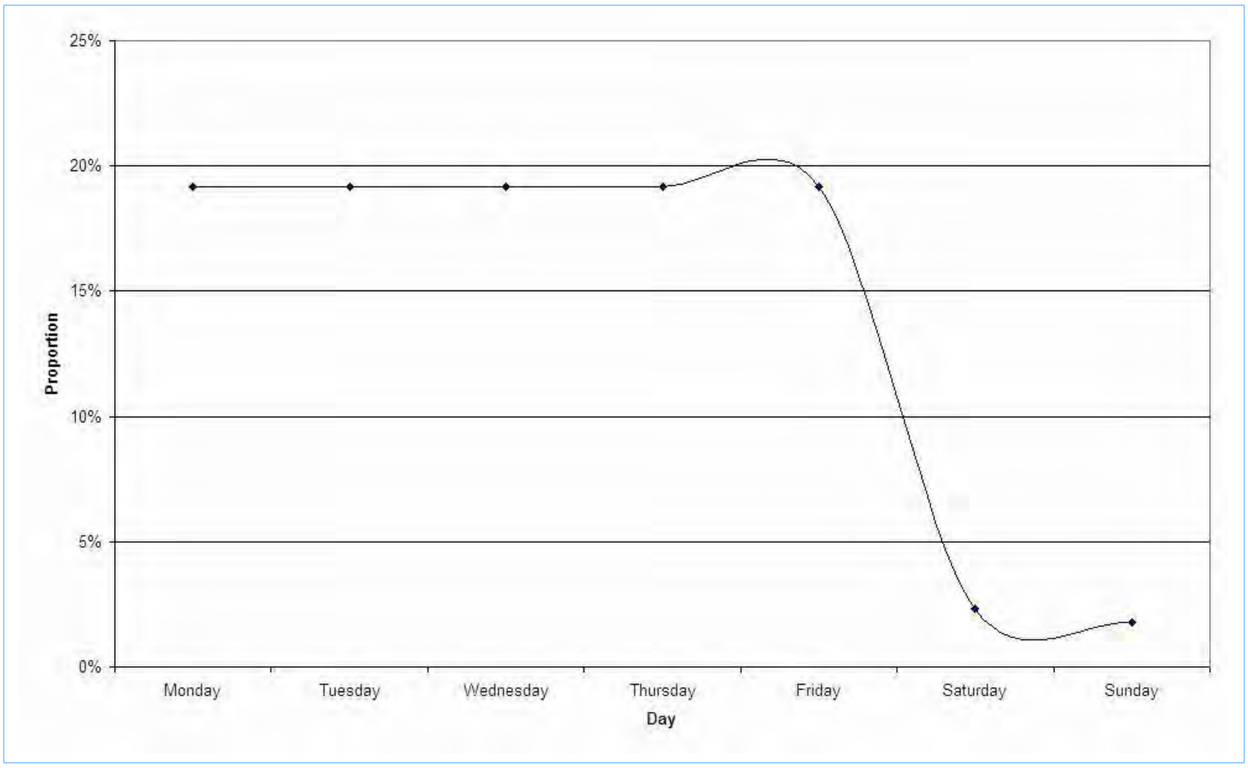

Figure 3-62: Lawn mowing and garden equipment (public open space) exhaust daily temporal profile

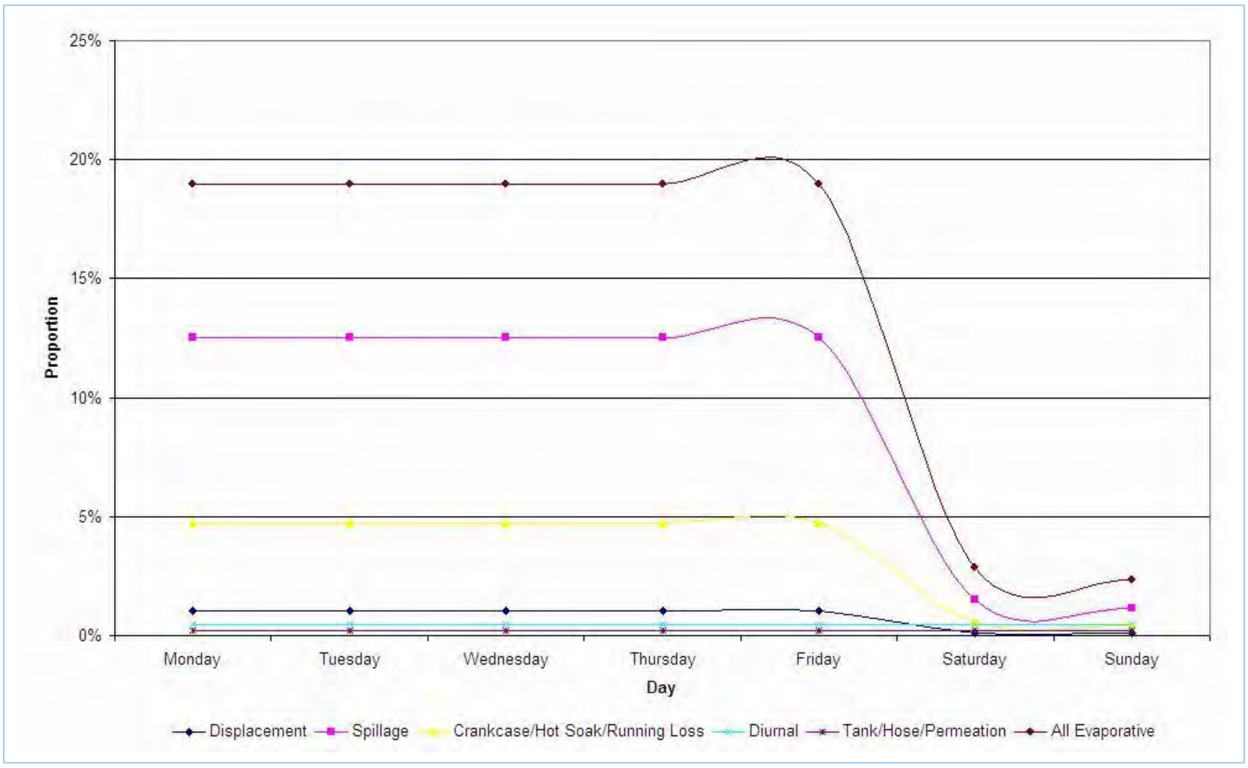

Figure 3-63: Lawn mowing and garden equipment (public open space) evaporative daily temporal profile

Monthly temporal variation profiles for exhaust emissions are presented in Table 3-139 and shown in Figure 3-64.

Table 3-139: Lawn mowing and garden equipment (public open space) exhaust monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	12.86	July	3.64
February	11.46	August	4.38
March	8.02	September	8.46
April	6.70	October	10.13
May	5.37	November	11.81
June	2.91	December	14.26

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-140 (weighted monthly composite) and shown in Figure 3-65 (weighted monthly composite by source type).

Table 3-140: Lawn mowing and garden equipment (public open space) evaporative monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	12.76	July	3.74
February	11.39	August	4.46
March	8.08	September	8.39
April	6.78	October	10.07
May	5.45	November	11.71
June	3.06	December	14.10

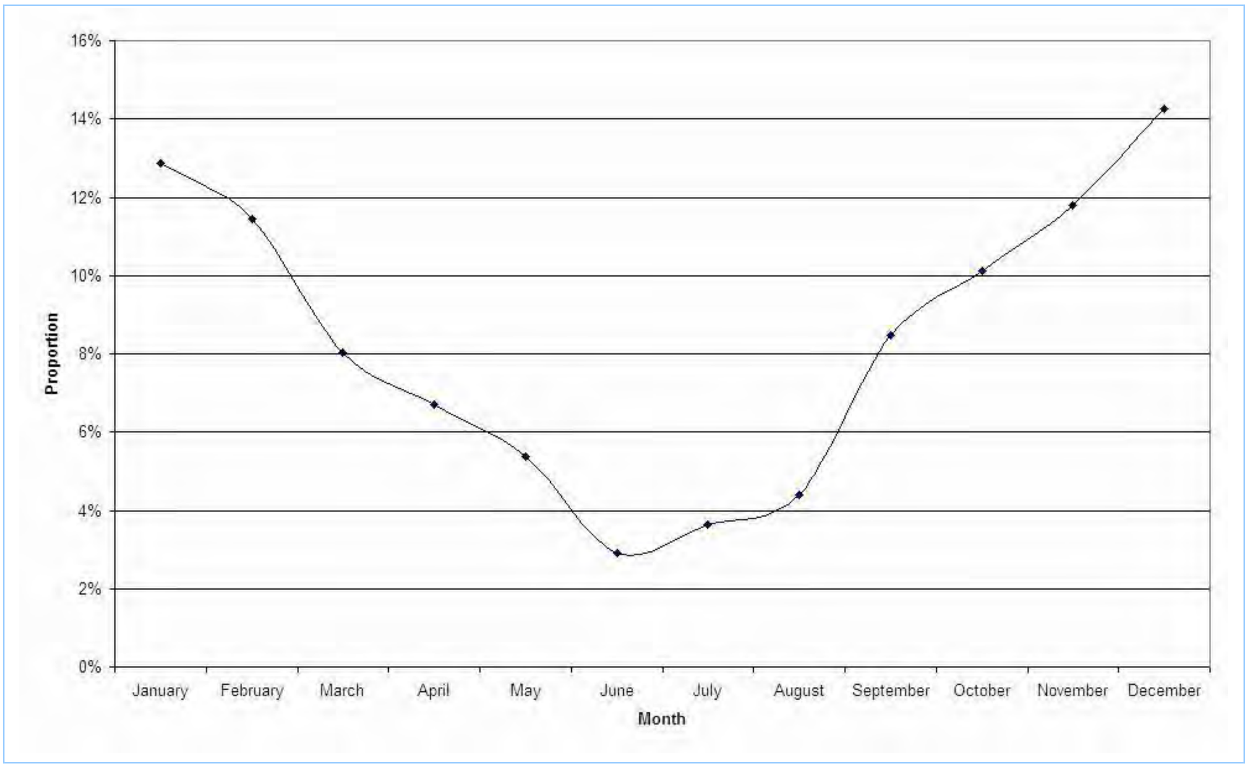

Figure 3-64: Lawn mowing and garden equipment (public open space) exhaust monthly temporal profile

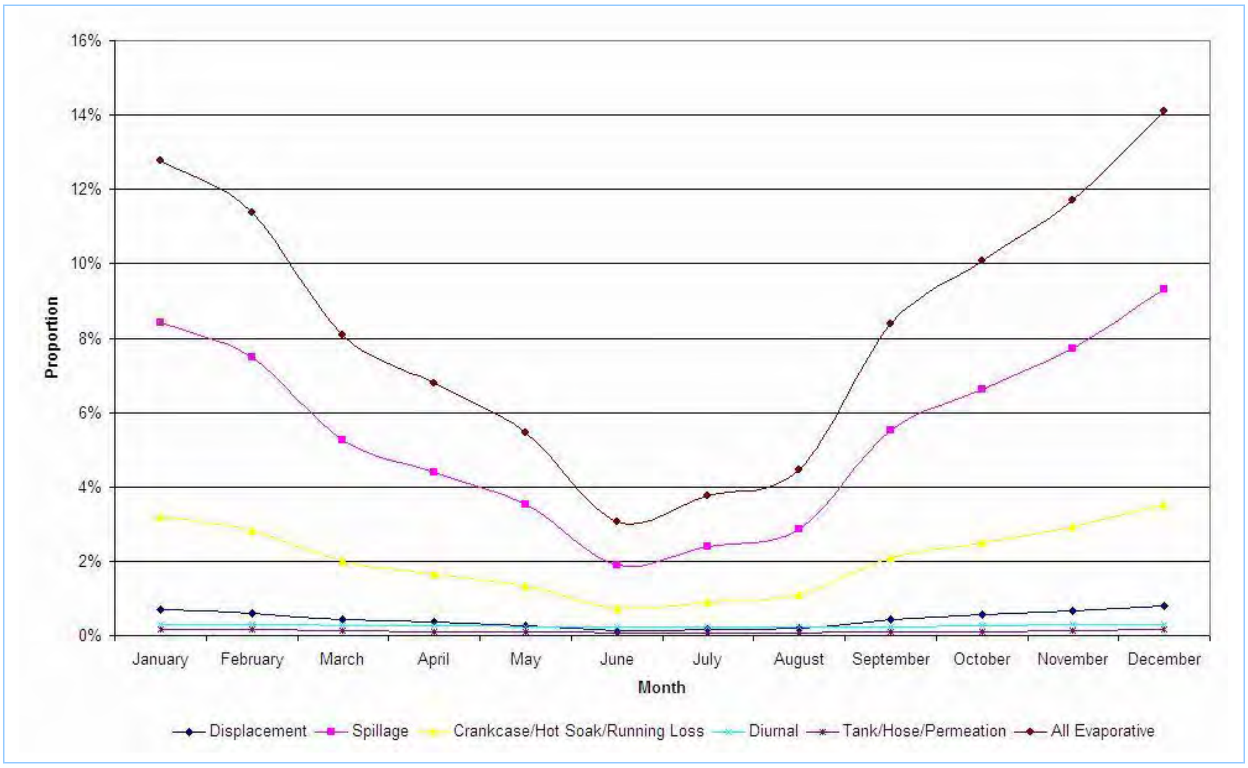

Figure 3-65: Lawn mowing and garden equipment (public open space) evaporative monthly temporal profile

3.7.7 Emission Estimates

Table 3-141 presents annual emissions of selected substances from lawn mowing and garden equipment by activity.

Table 3-141: Lawn mowing and garden equipment (public open space) emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Lawn Mowing and garden Equipment Exhaust (Public Open Space)	1,3-BUTADIENE	704	1,612	11,033	523	13,873
	ACETALDEHYDE	517	1,184	8,099	384	10,183
	BENZENE	6,436	14,733	100,821	4,776	126,767
	CARBON MONOXIDE	965,135	2,209,265	15,118,169	716,221	19,008,790
	FORMALDEHYDE	1,175	2,691	18,413	872	23,152
	ISOMERS OF XYLENE	22,583	51,694	353,746	16,759	444,782
	LEAD & COMPOUNDS	4.91	11	77	3.64	97
	OXIDES OF NITROGEN	10,427	23,869	163,335	7,738	205,369
	PARTICULATE MATTER ≤ 10 µm	7,358	16,843	115,255	5,460	144,915
	PARTICULATE MATTER ≤ 2.5µm	6,815	15,599	106,747	5,057	134,218
	POLYCYCLIC AROMATIC HYDROCARBONS	56	129	882	42	1,109
	SULFUR DIOXIDE	149	341	2,334	111	2,935
	TOLUENE	20,866	47,765	326,858	15,485	410,974
	TOTAL SUSPENDED PARTICULATE	7,585	17,363	118,819	5,629	149,397
	TOTAL VOLATILE ORGANIC COMPOUNDS	222,707	509,793	3,488,553	165,270	4,386,323
Lawn Mowing and Garden Equipment Evaporative (Public Open Space)	BENZENE	148	338	2,311	109	2,905
	ISOMERS OF XYLENE	104	238	1,629	77	2,049
	TOLUENE	359	822	5,628	267	7,077
	TOTAL VOLATILE ORGANIC COMPOUNDS	18,911	43,288	296,225	14,034	372,458

Table 3-142 presents annual emissions of selected substances from lawn mowing and garden equipment by source type.

Table 3-142: Lawn mowing and garden equipment (public open space) emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Exhaust - Petrol 2 Stroke	1,3-BUTADIENE	409	936	6,404	303	8,052
	ACETALDEHYDE	317	726	4,967	235	6,245
	BENZENE	4,794	10,974	75,093	3,558	94,418
	CARBON MONOXIDE	431,147	986,928	6,753,622	319,952	8,491,649
	FORMALDEHYDE	484	1,107	7,576	359	9,525
	ISOMERS OF XYLENE	20,482	46,886	320,842	15,200	403,410
	LEAD & COMPOUNDS	2.54	5.82	40	1.89	50
	OXIDES OF NITROGEN	938	2,148	14,698	696	18,481
	PARTICULATE MATTER ≤ 10 µm	5,996	13,726	93,930	4,450	118,103
	PARTICULATE MATTER ≤ 2.5µm	5,517	12,628	86,416	4,094	108,655
	POLYCYCLIC AROMATIC HYDROCARBONS	8.67	20	136	6.43	171
	SULFUR DIOXIDE	50	115	788	37	991
	TOLUENE	18,635	42,658	291,910	13,829	367,032
	TOTAL SUSPENDED PARTICULATE	6,182	14,151	96,835	4,588	121,756
	TOTAL VOLATILE ORGANIC COMPOUNDS	190,551	436,186	2,984,854	141,407	3,752,998
Exhaust - Petrol 4 Stroke	1,3-BUTADIENE	293	671	4,588	217	5,769
	ACETALDEHYDE	126	289	1,976	94	2,485
	BENZENE	1,614	3,695	25,285	1,198	31,792
	CARBON MONOXIDE	529,459	1,211,971	8,293,609	392,909	10,427,947
	FORMALDEHYDE	528	1,208	8,265	392	10,392
	ISOMERS OF XYLENE	2,086	4,775	32,674	1,548	41,083
	LEAD & COMPOUNDS	2.34	5.35	37	1.74	46
	OXIDES OF NITROGEN	2,118	4,849	33,179	1,572	41,718
	PARTICULATE MATTER ≤ 10 µm	451	1,033	7,068	335	8,887
	PARTICULATE MATTER ≤ 2.5µm	415	950	6,503	308	8,176
	POLYCYCLIC AROMATIC HYDROCARBONS	47	107	732	35	920
	SULFUR DIOXIDE	85	194	1,328	63	1,669
	TOLUENE	2,210	5,059	34,622	1,640	43,532
	TOTAL SUSPENDED PARTICULATE	465	1,065	7,287	345	9,162
	TOTAL VOLATILE ORGANIC COMPOUNDS	30,766	70,425	481,924	22,831	605,946
Exhaust – Diesel	1,3-BUTADIENE	2.59	5.92	41	1.92	51
	ACETALDEHYDE	74	169	1,156	55	1,453
	BENZENE	28	65	443	21	557

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	CARBON MONOXIDE	4,529	10,366	70,938	3,361	89,194
	FORMALDEHYDE	164	376	2,573	122	3,235
	ISOMERS OF XYLENE	15	34	230	11	290
	LEAD & COMPOUNDS	2.81×10^{-2}	6.44×10^{-2}	0.44	2.09×10^{-2}	0.55
	OXIDES OF NITROGEN	7,371	16,872	115,458	5,470	145,171
	PARTICULATE MATTER ≤ 10 µm	910	2,083	14,256	675	17,925
	PARTICULATE MATTER ≤ 2.5µm	883	2,021	13,829	655	17,387
	POLYCYCLIC AROMATIC HYDROCARBONS	0.94	2.16	15	0.70	19
	SULFUR DIOXIDE	14	32	219	10	275
	TOLUENE	21	48	326	15	410
	TOTAL SUSPENDED PARTICULATE	938	2,148	14,697	696	18,479
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,390	3,182	21,775	1,032	27,379
Evaporative	BENZENE	148	338	2,311	109	2,905
	ISOMERS OF XYLENE	104	238	1,629	77	2,049
	TOLUENE	359	822	5,628	267	7,077
	TOTAL VOLATILE ORGANIC COMPOUNDS	18,911	43,288	296,225	14,034	372,458

3.7.8 *Emission Projection Methodology*

Table 3-143 summarises the data used to estimate the emission projection factors for lawn mowing and garden equipment, while Figure 3-66 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-143: Lawn mowing and garden equipment (public open space) emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from lawn mowing and garden equipment (public open space)	Final energy consumption for commercial and services using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

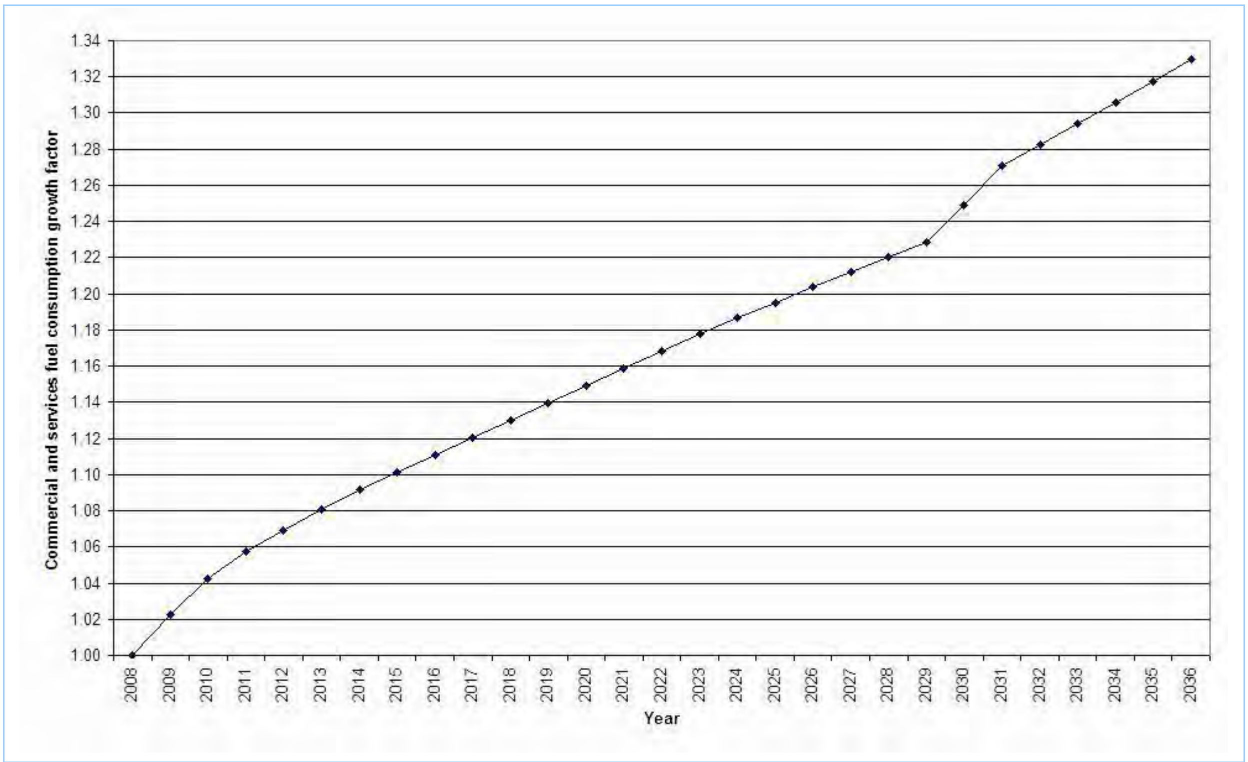

Figure 3-66: Lawn mowing and garden equipment (public open space) emission projection factors

3.8 Liquid Fuel Combustion

3.8.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes emissions of combustion products from liquid fuel fired residential space and water heaters.

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of liquid fuel fired residential space and water heater ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[42] located in the GMR. The survey results include data about: heater number; fuel type; quantity of fuel used; and frequency and duration of heater use by hour, day and month (TR, 2009).

- *Heater type*

The inventory includes small boilers, furnaces and heaters used in residential applications as follows:

  - *Space heater; and*
  - *Water heater.*

- *Fuel type*

The inventory includes residential space and water heaters that use distillate heating oil.

Table 3-144 presents the liquid fuel type and properties used in the inventory (Caltex, 2011; and USEPA, 2010b).

Table 3-144: Liquid fuel type and properties

Fuel type	Sulfur content (ppm)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Heating oil	500	0.820	37.6	87.25

3.8.2 *Emission Estimation Methodology*

Table 3-145 summarises the emission estimation methodology used for liquid fuel combustion.

[42] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.

Table 3-145: Liquid fuel combustion emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust emissions from liquid fuel combustion in space and water heaters	- *Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006)

Emissions of combustion products from liquid fuel fired residential space and water heaters have been estimated using fuel consumption based emission factors combined with activity rates. Activity rates include heater number, fuel type and quantity of fuel used (TR, 2009). Emissions have been determined using Equation 11 (Pechan, 2006):

$$E_i = C \times EF_i \qquad \textbf{Equation 11}$$

where:			
E_i	=	Emissions of substance i	(kg/year)
C	=	Heating oil consumption	(kL/year)
EF_i	=	Emission factor for substance i	(kg/kL)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)

3.8.3 *Activity Data*

Table 3-146 summarises the activity data used for liquid fuel combustion.

Table 3-146: Liquid fuel combustion activity data

Activity data	Activity data source
Liquid fuel consumption	- *Domestic Liquid Fuel Combustion Pollution Survey* (TR, 2009)
Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

A domestic survey of liquid fuel fired residential space and water heater ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: heater number; fuel type; quantity of fuel used; and frequency and duration of heater use by hour, day and month (TR, 2009).

The key considerations in designing and conducting a domestic survey include:

Survey method - The domestic survey has been conducted using the computer assisted telephone interview (CATI) method for recruiting households to complete either an on-line or mail-out questionnaire.

Sample size - To provide a reasonable level of precision for estimating liquid fuel combustion activity rates across all households in the GMR, the survey sample was sized accordingly. While a total of 832 households were recruited, 31 households were outside the GMR so they were excluded from the survey. Activity rates for liquid fuel combustion have been based on survey responses from 801 households in the GMR.

Confidence interval and confidence level - The confidence interval quantifies the uncertainty or range in possible values. For example, for a confidence interval of 3.5% and where 47% percent of the sample picks a particular answer one can be "sure" that if the question has been asked of the entire relevant population, between 43.5% (47-3.5) and 50.5% (47+3.5) would have picked that answer.

The confidence level quantifies the level of certainty to which an estimate can be trusted. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means one can be 95% certain. Most researchers use the 95% confidence level.

When combining the confidence level and confidence interval together, one can be 95% sure that the true answer for the entire relevant population is between 43.5% and 50.5% for the example described above.

Table 3-147 presents the theoretical confidence intervals for samples of varied sizes for characteristics with a population incidence of 50% or 50%, 75% or 25% and 90% or 10%.

Table 3-147: Confidence intervals at 95% confidence level by sample size for liquid fuel combustion survey

Sample size	Confidence interval at 95% confidence level		
	Endorsement rate of 50%/50%	Endorsement rate of 75%/25%	Endorsement rate of 90%/10%
100	9.8	8.5	5.9
150	8.0	6.9	4.8
200	6.9	6.0	4.2
300	5.7	4.9	3.4
400	4.9	4.2	2.9
500	4.4	3.8	2.6
600	4.0	3.5	2.4
800	3.5	3.0	2.1
1,000	3.1	2.7	1.9

The domestic survey of liquid fuel combustion randomly sampled 801 households from a population of 5,284,560 in 1,901,680 households, so survey items with a true population incidence of 50% will produce estimates within ±3.5% of the true population value in 95% of the samples.

Random sampling and stratification - Households were selected at random across the GMR to limit bias. In practice, actual samples are not truly random since respondents always have the right to decline an interview and others cannot be reached for a variety of reasons. To reduce the standard error of estimated population values, samples were stratified on a geographic basis into the following subpopulations by location:

Sydney region, sub-grouped into

- *North East*
- *North West*
- *South East*
- *South West*

Newcastle region

Wollongong region

Development of survey questionnaires – Three survey questionnaires were developed including: initial recruitment using the computer assisted telephone interview (CATI) method to capture household details using pre-coded questions within OzQuest on-line software; self complete main survey using pre-coded questions within OzQuest on-line software; and self complete main survey using a traditional hard copy mail-out with a reply paid envelope. The questionnaires request information about: heater number; fuel type; quantity of fuel used; and frequency and duration of heater use by hour, day and month. The domestic survey questionnaire form is included at Appendix B: Domestic Survey Form (TR, 2009).

Recruitment and data collection - A random sample of phone numbers was selected from the 64 local government areas (LGA) located in the GMR, stratified into Sydney, Newcastle and Wollongong regions.

As part of the computer assisted telephone interview (CATI), households were phoned up to five times to make contact and the interviewer asked to speak to an "adult household member who is familiar with any devices the household uses that might burn solid fuel (like wood or coal heaters), liquid fuel (like kerosene heaters or petrol lawn mowers) or gas fuel (like natural gas cooktops or heaters)". If required, arrangements were made to call back at a more convenient time when an appropriate adult household member would be available.

When an adult household member was available for interview, respondents were asked what LGA they lived in. If not in the GMR they were thanked and the interview was terminated. If in the GMR, they were then asked about the number of residents in the household, the dwelling type and which of the fuel burning devices were used by the household. All were then asked for their postcode and age group. Respondents in households that had none of the fuel burning devices were thanked and the interview terminated. All other respondents were then asked if they would be willing to complete a further questionnaire either on-line or by mail. If willing, contact details were recorded, and the interview concluded. Those who initially declined were read material emphasizing the importance of obtaining data from all households, whether they make little use of fuel burning devices or not and asked again if they would be willing to take part.

Consenting respondents were then either e-mailed a link to a self complete on-line main survey or mailed a self complete hard copy main survey. The mailed questionnaires included an identifying serial number on the front page with a letter from DECCW encouraging completion of the survey.

Main survey completions on-line and mail-out were closely monitored and households were phoned on two occasions in order to remind them to complete. Some respondents indicated they preferred to go through the questions on the phone. Data for these were entered into the on-line version of the questionnaire.

Data capture – Data from the three survey questionnaires (i.e. CATI, on-line main survey and hard copy main survey) have all been entered into a database which captures pre-coded questions using OzQuest on-line software. All data was then checked, cleaned and saved in a Microsoft® Excel™ 2003 workbook.

Survey timeframe - The survey took approximately 15 weeks to complete, from the time that questionnaire development commenced to the date data analysis and report were completed. The key tasks and milestones for the domestic survey are presented in Table 3-148.

Table 3-148: Liquid fuel combustion survey milestones

Task	Milestones
Questionnaire development commenced	11 August 2009
CATI recruitment commenced	18 September 2009
CATI recruitment completed	21 October 2009
Main survey completed	12 November 2009
Data analysis and report completed	26 November 2009

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the liquid fuel combustion survey results (TR, 2009). Table 3-149 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-149: Population and dwelling by LGA used to scale-up liquid fuel combustion survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[43]	Total dwelling
Ashfield	47,887	7,660	2,728	7,882	142	18,412
Auburn	69,555	7,358	2,326	11,421	284	21,390
Bankstown	174,326	7,781	8,028	41,407	287	57,503
Bathurst Regional	157	-	-	41	1	41
Baulkham Hills	170,925	2,345	5,004	46,441	137	53,928
Blacktown	286,162	3,915	9,712	77,217	700	91,544

[43] Caravan, cabin, houseboat, improvised home, tent, sleepers out, house or flat attached to a shop or office (TDC, 2009).

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[43]	Total dwelling
Blue Mountains	78,427	777	1,030	27,952	63	29,822
Botany Bay	33,316	4,244	1,974	5,777	100	12,095
Burwood	30,277	3,332	1,108	5,770	65	10,275
Camden	55,287	258	499	16,910	161	17,828
Campbelltown	150,373	1,333	8,057	39,856	97	49,343
Canada Bay	58,880	6,445	2,342	13,157	137	22,080
Canterbury	138,343	16,795	4,851	25,673	328	47,647
Cessnock	48,845	562	339	16,615	150	17,667
Dungog	7,659	23	60	2,581	38	2,702
Fairfield	189,024	7,302	6,172	43,571	198	57,243
Gosford	162,826	5,481	8,288	49,407	676	63,852
Goulburn Mulwaree	341	-	1	79	-	80
Great Lakes	4,062	10	29	1,301	44	1,383
Hawkesbury	62,416	899	1,674	18,441	241	21,254
Holroyd	95,192	6,969	3,562	22,399	144	33,074
Hornsby	160,612	9,018	4,454	40,736	265	54,472
Hunters Hill	9,295	898	318	1,892	3	3,111
Hurstville	81,935	7,352	3,548	18,534	111	29,545
Kiama	14,586	580	338	4,433	75	5,426
Kogarah	57,349	6,558	1,565	11,945	81	20,148
Ku-ring-gai	106,943	3,805	1,253	30,103	73	35,235
Lake Macquarie	195,295	3,160	4,849	63,598	926	72,532
Lane Cove	28,511	4,473	652	5,687	92	10,904
Leichhardt	39,692	4,537	6,175	5,998	278	16,988
Lithgow	19,595	227	341	6,350	59	6,977
Liverpool	178,554	6,938	5,352	42,517	317	55,125
Maitland	66,554	1,330	1,049	21,169	117	23,666
Manly	33,804	5,898	1,520	5,676	97	13,192
Marrickville	86,873	13,062	10,292	11,838	553	35,744
Mid-western Regional	3,412	25	14	1,149	17	1,205
Mosman	30,915	6,692	1,506	4,604	104	12,905
Muswellbrook	15,221	364	121	4,582	62	5,128
N/A	25,875	4,778	1,262	4,329	119	10,488
Newcastle	150,930	8,242	6,306	44,792	500	59,840
North Sydney	53,850	17,299	4,228	3,854	252	25,633
Oberon	1,803	4	5	438	5	452
Parramatta	152,570	16,729	6,975	29,743	348	53,796
Penrith	177,459	3,483	4,905	51,040	349	59,776
Pittwater	54,586	2,542	1,577	15,389	183	19,690
Port Stephens	59,017	756	1,587	18,809	482	21,634
Randwick	130,955	25,728	8,002	16,752	370	50,853

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[43]	Total dwelling
Rockdale	89,735	12,199	4,159	16,242	256	32,856
Ryde	105,073	11,196	5,519	22,448	111	39,275
Shellharbour	65,104	1,282	2,369	18,768	328	22,747
Shoalhaven	81	-	-	30	-	30
Singleton	22,222	405	275	6,357	132	7,169
Strathfield	38,732	5,612	806	6,543	45	13,006
Sutherland	212,924	16,252	8,522	52,450	274	77,498
Sydney	167,382	52,686	17,811	4,651	1,028	76,176
Unincorporated	42,682	9,672	2,028	5,866	146	17,713
Upper Hunter	350	-	-	66	-	66
Upper Lachlan	502	-	-	92	-	92
Warringah	141,123	16,643	3,029	32,008	175	51,854
Waverley	57,147	14,769	4,430	5,038	245	24,481
Willoughby	69,528	11,760	2,038	12,473	82	26,353
Wingecarribee	45,480	537	1,113	15,131	144	16,924
Wollondilly	42,871	168	292	13,634	133	14,227
Wollongong	193,292	11,210	7,296	52,219	992	71,717
Woollahra	44,773	12,138	3,128	4,232	71	19,569
Wyong	145,088	2,801	4,575	47,918	1,006	56,300
Grand Total	5,284,560	417,295	213,366	1,256,021	14,998	1,901,680

The total population of in-service liquid fuel fired residential space and water heaters have been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). In-service liquid fuel fired residential space and water heater population by dwelling type for the GMR is presented in Table 3-150 and shown in Figure 3-67.

Table 3-150: Liquid fuel fired residential space and water heater population in the GMR

Dwelling type	2008 statistics		
	Dwelling number	Heater number	Proportion of dwelling type with heater (%)
Flat, unit or apartment	417,295	9,171	2.20
Semi detached, terrace house or townhouse	213,366	3,616	1.69
Separate house	1,256,021	29,030	2.31
Other dwelling	14,998	-	-
Grand Total	1,901,680	41,817	2.20

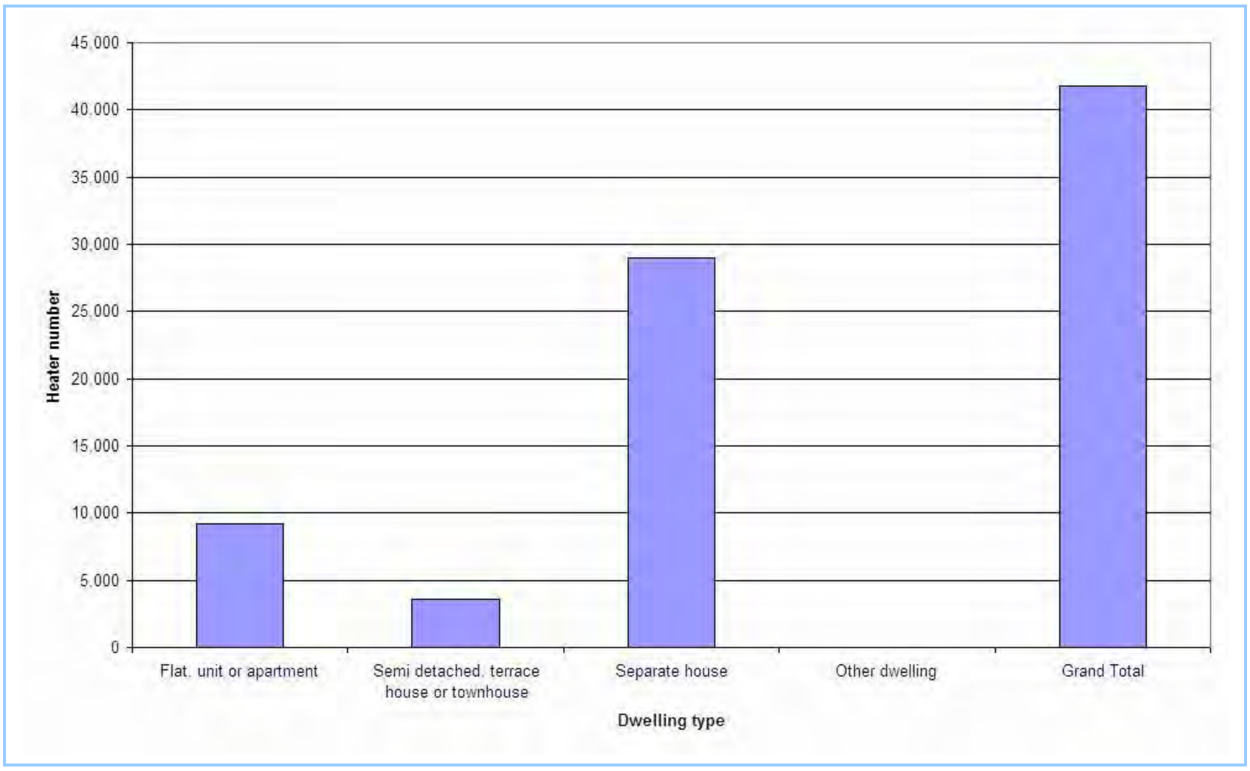

Figure 3-67: Liquid fuel fired residential space and water heater population in the GMR

The total consumption of heating oil has been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). Table 3-151 presents the residential space and water heater heating oil consumption estimates.

Table 3-151: Liquid fuel fired residential space and water heater fuel consumption in the GMR

Dwelling type	2008 heating oil consumption (kL/year)
Flat, unit or apartment	2,818
Semi detached, terrace house or townhouse	1,111
Separate house	8,919
Other dwelling	-
Grand Total	12,848

3.8.4 Emission and Speciation Factors

Table 3-152 summarises the emission and speciation factors used for liquid fuel combustion.

Table 3-152: Liquid fuel combustion emission and speciation factors

Emission source	Substance	Emission and speciation factor source[44]
Exhaust emissions from liquid fuel combustion	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Table 1.3-1 Residential furnace/Distillate oil fired, Table 1.3-2 No.2 Oil fired, Table 1.3-3 Residential furnace and Table 1.3-7 Distillate oil - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Criteria pollutants: TSP	- *Table 1.3-1 Residential furnace/Distillate oil fired and Table 1.3-2 No. 2 Oil fired - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Speciated NO_x	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
	Speciated VOC	- *RESIDENTIAL HEATING: DISTILLATE OIL Table 1 - Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *Table 1.3-9 Fuel oil combustion - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)* - *Profile number 0002 External combustion boiler distillate oil - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Organic air toxics	- *RESIDENTIAL HEATING: DISTILLATE OIL Table 1 - Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *Table 1.3-9 Fuel oil combustion - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)* - *Profile number 0002 External combustion boiler distillate oil - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Metal air toxics	- *RESIDENTIAL HEATING: DISTILLATE OIL Table 1 - Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *Table 1.3-10 Distillate fuel oil combustion and Table 1.3-11 No. 6 fuel oil combustion - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)* - *Profile number 1230130 External combustion kerosene fired boiler composite - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Polycyclic aromatic hydrocarbons: PAH	- *RESIDENTIAL HEATING: DISTILLATE OIL Table 1 - Documentation for the Final 2002 NonPoint Sector (FEB 06 version) National Emission Inventory for Criteria and Hazardous Air Pollutants* (Pechan, 2006) - *Table 1.3-9 Fuel oil combustion - AP 42, Fifth Edition, Volume I,*

[44] Where references are marked with an asterisk (i.e. *), distillate fired residential space and water heaters use residual oil emission data, which have been adjusted to distillate equivalent based on effective heating value of 140,000 BTU/US gal for distillate and 150,000 BTU/US gal for residual oil (USEPA, 2010b).

Emission source	Substance	Emission and speciation factor source[44]
		Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion (USEPA, 2010b)*
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *Table 4.54 Emission Factors – Household Heating and Cooking (Fossil Fuels) Oil - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Ammonia	- *Table III-1 Residential oil combustion -Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4	- *Table 1.3-3 Residential furnace - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Greenhouse gases: CO_2	- *Table 1.3-3 Fuel type No. 2 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)
	Greenhouse gases: N_2O	- *Table 1.3-8 Residential furnace - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.3 Fuel Oil Combustion* (USEPA, 2010b)

Table 3-153 presents emission factors for liquid fuel combustion.

Table 3-153: Liquid fuel combustion emission factors

Emission source	Emission factors (kg/kL)											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
Exhaust emissions from liquid fuel combustion	2.16	0.006	0.120	0.851	0.29	0.26	0.09	0.213	0.60	2,672.46	1.43×10^{-4}	3.76×10^{-10}

3.8.5 *Spatial Distribution of Emissions*

Table 3-154 summarises the data used for spatially allocating emissions from liquid fuel combustion.

Table 3-154: Liquid fuel combustion spatial data

Emission source	Spatial data	Spatial data source
Exhaust emissions from liquid fuel combustion	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from liquid fuel combustion have been spatially distributed according to heating oil consumption, which is proportional to total dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of heating oil consumption by LGA and region is presented in Table 3-155 and shown in Figure 3-68.

Table 3-155: Liquid fuel combustion spatial distribution of heating oil consumption by LGA and region

LGA	2008 proportion of annual heating oil consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.97	-	0.97
Auburn	-	-	1.13	-	1.13
Bankstown	-	-	3.03	-	3.03
Bathurst Regional	-	2.18×10^{-3}	-	-	2.18×10^{-3}
Baulkham Hills	-	2.39×10^{-3}	2.84	-	2.84
Blacktown	-	-	4.82	-	4.82
Blue Mountains	-	0.56	1.00	-	1.57
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.54	-	0.54
Camden	-	-	0.94	-	0.94
Campbelltown	-	-	2.60	-	2.60
Canada Bay	-	-	1.16	-	1.16
Canterbury	-	-	2.51	-	2.51
Cessnock	3.84×10^{-2}	0.89	-	-	0.93
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.01	-	3.01
Gosford	-	0.91	2.45	-	3.36
Goulburn Mulwaree	-	4.14×10^{-3}	-	-	4.14×10^{-3}
Great Lakes	-	6.80×10^{-2}	-	-	6.80×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.10	-	1.12
Holroyd	-	-	1.74	-	1.74
Hornsby	-	3.62×10^{-3}	2.86	-	2.87
Hunters Hill	-	-	0.16	-	0.16
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.29	-	-	0.29
Kogarah	-	-	1.06	-	1.06
Ku-ring-gai	-	-	1.85	-	1.85
Lake Macquarie	2.00	1.82	-	-	3.82
Lane Cove	-	-	0.57	-	0.57
Leichhardt	-	-	0.89	-	0.89
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	2.90	-	2.90
Maitland	9.39×10^{-2}	1.15	-	-	1.25
Manly	-	-	0.69	-	0.69
Marrickville	-	-	1.88	-	1.88
Mid-western Regional	-	5.16×10^{-2}	-	-	5.16×10^{-2}
Mosman	-	-	0.68	-	0.68
Muswellbrook	-	0.26	-	-	0.26
N/A	3.05×10^{-2}	5.58×10^{-2}	0.39	7.60×10^{-2}	0.55
Newcastle	3.15	-	-	-	3.15

LGA	2008 proportion of annual heating oil consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
North Sydney	-	-	1.35	-	1.35
Oberon	-	2.26×10^{-2}	-	-	2.26×10^{-2}
Parramatta	-	-	2.83	-	2.83
Penrith	-	-	3.15	-	3.15
Pittwater	-	-	1.04	-	1.04
Port Stephens	6.97×10^{-2}	1.07	-	-	1.14
Randwick	-	-	2.68	-	2.68
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.07	-	2.07
Shellharbour	-	0.89	-	0.31	1.20
Shoalhaven	-	1.50×10^{-3}	-	-	1.50×10^{-3}
Singleton	-	0.37	-	-	0.37
Strathfield	-	-	0.68	-	0.68
Sutherland	-	-	4.08	-	4.08
Sydney	-	-	4.01	-	4.01
Unincorporated	-	-	0.93	-	0.93
Upper Lachlan	-	6.05×10^{-4}	-	-	6.05×10^{-4}
Warringah	-	-	2.73	-	2.73
Waverley	-	-	1.29	-	1.29
Willoughby	-	-	1.39	-	1.39
Wingecarribee	-	0.88	4.72×10^{-3}	1.50×10^{-3}	0.89
Wollondilly	-	1.16×10^{-2}	0.74	3.91×10^{-4}	0.75
Wollongong	-	-	0.27	3.50	3.77
Woollahra	-	-	1.03	-	1.03
Wyong	-	2.96	-	-	2.96
Grand Total	5.38	12.78	77.95	3.89	100.00

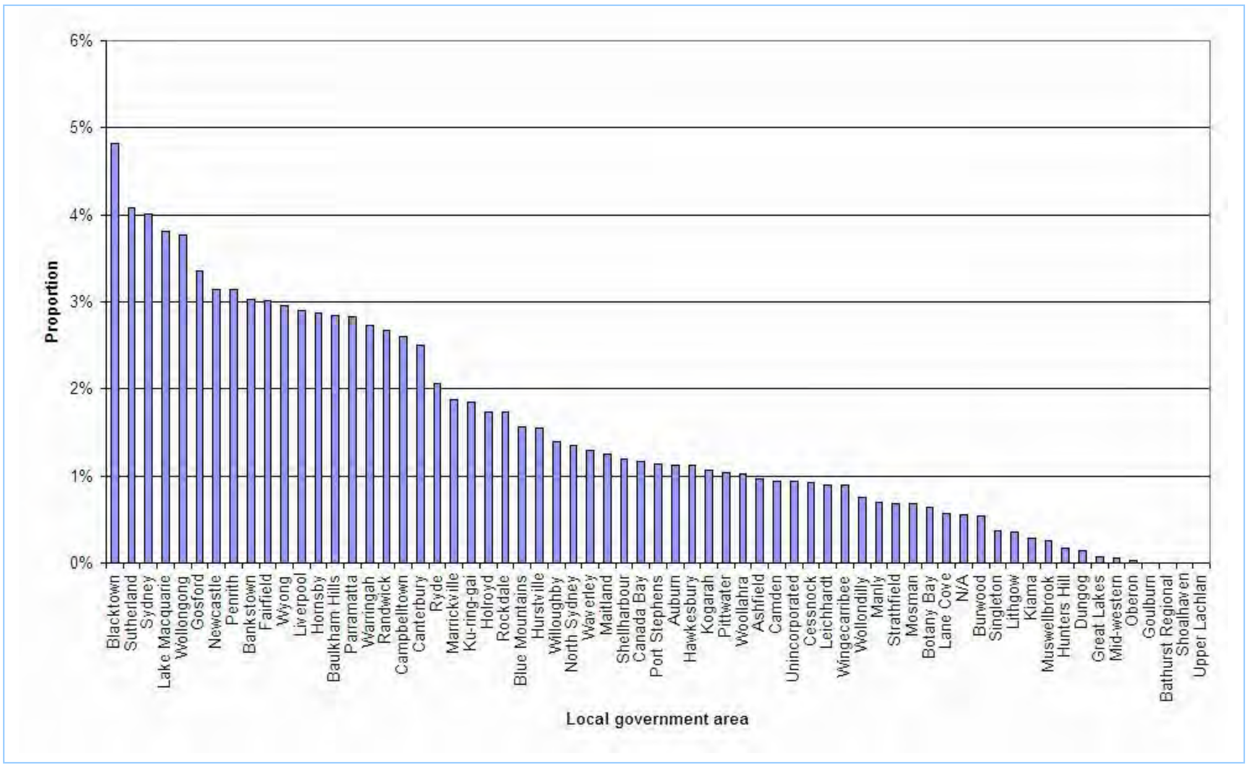

Figure 3-68: Liquid fuel combustion spatial distribution of heating oil consumption by LGA

Figure 3-69 shows the spatial distribution of liquid fuel combustion emissions.

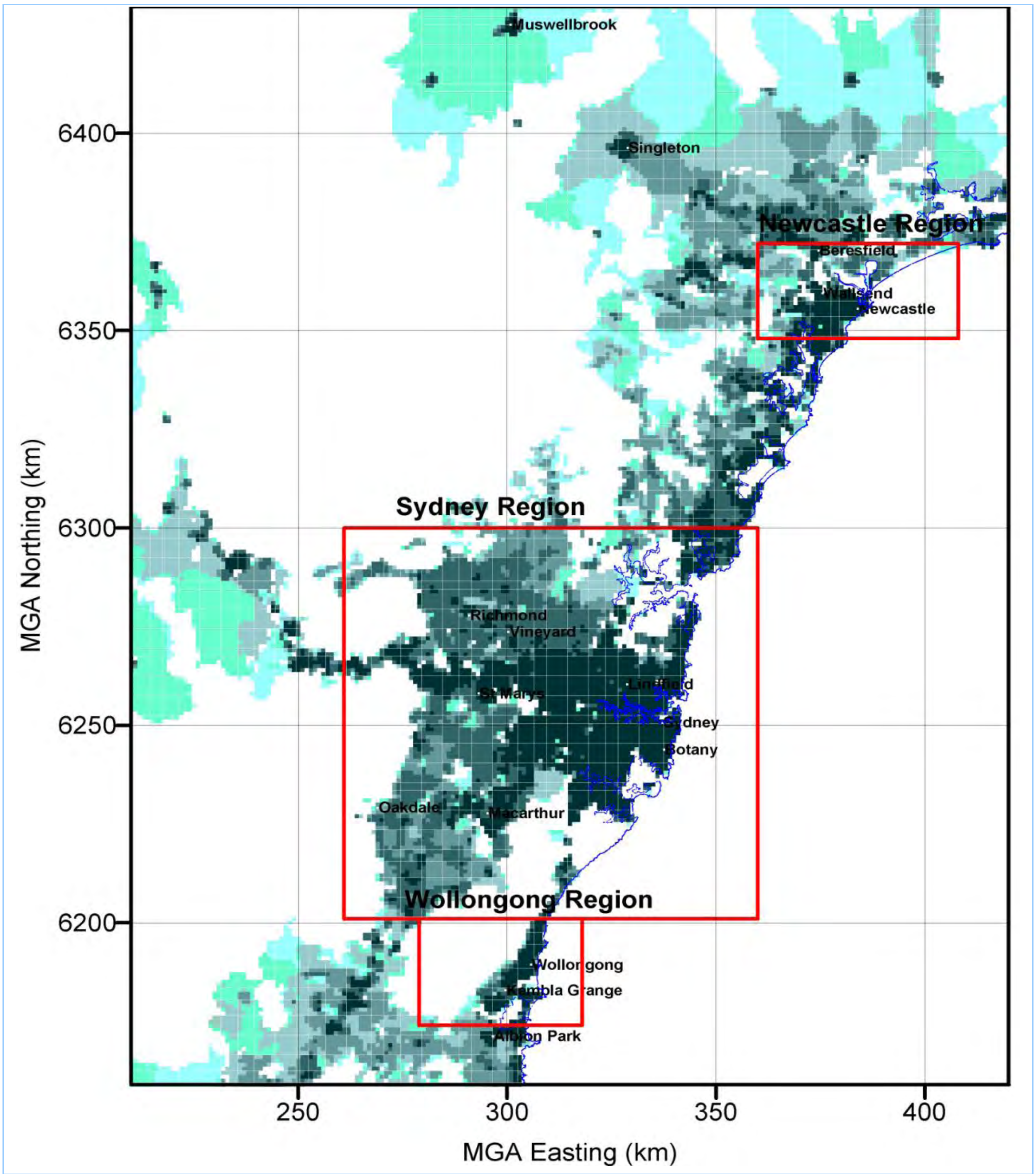

Figure 3-69: Liquid fuel combustion spatial distribution of emissions

3.8.6 Temporal Variation of Emissions

Table 3-156 summarises the data used to estimate the temporal variation in emissions from liquid fuel combustion.

Table 3-156: Liquid fuel combustion temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from liquid fuel combustion	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Liquid Fuel Combustion Pollution Survey* (TR, 2009)

The temporal variation in emissions from liquid fuel combustion have been estimated from heater number, fuel type, quantity of fuel used and frequency and duration of heater use by hour, day and month data (TR, 2009).

Hourly temporal variation profiles are presented in Table 3-157 and shown in Figure 3-70.

Table 3-157: Liquid fuel combustion hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	-	13	2.08
2	-	14	2.08
3	-	15	2.08
4	-	16	4.17
5	-	17	6.25
6	2.08	18	10.42
7	2.08	19	10.42
8	2.08	20	12.50
9	2.08	21	12.50
10	2.08	22	12.50
11	2.08	23	8.33
12	2.08	24	2.08

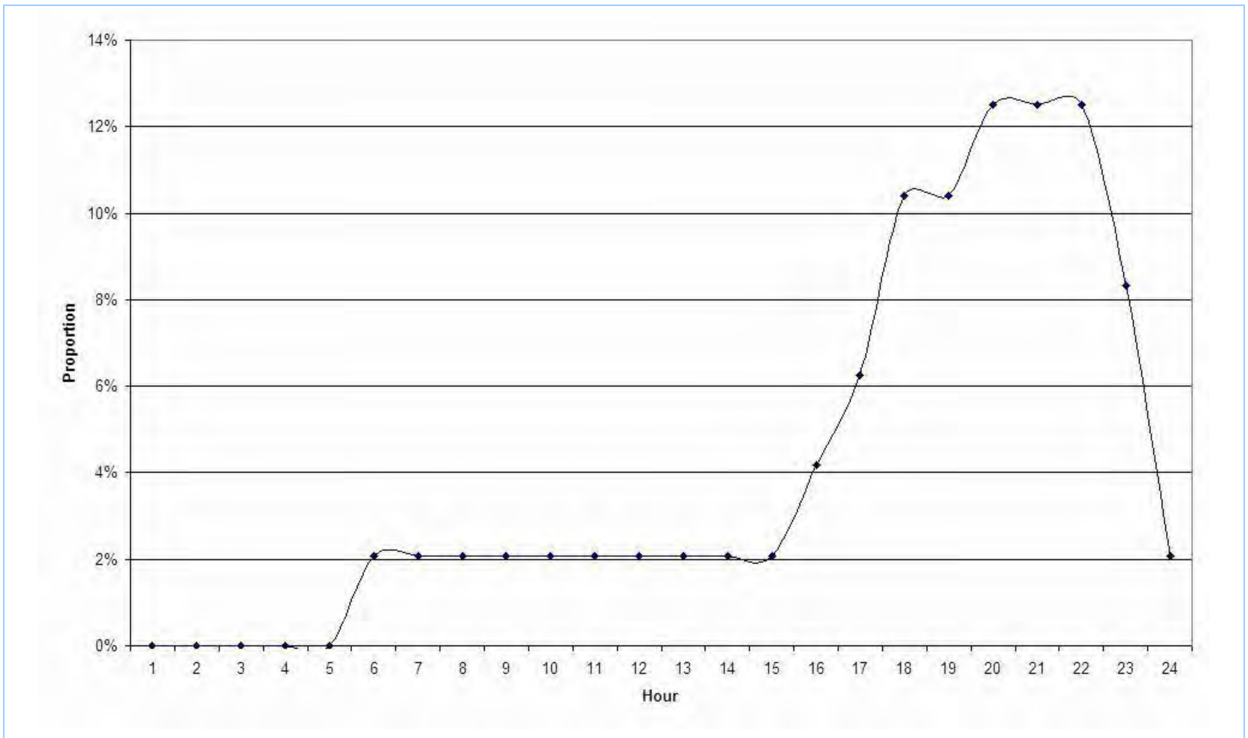

Figure 3-70: Liquid fuel combustion hourly temporal profile

Daily temporal variation profiles are presented in Table 3-158 and shown in Figure 3-71.

Table 3-158: Liquid fuel combustion daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	13.94	13.94	13.94	13.94	13.94	15.14	15.14

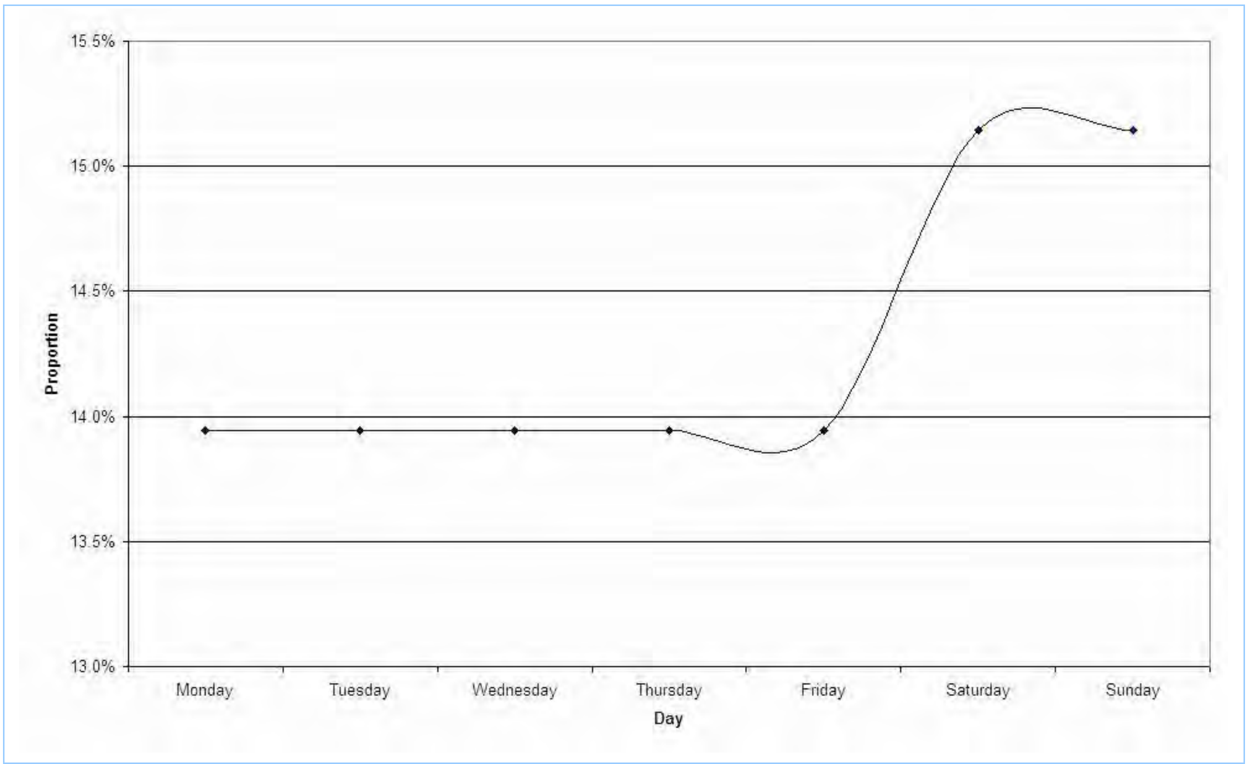

Figure 3-71: Liquid fuel combustion daily temporal profile

Monthly temporal variation profiles are presented in Table 3-159 and shown in Figure 3-72.

Table 3-159: Liquid fuel combustion monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	-	July	30.43
February	-	August	30.43
March	-	September	13.04
April	-	October	-
May	8.70	November	-
June	17.39	December	-

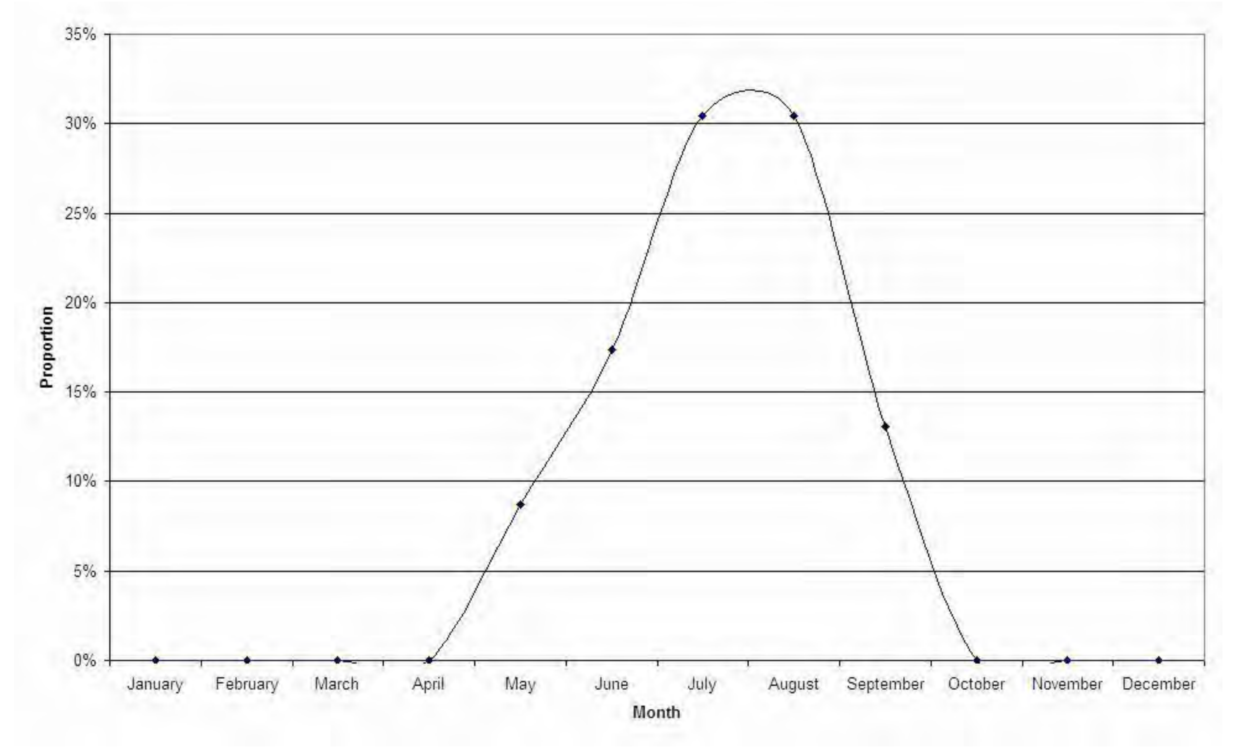

Figure 3-72: Liquid fuel combustion monthly temporal profile

3.8.7 *Emission Estimates*

Table 3-160 presents annual emissions of selected substances from liquid fuel combustion by activity.

Table 3-160: Liquid fuel combustion emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Liquid Fuel Combustion	ACETALDEHYDE	0.41	0.96	5.88	0.29	7.54
	BENZENE	1.74×10^{-2}	4.13×10^{-2}	0.25	1.26×10^{-2}	0.32
	CARBON MONOXIDE	414	984	6,001	299	7,699
	FORMALDEHYDE	2.78	6.61	40	2.01	52
	ISOMERS OF XYLENE	8.42×10^{-3}	2.0×10^{-2}	0.12	6.09×10^{-3}	0.16
	LEAD & COMPOUNDS	0.10	0.25	1.51	7.54×10^{-2}	1.94
	OXIDES OF NITROGEN	1,491	3,543	21,604	1,077	27,715
	PARTICULATE MATTER ≤ 10 µm	197	468	2,856	142	3,664
	PARTICULATE MATTER ≤ 2.5 µm	176	419	2,556	127	3,280
	POLYCYCLIC AROMATIC HYDROCARBONS	9.89×10^{-2}	0.24	1.43	7.15×10^{-2}	1.84
	SULFUR DIOXIDE	588	1,398	8,521	425	10,932
	TOLUENE	0.48	1.14	6.95	0.35	8.91
	TOTAL SUSPENDED PARTICULATE	273	650	3,961	197	5,081

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL VOLATILE ORGANIC COMPOUNDS	59	140	856	43	1,098

3.8.8 Emission Projection Methodology

Table 3-161 summarises the data used to estimate the emission projection factors for liquid fuel fired residential space and water heaters, while Figure 3-73 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-161: Liquid fuel combustion emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from liquid fuel combustion	Final energy consumption for residential using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

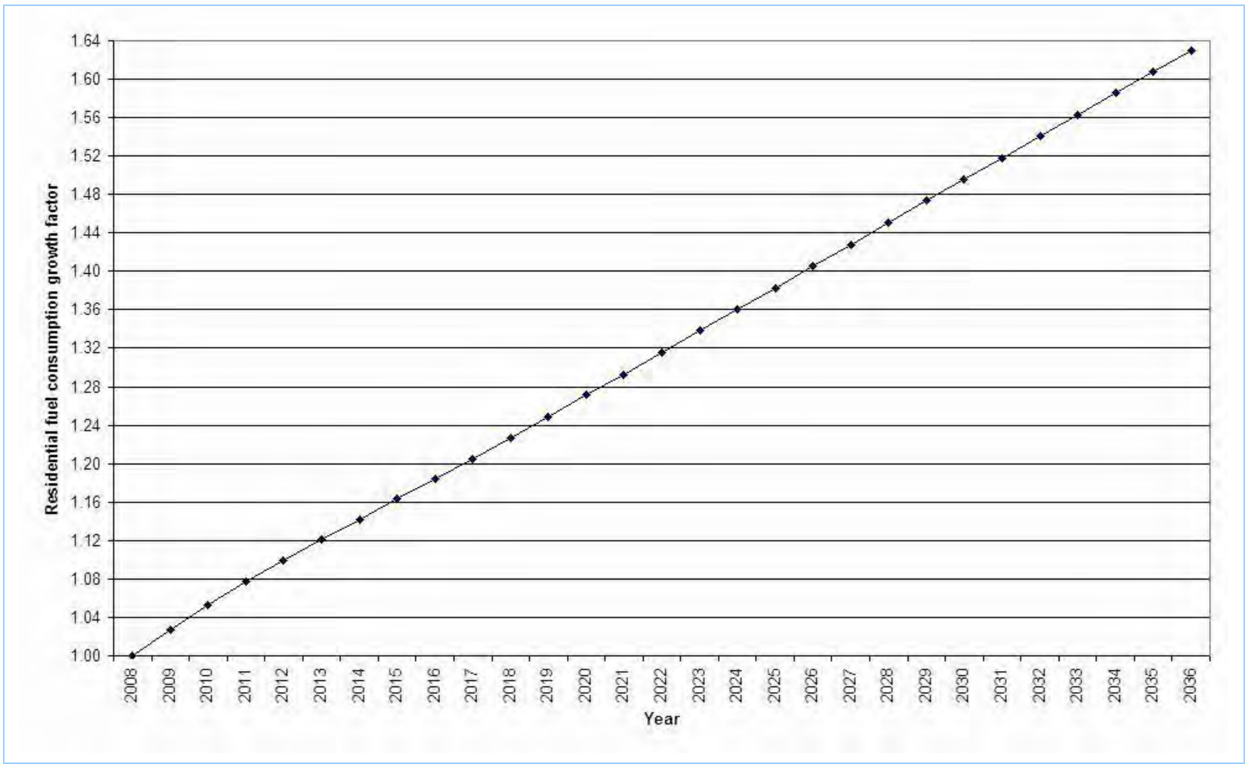

Figure 3-73: Liquid fuel combustion emission projection factors

3.9 Natural Gas Leakage

3.9.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes fugitive emissions from natural gas leakage. These emissions arise from losses through the natural gas reticulation system, which are the result of leaking fittings and the deterioration of piping.

Natural gas leakage is a source of carbon dioxide, hydrogen sulfide, methane, nitrogen and VOC emissions.

To estimate emissions from these sources, the following have been considered:

➢ *NSW natural gas network performance*

Unaccounted for gas (UAFG) for the period 2007-08 (DWE, 2009) and 2008-09 (II, 2009) in NSW has been used in combination with natural gas network access arrangement information (Jemena, 2009a; and Jemena, 2009b) and the fraction of UAFG allocated as leakage (DCC, 2009a) to estimate total natural gas leakage in the GMR.

➢ *Fuel type*

The inventory includes fugitive emissions of natural gas from the reticulation system.

Table 3-162 presents the natural gas properties used in the inventory (ABARE, 2009b; AGL, 2008; and USEPA, 1998a).

Table 3-162: Natural gas properties

Fuel type	Sulfur content		Density		Effective heating value		Carbon content (%)
Natural gas	3.36	ppm	0.753	kg/m^3	38.3	MJ/m^3	76

3.9.2 *Emission Estimation Methodology*

Table 3-163 summarises the emission estimation methodology used for fugitive emissions of natural gas from the reticulation system.

Table 3-163: Natural gas leakage emission estimation methodology

Emission source	Emission estimation methodology source
Fugitive emissions of natural gas from the reticulation system	- *National Greenhouse Accounts (NGA) Factors* (DCC, 2009a)

Fugitive emissions of natural gas from the reticulation system have been estimated using the natural gas leakage rate (DCC, 2009a) and composition (AGL, 2008) combined with activity rates. Activity rates include unaccounted for gas (UAFG) for the period 2007-08 (DWE, 2009) and 2008-09 (II, 2009) in NSW and estimated UAFG in the GMR based on natural gas network access arrangement information (Jemena, 2009a; and Jemena, 2009b). Emissions have been determined using Equation 12 (DCC, 2009a):

$$E_i = F \times UAFG \times 0.55 \times C_i$$ **Equation 12**

where:			
E_i	=	Emissions of substance i	(kg/year)
F	=	Flowrate of natural gas through reticulation network	(Mm^3/year)
UAFG	=	Fraction of unaccounted for gas	(Mm^3/Mm^3)
0.55	=	Fraction of UAFG allocated as leakage (Section 2.4.2.7; DCC, 2009a)	(Mm^3/Mm^3)
C_i	=	Composition of natural gas for substance i	(kg/Mm^3)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)

3.9.3 *Activity Data*

Table 3-164 summarises the activity data used for fugitive emissions of natural gas from the reticulation system.

Table 3-164: Natural gas leakage activity data

Activity data	Activity data source
Unaccounted for natural gas	- *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b) - *NSW gas networks Performance report 2007-08* (DWE, 2009) - *NSW gas networks Performance report 2008-09* (II, 2009)

NSW natural gas network performance reports have been used to estimate unaccounted for gas (UAFG) for the period 2007-08 (DWE, 2009) and 2008-09 (II, 2009) in NSW. Table 3-165 presents the quantities of natural gas entering the NSW network and delivered to NSW customers for the 2007-08 and 2008-09 reporting periods. The proportion of UAFG has been calculated from the difference between gas entering the NSW network and gas delivered to NSW customers[45].

Table 3-165: Unaccounted for gas (UAFG) in NSW natural gas network

Reporting period	NSW network length (km)	Gas entering NSW network		Gas delivered in NSW		UAFG in NSW		Proportion of UAFG (%)
		PJ/year	Mm^3/year	PJ/year	Mm^3/year	PJ/year	Mm^3/year	
2007-08	26,500	108	2,819.8	105.7	2,759.8	2.3	60.1	2.13
2008-09	26,696	111.5	2,911.2	109.5	2,859.0	2.0	52.2	1.79

45 Proportion of UAFG (%) = {(Gas entering NSW network – Gas delivered in NSW)/Gas entering NSW network} x 100/1 %.

Table 3-166 presents the quantities of natural gas entering the NSW network and delivered to NSW customers (DWE, 2009; and II, 2009). The proportion of UAFG has been calculated from the difference between gas entering the NSW network and gas delivered to NSW customers, while the fraction of UAFG allocated as leakage (DCC, 2009a) has been used to calculate natural gas leakage. Natural gas network access arrangement information (Jemena, 2009a; and Jemena, 2009b) for NSW has been used to estimate fugitive emissions of natural gas from the reticulation system in the GMR.

Table 3-166: Natural gas leakage in NSW and the GMR

Region	2008 gas entering the network		2008 gas delivered		2008 UAFG[46]		2008 natural gas leakage[47]		
	PJ/year	Mm³/year	PJ/year	Mm³/year	PJ/year	Mm³/year	PJ/year	Mm³/year	kg/year
GMR[48]	100.9	2,634.3	98.9	2,582.7	2.0	51.6	1.1	28.4	21,383,299
NSW[49]	109.8	2,865.5	107.6	2,809.4	2.2	56.1	1.2	30.9	23,260,207

3.9.4 Emission and Speciation Factors

Table 3-167 summarises the emission and speciation factors used for fugitive emissions of natural gas from the reticulation system.

Table 3-167: Natural gas leakage emission and speciation factors

Substance	Emission and speciation factor source
Criteria pollutants: VOC	- *Jemena Gas Networks (NSW) Ltd Access Arrangement* (JEMENA, 2009a) - *Jemena Gas Networks (NSW) Ltd Access Arrangement Information* (JEMENA, 2009b) - *NSW gas networks Performance report 2007-08* (DWE, 2009) - *NSW gas networks Performance report 2008-09* (II, 2009) - *National Greenhouse Accounts (NGA) Factors* (DCC, 2009a) - *National Greenhouse and Energy Reporting System Measurement, Technical Guidelines for the Estimation of Greenhouse Gas Emissions by Facilities in Australia* (DCC, 2009b)
Speciated VOC	- *AGL Natural Gas, Chemwatch Material Safety Data Sheet* (AGL, 2008)
Organic air toxics	- *Eastern Gas Pipeline Measurement Manual* (JEMENA, 2009c) - *Eastern Gas Pipeline Operations Manual* (JEMENA, 2009d)

Table 3-168 presents the composition of natural gas in both volume and mass proportions. The ideal gas equation[50,51] has been used to convert mole % to mass % proportions.

[46] Proportion of UAFG is 1.96% (DWE, 2009; and II, 2009).
[47] The fraction of UAFG allocated as leakage is 0.55 (DCC, 2009a).
[48] Approximately 91.9% of natural gas for NSW is consumed in the GMR (Jemena, 2009a; and Jemena, 2009b).
[49] 2008 calendar year is the average of 2007-08 (DWE, 2009) and 2008-09 (II, 2009) financial years.
[50] $PV = nRT$ (where: P = pressure (101.325 kPa); V = volume (L); n = number of mole (mole); R = universal gas constant (8.31442 $J.K^{-1}.mole^{-1}$); and T = temperature (288.15 K).

Table 3-168: Natural gas composition

Substance	Mole[52] (%)	Mass (%)
Butane	trace	trace
Carbon dioxide	2	4.91
Ethane	8	13.41
Hydrogen sulfide	5.7[53] mg/m^3	7.57×10^{-4}
Methane	88.5	79.16
Nitrogen	1.3	2.03
Pentane	trace	trace
Propane	0.2	0.49
Total	100	100

Table 3-169 presents emission factors for fugitive emissions of natural gas from the reticulation system.

Table 3-169: Natural gas leakage emission factors

Emission source	Emission factors (kg/Mm^3)		
	VOC	CH_4	CO_2
Fugitive emissions of natural gas from the reticulation system	104,747	596,360	36,972

3.9.5 Spatial Distribution of Emissions

Table 3-170 summarises the data used for spatially allocating fugitive emissions of natural gas from the reticulation system.

Table 3-170: Natural gas leakage spatial data

Emission source	Spatial data	Spatial data source
Fugitive emissions of natural gas from the reticulation system	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Fugitive emissions of natural gas from the reticulation system have been spatially distributed according to natural gas leakage, which is proportional to total dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of natural gas leakage by LGA and region are presented in Table 3-171 and shown in Figure 3-74.

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[51] Original formulation published by Benoît Paul Émile Clapeyron in 1834 (1799 – 1864) as a combination of Boyle's law (published by Robert Boyle in 1662 (1627 – 1691)) and Charles's law (published by Joseph Louis Gay-Lussac in 1802 (1778 – 1850) and attributed to Jacques Alexandre César Charles (1746 – 1823)).

[52] *AGL Natural Gas, Chemwatch Material Safety Data Sheet* (AGL, 2008).

[53] *Eastern Gas Pipeline Measurement Manual* (JEMENA, 2009c) and *Eastern Gas Pipeline Operations Manual* (JEMENA, 2009d).

Table 3-171: Natural gas leakage spatial distribution by LGA and region

LGA	2008 proportion of annual natural gas leakage (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.97	-	0.97
Auburn	-	-	1.13	-	1.13
Bankstown	-	-	3.03	-	3.03
Bathurst Regional	-	2.18×10^{-3}	-	-	2.18×10^{-3}
Baulkham Hills	-	2.39×10^{-3}	2.84	-	2.84
Blacktown	-	-	4.82	-	4.82
Blue Mountains	-	0.56	1.00	-	1.57
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.54	-	0.54
Camden	-	-	0.94	-	0.94
Campbelltown	-	-	2.60	-	2.60
Canada Bay	-	-	1.16	-	1.16
Canterbury	-	-	2.51	-	2.51
Cessnock	3.84×10^{-2}	0.89	-	-	0.93
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.01	-	3.01
Gosford	-	0.91	2.45	-	3.36
Goulburn Mulwaree	-	4.14×10^{-3}	-	-	4.14×10^{-3}
Great Lakes	-	6.80×10^{-2}	-	-	6.80×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.10	-	1.12
Holroyd	-	-	1.74	-	1.74
Hornsby	-	3.62×10^{-3}	2.86	-	2.87
Hunters Hill	-	-	0.16	-	0.16
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.29	-	-	0.29
Kogarah	-	-	1.06	-	1.06
Ku-ring-gai	-	-	1.85	-	1.85
Lake Macquarie	2.00	1.82	-	-	3.82
Lane Cove	-	-	0.57	-	0.57
Leichhardt	-	-	0.89	-	0.89
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	2.90	-	2.90
Maitland	9.39×10^{-2}	1.15	-	-	1.25
Manly	-	-	0.69	-	0.69
Marrickville	-	-	1.88	-	1.88
Mid-western Regional	-	5.16×10^{-2}	-	-	5.16×10^{-2}
Mosman	-	-	0.68	-	0.68
Muswellbrook	-	0.26	-	-	0.26
N/A	3.05×10^{-2}	5.58×10^{-2}	0.39	7.60×10^{-2}	0.55
Newcastle	3.15	-	-	-	3.15
North Sydney	-	-	1.35	-	1.35
Oberon	-	2.26×10^{-2}	-	-	2.26×10^{-2}
Parramatta	-	-	2.83	-	2.83
Penrith	-	-	3.15	-	3.15
Pittwater	-	-	1.04	-	1.04

LGA	2008 proportion of annual natural gas leakage (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Port Stephens	6.97×10^{-2}	1.07	-	-	1.14
Randwick	-	-	2.68	-	2.68
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.07	-	2.07
Shellharbour	-	0.89	-	0.31	1.20
Shoalhaven	-	1.50×10^{-3}	-	-	1.50×10^{-3}
Singleton	-	0.37	-	-	0.37
Strathfield	-	-	0.68	-	0.68
Sutherland	-	-	4.08	-	4.08
Sydney	-	-	4.01	-	4.01
Unincorporated	-	-	0.93	-	0.93
Upper Lachlan	-	6.05×10^{-4}	-	-	6.05×10^{-4}
Warringah	-	-	2.73	-	2.73
Waverley	-	-	1.29	-	1.29
Willoughby	-	-	1.39	-	1.39
Wingecarribee	-	0.88	4.72×10^{-3}	1.50×10^{-3}	0.89
Wollondilly	-	1.16×10^{-2}	0.74	3.91×10^{-4}	0.75
Wollongong	-	-	0.27	3.50	3.77
Woollahra	-	-	1.03	-	1.03
Wyong	-	2.96	-	-	2.96
Grand Total	5.38	12.78	77.95	3.89	100.00

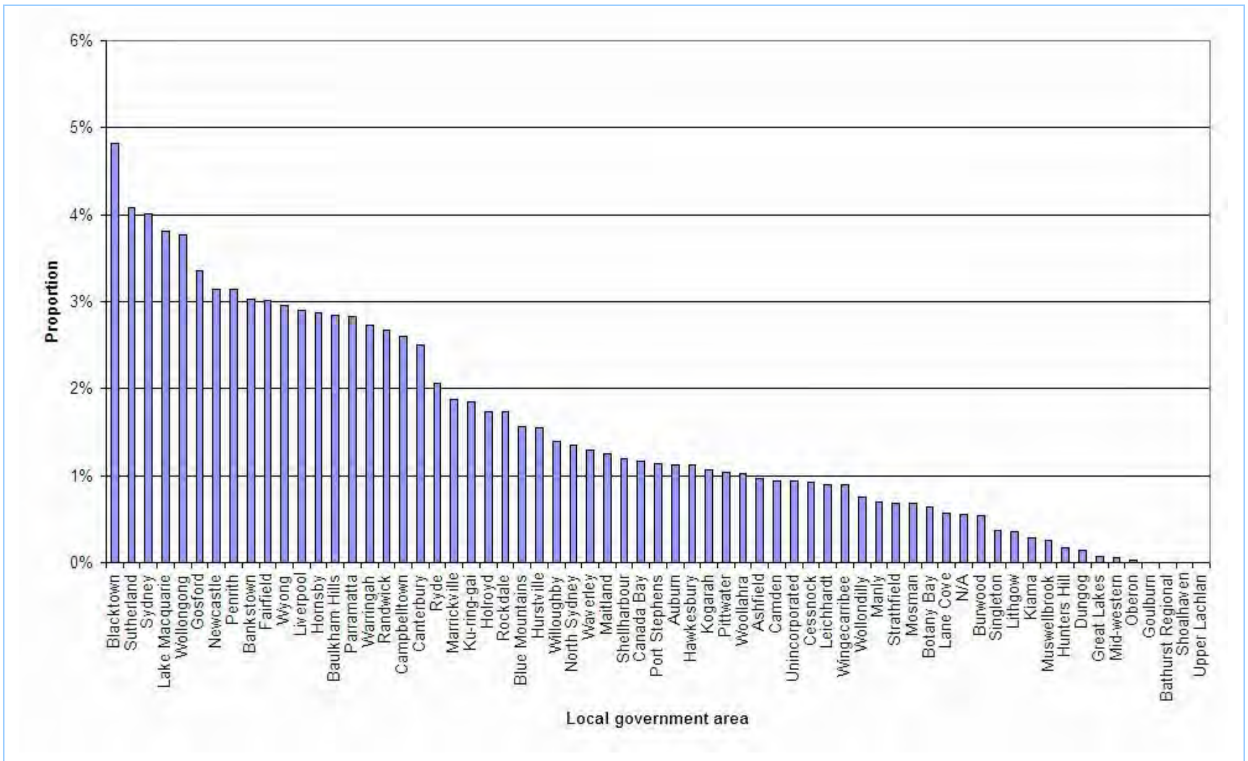

Figure 3-74: Natural gas leakage spatial distribution by LGA

Figure 3-75 shows the spatial distribution of fugitive emissions of natural gas from the reticulation system.

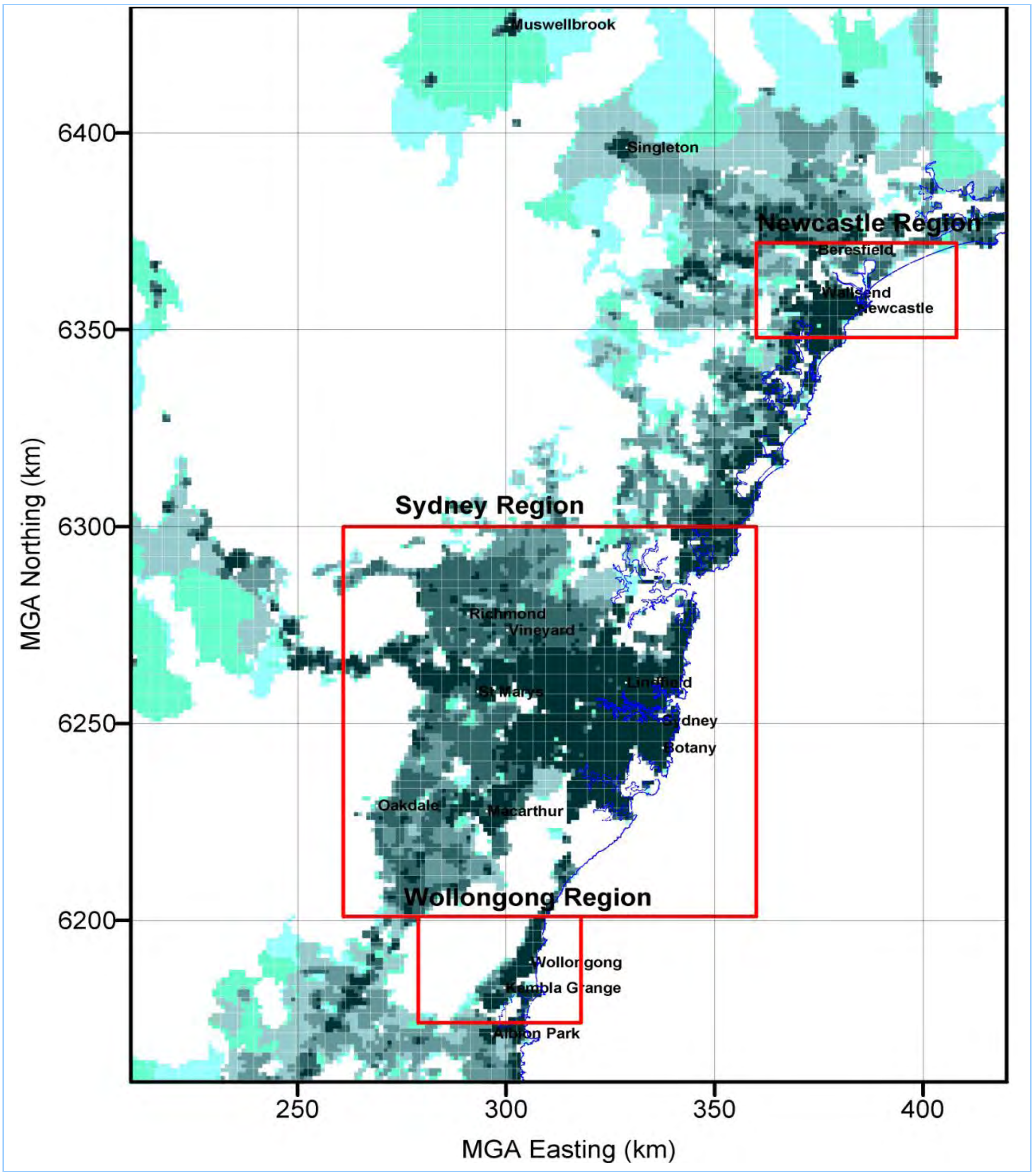

Figure 3-75: Natural gas leakage spatial distribution of emissions

3.9.6 *Temporal Variation of Emissions*

Table 3-172 summarises the data used to estimate the temporal variation in fugitive emissions of natural gas from the reticulation system.

Table 3-172: Natural gas leakage temporal data

Emission source	Temporal data	Temporal data source
Fugitive emissions of natural gas from the reticulation system	Monthly and daily: Daily natural gas flow	- *National Gas Market Bulletin Board, Daily Natural Gas Flow, 1 August 2008 to 31 July 2009* (AEMOL, 2009)
	Hourly: Source type specific temporal allocation factors	- *Stationary Fuel Comb /Residential /Natural Gas /Total: All Combustor Types - Weekday diurnal profile number 26 and Weekend diurnal profile number 26 - CAIR Platform Temporal Allocation* (USEPA, 2005)

The daily and monthly temporal variation in fugitive emissions of natural gas from the reticulation system have been estimated from daily natural gas flow data (AEMOL, 2009), while the hourly temporal variation in emissions have been estimated from generic temporal profiles (USEPA, 2005).

Hourly temporal variation profiles are presented in Table 3-173 and shown in Figure 3-76.

Table 3-173: Natural gas leakage hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	1.98	13	6.20
2	1.86	14	6.31
3	1.82	15	6.35
4	1.87	16	6.24
5	2.10	17	5.94
6	2.50	18	5.48
7	3.11	19	5.31
8	3.88	20	5.09
9	4.67	21	4.25
10	5.28	22	3.27
11	5.71	23	2.57
12	6.04	24	2.18

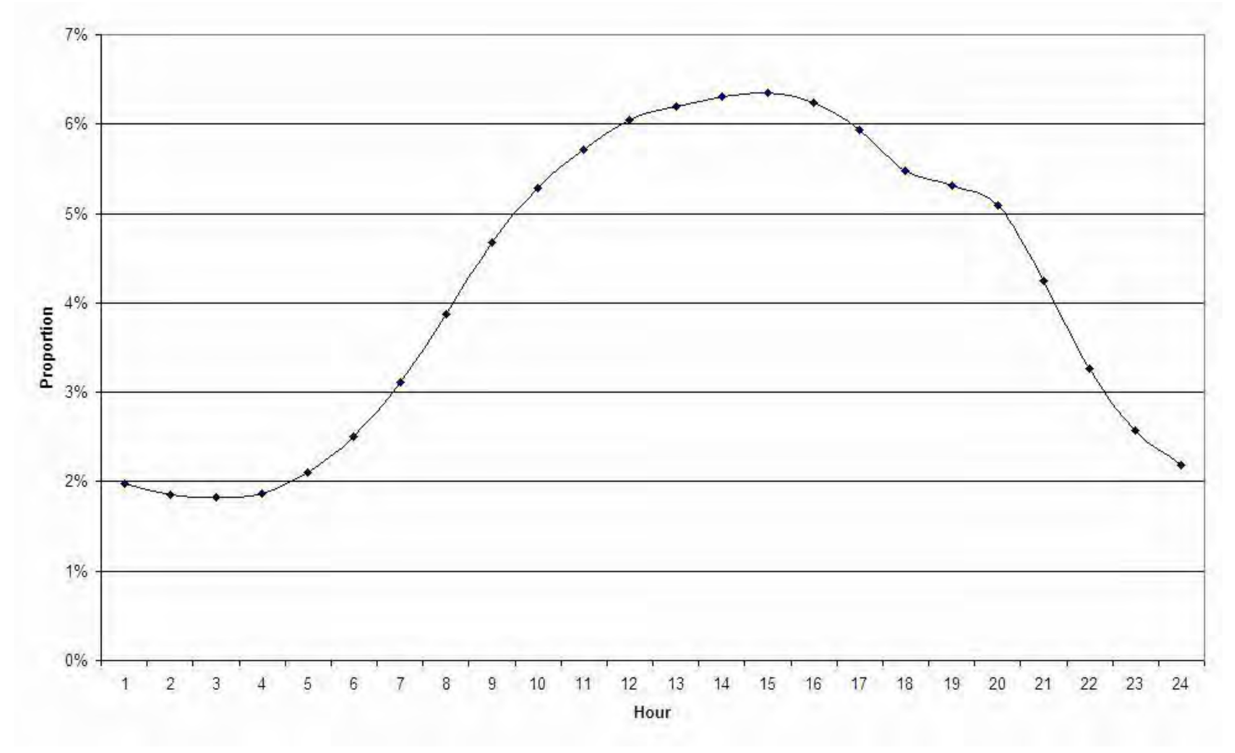

Figure 3-76: Natural gas leakage hourly temporal profile

Daily temporal variation profiles are presented in Table 3-174 and shown in Figure 3-77.

Table 3-174: Natural gas leakage daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.78	15.48	15.70	15.56	14.91	11.52	12.06

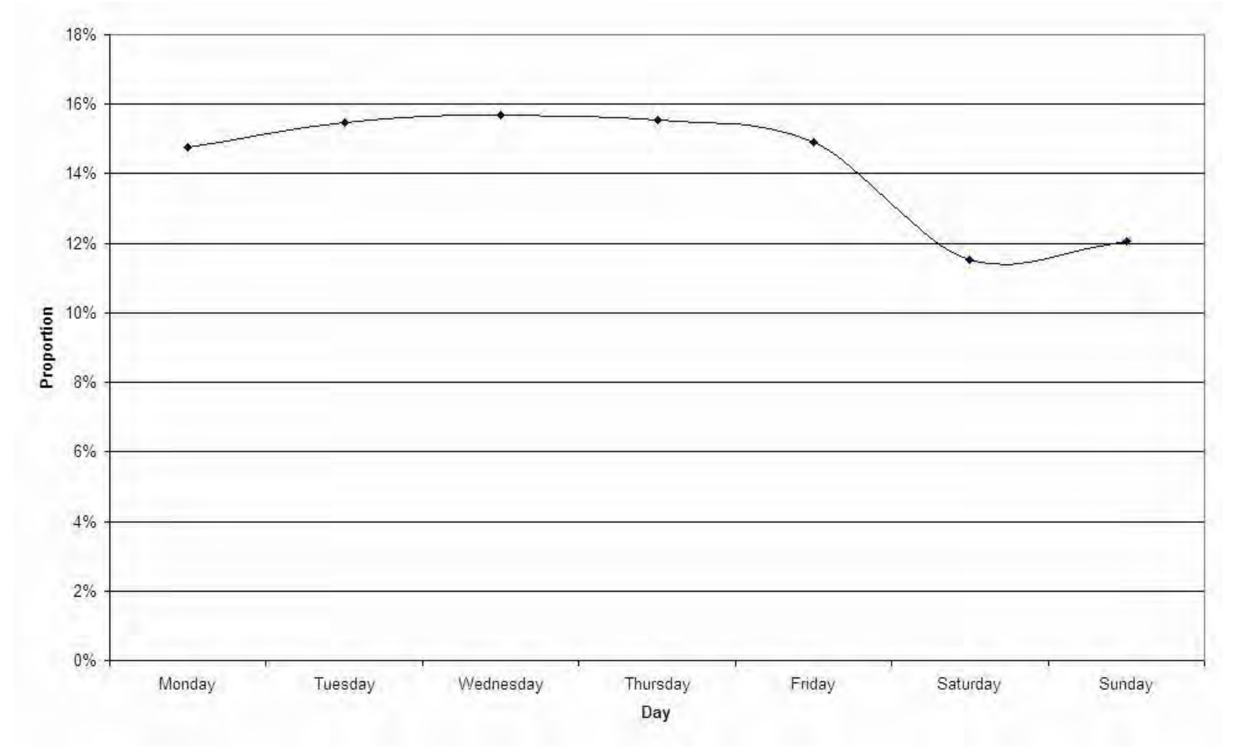

Figure 3-77: Natural gas leakage daily temporal profile

Monthly temporal variation profiles are presented in Table 3-175 and shown in Figure 3-78.

Table 3-175: Natural gas leakage monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	7.48	July	10.87
February	7.44	August	9.76
March	7.18	September	8.09
April	8.14	October	7.84
May	8.81	November	7.81
June	9.72	December	6.86

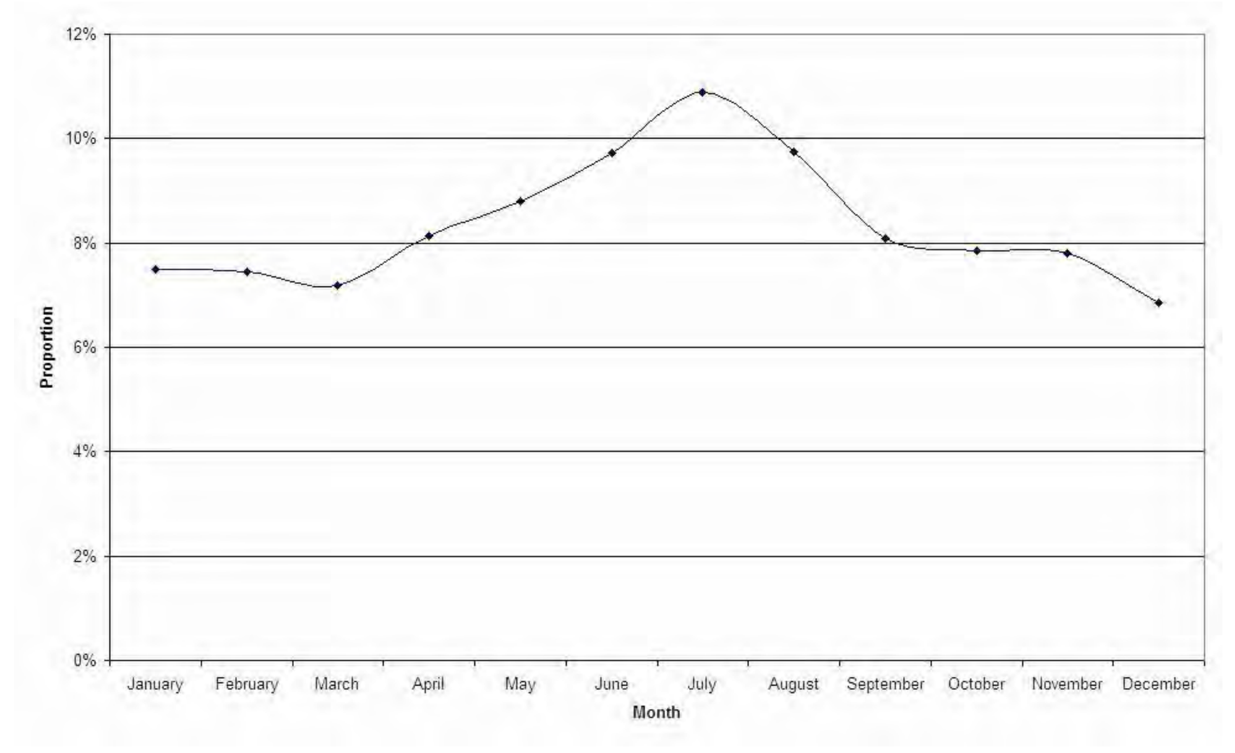

Figure 3-78: Natural gas leakage monthly temporal profile

3.9.7 *Emission Estimates*

Table 3-176 presents annual emissions of selected substances from the natural gas reticulation system by activity.

Table 3-176: Natural gas leakage emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Natural Gas Leakage	TOTAL VOLATILE ORGANIC COMPOUNDS	159,909	380,091	2,317,515	115,548	2,973,063

3.9.8 *Emission Projection Methodology*

Table 3-177 summarises the data used to estimate the emission projection factors from the natural gas reticulation system, while Figure 3-79 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-177: Natural gas leakage emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Fugitive emissions of natural gas from the reticulation system	Primary energy consumption for all sectors using natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

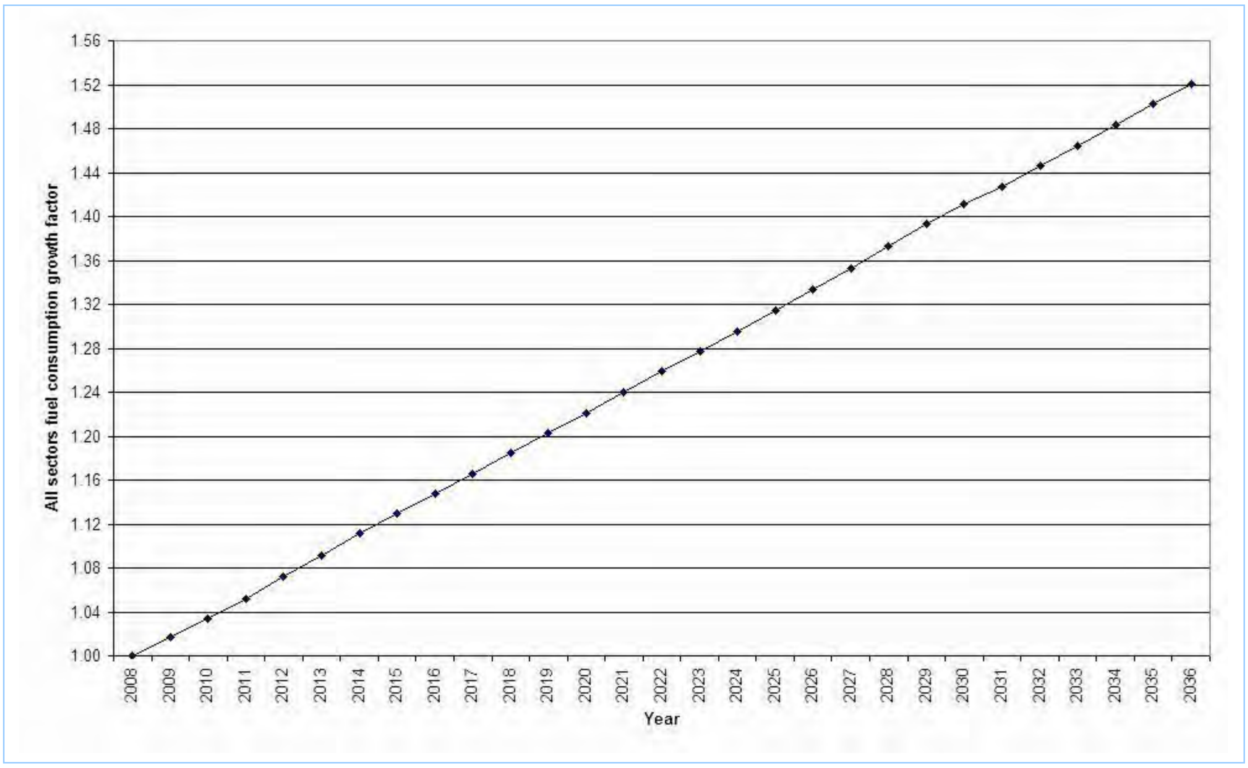

Figure 3-79: Natural gas leakage emission projection factors

3.10 Portable Fuel Containers (domestic)

3.10.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from portable fuel containers. These emissions arise:

- From refuelling (i.e. vapour displacement and spillage);
- During transport (i.e. spillage);
- Due to temperature changes (i.e. diurnal); and
- Via permeation (i.e. plastic fuel containers).

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[54] located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; frequency and duration of equipment use by hour, day and season; lawn area; and proportion of private and commercial usage (TR, 2009). The survey data have been used to estimate the lawn mowing and garden equipment petrol consumption, the number of portable fuel containers and their usage.

Figure 3-80 shows how the domestic survey results have been used to estimate lawn mowing and garden equipment petrol consumption (USEPA, 2009). The estimated petrol consumption has been combined with emission factors from the technical literature (CARB, 1999; and USEPA, 2007b) to develop an inventory of portable fuel container emissions.

[54] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.

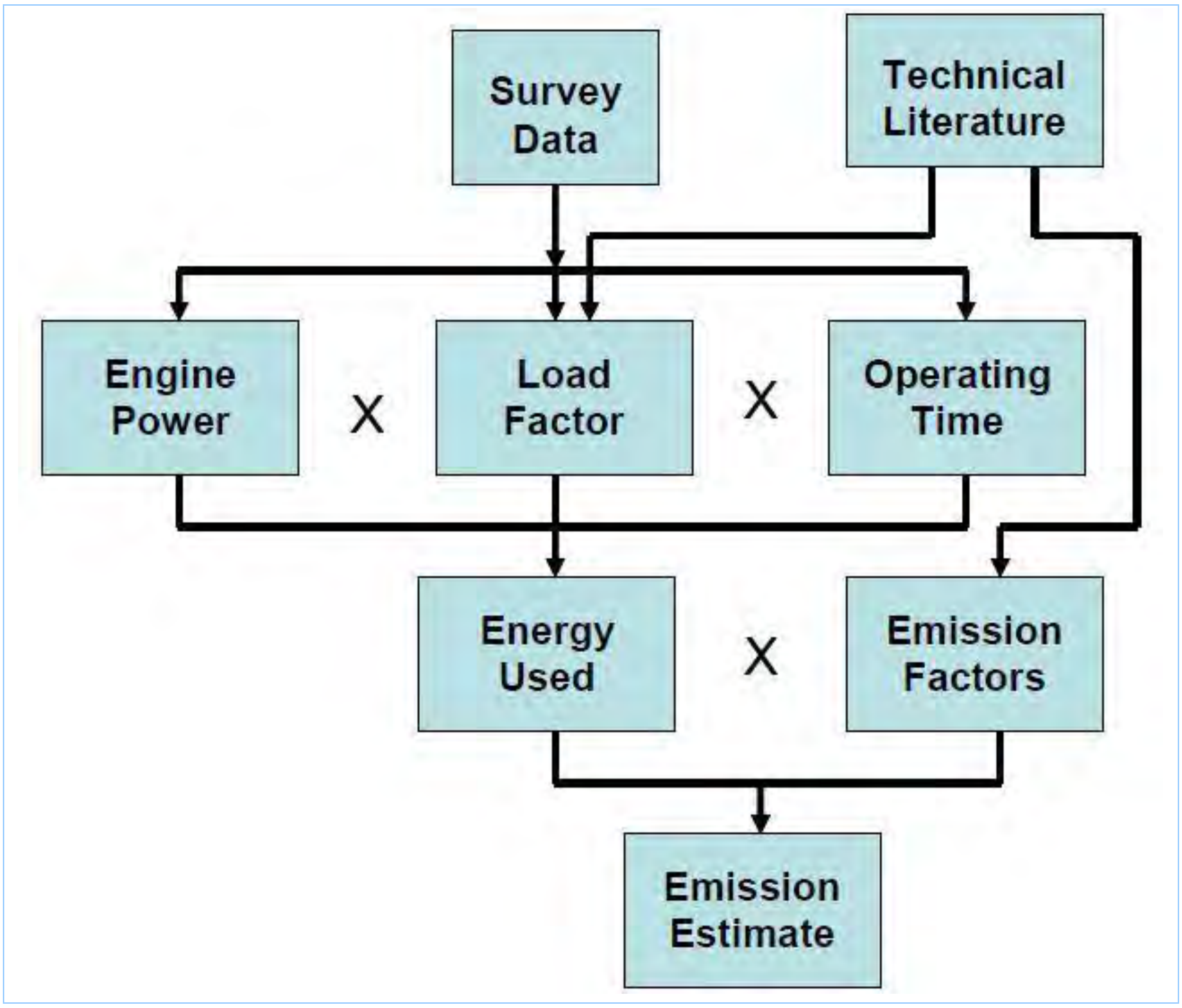

Figure 3-80: Portable fuel containers (domestic) - use of survey data

➢ *Portable fuel container type*

The inventory includes portable fuel containers with an average size of 8.86 litres (CARB, 1999; and USEPA, 2007b) for domestic use, which are constructed of:

- *Metal; and*
- *Plastic.*

➢ *Fuel type*

The inventory includes portable fuel containers that use automotive gasoline (petrol).

Table 3-178 presents the fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009). The sulfur and oxygen contents are requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008), which are relevant for the 2008 calendar year. Weighted average sulfur and oxygen contents have been calculated from *Australian Petroleum Statistics 2008* (DRET, 2009) and the requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008).

Table 3-178: Portable fuel containers (domestic) fuel type and properties

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive gasoline (petrol)	150 - All grades[55]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[56]	2.84 – Weighted average[57]			

➢ *Source type*

The inventory includes evaporative emissions from portable fuel containers.

Evaporation occurs in a number of ways, including:

- *Refuelling emissions* are the vapours displaced from the portable fuel container when it is filled plus any spillage that may occur;
- *Transport emissions* arise when any spillage occurs while the portable fuel container is in transit;
- *Diurnal emissions* arise with temperature changes that occur throughout the day. As the air temperature increases, the fuel temperature in the portable fuel container increases and begins to evaporate; and
- *Permeation emissions* occur when fuel moves through the walls of the portable fuel container. Since the outer surfaces of the portable fuel container are exposed to air, petrol molecules permeate through them and are directly emitted. Permeation is most common through plastic portable fuel containers.

Evaporative emissions mainly include VOC (total and speciated).

3.10.2 *Emission Estimation Methodology*

Table 3-179 summarises the emission estimation methodologies used for portable fuel containers.

Table 3-179: Portable fuel containers (domestic) emission estimation methodologies

Emission source	Emission estimation methodology source
Evaporative emissions from portable fuel containers (domestic)	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b)

[55] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[56] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[57] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

Lawn mowing and garden equipment petrol consumption has been estimated using equipment population and activity data in combination with load and transient adjustment factors within the *NONROAD2008a Model* (USEPA, 2009).

Evaporative emission factors from portable fuel containers have been adjusted according to ambient temperature and Reid vapour pressure (RVP) of petrol (EEA, 2010; CARB, 1999; and USEPA, 2007b).

Equipment population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and seasonal basis. Equipment population and activity rates have been derived from a domestic survey (TR, 2009) and sales data (AIA, 2005). Petrol consumption has been determined using Equation 13 within the *NONROAD2008a Model* (USEPA, 2009):

$$\mathbf{PC_{i,j,k} = P_{i,j,k} \times A_{i,j,k} \times HP_{i,j,k} \times LF_{i,j,k} \times TAF_{i,j,k} \times BSFC_{i,j,k} \times 1.36 \times 0.4536 / 1000} \qquad \text{Equation 13}$$

where:			
$PC_{i,j,k}$	=	Consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k	(kL/year)
$P_{i,j,k}$	=	Population of lawn mowing and garden equipment type i, engine type j and engine power range k	(number)
$A_{i,j,k}$	=	Activity of lawn mowing and garden equipment type i, engine type j and engine power range k	(h/year)
$HP_{i,j,k}$	=	Maximum rated power of lawn mowing and garden equipment type i, engine type j and engine power range k	(hp)
$LF_{i,j,k}$	=	Fractional load factor for lawn mowing and garden equipment type i, engine type j and engine power range k	(hp/hp)
$TAF_{i,j,k}$	=	Fractional transient adjustment factor for lawn mowing and garden equipment type i, engine type j and engine power range k	$(g.(hp.h)^{-1}/g.(hp.h)^{-1})$
$BSFC_{i,j,k}$	=	Brake specific fuel consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k	(lb/hp.h)
i	=	Lawn mowing and garden equipment type (either “Chainsaw”, “Chipper/Mulcher/Shredder”, “Leafblower/Vacuum”, “Pressure washer”, “Push lawnmower”, “Ride-on lawnmower” or “Trimmer/Edger/Brush cutter”)	(-)
j	=	Engine type (either “2-stroke petrol” or “4-stroke-petrol”)	(-)
k	=	Engine power range	(hp)
1.36	=	Specific volume of petrol (ABARE, 2009b)	(L/kg)
0.4536	=	Conversion factor	(kg/lb)
1000	=	Conversion factor	(L/kL)

The number of portable fuel containers has been estimated using petrol consumption combined with residential portable fuel container survey data within Equation 14 (CARB, 1999):

$$N = PC_{i,j,k} \times 1000 / 14.9 \times 3.7862$$ **Equation 14**

where:			
N	=	Number of portable fuel containers	
$PC_{i,j,k}$	=	Consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k (Equation 13)	(kL/year)
14.9	=	Petrol throughput for each portable fuel container (2.34 US gal/refill/portable fuel container x 6.4 refill/year) (Part A - Section 4 c and Table 3; CARB, 1999)	(US gal/portable fuel container/year)
i	=	Lawn mowing and garden equipment type (either "Chainsaw", "Chipper/Mulcher/Shredder", "Leafblower/Vacuum", "Pressure washer", "Push lawnmower", "Ride-on lawnmower" or "Trimmer/Edger/Brush cutter")	(-)
j	=	Engine type (either "2-stroke petrol" or "4-stroke-petrol")	(-)
k	=	Engine power range	(hp)
1000	=	Conversion factor	(L/kL)
3.7862	=	Conversion factor	(L/US gal)

Vapour displacement emissions of VOC from portable fuel containers during refuelling have been estimated using the volume of petrol dispensed combined with ambient temperature and RVP of petrol data within Equation 15 (USEPA, 2009):

$$E_{VOC} = e^{(-1.2798 - 0.0049 \times (T_d - T_a) + 0.0203 \times T_d + 0.1315 \times RVP)} \times PD / 3.7862$$ **Equation 15**

where:			
E_{VOC}	=	Vapour displacement emissions of VOC during refuelling	(kg/year)
T_d	=	Temperature of petrol dispensed ($T_d = 62 + 0.6 \times (T_a - 62)$) (USEPA, 2009)	(°F)
T_a	=	Temperature of ambient air	(°F)
RVP	=	Reid vapour pressure of petrol	(psia)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 13)	(kL/year)
3.7862	=	Conversion factor	(L/US gal)

Spillage emissions of VOC from portable fuel containers during refuelling have been estimated using the volume of petrol dispensed combined with emission factors within Equation 16 (USEPA, 2007b):

$$E_{VOC} = 0.3128 \times PD / 3.7862$$ **Equation 16**

where:			
E_{VOC}	=	Petrol spillage emissions of VOC during refuelling	(kg/year)
0.3128	=	Petrol spillage VOC emission factor during refuelling (Section 2.2.2; USEPA, 2007b)	(g/US gal)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 13)	(kL/year)

where:			
3.7862	=	Conversion factor	(L/US gal)

Spillage emissions of VOC from portable fuel containers during transport have been estimated using the volume of petrol dispensed combined with emission factors within Equation 17 (CARB, 1999):

$$\mathbf{E_{VOC,i} = EF_{VOC,i} \times PC_i \times PD \,/\, 3.7862} \qquad \textbf{Equation 17}$$

where:			
$E_{VOC,i}$	=	Petrol spillage emissions of VOC during transport for portable fuel container condition i	(kg/year)
$EF_{VOC,i}$	=	Petrol spillage VOC emission factor for portable fuel container condition i – 9.829 (23 g/refill ÷ 2.34 US gal/refill) and 13.889 (32.5 g/refill ÷ 2.34 US gal/refill) for closed and open, respectively (Part A - Section 4 c and Table 3; CARB, 1999)	(g/US gal)
PC_i	=	Proportion of portable fuel containers transported in condition i - 66% and 34% for closed and open, respectively (Part A - Table 3; CARB, 1999)	(%)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 13)	(kL/year)
i	=	Portable fuel container condition (either "closed" or "open")	(-)
3.7862	=	Conversion factor	(L/US gal)

Diurnal emissions of VOC from closed portable fuel containers during storage have been estimated using the volume and number of containers combined with emission factors within Equation 18 (CARB, 1999):

$$\mathbf{E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PF/100 \times PC_{i,j}/100 \times V \times N \times 365 \,/\, 1000} \qquad \textbf{Equation 18}$$

where:			
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Diurnal VOC emission factor for portable fuel container condition i and type j – 1.38 and 0.44 for closed plastic and metal, respectively (Part A - Section 4 b; CARB, 1999)	(g/US gal/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
PF	=	Petrol fill rate of portable fuel containers – 49% (Part A - Table 3; CARB, 1999)	(%)
$PC_{i,j}$	=	Proportion of portable fuel containers stored in condition i and type j - 53% and 13% for closed plastic and metal, respectively (Part A - Table 3; CARB, 1999)	(%)
V	=	Volume of portable fuel containers – 2.34 (Part A - Table 3; CARB, 1999)	(US gal)
N	=	Number of portable fuel containers (Equation 14)	(number)
i	=	Portable fuel container condition ("closed")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)

where:			
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

Diurnal emissions of VOC from open portable fuel containers during storage have been estimated using the volume and number of containers combined with emission factors within Equation 19 (CARB, 1999):

$$\mathbf{E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PC_{i,j}/100 \times N \times 365 / 1000} \quad \textbf{Equation 19}$$

where:			
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Diurnal VOC emission factor for portable fuel container condition i and type j – 21.8 and 21.8 for open plastic and metal, respectively (Part A - Section 4 b; CARB, 1999)	(g/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
$PC_{i,j}$	=	Proportion of portable fuel containers stored in condition i and type j - 23% and 11% for open plastic and metal, respectively (Part A - Table 3; CARB, 1999)	(%)
N	=	Number of portable fuel containers (Equation 14)	(number)
i	=	Portable fuel container condition ("open")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

Diurnal emissions of VOC from portable fuel containers during storage have been adjusted using ambient temperature and RVP of petrol data for hourly, daily and monthly time periods within Equation 20 (EEA, 2010):

$$\mathbf{E_{VOC,i,j,k} = E_{VOC,i,j} \times \left(RVP_k \times 10^{(AT_{s,k}+B)}\right) \Big/ \sum_{k=1}^{n} \left(RVP_k \times 10^{(AT_{s,k}+B)}\right)} \quad \textbf{Equation 20}$$

where:			
$E_{VOC,i,j,k}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i, type j and time interval k	(kg/time interval)
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j (Equation 18 and Equation 19)	(kg/year)
RVP_k	=	Reid vapour pressure of petrol for time interval k	(kPa)
A	=	$0.000007047 \times RVP_k + 0.0132$ (Table 3-11; EEA, 2010)	(kPa)
$T_{s,k}$	=	Portable fuel container storage temperature for time interval k ($T_{s,k} = T_{a,k} + 5$) (Section 2.3; USEPA, 2007b)	(°C)
$T_{a,k}$	=	Temperature of ambient air for time interval k	(°C)
B	=	$0.0002311 \times RVP_k - 0.5236$ (Table 3-11; EEA, 2010)	(kPa)

where:			
i	=	Portable fuel container condition (either "closed" or "open")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
k	=	Time interval (either "24" for hour, "7" for day or "12" for month)	(number)
n	=	$\begin{cases} 24 \text{ for k = hour} \\ 7 \text{ for k = day} \\ 12 \text{ for k = month} \end{cases}$	(number)

Permeation emissions of VOC from closed portable fuel containers during storage have been estimated using the volume and number of containers combined with ambient temperature data and emission factors within Equation 21 (CARB, 1999)[58]:

$$E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PF/100 \times PC_{i,j}/100 \times V \times N \times e^{(0.0327 \times (T_s - 85.53))} \times 365 / 1000 \qquad \textbf{Equation 21}$$

where:			
$E_{VOC,i,j}$	=	Permeation emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Permeation VOC emission factor for portable fuel container condition i and type j – 1.57 and 0.06 for closed plastic and metal, respectively (Part A - Section 4 a; CARB, 1999)	(g/US gal/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
PF	=	Petrol fill rate of portable fuel containers – 49%(Part A - Table 3; CARB, 1999)	(%)
PC_i	=	Proportion of portable fuel containers stored in condition i and type j - 53% and 13% for closed plastic and metal, respectively (Part A - Table 3; CARB, 1999)	(%)
V	=	Volume of portable fuel containers (Part A - Table 3; CARB, 1999)	(US gal)
N	=	Number of portable fuel containers (Equation 14)	(number)
T_s	=	Portable fuel container storage temperature ($T_s = T_a + 5$) (Section 2.3; USEPA, 2007b)	(°F)
T_a	=	Temperature of ambient air	(°F)
i	=	Portable fuel container condition ("closed")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

3.10.3 Activity Data

Table 3-180 summarises the activity data used for portable fuel containers.

[58] Since the diurnal emissions of VOC from open portable fuel containers are significantly higher than permeation emissions, Equation 19 combines both diurnal and permeation emissions for open containers (CARB, 1999).

Table 3-180: Portable fuel containers (domestic) activity data

Activity data	Activity data source
Petrol consumption	- *NONROAD2008a Model* (USEPA, 2009) using: *Domestic Lawn Mowing Pollution Survey* (TR, 2009); *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009); and *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)
Portable fuel container survey data	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999)

A domestic survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; frequency and duration of equipment use by hour, day and season; lawn area; and proportion of private and commercial usage (TR, 2009).

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the lawn mowing and garden equipment survey results (TR, 2009).

Lawn mowing and garden equipment sales data for the 2003 and 2004 calendar years (AIA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and non-handheld/handheld equipment with a given maximum power rating, while the lawn mowing and garden equipment survey results (TR, 2009) have been used to estimate the total number of in-service equipment.

A detailed discussion about the activity data used to estimate petrol consumption from lawn mowing and garden equipment is presented in Section 3.6.3.

The domestic survey (TR, 2009), dwelling estimates (TDC, 2009) and sales (AIA, 2005) data have been used to estimate petrol consumption from lawn mowing and garden equipment. Table 3-181 presents the portable fuel container petrol throughput estimates by lawn mowing and garden equipment type from the *NONROAD2008a Model* (USEPA, 2009).

Table 3-181: Portable fuel containers (domestic) petrol throughput in the GMR

Classification	Equipment description	2008 petrol throughput (kL/year)		
		2-stroke petrol	4-stroke petrol	Grand Total
Commercial Equipment	Pressure Washers	-	233	233
Commercial Equipment Total		-	233	233
Lawn and Garden Equipment (com)	Lawn mowers	1,459	4,821	6,280
	Leafblowers/Vacuums	484	288	772
	Other Lawn & Garden Eqp.	11	4	15
	Rear Engine Riding Mowers	325	2,690	3,014
	Trimmers/Edgers/Brush Cutter	1,938	541	2,479
Lawn and Garden Equipment (com) Total		4,217	8,344	12,560
Lawn and Garden Equipment (res)	Chain Saws < 6 HP	1,206	214	1,421
	Lawn mowers	3,988	13,875	17,864

Classification	Equipment description	2008 petrol throughput (kL/year)		
		2-stroke petrol	4-stroke petrol	Grand Total
	Leafblowers/Vacuums	1,500	772	2,272
	Other Lawn & Garden Eqp.	174	63	236
	Rear Engine Riding Mowers	628	5,204	5,832
	Shredders < 6 HP	19	129	148
	Trimmers/Edgers/Brush Cutter	3,933	1,691	5,624
Lawn and Garden Equipment (res) Total		11,448	21,948	33,396
Grand Total		15,665	30,525	46,190

Residential portable fuel container survey data, which includes container storage capacity, type and storage condition (CARB, 1999) have been combined with the petrol throughput estimates to determine the number of portable fuel containers and their emissions. Table 3-182 presents a summary of the residential portable fuel container survey data and estimated number of portable fuel containers.

Table 3-182: Portable fuel containers (domestic) survey data and estimates

Residential portable fuel container parameter	Measure	
Estimated number of portable fuel containers	818,751	
Weighted average container storage capacity	2.34 US gal[59]	
Weighted average stored petrol volume	49%	
Containers stored with petrol	70%	
Container type	plastic - 76%	metal - 24%
Plastic container storage condition	open - 23%	closed - 53%
Metal container storage condition	open - 11%	closed - 13%
All containers storage condition	open - 34%	closed - 66%

Table 3-183 presents the petrol throughput, weighted average petrol RVP (PCO, 2011) and monthly average ambient temperature (Hurley, 2005) data used to estimate portable fuel container emissions.

Table 3-183: Portable fuel containers (domestic) petrol throughput, RVP and ambient temperature by month

Month	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
January	1,568,284	5,938	8.99	62.0	76.7	24.8
February	1,397,507	5,291	8.99	62.0	74.7	23.7
March	978,959	3,707	9.94	68.5	67.6	19.8
April	817,312	3,095	10.88	75.0	59.9	15.5

[59] 1 US gallon (US gal) is equivalent to 3.7862 Litres (L) (USEPA, 1995a).

Month	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
May	655,664	2,482	10.88	75.0	54.5	12.5
June	354,435	1,342	10.88	75.0	50.5	10.3
July	444,660	1,684	10.88	75.0	48.0	8.9
August	534,886	2,025	10.88	75.0	49.3	9.6
September	1,032,232	3,908	10.88	75.0	54.4	12.5
October	1,236,209	4,681	10.88	75.0	60.2	15.7
November	1,440,186	5,453	9.94	68.5	68.3	20.2
December	1,739,060	6,584	8.99	62.0	76.4	24.7
Annual	12,199,393	46,190	9.96	68.7	61.7	16.5

Table 3-184 presents the petrol throughput, weighted average petrol RVP (PCO, 2011) and hourly average ambient temperature (Hurley, 2005) data used to estimate portable fuel container emissions.

Table 3-184: Portable fuel containers (domestic) petrol throughput, RVP and ambient temperature by hour

Hour	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
1	-	-	9.96	68.7	50.4	10.2
2	-	-	9.96	68.7	49.8	9.9
3	-	-	9.96	68.7	49.3	9.6
4	-	-	9.96	68.7	49.0	9.4
5	-	-	9.96	68.7	48.7	9.3
6	-	-	9.96	68.7	49.4	9.7
7	31,161	118	9.96	68.7	53.9	12.2
8	93,482	354	9.96	68.7	61.3	16.3
9	358,347	1,357	9.96	68.7	68.9	20.5
10	1,230,846	4,660	9.96	68.7	74.4	23.5
11	2,305,888	8,731	9.96	68.7	77.7	25.4
12	1,464,550	5,545	9.96	68.7	79.6	26.4
13	981,560	3,716	9.96	68.7	80.2	26.8
14	934,819	3,539	9.96	68.7	79.6	26.5
15	1,121,783	4,247	9.96	68.7	77.9	25.5
16	1,339,908	5,073	9.96	68.7	75.0	23.9
17	1,417,809	5,368	9.96	68.7	70.5	21.4
18	716,695	2,714	9.96	68.7	64.4	18.0
19	171,384	649	9.96	68.7	58.7	14.9
20	31,161	118	9.96	68.7	54.9	12.7
21	-	-	9.96	68.7	53.1	11.7
22	-	-	9.96	68.7	52.1	11.1
23	-	-	9.96	68.7	51.4	10.8
24	-	-	9.96	68.7	50.8	10.5
Annual	12,199,393	46,190	9.96	68.7	61.7	16.5

3.10.4 Emission and Speciation Factors

Table 3-185 summarises the emission and speciation factors used for portable fuel containers.

Table 3-185: Portable fuel containers (domestic) emission and speciation factors

Emission source	Substance	Emission and speciation factor source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (domestic)	Criteria pollutants: VOC	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b) - *NONROAD2008a Model* (USEPA, 2009)
	Speciated VOC	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	Organic air toxics	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)

Table 3-186 presents average activity weighted emission factors for portable fuel containers.

Table 3-186: Portable fuel containers (domestic) emission factors

Emission source	Emission factor (kg/kL)
	VOC
Vapour displacement during refuelling	1.0129
Spillage during refuelling	0.0826
Spillage during transport	2.9606
Diurnal during storage	37.6636
Permeation during storage	2.4949
Grand Total	44.2146

3.10.5 Spatial Distribution of Emissions

Table 3-187 summarises the data used for spatially allocating emissions from portable fuel containers.

Table 3-187: Portable fuel containers (domestic) spatial data

Emission source	Spatial data	Spatial data source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (domestic)	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from portable fuel containers have been spatially distributed according to petrol throughput, which is proportional to free standing dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of petrol throughput by LGA and region is presented in Table 3-188 and shown in Figure 3-81.

Table 3-188: Portable fuel containers (domestic) spatial distribution of petrol throughput by LGA and region

LGA	2008 proportion of annual petrol throughput (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.72	-	0.72
Auburn	-	-	0.94	-	0.94
Bankstown	-	-	3.37	-	3.37
Bathurst Regional	-	2.78×10^{-3}	-	-	2.78×10^{-3}
Baulkham Hills	-	2.50×10^{-3}	3.50	-	3.50
Blacktown	-	-	5.92	-	5.92
Blue Mountains	-	0.70	1.28	-	1.97
Botany Bay	-	-	0.53	-	0.53
Burwood	-	-	0.47	-	0.47
Camden	-	-	1.19	-	1.19
Campbelltown	-	-	3.26	-	3.26
Canada Bay	-	-	1.06	-	1.06
Canterbury	-	-	2.08	-	2.08
Cessnock	4.90×10^{-2}	1.11	-	-	1.15
Dungog	-	0.18	-	-	0.18
Fairfield	-	-	3.39	-	3.39
Gosford	-	1.06	2.87	-	3.93
Goulburn Mulwaree	-	5.41×10^{-3}	-	-	5.41×10^{-3}
Great Lakes	-	8.49×10^{-2}	-	-	8.49×10^{-2}
Hawkesbury	-	2.90×10^{-2}	1.34	-	1.37
Holroyd	-	-	1.77	-	1.77
Hornsby	-	4.26×10^{-3}	3.07	-	3.08
Hunters Hill	-	-	0.15	-	0.15
Hurstville	-	-	1.50	-	1.50
Kiama	-	0.32	-	-	0.32
Kogarah	-	-	0.92	-	0.92
Ku-ring-gai	-	-	2.14	-	2.14
Lake Macquarie	2.46	2.21	-	-	4.66
Lane Cove	-	-	0.43	-	0.43
Leichhardt	-	-	0.83	-	0.83
Lithgow	-	0.45	-	-	0.45
Liverpool	-	-	3.26	-	3.26
Maitland	0.12	1.39	-	-	1.51
Manly	-	-	0.49	-	0.49
Marrickville	-	-	1.51	-	1.51
Mid-western Regional	-	6.41×10^{-2}	-	-	6.41×10^{-2}
Mosman	-	-	0.42	-	0.42
Muswellbrook	-	0.31	-	-	0.31
N/A	1.46×10^{-2}	6.58×10^{-2}	0.27	3.05×10^{-2}	0.38
Newcastle	3.48	-	-	-	3.48
North Sydney	-	-	0.55	-	0.55
Oberon	-	2.87×10^{-2}	-	-	2.87×10^{-2}
Parramatta	-	-	2.50	-	2.50
Penrith	-	-	3.81	-	3.81

LGA	2008 proportion of annual petrol throughput (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Pittwater	-	-	1.16	-	1.16
Port Stephens	7.89×10^{-2}	1.31	-	-	1.39
Randwick	-	-	1.69	-	1.69
Rockdale	-	-	1.39	-	1.39
Ryde	-	-	1.90	-	1.90
Shellharbour	-	1.10	-	0.34	1.44
Shoalhaven	-	2.06×10^{-3}	-	-	2.06×10^{-3}
Singleton	-	0.44	-	-	0.44
Strathfield	-	-	0.50	-	0.50
Sutherland	-	-	4.15	-	4.15
Sydney	-	-	1.53	-	1.53
Unincorporated	-	-	0.54	-	0.54
Upper Lachlan	-	8.65×10^{-4}	-	-	8.65×10^{-4}
Warringah	-	-	2.39	-	2.39
Waverley	-	-	0.64	-	0.64
Willoughby	-	-	0.99	-	0.99
Wingecarribee	-	1.10	6.02×10^{-3}	1.94×10^{-3}	1.11
Wollondilly	-	1.49×10^{-2}	0.93	4.83×10^{-4}	0.95
Wollongong	-	-	0.33	3.72	4.05
Woollahra	-	-	0.50	-	0.50
Wyong	-	3.57	-	-	3.57
Grand Total	6.20	15.55	74.16	4.09	100.00

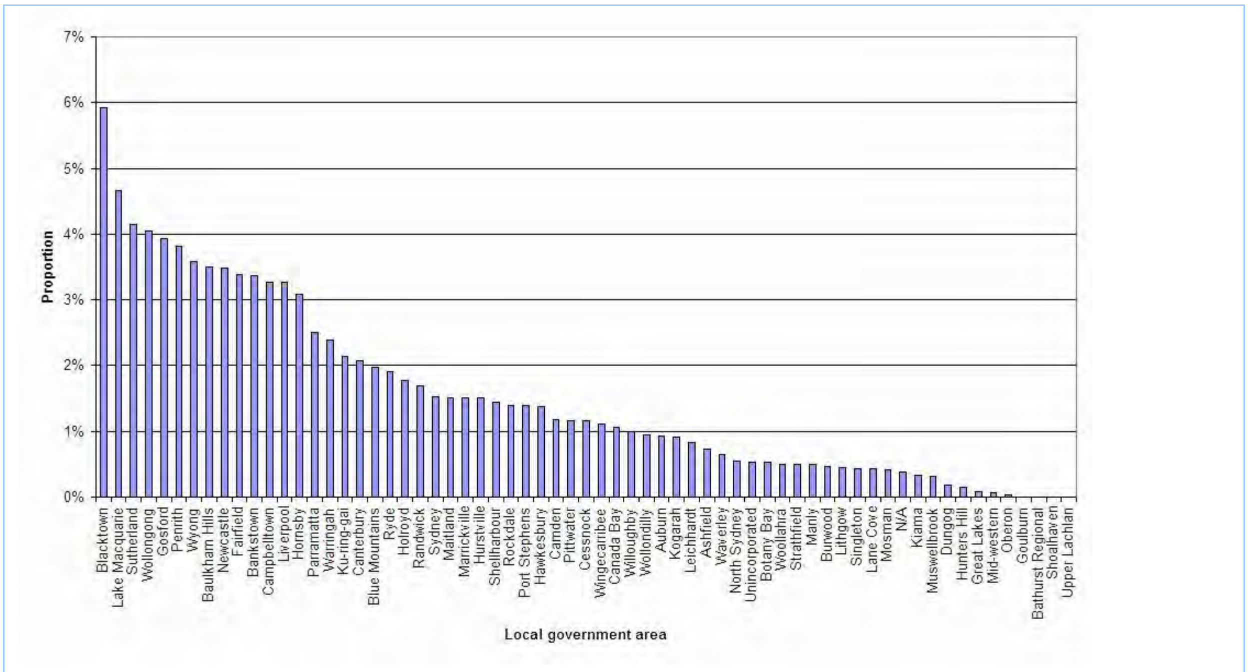

Figure 3-81: Portable fuel containers (domestic) spatial distribution of petrol throughput by LGA

Figure 3-82 shows the spatial distribution of portable fuel container emissions.

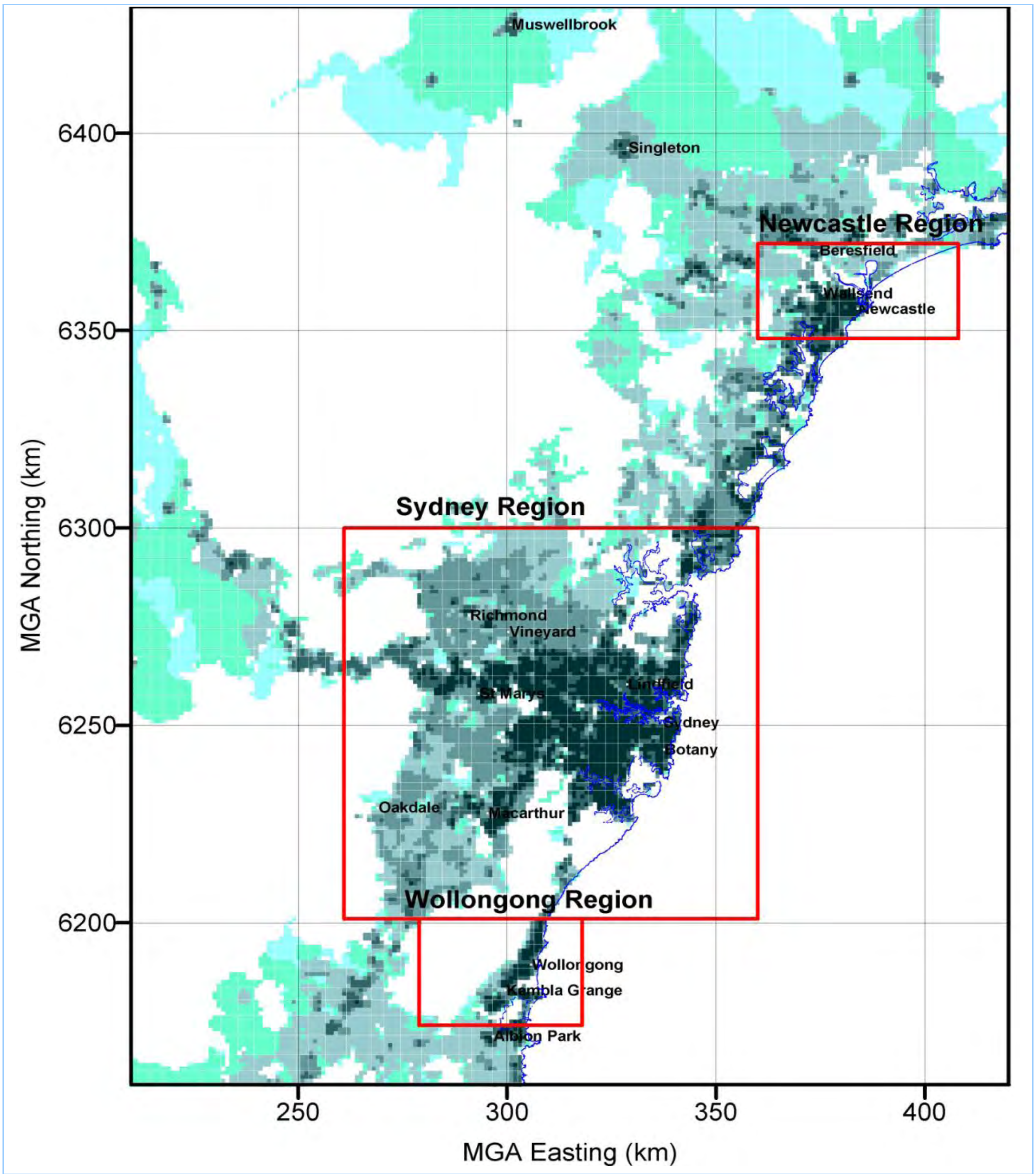

Figure 3-82: Portable fuel containers (domestic) spatial distribution of emissions

3.10.6 Temporal Variation of Emissions

Table 3-189 summarises the data used to estimate the temporal variation in emissions from portable fuel containers.

Table 3-189: Portable fuel containers (domestic) temporal data

Emission source	Temporal data	Temporal data source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (domestic)	Monthly, daily and hourly: Derived from domestic survey combined with hourly meteorological data (temperature (Kelvin) and monthly petrol Reid vapour pressure (RVP)	- *Domestic Lawn Mowing Pollution Survey* (TR, 2009) - *The Air Pollution Model (TAPM) Version 3* (Hurley, 2005) - *Protection of the Environment Operations (Clean Air) Regulation 2010* (PCO, 2011)

The domestic survey (TR, 2009), dwelling estimates (TDC, 2009) and sales (AIA, 2005) data have been used to estimate hourly, daily and monthly petrol consumption from lawn mowing and garden equipment within the *NONROAD2008a Model* (USEPA, 2009). The temporal variation in evaporative emissions from portable fuel containers have been estimated using the hourly, daily and monthly petrol throughput estimates by lawn mowing and garden equipment type combined with petrol RVP (PCO, 2011) and ambient temperature (Hurley, 2005) data within Equation 15 to Equation 21.

The temporal variation in evaporative emissions of VOC from portable fuel containers is a function of a number of factors including, temperature, RVP of petrol, volume of petrol dispensed and/or volume and number of portable fuel containers, so annual emissions have been apportioned to hourly, daily and monthly time periods using Equation 22:

$$\mathbf{E_{VOC,i,j,k} = E_{VOC,i,j} \times f(T_k, RVP_k, PD_k, V, N) \Big/ \sum_{k=1}^{n} f(T_k, RVP_k, PD_k, V, N)} \qquad \textbf{Equation 22}$$

where:			
$E_{VOC,i,j,k}$	=	Evaporative emissions of VOC for portable fuel container emission source i, type j and time interval k	(kg/time interval)
$E_{VOC,i,j}$	=	Evaporative emissions of VOC for portable fuel container emission source i and type j (Equation 15 to Equation 21)	(kg/year)
T_k	=	Temperature for time interval k	(°C)
RVP_k	=	Reid vapour pressure of petrol for time interval k	(kPa)
PD_k	=	Volume of petrol dispensed for time interval k	(kL/time interval)
V	=	Volume of portable fuel containers – 8.86 (Part A - Table 3; CARB, 1999)	(L)
N	=	Number of portable fuel containers (Equation 14)	(number)
i	=	Portable fuel container emission source (either "vapour displacement", "spillage", "diurnal" or "storage")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
k	=	Time interval (either "24" for hour, "7" for day or "12" for month)	(number)
n	=	$\left\}\begin{array}{l} 24 \text{ for k = hour} \\ 7 \text{ for k = day} \\ 12 \text{ for k = month} \end{array}\right.$	(number)

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-190 (weighted hourly composite) and shown in Figure 3-83 (weighted hourly composite by source type).

Table 3-190: Portable fuel containers (domestic) hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	3.12	2.73	13	5.86	6.15
2	3.09	2.70	14	5.78	6.03
3	3.06	2.68	15	5.69	6.13
4	3.04	2.66	16	5.51	6.18
5	3.02	2.65	17	5.14	5.92
6	3.06	2.68	18	4.34	4.51
7	3.34	2.95	19	3.71	3.41
8	3.85	3.47	20	3.40	3.01
9	4.54	4.33	21	3.28	2.87
10	5.40	5.98	22	3.22	2.82
11	6.21	7.81	23	3.18	2.78
12	6.02	6.78	24	3.14	2.75

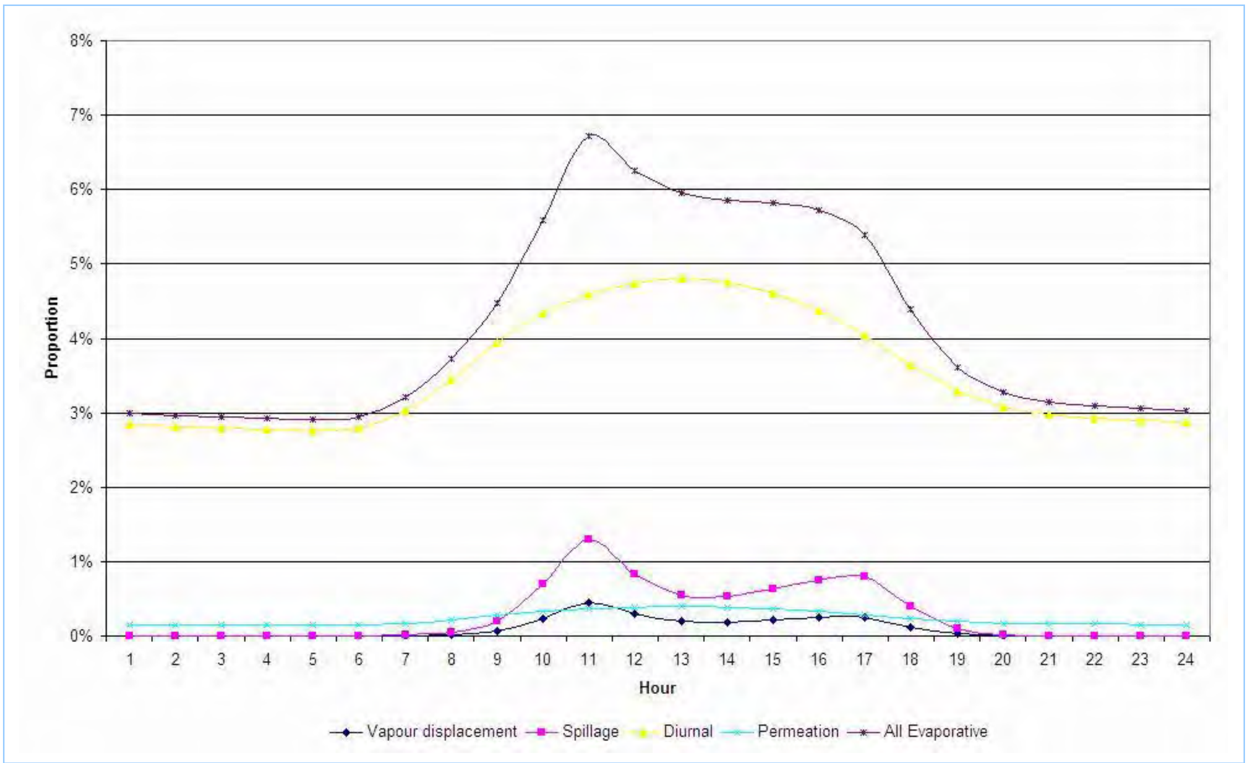

Figure 3-83: Portable fuel containers (domestic) hourly temporal profile

Daily temporal variation profiles for evaporative emissions are presented in Table 3-191 (weighted daily composite) and shown in Figure 3-84 (weighted daily composite by source type).

Table 3-191: Portable fuel containers (domestic) daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	13.73	13.73	13.73	13.73	13.73	15.67	15.67

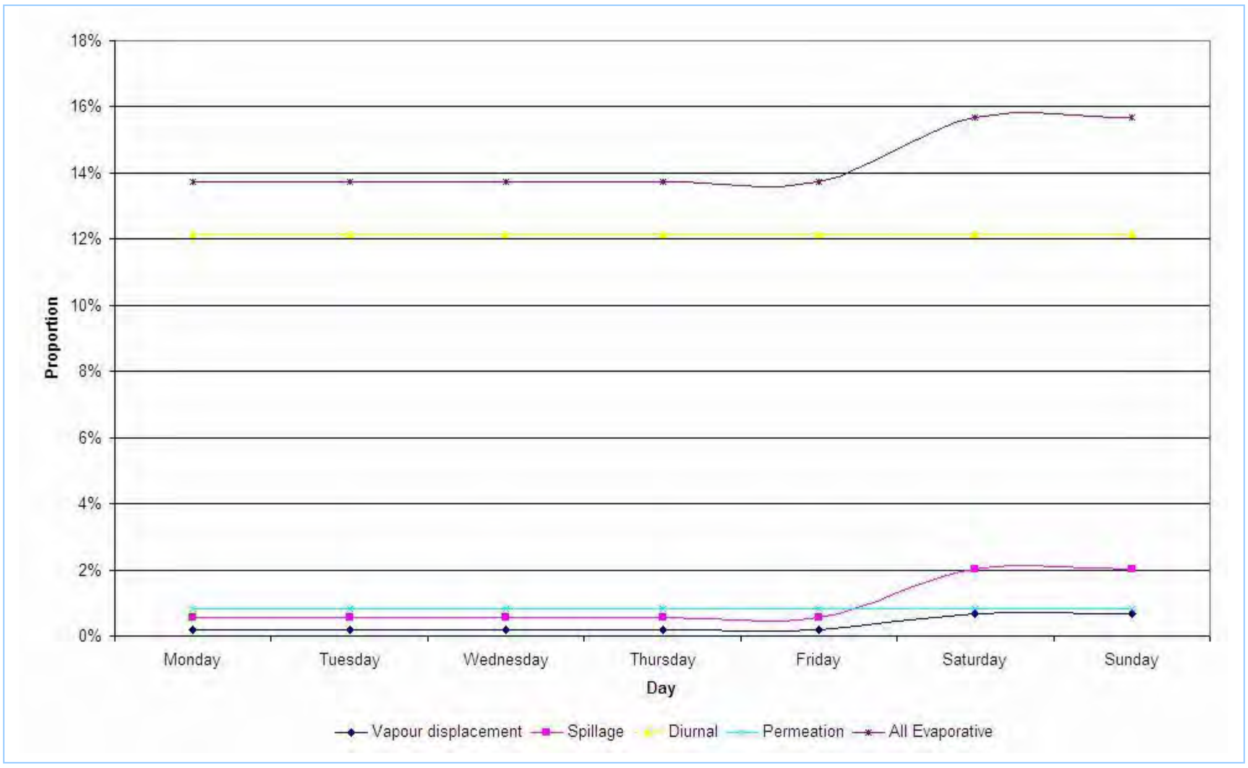

Figure 3-84: Portable fuel containers (domestic) daily temporal profile

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-192 (weighted monthly composite) and shown in Figure 3-85 (weighted monthly composite by source type).

Table 3-192: Portable fuel containers (domestic) monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	9.92	July	6.54
February	9.46	August	6.75
March	8.87	September	7.76
April	8.36	October	8.72
May	7.49	November	9.34
June	6.77	December	10.01

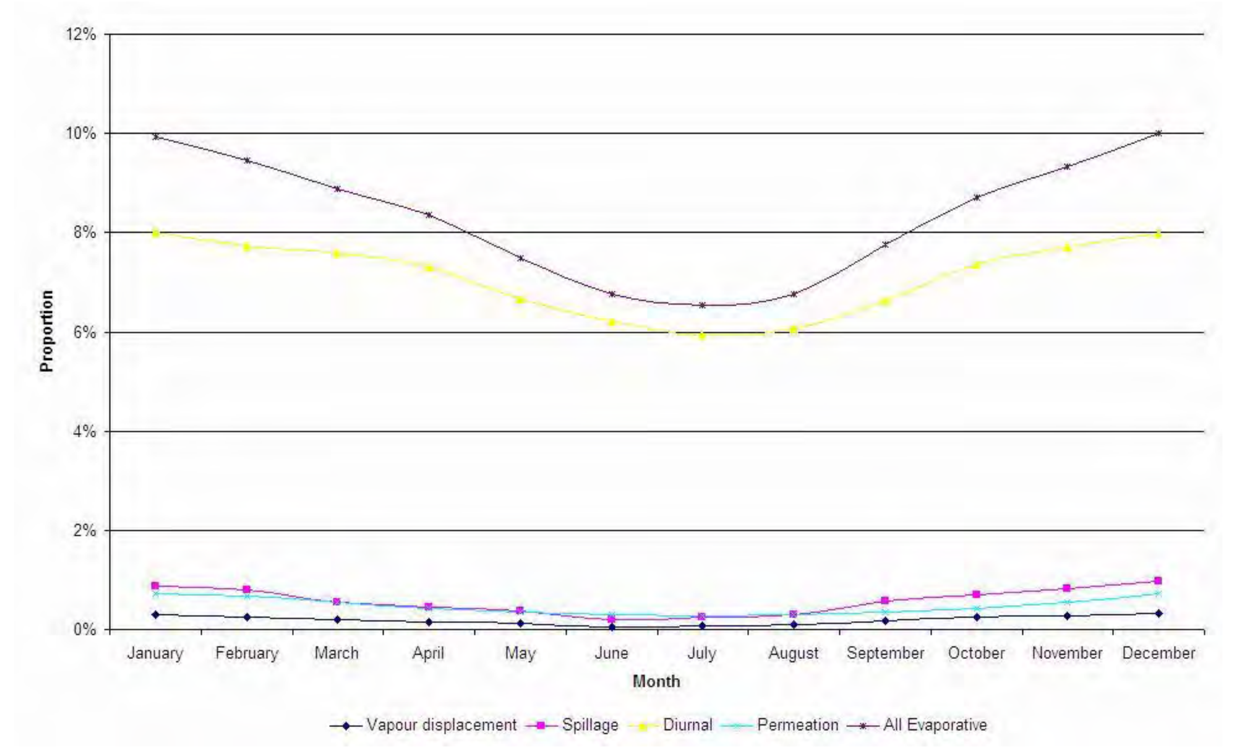

Figure 3-85: Portable fuel containers (domestic) monthly temporal profile

3.10.7 *Emission Estimates*

Table 3-193 presents annual emissions of selected substances from portable fuel containers by activity.

Table 3-193: Portable fuel containers (domestic) emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Portable Fuel Containers (Domestic)	BENZENE	987	2,478	11,813	652	15,930
	ISOMERS OF XYLENE	696	1,747	8,330	460	11,232
	TOLUENE	2,405	6,035	28,775	1,588	38,803
	TOTAL VOLATILE ORGANIC COMPOUNDS	126,557	317,638	1,514,493	83,576	2,042,263

3.10.8 *Emission Projection Methodology*

Table 3-194 summarises the data used to estimate the emission projection factors for portable fuel containers, while Figure 3-86 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-194: Portable fuel containers (domestic) emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Vapour displacement, spillage, diurnal and permeation	Total dwelling	- *Forecasts for Total Dwelling*

Emission source	Projection factor surrogate	Projection factor source
emissions from portable fuel containers (domestic)	growth	*from 2006 to 2036* (TDC, 2009)

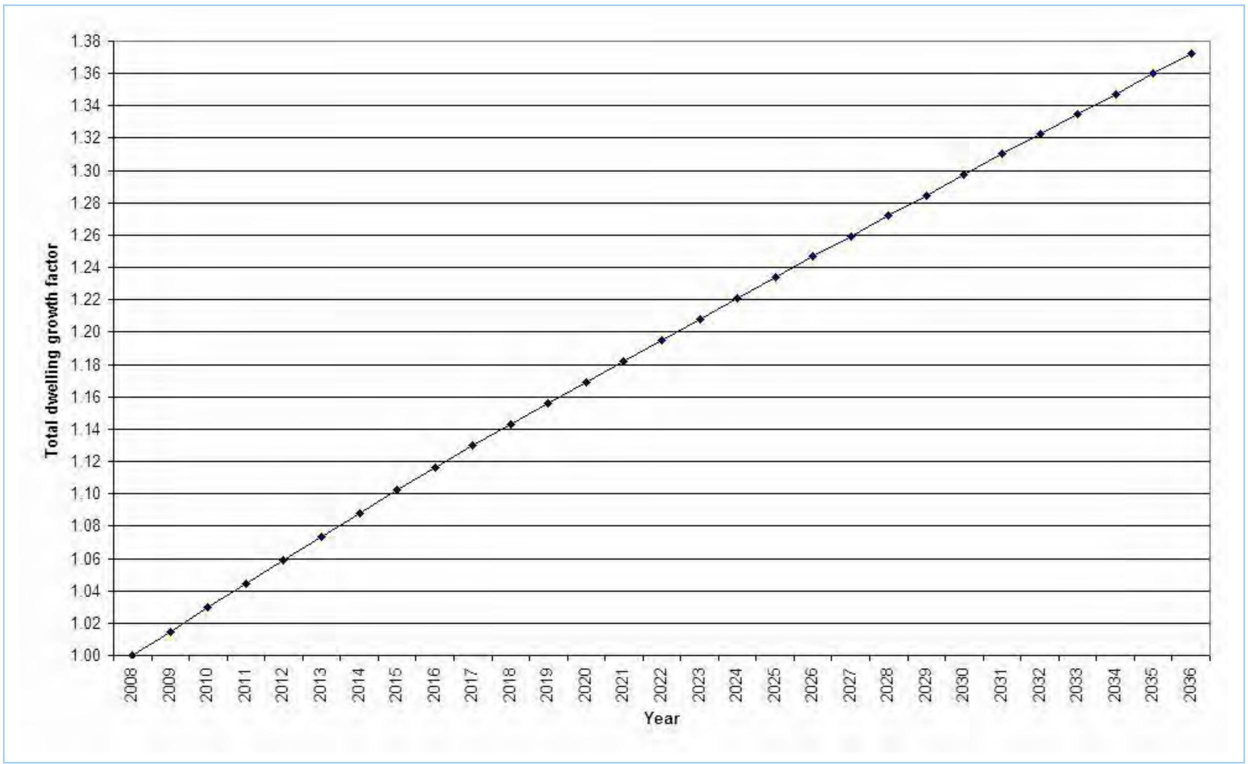

Figure 3-86: Portable fuel containers (domestic) emission projection factors

3.11 Portable Fuel Containers (public open space)

3.11.1 *Emission Source Description*

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from portable fuel containers. These emissions arise:

- From refuelling (i.e. vapour displacement and spillage);
- During transport (i.e. spillage);
- Due to temperature changes (i.e. diurnal); and
- Via permeation (i.e. plastic fuel containers).

To estimate emissions from these sources, the following have been considered:

- *Commercial survey*

A commercial survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes 5 golf courses and 9 LGA[60] located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; and frequency and duration of equipment use by hour, day and season (DECC, 2007b). The survey data have been used to estimate the lawn mowing and garden equipment petrol consumption, the number of portable fuel containers and their usage.

Figure 3-87 shows how the commercial survey results have been used to estimate lawn mowing and garden equipment petrol consumption (USEPA, 2009). The estimated petrol consumption has been combined with emission factors from the technical literature (CARB, 1999; and USEPA, 2007b) to develop an inventory of portable fuel container emissions.

[60] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 59 LGA plus the two areas designated N/A and unincorporated.

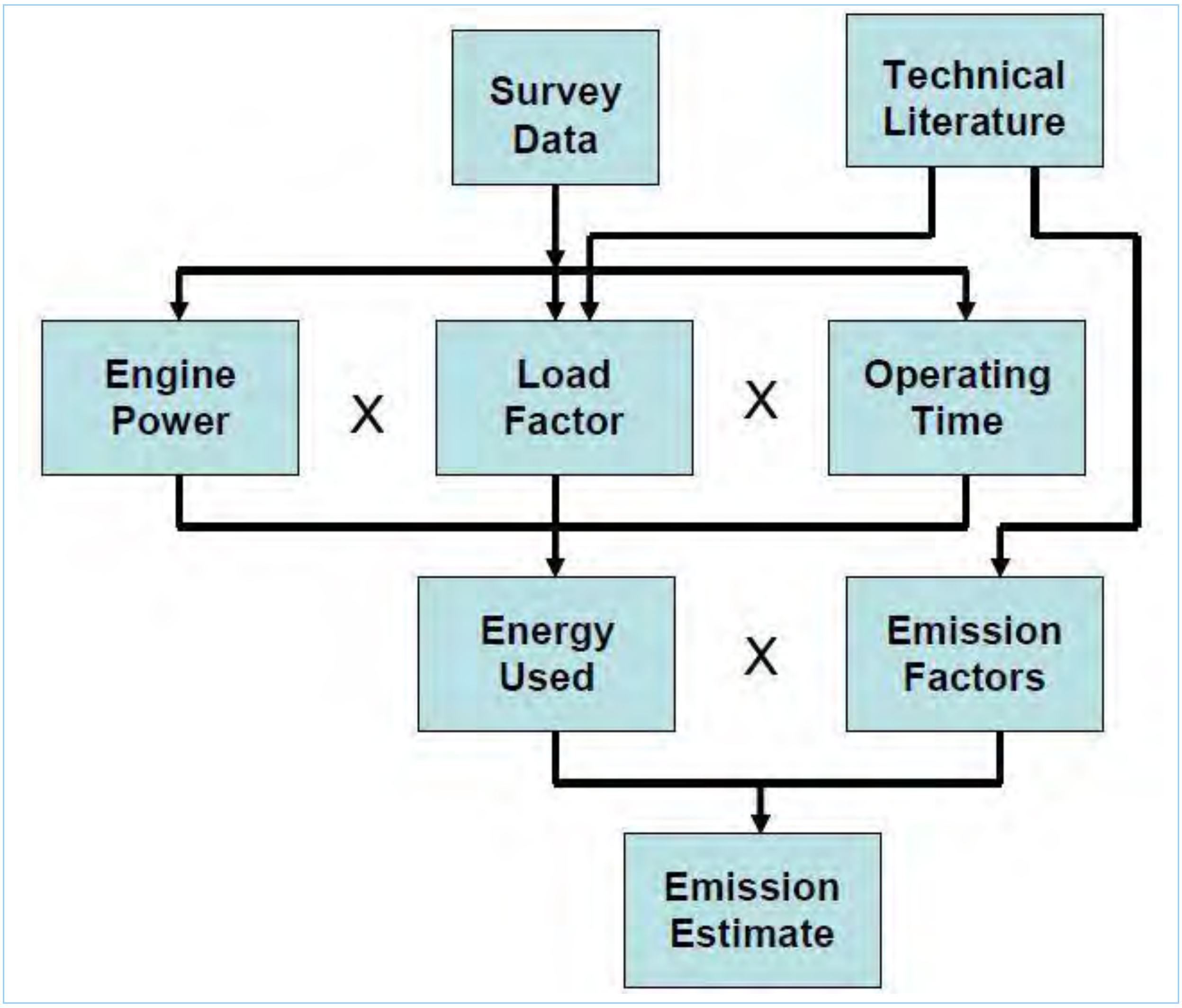

Figure 3-87: Portable fuel containers (public open space) - use of survey data

- *Portable fuel container type*

The inventory includes portable fuel containers with an average size of 12.99 litres (CARB, 1999; and USEPA, 2007b) for commercial use, which are constructed of:

  - *Metal; and*
  - *Plastic.*

- *Fuel type*

The inventory includes portable fuel containers that use automotive gasoline (petrol).

Table 3-195 presents the fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009). The sulfur and oxygen contents are requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008), which are relevant for the 2008 calendar year. Weighted average sulfur and oxygen contents have been calculated from *Australian Petroleum Statistics 2008* (DRET, 2009) and the requirements of the *Fuel Standard (Petrol) Determination 2001* (Attorney-General's Department, 2008).

Table 3-195: Portable fuel containers (public open space) fuel type and properties

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive gasoline (petrol)	150 - All grades[61]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[62]	2.84 – Weighted average[63]			

- *Source type*

The inventory includes evaporative emissions from portable fuel containers.

Evaporation occurs in a number of ways, including:

- *Refuelling emissions* are the vapours displaced from the portable fuel container when it is filled plus any spillage that may occur;
- *Transport emissions* arise when any spillage occurs while the portable fuel container is in transit;
- *Diurnal emissions* arise with temperature changes that occur throughout the day. As the air temperature increases, the fuel temperature in the portable fuel container increases and begins to evaporate; and
- *Permeation emissions* occur when fuel moves through the walls of the portable fuel container. Since the outer surfaces of the portable fuel container are exposed to air, petrol molecules permeate through them and are directly emitted. Permeation is most common through plastic portable fuel containers.

Evaporative emissions mainly include VOC (total and speciated).

3.11.2 Emission Estimation Methodology

Table 3-196 summarises the emission estimation methodologies used for portable fuel containers.

Table 3-196: Portable fuel containers (public open space) emission estimation methodologies

Emission source	Emission estimation methodology source
Evaporative emissions from portable fuel containers (public open space)	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b)

[61] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[62] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[63] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

Lawn mowing and garden equipment petrol consumption has been estimated using equipment population and activity data in combination with load and transient adjustment factors within the *NONROAD2008a Model* (USEPA, 2009).

Evaporative emission factors from portable fuel containers have been adjusted according to ambient temperature and Reid vapour pressure (RVP) of petrol (EEA, 2010; CARB, 1999; and USEPA, 2007b).

Equipment population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and seasonal basis. Equipment population and activity rates have been derived from a commercial survey (DECC, 2007b) and sales data (AIA, 2005). Petrol consumption has been determined using Equation 23 within the *NONROAD2008a Model* (USEPA, 2009):

$$\mathbf{PC_{i,j,k} = P_{i,j,k} \times A_{i,j,k} \times HP_{i,j,k} \times LF_{i,j,k} \times TAF_{i,j,k} \times BSFC_{i,j,k} \times 1.36 \times 0.4536 / 1000} \qquad \textbf{Equation 23}$$

where:			
$PC_{i,j,k}$	=	Consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k	(kL/year)
$P_{i,j,k}$	=	Population of lawn mowing and garden equipment type i, engine type j and engine power range k	(number)
$A_{i,j,k}$	=	Activity of lawn mowing and garden equipment type i, engine type j and engine power range k	(h/year)
$HP_{i,j,k}$	=	Maximum rated power of lawn mowing and garden equipment type i, engine type j and engine power range k	(hp)
$LF_{i,j,k}$	=	Fractional load factor for lawn mowing and garden equipment type i, engine type j and engine power range k	(hp/hp)
$TAF_{i,j,k}$	=	Fractional transient adjustment factor for lawn mowing and garden equipment type i, engine type j and engine power range k	$(g.(hp.h)^{-1}/ g.(hp.h)^{-1})$
$BSFC_{i,j,k}$	=	Brake specific fuel consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k	(lb/hp.h)
i	=	Lawn mowing and garden equipment type (either “Chainsaw”, “Chipper/Stump grinder”, “Commercial mower”, “Commercial turf equipment”, “Front mower”, “Golf cart”, “Lawn and garden tractor”, “Leafblower/Vacuum”, “Other lawn and garden equipment”, “Push lawnmower”, “Rear engine ride-on lawnmower”, “Rotary tiller”, “Shredder”, “Speciality vehicle cart” or “Trimmer/Edger/Brush cutter”)	(-)
j	=	Engine type (either “2-stroke petrol” or “4-stroke-petrol”)	(-)
k	=	Engine power range	(hp)
1.36	=	Specific volume of petrol (ABARE, 2009b)	(L/kg)
0.4536	=	Conversion factor	(kg/lb)
1000	=	Conversion factor	(L/kL)

The number of portable fuel containers has been estimated using petrol consumption combined with commercial portable fuel container survey data within Equation 24 (CARB, 1999):

$$N = PC_{i,j,k} \times 1000 / 1206.9 \times 3.7862$$ **Equation 24**

where:			
N	=	Number of portable fuel containers	
$PC_{i,j,k}$	=	Consumption of petrol from lawn mowing and garden equipment type i, engine type j and engine power range k (Equation 23)	(kL/year)
1206.9	=	Petrol throughput for each portable fuel container (3.43 US gal/refill/portable fuel container x 351.9 refill/year) (Part B - Table 8 and Section 3 c; CARB, 1999)	(US gal/portable fuel container/year)
i	=	Lawn mowing and garden equipment type (either "Chainsaw", "Chipper/Stump grinder", "Commercial mower", "Commercial turf equipment", "Front mower", "Golf cart", "Lawn and garden tractor", "Leafblower/Vacuum", "Other lawn and garden equipment", "Push lawnmower", "Rear engine ride-on lawnmower", "Rotary tiller", "Shredder", "Speciality vehicle cart" or "Trimmer/Edger/Brush cutter")	(-)
j	=	Engine type (either "2-stroke petrol" or "4-stroke-petrol")	(-)
k	=	Engine power range	(hp)
1000	=	Conversion factor	(L/kL)
3.7862	=	Conversion factor	(L/US gal)

Vapour displacement emissions of VOC from portable fuel containers during refuelling have been estimated using the volume of petrol dispensed combined with ambient temperature and RVP of petrol data within Equation 25 (USEPA, 2009):

$$E_{VOC} = e^{(-1.2798 - 0.0049 \times (T_d - T_a) + 0.0203 \times T_d + 0.1315 \times RVP)} \times PD / 3.7862$$ **Equation 25**

where:			
E_{VOC}	=	Vapour displacement emissions of VOC during refuelling	(kg/year)
T_d	=	Temperature of petrol dispensed ($T_d = 62 + 0.6 \times (T_a - 62)$) (USEPA, 2009)	(°F)
T_a	=	Temperature of ambient air	(°F)
RVP	=	Reid vapour pressure of petrol	(psia)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 23)	(kL/year)
3.7862	=	Conversion factor	(L/US gal)

Spillage emissions of VOC from portable fuel containers during refuelling have been estimated using the volume of petrol dispensed combined with emission factors within Equation 26 (USEPA, 2007b):

$$E_{VOC} = 0.3128 \times PD / 3.7862$$ **Equation 26**

where:			
E_{VOC}	=	Petrol spillage emissions of VOC during refuelling	(kg/year)

where:			
0.3128	=	Petrol spillage VOC emission factor during refuelling (Section 2.2.2; USEPA, 2007b)	(g/US gal)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 23)	(kL/year)
3.7862	=	Conversion factor	(L/US gal)

Spillage emissions of VOC from portable fuel containers during transport have been estimated using the volume of petrol dispensed combined with emission factors within Equation 27 (CARB, 1999):

$$\mathbf{E_{VOC,i} = EF_{VOC,i} \times PC_i \times PD / 3.7862} \qquad \textbf{Equation 27}$$

where:			
$E_{VOC,i}$	=	Petrol spillage emissions of VOC during transport for portable fuel container condition i	(kg/year)
$EF_{VOC,i}$	=	Petrol spillage VOC emission factor for portable fuel container condition i – 9.829 (23 g/refill ÷ 2.34 US gal/refill) and 13.889 (32.5 g/refill ÷ 2.34 US gal/refill) for closed and open, respectively (Part A - Table 3 and Section 4 c and Part B - Section 3 c; CARB, 1999)	(g/US gal)
PC_i	=	Proportion of portable fuel containers transported in condition i - 51% and 49% for closed and open, respectively (Part B - Table 8; CARB, 1999)	(%)
PD	=	Volume of petrol dispensed - $PC_{i,j,k}$ (Equation 23)	(kL/year)
i	=	Portable fuel container condition (either “closed” or “open”)	(-)
3.7862	=	Conversion factor	(L/US gal)

Diurnal emissions of VOC from closed portable fuel containers during storage have been estimated using the volume and number of containers combined with emission factors within Equation 28 (CARB, 1999):

$$\mathbf{E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PF/100 \times PC_{i,j}/100 \times V \times N \times 365 / 1000} \qquad \textbf{Equation 28}$$

where:			
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Diurnal VOC emission factor for portable fuel container condition i and type j – 1.38 and 0.44 for closed plastic and metal, respectively (Part B - Section 3 b; CARB, 1999)	(g/US gal/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
PF	=	Petrol fill rate of portable fuel containers – 49% (Part A - Table 3; CARB, 1999)	(%)
$PC_{i,j}$	=	Proportion of portable fuel containers stored in condition i and type j - 33% and 18% for closed plastic and metal, respectively (Part B - Table 8; CARB, 1999)	(%)
V	=	Volume of portable fuel containers – 3.43 (Part B - Table 8; CARB, 1999)	(US gal)

where:			
N	=	Number of portable fuel containers (Equation 24)	(number)
i	=	Portable fuel container condition ("closed")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

Diurnal emissions of VOC from open portable fuel containers during storage have been estimated using the volume and number of containers combined with emission factors within Equation 29 (CARB, 1999):

$$\mathbf{E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PC_{i,j}/100 \times N \times 365 / 1000} \qquad \textbf{Equation 29}$$

where:			
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Diurnal VOC emission factor for portable fuel container condition i and type j – 21.8 and 21.8 for open plastic and metal, respectively (Part B - Section 3 b; CARB, 1999)	(g/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
$PC_{i,j}$	=	Proportion of portable fuel containers stored in condition i and type j - 39% and 10% for open plastic and metal, respectively (Part B - Table 8; CARB, 1999)	(%)
N	=	Number of portable fuel containers (Equation 24)	(number)
i	=	Portable fuel container condition ("open")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

Diurnal emissions of VOC from portable fuel containers during storage have been adjusted using ambient temperature and RVP of petrol data for hourly, daily and monthly time periods within Equation 30 (EEA, 2010):

$$\mathbf{E_{VOC,i,j,k} = E_{VOC,i,j} \times \left(RVP_k \times 10^{(AT_{s,k} + B)}\right) \Big/ \sum_{k=1}^{n} \left(RVP_k \times 10^{(AT_{s,k} + B)}\right)} \qquad \textbf{Equation 30}$$

where:			
$E_{VOC,i,j,k}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i, type j and time interval k	(kg/time interval)
$E_{VOC,i,j}$	=	Diurnal emissions of VOC during storage for portable fuel container condition i and type j (Equation 28 and Equation 29)	(kg/year)
RVP_k	=	Reid vapour pressure of petrol for time interval k	(kPa)
A	=	$0.000007047 \times RVP_k + 0.0132$ (Table 3-11; EEA, 2010)	(kPa)

where:			
$T_{s,k}$	=	Portable fuel container storage temperature for time interval k ($T_{s,k} = T_{a,k} + 5$) (Section 2.3; USEPA, 2007b)	(°C)
$T_{a,k}$	=	Temperature of ambient air for time interval k	(°C)
B	=	$0.0002311 \times RVP_k - 0.5236$ (Table 3-11; EEA, 2010)	(kPa)
i	=	Portable fuel container condition (either "closed" or "open")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
k	=	Time interval (either "24" for hour, "7" for day or "12" for month)	(number)
n	=	$\begin{cases} 24 & \text{for } k = \text{hour} \\ 7 & \text{for } k = \text{day} \\ 12 & \text{for } k = \text{month} \end{cases}$	(number)

Permeation emissions of VOC from closed portable fuel containers during storage have been estimated using the volume and number of containers combined with ambient temperature data and emission factors within Equation 31 (CARB, 1999)[64]:

$$\mathbf{E_{VOC,i,j} = EF_{VOC,i,j} \times PSP/100 \times PF/100 \times PC_{i,j}/100 \times V \times N \times e^{(0.0327 \times (T_s - 85.53))} \times 365 / 1000} \qquad \textbf{Equation 31}$$

where:			
$E_{VOC,i,j}$	=	Permeation emissions of VOC during storage for portable fuel container condition i and type j	(kg/year)
$EF_{VOC,i,j}$	=	Permeation VOC emission factor for portable fuel container condition i and type j – 1.57 and 0.06 for closed plastic and metal, respectively (Part B - Section 3 a; CARB, 1999)	(g/US gal/day)
PSP	=	Proportion of portable fuel containers stored with petrol – 70% (Part A - Table 3; CARB, 1999)	(%)
PF	=	Petrol fill rate of portable fuel containers – 49%(Part A - Table 3; CARB, 1999)	(%)
PC_i	=	Proportion of portable fuel containers stored in condition i and type j - 33% and 18% for closed plastic and metal, respectively (Part B - Table 8; CARB, 1999)	(%)
V	=	Volume of portable fuel containers (Part B - Table 8; CARB, 1999)	(US gal)
N	=	Number of portable fuel containers (Equation 24)	(number)
T_s	=	Portable fuel container storage temperature ($T_s = T_a + 5$) (Section 2.3; USEPA, 2007b)	(°F)
T_a	=	Temperature of ambient air	(°F)
i	=	Portable fuel container condition ("closed")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
365	=	Conversion factor	(day/year)
1000	=	Conversion factor	(g/kg)

[64] Since the diurnal emissions of VOC from open portable fuel containers are significantly higher than permeation emissions, Equation 29 combines both diurnal and permeation emissions for open containers (CARB, 1999).

3.11.3 Activity Data

Table 3-197 summarises the activity data used for portable fuel containers.

Table 3-197: Portable fuel containers (public open space) activity data

Activity data	Activity data source
Petrol consumption	- *NONROAD2008a Model* (USEPA, 2009) using: *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b); *Australian Course Directory* (Iseekgolf.com, 2011); *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009); and *NSW Lawn Mowing and Garden Equipment Sales, Unit Cost and Operating Life Data for 2000 to 2004* (AIA, 2005)
Portable fuel container survey data	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999)

A commercial survey of lawn mowing and garden equipment ownership and usage has been conducted, which includes 5 golf courses and 9 LGA located in the GMR. The survey results include data about: equipment type, number and age; engine type and fuel used; and frequency and duration of equipment use by hour, day and season (DECC, 2007b).

The 5 golf courses surveyed include Castle Hill Country Club, Killara Golf Club, Manly Golf Club, Pennant Hills Golf Course and St Michaels Golf Club (DECC, 2007b). The golf course survey results (DECC, 2007b) have been used to scale-up activity data to the 162 golf courses in the GMR (Iseekgolf.com, 2011) using the average activity levels for each golf course.

The 9 LGA surveyed include Auburn, Bankstown, Canada Bay, Great Lakes, Kiama, Ku-ring-gai, Newcastle, Port Stephens and Strathfield (DECC, 2007b). While the GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated, the LGA survey results (DECC, 2007b) have been used to scale-up activity data to 59 LGA, plus the two areas designated N/A and unincorporated, using a linear regression of activity levels for each LGA.

Lawn mowing and garden equipment sales data for the 2003 and 2004 calendar years (AIA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and non-handheld/handheld equipment with a given maximum power rating, while the lawn mowing and garden equipment survey results (DECC, 2007b) have been used to estimate the total number of in-service equipment.

A detailed discussion about the activity data used to estimate petrol consumption from lawn mowing and garden equipment is presented in Section 3.7.3.

The commercial survey (DECC, 2007b), golf course (Iseekgolf.com, 2011), population estimates (TDC, 2009) and sales (AIA, 2005) data have been used to estimate petrol consumption from lawn mowing and garden equipment. Table 3-198 presents the portable fuel container petrol throughput estimates by lawn mowing and garden equipment type from the *NONROAD2008a Model* (USEPA, 2009).

Table 3-198: Portable fuel containers (public open space) petrol throughput in the GMR

Classification	Equipment description	2008 petrol throughput (kL/year)		
		2-stroke petrol	4-stroke petrol	Grand Total
Lawn and Garden Equipment (com)	Chain Saws < 6 HP	1,663	-	1,663
	Chippers/Stump Grinders	-	204	204
	Commercial Turf Equipment	56	659	715
	Front Mowers	-	1,780	1,780
	Lawn & Garden Tractors	-	91	91
	Lawn mowers	1,214	1,660	2,874
	Leafblowers/Vacuums	2,500	186	2,686
	Other Lawn & Garden Eqp.	307	2,334	2,641
	Rear Engine Riding Mowers	-	101	101
	Rotary Tillers < 6 HP	-	55	55
	Shredders < 6 HP	-	6	6
	Trimmers/Edgers/Brush Cutter	4,274	-	4,274
Lawn and Garden Equipment (com) Total		10,014	7,076	17,090
Recreational Equipment	Golf Carts	-	2,136	2,136
	Speciality Vehicle Carts	-	-	-
Recreational Equipment Total		-	2,136	2,136
Grand Total		10,014	9,212	19,226

Commercial portable fuel container survey data, which includes container storage capacity, type and storage condition (CARB, 1999) have been combined with the petrol throughput estimates to determine the number of portable fuel containers and their emissions. Table 3-199 presents a summary of the commercial portable fuel container survey data.

Table 3-199: Portable fuel containers (public open space) survey data and estimates

Commercial portable fuel container parameter	Measure	
Estimated number of portable fuel containers	4,207	
Weighted average container storage capacity	3.43 US gal[65]	
Weighted average stored petrol volume	49%	
Containers stored with petrol	70%	
Container type	plastic - 72%	metal – 28%
Plastic container storage condition	open - 39%	closed – 33%
Metal container storage condition	open - 10%	closed - 18%
All containers storage condition	open - 49%	closed – 51%

[65] 1 US gallon (US gal) is equivalent to 3.7862 Litres (L) (USEPA, 1995a).

Table 3-200 presents the petrol throughput, weighted average petrol RVP (PCO, 2011) and monthly average ambient temperature (Hurley, 2005) data used to estimate portable fuel container emissions.

Table 3-200: Portable fuel containers (public open space) petrol throughput, RVP and ambient temperature by month

Month	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
January	652,781	2,472	8.99	62.0	76.7	24.8
February	581,697	2,202	8.99	62.0	74.7	23.7
March	407,481	1,543	9.94	68.5	67.6	19.8
April	340,197	1,288	10.88	75.0	59.9	15.5
May	272,913	1,033	10.88	75.0	54.5	12.5
June	147,530	559	10.88	75.0	50.5	10.3
July	185,085	701	10.88	75.0	48.0	8.9
August	222,640	843	10.88	75.0	49.3	9.6
September	429,655	1,627	10.88	75.0	54.4	12.5
October	514,558	1,948	10.88	75.0	60.2	15.7
November	599,461	2,270	9.94	68.5	68.3	20.2
December	723,865	2,741	8.99	62.0	76.4	24.7
Annual	5,077,863	19,226	9.96	68.7	61.7	16.5

Table 3-201 presents the petrol throughput, weighted average petrol RVP (PCO, 2011) and hourly average ambient temperature (Hurley, 2005) data used to estimate portable fuel container emissions.

Table 3-201: Portable fuel containers (public open space) petrol throughput, RVP and ambient temperature by hour

Hour	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
1	-	-	9.96	68.7	50.4	10.2
2	-	-	9.96	68.7	49.8	9.9
3	-	-	9.96	68.7	49.3	9.6
4	-	-	9.96	68.7	49.0	9.4
5	7,622	29	9.96	68.7	48.7	9.3
6	28,793	109	9.96	68.7	49.4	9.7
7	234,303	887	9.96	68.7	53.9	12.2
8	541,572	2,051	9.96	68.7	61.3	16.3
9	543,646	2,058	9.96	68.7	68.9	20.5
10	543,646	2,058	9.96	68.7	74.4	23.5
11	543,646	2,058	9.96	68.7	77.7	25.4
12	543,646	2,058	9.96	68.7	79.6	26.4
13	543,646	2,058	9.96	68.7	80.2	26.8
14	543,646	2,058	9.96	68.7	79.6	26.5
15	543,646	2,058	9.96	68.7	77.9	25.5
16	397,881	1,506	9.96	68.7	75.0	23.9
17	62,167	235	9.96	68.7	70.5	21.4
18	-	-	9.96	68.7	64.4	18.0
19	-	-	9.96	68.7	58.7	14.9

Hour	Petrol throughput (US gal)	Petrol throughput (kL)	RVP (psi)	RVP (kPa)	T_a (°F)	T_a (°C)
20	-	-	9.96	68.7	54.9	12.7
21	-	-	9.96	68.7	53.1	11.7
22	-	-	9.96	68.7	52.1	11.1
23	-	-	9.96	68.7	51.4	10.8
24	-	-	9.96	68.7	50.8	10.5
Annual	5,077,863	19,226	9.96	68.7	61.7	16.5

3.11.4 *Emission and Speciation Factors*

Table 3-202 summarises the emission and speciation factors used for portable fuel containers.

Table 3-202: Portable fuel containers (public open space) emission and speciation factors

Emission source	Substance	Emission and speciation factor source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (public open space)	Criteria pollutants: VOC	- *Public Meeting to Consider Approval of California's Portable Gasoline Container Emissions Inventory* (CARB, 1999) - *Estimating Emissions Associated with Portable Fuel Containers (PFCs)* (USEPA, 2007b) - *NONROAD2008a Model* (USEPA, 2009)
	Speciated VOC	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	Organic air toxics	- *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)

Table 3-203 presents average activity weighted emission factors for portable fuel containers.

Table 3-203: Portable fuel containers (public open space) emission factors

Emission source	Emission factor (kg/kL)
	VOC
Vapour displacement during refuelling	1.0129
Spillage during refuelling	0.0826
Spillage during transport	3.1214
Diurnal during storage	0.6475
Permeation during storage	0.0284
Grand Total	4.8929

3.11.5 *Spatial Distribution of Emissions*

Table 3-204 summarises the data used for spatially allocating emissions from portable fuel containers.

Table 3-204: Portable fuel containers (public open space) spatial data

Emission source	Spatial data	Spatial data source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (public open space)	Gridded 1 km x 1 km population estimates (≥ 50 per grid cell)	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from portable fuel containers have been spatially distributed according to petrol throughput, which is proportional to population ≥ 50 persons in each 1 km by 1 km grid cell (TDC, 2009). The proportion of petrol throughput by LGA and region is presented in Table 3-205 and shown in Figure 3-88.

Table 3-205: Portable fuel containers (public open space) spatial distribution of petrol throughput by LGA and region

LGA	2008 proportion of annual petrol throughput (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.92	-	0.92
Auburn	-	-	1.34	-	1.34
Bankstown	-	-	3.36	-	3.36
Baulkham Hills	-	-	3.23	-	3.23
Blacktown	-	-	5.51	-	5.51
Blue Mountains	-	0.48	1.00	-	1.48
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.58	-	0.58
Camden	-	-	1.04	-	1.04
Campbelltown	-	-	2.88	-	2.88
Canada Bay	-	-	1.14	-	1.14
Canterbury	-	-	2.67	-	2.67
Cessnock	3.36×10^{-2}	0.79	-	-	0.83
Dungog	-	6.63×10^{-2}	-	-	6.63×10^{-2}
Fairfield	-	-	3.64	-	3.64
Gosford	-	0.85	2.22	-	3.06
Great Lakes	-	3.15×10^{-2}	-	-	3.15×10^{-2}
Hawkesbury	-	5.14×10^{-3}	1.04	-	1.04
Holroyd	-	-	1.84	-	1.84
Hornsby	-	-	3.06	-	3.06
Hunters Hill	-	-	0.18	-	0.18
Hurstville	-	-	1.58	-	1.58
Kiama	-	0.26	-	-	0.26
Kogarah	-	-	1.11	-	1.11
Ku-ring-gai	-	-	2.06	-	2.06
Lake Macquarie	1.98	1.72	-	-	3.70
Lane Cove	-	-	0.55	-	0.55
Leichhardt	-	-	0.77	-	0.77
Lithgow	-	0.29	-	-	0.29
Liverpool	-	-	3.40	-	3.40

LGA	2008 proportion of annual petrol throughput (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Maitland	0.10	1.11	-	-	1.21
Manly	-	-	0.65	-	0.65
Marrickville	-	-	1.68	-	1.68
Mid-western Regional	-	3.67×10^{-2}	-	-	3.67×10^{-2}
Mosman	-	-	0.60	-	0.60
Muswellbrook	-	0.23	-	-	0.23
N/A	2.48×10^{-2}	5.06×10^{-2}	0.36	6.08×10^{-2}	0.49
Newcastle	2.90	-	-	-	2.90
North Sydney	-	-	1.04	-	1.04
Oberon	-	1.64×10^{-2}	-	-	1.64×10^{-2}
Parramatta	-	-	2.94	-	2.94
Penrith	-	-	3.36	-	3.36
Pittwater	-	-	1.05	-	1.05
Port Stephens	3.70×10^{-2}	0.98	-	-	1.02
Randwick	-	-	2.53	-	2.53
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.03	-	2.03
Shellharbour	-	0.94	-	0.30	1.24
Singleton	-	0.30	-	-	0.30
Strathfield	-	-	0.75	-	0.75
Sutherland	-	-	4.10	-	4.10
Sydney	-	-	3.23	-	3.23
Unincorporated	-	-	0.82	-	0.82
Warringah	-	-	2.72	-	2.72
Waverley	-	-	1.10	-	1.10
Willoughby	-	-	1.34	-	1.34
Wingecarribee	-	0.73	1.48×10^{-3}	-	0.73
Wollondilly	-	1.10×10^{-2}	0.60	-	0.61
Wollongong	-	-	0.29	3.41	3.70
Woollahra	-	-	0.86	-	0.86
Wyong	-	2.72	-	-	2.72
Grand Total	5.08	11.62	79.53	3.77	100.00

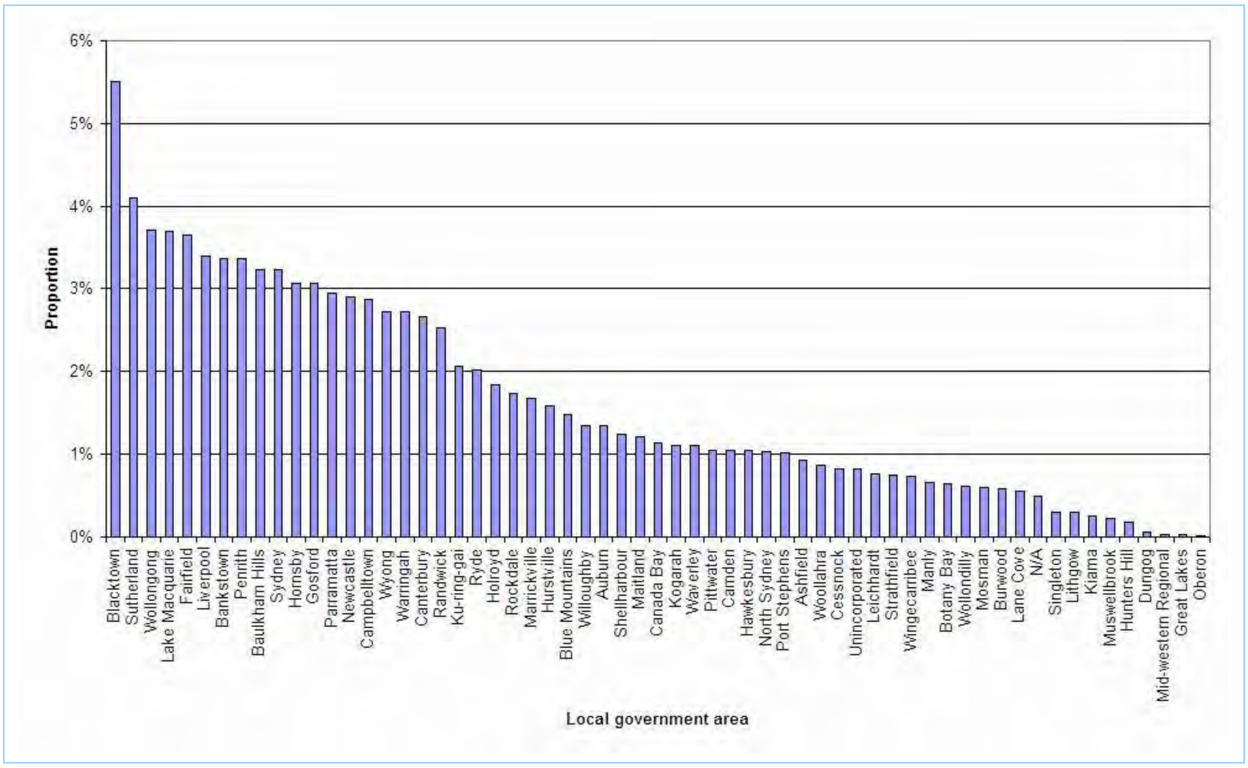

Figure 3-88: Portable fuel containers (public open space) spatial distribution of petrol throughput by LGA

Figure 3-89 shows the spatial distribution of portable fuel container emissions.

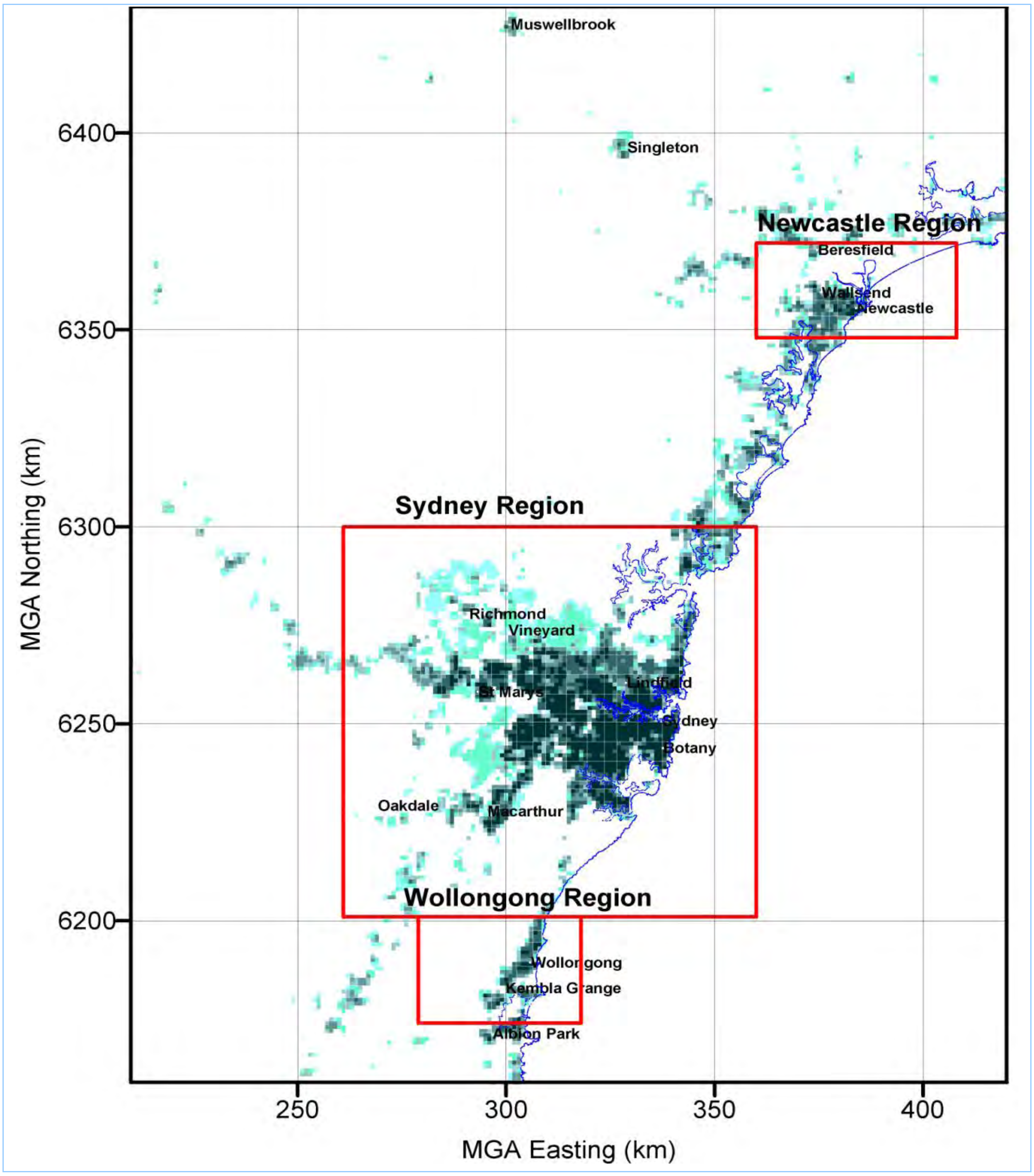

Figure 3-89: Portable fuel containers (public open space) spatial distribution of emissions

3.11.6 Temporal Variation of Emissions

Table 3-206 summarises the data used to estimate the temporal variation in emissions from portable fuel containers.

Table 3-206: Portable fuel containers (public open space) temporal data

Emission source	Temporal data	Temporal data source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (public open space)	Monthly, daily and hourly: Derived from commercial survey combined with hourly meteorological data (temperature (Kelvin) and monthly petrol Reid vapour pressure (RVP)	- *Public Open Space Lawn Mowing Pollution Survey* (DECC, 2007b) - *The Air Pollution Model (TAPM) Version 3* (Hurley, 2005) - *Protection of the Environment Operations (Clean Air) Regulation 2010* (PCO, 2011)

The commercial survey (DECC, 2007b), golf course (Iseekgolf.com, 2011), population estimates (TDC, 2009) and sales (AIA, 2005) data have been used to estimate hourly, daily and monthly petrol consumption from lawn mowing and garden equipment within the *NONROAD2008a Model* (USEPA, 2009). The temporal variation in evaporative emissions from portable fuel containers have been estimated using the hourly, daily and monthly petrol throughput estimates by lawn mowing and garden equipment type combined with petrol RVP (PCO, 2011) and ambient temperature (Hurley, 2005) data within Equation 25 to Equation 31.

The temporal variation in evaporative emissions of VOC from portable fuel containers is a function of a number of factors including, temperature, RVP of petrol, volume of petrol dispensed and/or volume and number of portable fuel containers, so annual emissions have been apportioned to hourly, daily and monthly time periods using Equation 32:

$$E_{VOC,i,j,k} = E_{VOC,i,j} \times f(T_k, RVP_k, PD_k, V, N) \Big/ \sum_{k=1}^{n} f(T_k, RVP_k, PD_k, V, N)$$ **Equation 32**

where:			
$E_{VOC,i,j,k}$	=	Evaporative emissions of VOC for portable fuel container emission source i, type j and time interval k	(kg/time interval)
$E_{VOC,i,j}$	=	Evaporative emissions of VOC for portable fuel container emission source i and type j (Equation 25 to Equation 31)	(kg/year)
T_k	=	Temperature for time interval k	(°C)
RVP_k	=	Reid vapour pressure of petrol for time interval k	(kPa)
PD_k	=	Volume of petrol dispensed for time interval k	(kL/time interval)
V	=	Volume of portable fuel containers – 8.86 (Part B - Table 8; CARB, 1999)	(L)
N	=	Number of portable fuel containers (Equation 24)	(number)
i	=	Portable fuel container emission source (either "vapour displacement", "spillage", "diurnal" or "storage")	(-)
j	=	Portable fuel container type (either "metal" or "plastic")	(-)
k	=	Time interval (either "24" for hour, "7" for day or "12" for month)	(number)
n	=	$\left\} \begin{array}{l} 24 \text{ for } k = \text{hour} \\ 7 \text{ for } k = \text{day} \\ 12 \text{ for } k = \text{month} \end{array} \right.$	(number)

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-207 (weighted hourly composite) and shown in Figure 3-90 (weighted hourly composite by source type).

Table 3-207: Portable fuel containers (public open space) hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	0.35	1.75	13	10.38	8.17
2	0.35	1.73	14	10.35	8.12
3	0.35	1.72	15	10.27	8.00
4	0.34	1.71	16	7.57	6.44
5	0.47	1.77	17	1.59	3.09
6	0.82	1.97	18	0.46	2.26
7	4.25	3.91	19	0.41	2.04
8	9.58	6.96	20	0.38	1.90
9	9.89	7.41	21	0.37	1.84
10	10.12	7.76	22	0.36	1.81
11	10.27	7.99	23	0.36	1.78
12	10.35	8.12	24	0.36	1.77

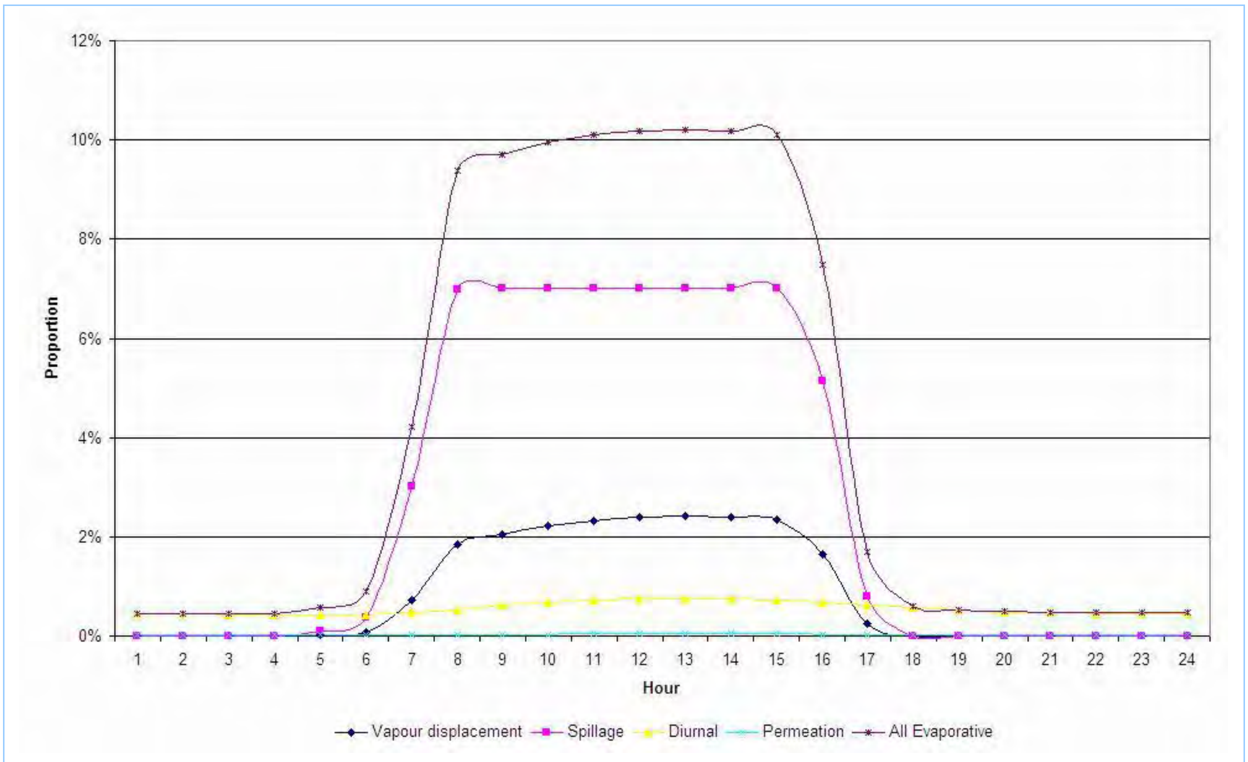

Figure 3-90: Portable fuel containers (public open space) hourly temporal profile

Daily temporal variation profiles for evaporative emissions are presented in Table 3-208 (weighted daily composite) and shown in Figure 3-91 (weighted daily composite by source type).

Table 3-208: Portable fuel containers (public open space) daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	18.51	18.51	18.51	18.51	18.51	3.97	3.49

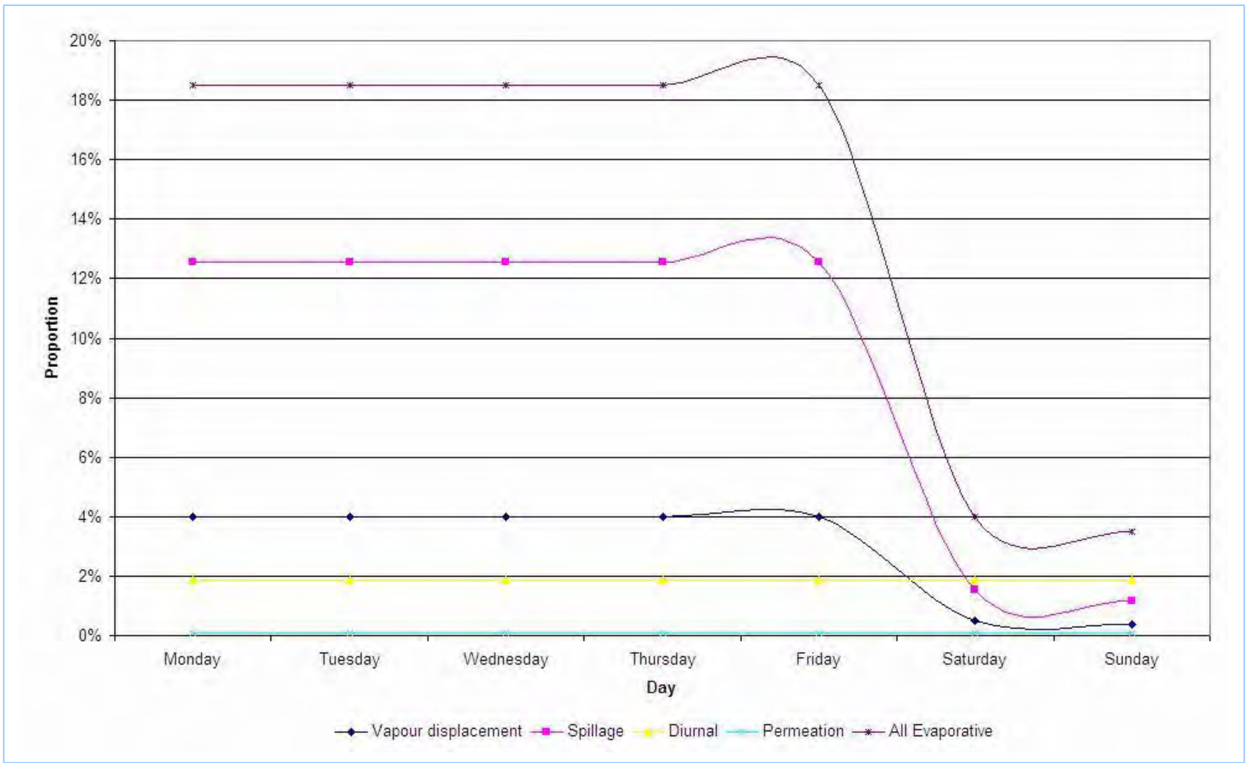

Figure 3-91: Portable fuel containers (public open space) daily temporal profile

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-209 (weighted monthly composite) and shown in Figure 3-92 (weighted monthly composite by source type).

Table 3-209: Portable fuel containers (public open space) monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	12.47	July	4.00
February	11.14	August	4.65
March	8.18	September	8.29
April	7.00	October	10.01
May	5.66	November	11.50
June	3.44	December	13.66

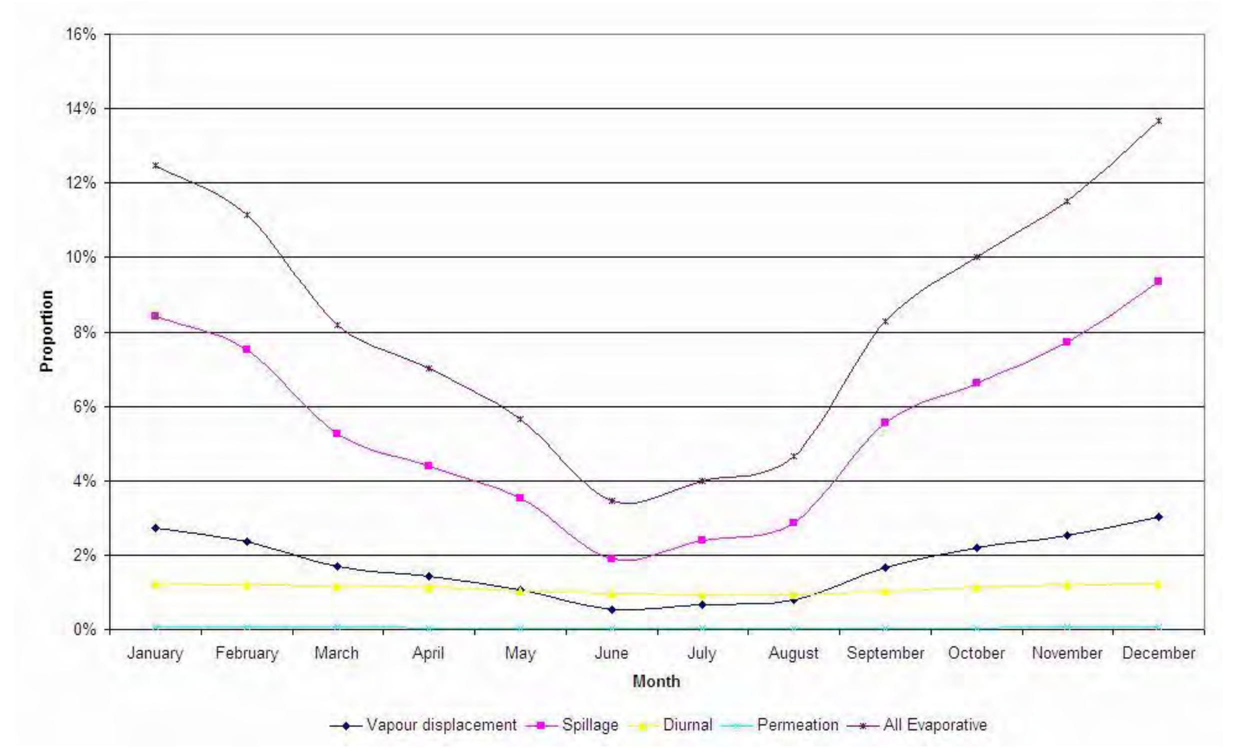

Figure 3-92: Portable fuel containers (public open space) monthly temporal profile

3.11.7 Emission Estimates

Table 3-210 presents annual emissions of selected substances from portable fuel containers by activity.

Table 3-210: Portable fuel containers (public open space) emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Portable Fuel Containers (Public Open Space)	BENZENE	37	85	584	28	734
	ISOMERS OF XYLENE	26	60	411	19	517
	TOLUENE	91	208	1,422	67	1,787
	TOTAL VOLATILE ORGANIC COMPOUNDS	4,776	10,933	74,817	3,544	94,070

3.11.8 Emission Projection Methodology

Table 3-211 summarises the data used to estimate the emission projection factors for portable fuel containers, while Figure 3-93 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-211: Portable fuel containers (public open space) emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Vapour displacement, spillage, diurnal and permeation emissions from portable fuel containers (public open space)	Final energy consumption for commercial and services using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

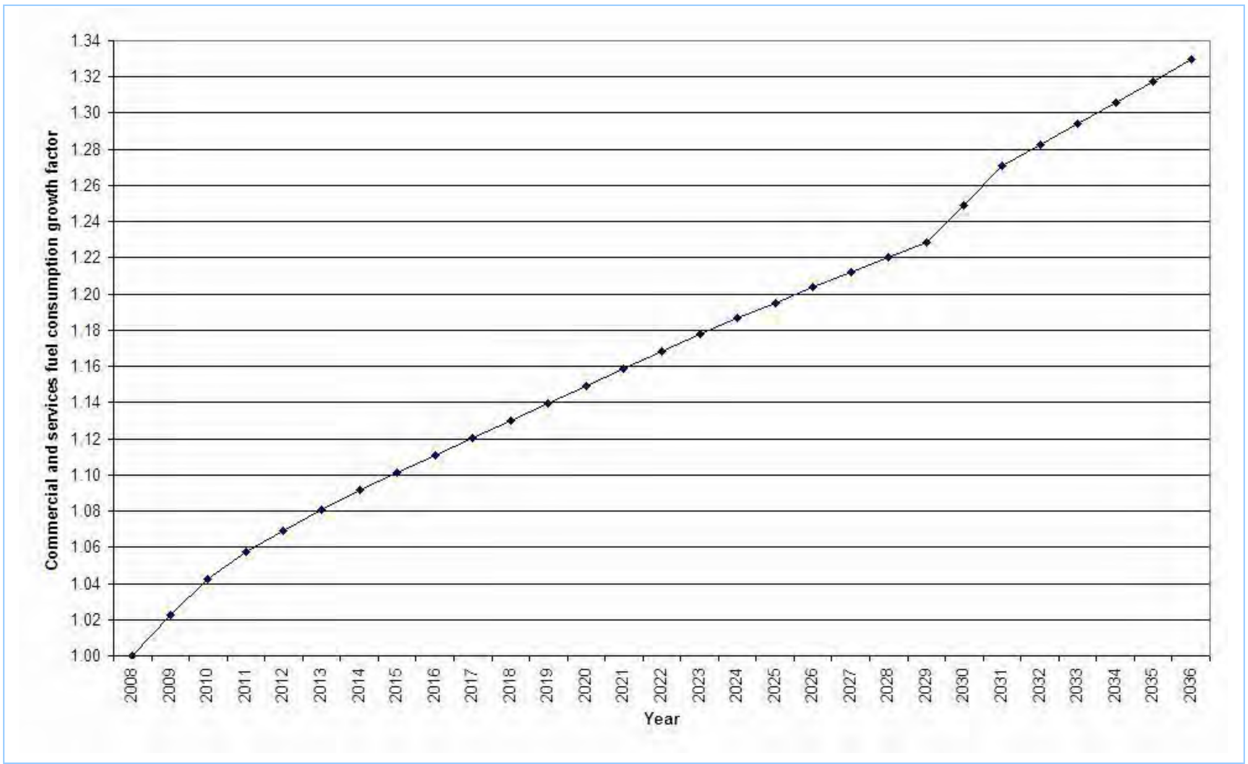

Figure 3-93: Portable fuel containers (public open space) emission projection factors

3.12 Solid Fuel Combustion

3.12.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of combustion products from wood fuel fired residential space heaters.

To estimate emissions from these sources, the following have been considered:

- *Domestic survey*

A domestic survey of wood fuel fired residential space heater ownership and usage has been conducted, which includes each of the 64 local government areas (LGA)[66] located in the GMR. The survey results include data about: heater type, number and age; amount, type and source of wood used; and frequency and duration of heater use by hour, day and month (TR, 2009).

- *Heater type*

The inventory includes wood fuel fired space heaters used in residential applications as follows:

  - *Slow combustion heater with compliance plate*[67];
  - *Slow combustion heater without compliance plate*[68];
  - *Open fireplace; and*
  - *Potbelly stove.*

- *Fuel type*

The inventory includes residential space heaters that use wood.

Table 3-212 presents the solid fuel type and properties used in the inventory (ABARE, 2009b; DPI, 2007; and USEPA, 2000).

Table 3-212: Solid fuel type and properties

Fuel type	Sulfur content	Density		Effective heating value		Carbon content (%)
Wood	-	769	kg/m^3	16.2	MJ/kg	45

[66] The GMR includes 64 local government areas (LGA), plus two areas designated N/A and unincorporated. N/A areas are those located near the coastline and the majority area within the 1 km by 1 km grid cell lies over water. Unincorporated areas are those areas which are not under the responsibility of an incorporated local government. Emissions have been estimated for 64 LGA plus the two areas designated N/A and unincorporated.
[67] This includes appliances with plates attached and marked in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b.
[68] This includes appliances without plates attached and not marked in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b.

3.12.2 Emission Estimation Methodology

Table 3-213 summarises the emission estimation methodology used for solid fuel combustion.

Table 3-213: Solid fuel combustion emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust emissions from wood fuel combustion in space heaters	- *2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs* (Pechan, 2009c)

Emissions of combustion products from wood fuel fired residential space heaters have been estimated using fuel consumption based emission factors combined with activity rates. Activity rates include heater type, number and quantity of wood used (TR, 2009). Emissions have been determined using Equation 33 (Pechan, 2009c):

$$E_{i,j} = C_j \times EF_{i,j} \qquad \textbf{Equation 33}$$

where:			
$E_{i,j}$	=	Emissions of substance i from residential space heater type j	(kg/year)
C_j	=	Wood fuel consumption for residential space heater type j	(tonne/year)
$EF_{i,j}$	=	Emission factor for substance i and residential space heater type j	(kg/tonne)
i	=	Substance (either "criteria pollutants", "speciated NO_x", "speciated VOC", "organic air toxics", "metal air toxics", "PAH", "PCDD and PCDF", "ammonia" or "greenhouse gases")	(-)
j	=	Residential space heater type (either "slow combustion heater with compliance plate", "slow combustion heater without compliance plate", "open fireplace" or "potbelly stove ")	(-)

3.12.3 Activity Data

Table 3-214 summarises the activity data used for solid fuel combustion.

Table 3-214: Solid fuel combustion activity data

Activity data	Activity data source
Wood heater type, number and fuel consumption	- *Domestic Wood Heater Pollution Survey* (TR, 2009)
Gridded 1 km x 1 km total dwelling estimates required to scale-up domestic survey	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

A domestic survey of solid fuel fired residential space heater ownership and usage has been conducted, which includes each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: heater type, number and age; amount, type and source of solid fuel used; and frequency and duration of heater use by hour, day and month (TR, 2009).

The key considerations in designing and conducting a domestic survey include:

Survey method - The domestic survey has been conducted using the computer assisted telephone interview (CATI) method for recruiting households to complete either an on-line or mail-out questionnaire.

Sample size - To provide a reasonable level of precision for estimating solid fuel combustion activity rates across all households in the GMR, the survey sample was sized accordingly. While a total of 832 households were recruited, 31 households were outside the GMR so they were excluded from the survey. Activity rates for solid fuel combustion have been based on survey responses from 801 households in the GMR.

Confidence interval and confidence level - The confidence interval quantifies the uncertainty or range in possible values. For example, for a confidence interval of 3.5% and where 47% percent of the sample picks a particular answer one can be "sure" that if the question has been asked of the entire relevant population, between 43.5% (47-3.5) and 50.5% (47+3.5) would have picked that answer.

The confidence level quantifies the level of certainty to which an estimate can be trusted. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means one can be 95% certain. Most researchers use the 95% confidence level.

When combining the confidence level and confidence interval together, one can be 95% sure that the true answer for the entire relevant population is between 43.5% and 50.5% for the example described above.

Table 3-215 presents the theoretical confidence intervals for samples of varied sizes for characteristics with a population incidence of 50% or 50%, 75% or 25% and 90% or 10%.

Table 3-215: Confidence intervals at 95% confidence level by sample size for solid fuel combustion survey

Sample size	Confidence interval at 95% confidence level		
	Endorsement rate of 50%/50%	Endorsement rate of 75%/25%	Endorsement rate of 90%/10%
100	9.8	8.5	5.9
150	8.0	6.9	4.8
200	6.9	6.0	4.2
300	5.7	4.9	3.4
400	4.9	4.2	2.9
500	4.4	3.8	2.6
600	4.0	3.5	2.4
800	3.5	3.0	2.1
1,000	3.1	2.7	1.9

The domestic survey of solid fuel combustion randomly sampled 801 households from a population of 5,284,560 in 1,901,680 households, so survey items with a true population incidence of 50% will produce estimates within ±3.5% of the true population value in 95% of the samples.

Random sampling and stratification - Households were selected at random across the GMR to limit bias. In practice, actual samples are not truly random since respondents always have the right to decline an interview and others cannot be reached for a variety of reasons. To reduce the standard error of estimated population values, samples were stratified on a geographic basis into the following subpopulations by location:

Sydney region, sub-grouped into

- *North East*
- *North West*
- *South East*
- *South West*

Newcastle region

Wollongong region

Development of survey questionnaires – Three survey questionnaires were developed including: initial recruitment using the computer assisted telephone interview (CATI) method to capture household details using pre-coded questions within OzQuest on-line software; self complete main survey using pre-coded questions within OzQuest on-line software; and self complete main survey using a traditional hard copy mail-out with a reply paid envelope. The questionnaires request information about: heater number; fuel type; quantity of fuel used; and frequency and duration of heater use by hour, day and month. The domestic survey questionnaire form is included at Appendix B: Domestic Survey Form (TR, 2009).

Recruitment and data collection - A random sample of phone numbers was selected from the 64 local government areas (LGA) located in the GMR, stratified into Sydney, Newcastle and Wollongong regions.

As part of the computer assisted telephone interview (CATI), households were phoned up to five times to make contact and the interviewer asked to speak to an "adult household member who is familiar with any devices the household uses that might burn solid fuel (like wood or coal heaters), liquid fuel (like kerosene heaters or petrol lawn mowers) or gas fuel (like natural gas cooktops or heaters)". If required, arrangements were made to call back at a more convenient time when an appropriate adult household member would be available.

When an adult household member was available for interview, respondents were asked what LGA they lived in. If not in the GMR they were thanked and the interview was terminated. If in the GMR, they were then asked about the number of residents in the household, the dwelling type and which of the fuel burning devices were used by the household. All were then asked for their postcode and age group. Respondents in households that had none of the fuel burning devices were thanked and the interview terminated. All other respondents were then asked if they would be willing to complete a further questionnaire either on-line or by mail. If willing, contact details were recorded, and the interview concluded. Those who initially declined were read material emphasizing the importance of obtaining data from all households, whether they make little use of fuel burning devices or not and asked again if they would be willing to take part.

Consenting respondents were then either e-mailed a link to a self complete on-line main survey or mailed a self complete hard copy main survey. The mailed questionnaires included an identifying serial number on the front page with a letter from DECCW encouraging completion of the survey.

Main survey completions on-line and mail-out were closely monitored and households were phoned on two occasions in order to remind them to complete. Some respondents indicated they preferred to go through the questions on the phone. Data for these were entered into the on-line version of the questionnaire.

Data capture – Data from the three survey questionnaires (i.e. CATI, on-line main survey and hard copy main survey) have all been entered into a database which captures pre-coded questions using OzQuest on-line software. All data was then checked, cleaned and saved in a Microsoft® Excel™ 2003 workbook.

Survey timeframe - The survey took approximately 15 weeks to complete, from the time that questionnaire development commenced to the date data analysis and report were completed. The key tasks and milestones for the domestic survey are presented in Table 3-216.

Table 3-216: Solid fuel combustion survey milestones

Task	Milestones
Questionnaire development commenced	11 August 2009
CATI recruitment commenced	18 September 2009
CATI recruitment completed	21 October 2009
Main survey completed	12 November 2009
Data analysis and report completed	26 November 2009

Gridded 1 km by 1 km dwelling estimates (TDC, 2009) have been used to scale-up the solid fuel combustion survey results (TR, 2009). Table 3-217 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-217: Population and dwelling by LGA used to scale-up solid fuel combustion survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[69]	Total dwelling
Ashfield	47,887	7,660	2,728	7,882	142	18,412

[69] Caravan, cabin, houseboat, improvised home, tent, sleepers out, house or flat attached to a shop or office (TDC, 2009).

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[69]	Total dwelling
Auburn	69,555	7,358	2,326	11,421	284	21,390
Bankstown	174,326	7,781	8,028	41,407	287	57,503
Bathurst Regional	157	-	-	41	1	41
Baulkham Hills	170,925	2,345	5,004	46,441	137	53,928
Blacktown	286,162	3,915	9,712	77,217	700	91,544
Blue Mountains	78,427	777	1,030	27,952	63	29,822
Botany Bay	33,316	4,244	1,974	5,777	100	12,095
Burwood	30,277	3,332	1,108	5,770	65	10,275
Camden	55,287	258	499	16,910	161	17,828
Campbelltown	150,373	1,333	8,057	39,856	97	49,343
Canada Bay	58,880	6,445	2,342	13,157	137	22,080
Canterbury	138,343	16,795	4,851	25,673	328	47,647
Cessnock	48,845	562	339	16,615	150	17,667
Dungog	7,659	23	60	2,581	38	2,702
Fairfield	189,024	7,302	6,172	43,571	198	57,243
Gosford	162,826	5,481	8,288	49,407	676	63,852
Goulburn Mulwaree	341	-	1	79	-	80
Great Lakes	4,062	10	29	1,301	44	1,383
Hawkesbury	62,416	899	1,674	18,441	241	21,254
Holroyd	95,192	6,969	3,562	22,399	144	33,074
Hornsby	160,612	9,018	4,454	40,736	265	54,472
Hunters Hill	9,295	898	318	1,892	3	3,111
Hurstville	81,935	7,352	3,548	18,534	111	29,545
Kiama	14,586	580	338	4,433	75	5,426
Kogarah	57,349	6,558	1,565	11,945	81	20,148
Ku-ring-gai	106,943	3,805	1,253	30,103	73	35,235
Lake Macquarie	195,295	3,160	4,849	63,598	926	72,532
Lane Cove	28,511	4,473	652	5,687	92	10,904
Leichhardt	39,692	4,537	6,175	5,998	278	16,988
Lithgow	19,595	227	341	6,350	59	6,977
Liverpool	178,554	6,938	5,352	42,517	317	55,125
Maitland	66,554	1,330	1,049	21,169	117	23,666
Manly	33,804	5,898	1,520	5,676	97	13,192
Marrickville	86,873	13,062	10,292	11,838	553	35,744
Mid-western Regional	3,412	25	14	1,149	17	1,205
Mosman	30,915	6,692	1,506	4,604	104	12,905
Muswellbrook	15,221	364	121	4,582	62	5,128
N/A	25,875	4,778	1,262	4,329	119	10,488
Newcastle	150,930	8,242	6,306	44,792	500	59,840
North Sydney	53,850	17,299	4,228	3,854	252	25,633
Oberon	1,803	4	5	438	5	452
Parramatta	152,570	16,729	6,975	29,743	348	53,796

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[69]	Total dwelling
Penrith	177,459	3,483	4,905	51,040	349	59,776
Pittwater	54,586	2,542	1,577	15,389	183	19,690
Port Stephens	59,017	756	1,587	18,809	482	21,634
Randwick	130,955	25,728	8,002	16,752	370	50,853
Rockdale	89,735	12,199	4,159	16,242	256	32,856
Ryde	105,073	11,196	5,519	22,448	111	39,275
Shellharbour	65,104	1,282	2,369	18,768	328	22,747
Shoalhaven	81	-	-	30	-	30
Singleton	22,222	405	275	6,357	132	7,169
Strathfield	38,732	5,612	806	6,543	45	13,006
Sutherland	212,924	16,252	8,522	52,450	274	77,498
Sydney	167,382	52,686	17,811	4,651	1,028	76,176
Unincorporated	42,682	9,672	2,028	5,866	146	17,713
Upper Hunter	350	-	-	66	-	66
Upper Lachlan	502	-	-	92	-	92
Warringah	141,123	16,643	3,029	32,008	175	51,854
Waverley	57,147	14,769	4,430	5,038	245	24,481
Willoughby	69,528	11,760	2,038	12,473	82	26,353
Wingecarribee	45,480	537	1,113	15,131	144	16,924
Wollondilly	42,871	168	292	13,634	133	14,227
Wollongong	193,292	11,210	7,296	52,219	992	71,717
Woollahra	44,773	12,138	3,128	4,232	71	19,569
Wyong	145,088	2,801	4,575	47,918	1,006	56,300
Grand Total	5,284,560	417,295	213,366	1,256,021	14,998	1,901,680

The total population of in-service wood fuel fired residential space heaters have been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). In-service wood fuel fired residential space heater population by dwelling type for the GMR is presented in Table 3-218 and shown in Figure 3-94.

Table 3-218: Wood fuel fired residential space heater population by dwelling type in the GMR

Dwelling type	2008 statistics		
	Dwelling number	Heater number	Proportion of dwelling type with heater (%)
Flat, unit or apartment	417,295	-	-
Semi detached, terrace house or townhouse	213,366	14,466	6.78
Separate house	1,256,021	239,979	19.11
Other dwelling	14,998	-	-
Grand Total	1,901,680	254,445	13.38

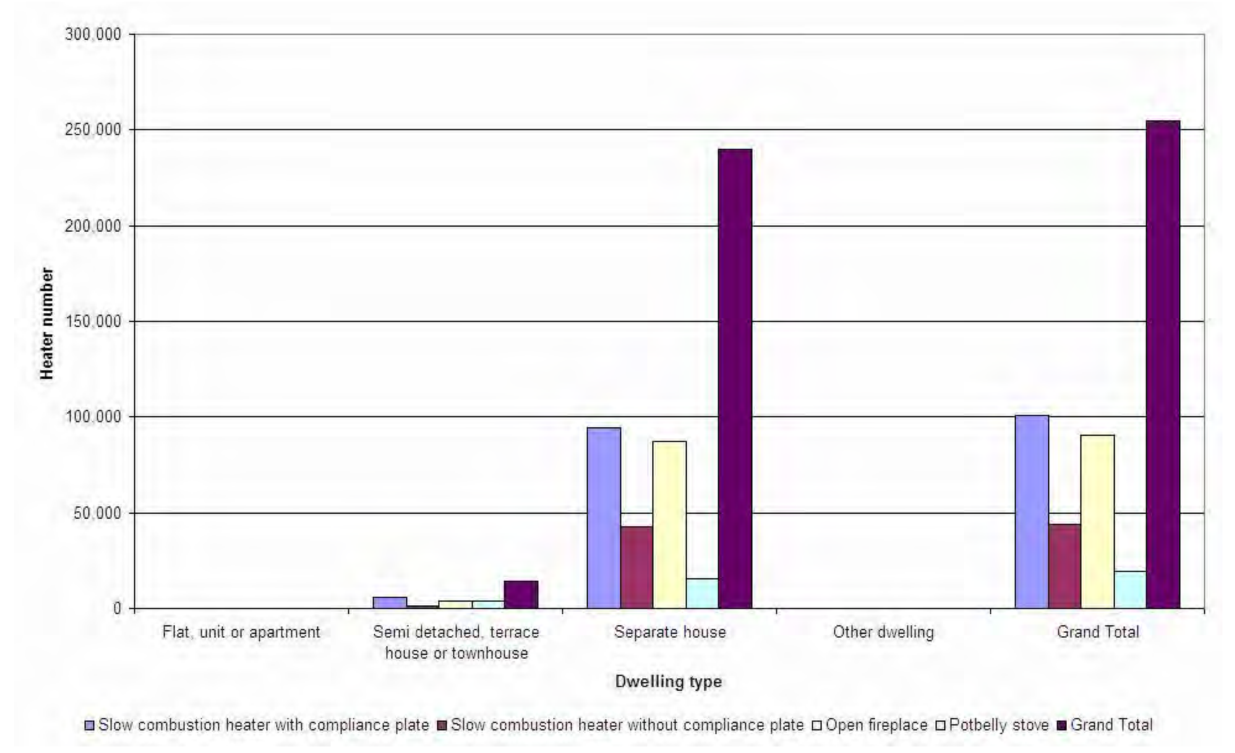

Figure 3-94: Wood fuel fired residential space heater population by dwelling type in the GMR

In-service wood fuel fired residential space heater population by fuel type for the GMR are presented in Table 3-219 and shown in Figure 3-95.

Table 3-219: Wood fuel fired residential space heater population by heater type in the GMR

Dwelling type	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Flat, unit or apartment	-	-	-	-	-
Semi detached, terrace house or townhouse	6,120	1,113	3,616	3,616	14,466
Separate house	94,533	42,875	87,089	15,483	239,979
Other dwelling	-	-	-	-	
Grand Total	100,653	43,987	90,706	19,099	254,445

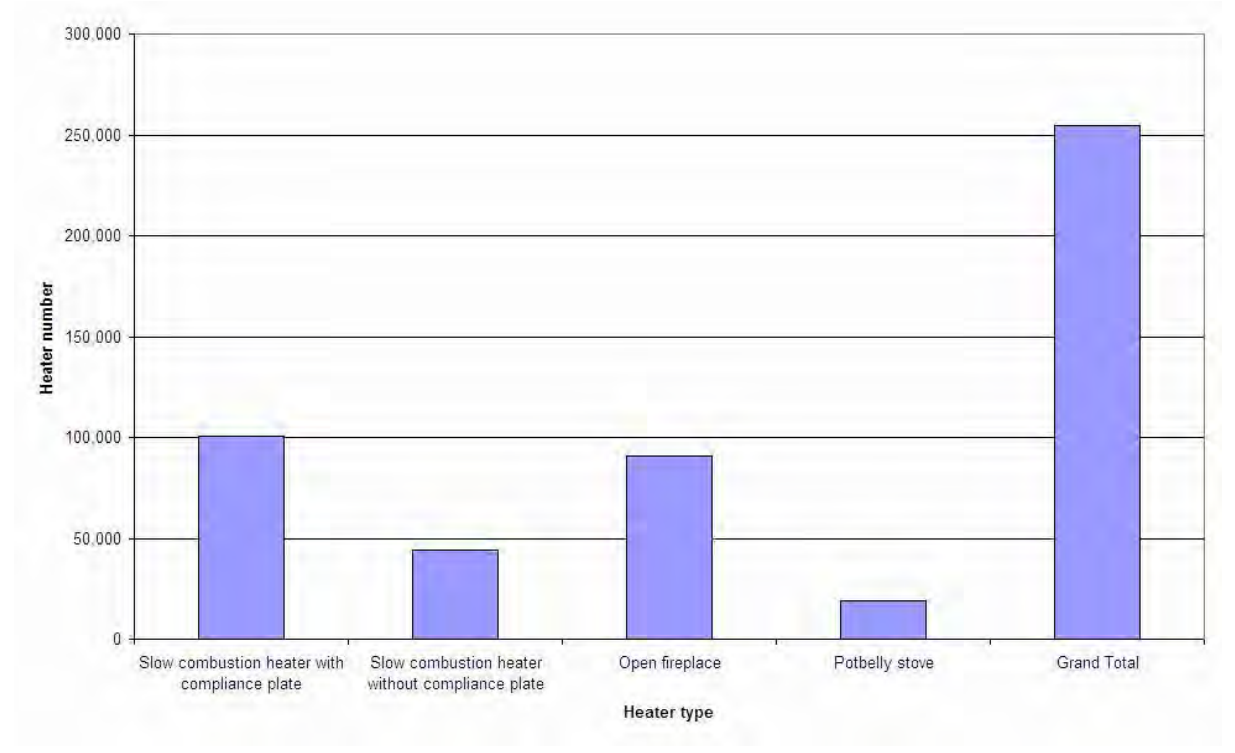

Figure 3-95: Wood fuel fired residential space heater population by heater type in the GMR

The total consumption of wood has been estimated by combining the domestic survey results (TR, 2009) and gridded 1 km by 1 km dwelling estimates (TDC, 2009). Table 3-220 presents the residential space heater wood fuel consumption estimates by heater type and dwelling type.

Table 3-220: Wood fuel fired residential space heater fuel consumption in the GMR

Dwelling type	2008 wood consumption (tonne/year)				
	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Flat, unit or apartment	-	-	-	-	-
Semi detached, terrace house or townhouse	17,781	3,221	7,275	8,388	36,664
Separate house	274,654	124,093	175,196	35,909	609,852
Other dwelling	-	-	-	-	-
Grand Total	292,435	127,314	182,471	44,296	646,517

Table 3-221 presents the average age and fuel consumption of wood fuel fired residential space heaters in the GMR (TR, 2009).

Table 3-221: Wood fuel fired residential space heater average age and wood consumption in the GMR

Heater type	2008 statistics	
	Average age (year)	Average wood consumption (tonne/heater/year)
Slow combustion heater with compliance plate	12	2.9
Slow combustion heater without compliance plate	17	2.9
Open fireplace	22	2.0
Potbelly stove	14	2.3
Grand Total	16	2.5

3.12.4 *Emission and Speciation Factors*

Table 3-222 summarises the emission and speciation factors used for solid fuel combustion.

Table 3-222: Solid fuel combustion emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: CO, NO_x, PM_{10}, SO_2 and VOC	Slow combustion heater with compliance plate	- *2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Open fireplace	- *2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
Criteria pollutants: $PM_{2.5}$ and TSP	Slow combustion heater with compliance plate	- *PMPROF 424 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Slow combustion heater without compliance plate	
	Open fireplace	

<table>
<tr><th>Substance</th><th>Emission source</th><th>Emission and speciation factor source</th></tr>
<tr><td></td><td>Potbelly stove</td><td></td></tr>
<tr><td rowspan="4">Speciated NO_x</td><td>Slow combustion heater with compliance plate</td><td rowspan="4">- Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors (USEPA, 2003)</td></tr>
<tr><td>Slow combustion heater without compliance plate</td></tr>
<tr><td>Open fireplace</td></tr>
<tr><td>Potbelly stove</td></tr>
<tr><td rowspan="4">Speciated VOC</td><td>Slow combustion heater with compliance plate</td><td>- 2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)
- Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td>Slow combustion heater without compliance plate</td><td>- 2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)
- Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td>Open fireplace</td><td>- 2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)
- Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td>Potbelly stove</td><td>- 2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)
- Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)</td></tr>
<tr><td>Organic air toxics</td><td>Slow combustion heater with compliance plate</td><td>- 2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)
- Profile number 4642 Fireplace wood combustion</td></tr>
</table>

Substance	Emission source	Emission and speciation factor source
		pine wood - Speciate 4.2 Database Development Documentation (Pechan, 2009a)
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Open fireplace	- *2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Profile number 4642 Fireplace wood combustion pine wood - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Metal air toxics	Slow combustion heater with compliance plate	- *2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Composite profile number 3831, 3832, 3833, 3835, 3846 and 3856 Residential wood burning - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Composite profile number 3831, 3832, 3833, 3835, 3846 and 3856 Residential wood burning - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Open fireplace	- *2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn &*

Substance	Emission source	Emission and speciation factor source
		2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c) - *Composite profile number 3831, 3832, 3833, 3835, 3846 and 3856 Residential wood burning - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)* - *Composite profile number 3831, 3832, 3833, 3835, 3846 and 3856 Residential wood burning - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Polycyclic aromatic hydrocarbons: PAH	Slow combustion heater with compliance plate	- *2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Open fireplace	- *Table 1.10-3 Conventional stove - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.10 Residential Wood Stoves* (USEPA, 1996b)
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	Slow combustion heater with compliance plate	- *Table 4.51 Emission Factors – Household Heating and Cooking (Biomass) - Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	Slow combustion heater without compliance plate	
	Open fireplace	
	Potbelly stove	
Ammonia	Slow combustion heater with compliance plate	- *2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs*

Substance	Emission source	Emission and speciation factor source
		(Pechan, 2009c)
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Open fireplace	- *2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
Greenhouse gases: CH_4	Slow combustion heater with compliance plate	- *2104008320 Woodstove: freestanding, EPA certified, non-catalytic - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Slow combustion heater without compliance plate	- *2104008310 Woodstove: freestanding, non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Open fireplace	- *2104008100 Fireplace: general - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
	Potbelly stove	- *2104008210 Woodstove: fireplace inserts; non-EPA certified - 2008 National Emissions Inventory, 2008 Nonpoint Emission Estimates, Residential Heating, 2104008nnn & 2104009000, Residential Wood Combustion and Wax Firelogs (Pechan, 2009c)*
Greenhouse gases: CO_2	Slow combustion heater with compliance plate	- *Greenhouse Gases from Small-Scale Combustion Devices in Developing Countries: Phase IIA Household Stoves in India* (USEPA, 2000)
	Slow combustion heater without compliance plate	
	Open fireplace	
	Potbelly stove	
Greenhouse gases: N_2O	Slow combustion heater with	- *Table 1.9-1 - AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.9*

Substance	Emission source	Emission and speciation factor source
	compliance plate	*Residential Fireplaces* (USEPA, 1996a)
	Slow combustion heater without compliance plate	
	Open fireplace	
	Potbelly stove	

Table 3-223 presents emission factors for wood fuel fired residential space heaters.

Table 3-223: Solid fuel combustion emission factors

Emission source	Emission factors (kg/tonne)											
	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
Slow combustion heater with compliance plate	1.14	0.150	0.450	0.200	9.80	9.43	6.00	14.20	70.40	1,387.79	0.1014	4.10×10^{-9}
Slow combustion heater without compliance plate	1.40	0.150	0.850	0.200	15.30	14.73	26.50	32.00	115.40	1,146.19	0.2269	4.10×10^{-9}
Open fireplace	1.30	0.150	0.900	0.200	11.80	11.36	9.45	7.20	74.50	1,357.88	0.3650	4.10×10^{-9}
Potbelly stove	1.40	0.150	0.850	0.200	15.30	14.73	26.50	32.00	115.40	1,146.19	0.2269	4.10×10^{-9}

3.12.5 Spatial Distribution of Emissions

Table 3-224 summarises the data used for spatially allocating emissions from solid fuel combustion.

Table 3-224: Solid fuel combustion spatial data

Emission source	Spatial data	Spatial data source
Exhaust emissions from wood fuel combustion in space heaters	Gridded 1 km x 1 km free standing dwelling estimates	- *Forecasts for Free Standing Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from solid fuel combustion have been spatially distributed according to wood consumption, which is proportional to free standing dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of wood consumption by LGA and region is presented in Table 3-225 and shown in Figure 3-96.

Table 3-225: Solid fuel combustion spatial distribution of wood consumption by LGA and region

LGA	2008 proportion of annual wood consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.72	-	0.72
Auburn	-	-	0.94	-	0.94
Bankstown	-	-	3.37	-	3.37
Bathurst Regional	-	2.78×10^{-3}	-	-	2.78×10^{-3}
Baulkham Hills	-	2.50×10^{-3}	3.50	-	3.50
Blacktown	-	-	5.92	-	5.92
Blue Mountains	-	0.70	1.28	-	1.97
Botany Bay	-	-	0.53	-	0.53
Burwood	-	-	0.47	-	0.47
Camden	-	-	1.19	-	1.19
Campbelltown	-	-	3.26	-	3.26
Canada Bay	-	-	1.06	-	1.06
Canterbury	-	-	2.08	-	2.08
Cessnock	4.90×10^{-2}	1.11	-	-	1.15
Dungog	-	0.18	-	-	0.18
Fairfield	-	-	3.39	-	3.39
Gosford	-	1.06	2.87	-	3.93
Goulburn Mulwaree	-	5.41×10^{-3}	-	-	5.41×10^{-3}
Great Lakes	-	8.49×10^{-2}	-	-	8.49×10^{-2}
Hawkesbury	-	2.90×10^{-2}	1.34	-	1.37
Holroyd	-	-	1.77	-	1.77
Hornsby	-	4.26×10^{-3}	3.07	-	3.08
Hunters Hill	-	-	0.15	-	0.15
Hurstville	-	-	1.50	-	1.50
Kiama	-	0.32	-	-	0.32
Kogarah	-	-	0.92	-	0.92
Ku-ring-gai	-	-	2.14	-	2.14
Lake Macquarie	2.46	2.21	-	-	4.66

LGA	2008 proportion of annual wood consumption (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Lane Cove	-	-	0.43	-	0.43
Leichhardt	-	-	0.83	-	0.83
Lithgow	-	0.45	-	-	0.45
Liverpool	-	-	3.26	-	3.26
Maitland	0.12	1.39	-	-	1.51
Manly	-	-	0.49	-	0.49
Marrickville	-	-	1.51	-	1.51
Mid-western Regional	-	6.41×10^{-2}	-	-	6.41×10^{-2}
Mosman	-	-	0.42	-	0.42
Muswellbrook	-	0.31	-	-	0.31
N/A	1.46×10^{-2}	6.58×10^{-2}	0.27	3.05×10^{-2}	0.38
Newcastle	3.48	-	-	-	3.48
North Sydney	-	-	0.55	-	0.55
Oberon	-	2.87×10^{-2}	-	-	2.87×10^{-2}
Parramatta	-	-	2.50	-	2.50
Penrith	-	-	3.81	-	3.81
Pittwater	-	-	1.16	-	1.16
Port Stephens	7.89×10^{-2}	1.31	-	-	1.39
Randwick	-	-	1.69	-	1.69
Rockdale	-	-	1.39	-	1.39
Ryde	-	-	1.90	-	1.90
Shellharbour	-	1.10	-	0.34	1.44
Shoalhaven	-	2.06×10^{-3}	-	-	2.06×10^{-3}
Singleton	-	0.44	-	-	0.44
Strathfield	-	-	0.50	-	0.50
Sutherland	-	-	4.15	-	4.15
Sydney	-	-	1.53	-	1.53
Unincorporated	-	-	0.54	-	0.54
Upper Lachlan	-	8.65×10^{-4}	-	-	8.65×10^{-4}
Warringah	-	-	2.39	-	2.39
Waverley	-	-	0.64	-	0.64
Willoughby	-	-	0.99	-	0.99
Wingecarribee	-	1.10	6.02×10^{-3}	1.94×10^{-3}	1.11
Wollondilly	-	1.49×10^{-2}	0.93	4.83×10^{-4}	0.95
Wollongong	-	-	0.33	3.72	4.05
Woollahra	-	-	0.50	-	0.50
Wyong	-	3.57	-	-	3.57
Grand Total	6.20	15.55	74.16	4.09	100.00

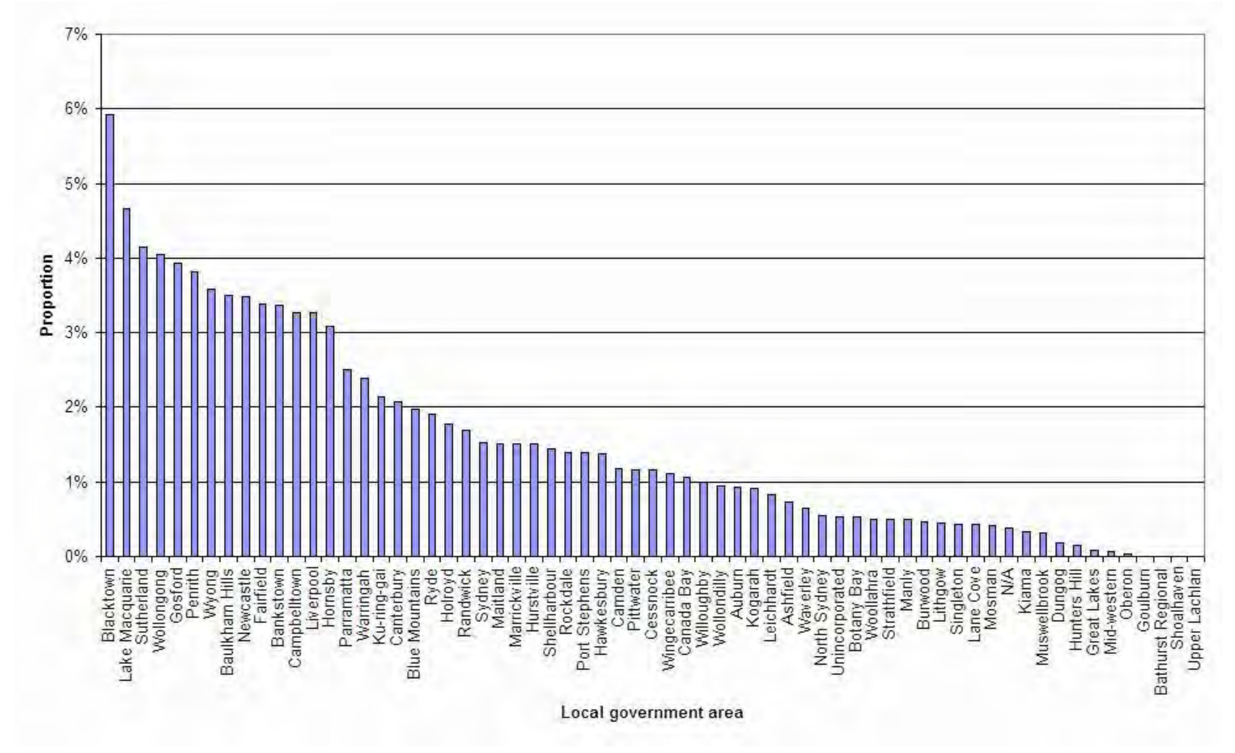

Figure 3-96: Solid fuel combustion spatial distribution of wood consumption by LGA and region

The proportion of total dwellings with wood fuel fired residential space heaters by LGA is presented in Table 3-226 and shown in Figure 3-97.

Table 3-226: Wood fuel fired residential space heater ownership by LGA

LGA	2008 proportion of total dwellings (%)				
	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Ashfield	3.95	1.73	3.56	0.75	9.98
Auburn	4.40	1.92	3.97	0.84	11.13
Bankstown	5.89	2.57	5.31	1.12	14.89
Bathurst Regional	6.74	2.95	6.08	1.28	17.04
Baulkham Hills	6.53	2.86	5.89	1.24	16.52
Blacktown	6.50	2.84	5.86	1.23	16.44
Blue Mountains	6.66	2.91	6.00	1.26	16.83
Botany Bay	4.39	1.92	3.96	0.83	11.10
Burwood	4.59	2.00	4.13	0.87	11.59
Camden	6.69	2.92	6.03	1.27	16.91
Campbelltown	6.65	2.91	5.99	1.26	16.81
Canada Bay	4.81	2.10	4.33	0.91	12.15
Canterbury	4.39	1.92	3.95	0.83	11.09
Cessnock	6.58	2.87	5.93	1.25	16.62
Dungog	6.92	3.02	6.24	1.31	17.50
Fairfield	5.95	2.60	5.36	1.13	15.05

LGA	2008 proportion of total dwellings (%)				
	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Gosford	6.19	2.70	5.58	1.17	15.65
Goulburn Mulwaree	6.90	3.02	6.22	1.31	17.46
Great Lakes	6.61	2.89	5.95	1.25	16.70
Hawkesbury	6.48	2.83	5.84	1.23	16.39
Holroyd	5.38	2.35	4.85	1.02	13.59
Hornsby	5.68	2.48	5.12	1.08	14.37
Hunters Hill	4.87	2.13	4.38	0.92	12.30
Hurstville	5.12	2.24	4.61	0.97	12.94
Kiama	6.02	2.63	5.43	1.14	15.23
Kogarah	4.59	2.01	4.14	0.87	11.61
Ku-ring-gai	6.10	2.66	5.49	1.16	15.41
Lake Macquarie	6.46	2.82	5.83	1.23	16.34
Lane Cove	3.98	1.74	3.59	0.76	10.07
Leichhardt	4.91	2.15	4.42	0.93	12.41
Lithgow	6.68	2.92	6.02	1.27	16.90
Liverpool	5.94	2.60	5.36	1.13	15.02
Maitland	6.43	2.81	5.80	1.22	16.26
Manly	3.74	1.63	3.37	0.71	9.45
Marrickville	4.24	1.85	3.82	0.80	10.72
Mid-western Regional	6.57	2.87	5.92	1.25	16.62
Mosman	3.24	1.42	2.92	0.62	8.20
Muswellbrook	6.39	2.79	5.76	1.21	16.16
N/A	3.65	1.60	3.29	0.69	9.23
Newcastle	5.85	2.56	5.27	1.11	14.79
North Sydney	2.16	0.94	1.95	0.41	5.46
Oberon	6.72	2.94	6.05	1.27	16.98
Parramatta	4.68	2.04	4.21	0.89	11.82
Penrith	6.41	2.80	5.78	1.22	16.21
Pittwater	5.90	2.58	5.32	1.12	14.92
Port Stephens	6.45	2.82	5.82	1.22	16.31
Randwick	3.33	1.46	3.00	0.63	8.43
Rockdale	4.25	1.86	3.83	0.81	10.75
Ryde	4.88	2.13	4.40	0.93	12.33
Shellharbour	6.37	2.78	5.74	1.21	16.09
Shoalhaven	7.23	3.16	6.52	1.37	18.28
Singleton	6.34	2.77	5.71	1.20	16.02
Strathfield	3.87	1.69	3.49	0.73	9.78
Sutherland	5.39	2.36	4.86	1.02	13.62
Sydney	2.02	0.88	1.82	0.38	5.11
Unincorporated	3.05	1.33	2.75	0.58	7.72
Upper Lachlan	7.57	3.31	6.82	1.44	19.14
Warringah	4.63	2.02	4.17	0.88	11.70

LGA	2008 proportion of total dwellings (%)				
	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Waverley	2.65	1.16	2.39	0.50	6.70
Willoughby	3.77	1.65	3.40	0.72	9.54
Wingecarribee	6.58	2.87	5.93	1.25	16.62
Wollondilly	6.71	2.93	6.05	1.27	16.96
Wollongong	5.68	2.48	5.12	1.08	14.37
Woollahra	2.58	1.13	2.32	0.49	6.51
Wyong	6.39	2.79	5.75	1.21	16.14
Grand Total	5.29	2.31	4.77	1.00	13.38

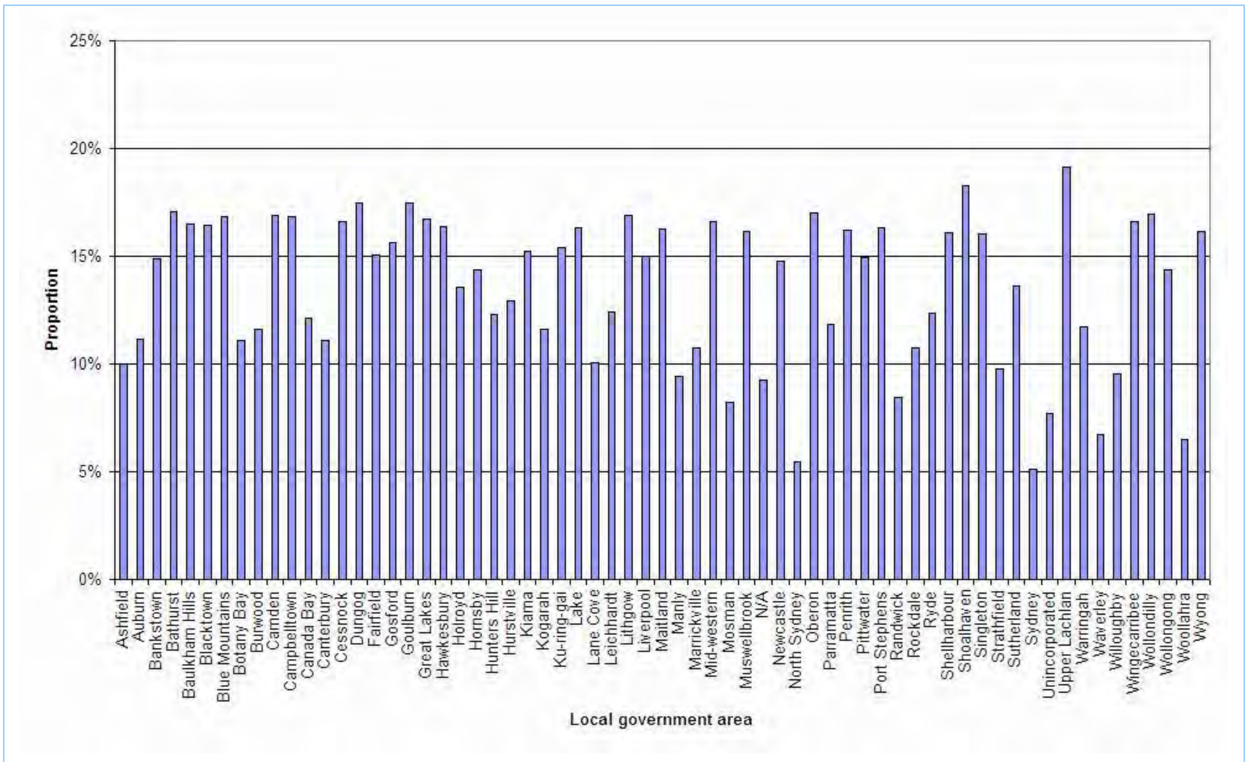

Figure 3-97: Wood fuel fired residential space heater ownership by LGA

The proportion of total dwellings with wood fuel fired residential space heaters by region is presented in Table 3-227 and shown in Figure 3-98.

Table 3-227: Wood fuel fired residential space heater ownership by region

Region	2008 proportion of total dwellings (%)				
	Slow combustion heater with compliance plate	Slow combustion heater without compliance plate	Open fireplace	Potbelly stove	Grand Total
Newcastle	6.10	2.66	5.50	1.16	15.42
Non Urban	6.44	2.81	5.80	1.22	16.28
Sydney	5.04	2.20	4.54	0.96	12.73
Wollongong	5.57	2.44	5.02	1.06	14.09
Grand Total	5.29	2.31	4.77	1.00	13.38

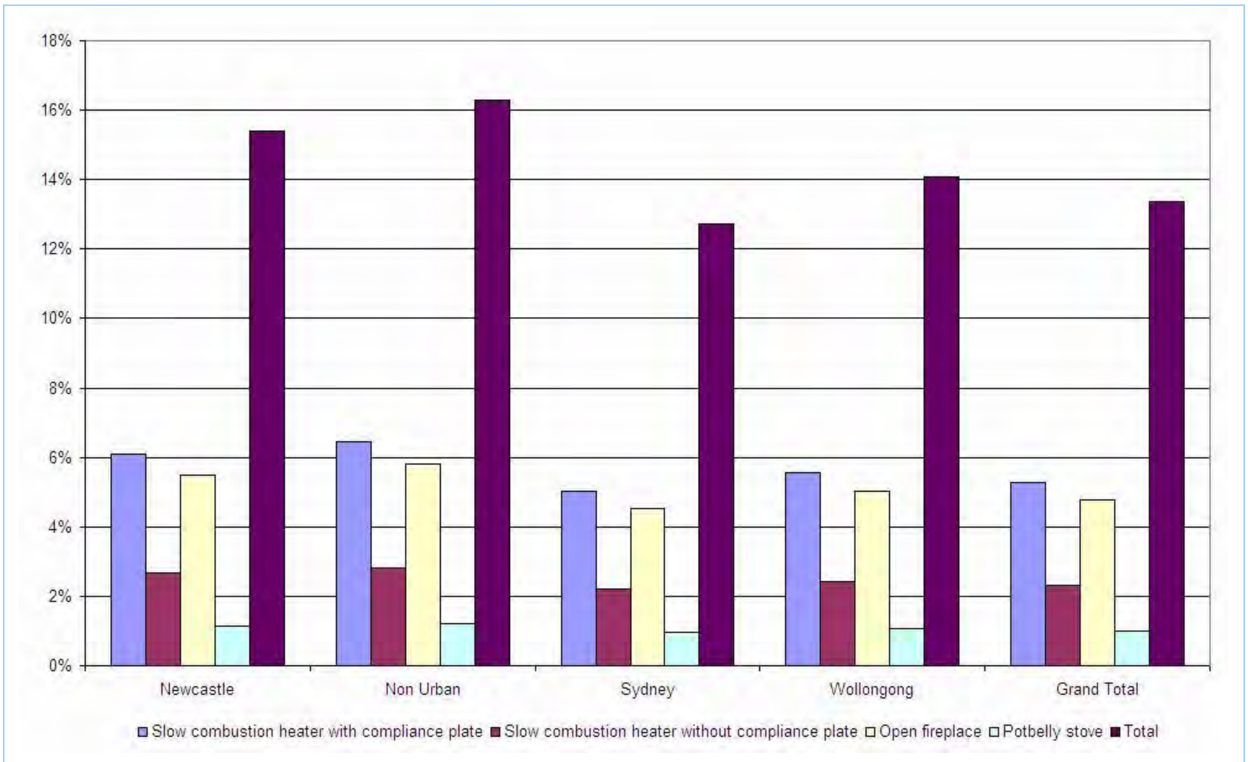

Figure 3-98: Wood fuel fired residential space heater ownership by region

Figure 3-99 shows the spatial distribution of solid fuel combustion emissions.

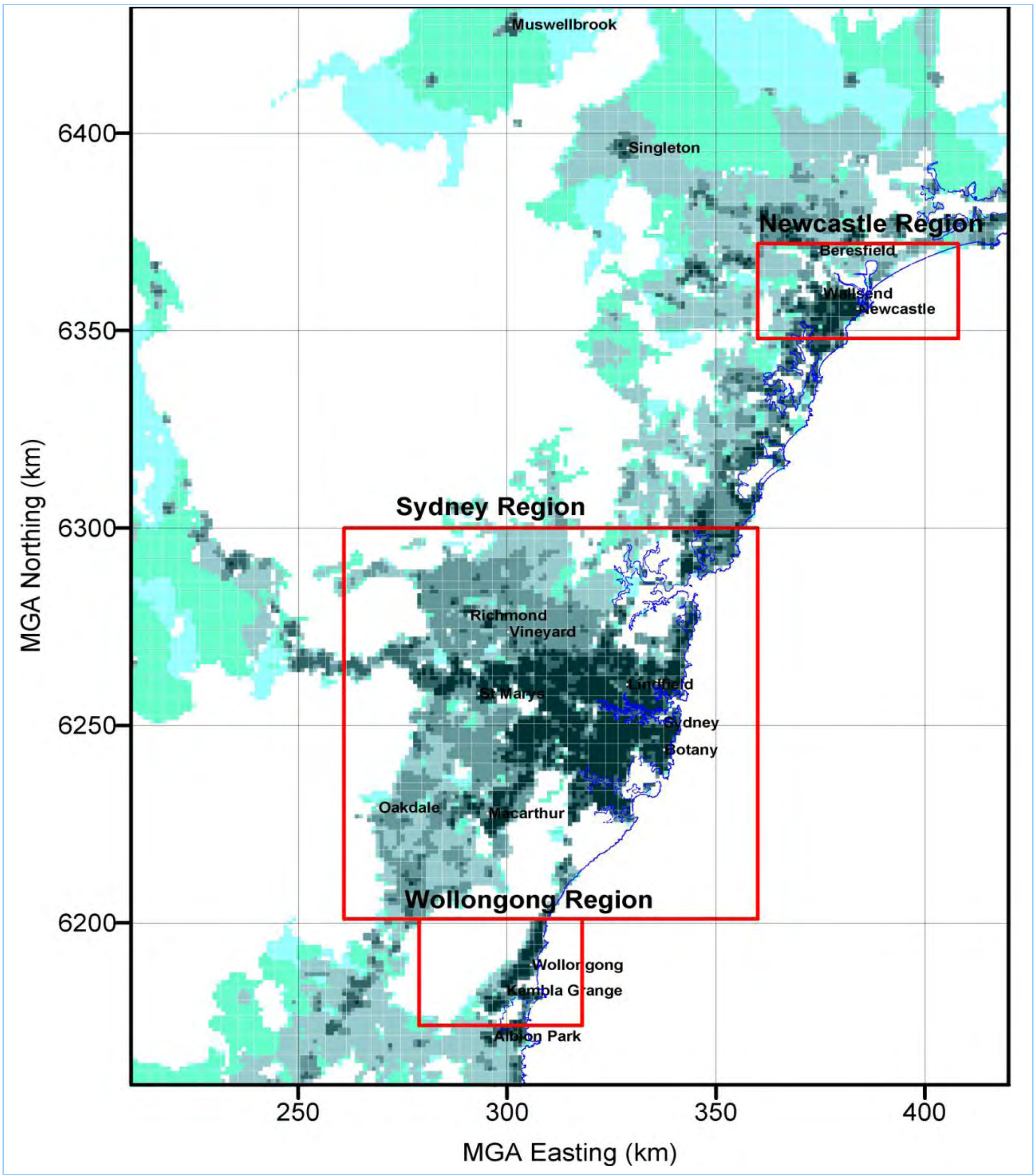

Figure 3-99: Solid fuel combustion spatial distribution of emissions

3.12.6 Temporal Variation of Emissions

Table 3-228 summarises the data used to estimate the temporal variation in emissions from solid fuel combustion.

Table 3-228: Solid fuel combustion temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from wood fuel combustion in space heaters	Monthly, daily and hourly: Derived from domestic survey	- *Domestic Barbecue Pollution Survey* (TR, 2009)

The temporal variation in emissions from solid fuel combustion have been estimated from heater type, number and age; amount, type and source of wood used; and frequency and duration of heater use by hour, day and month data (TR, 2009).

Hourly temporal variation profiles are presented in Table 3-229 and shown in Figure 3-100.

Table 3-229: Solid fuel combustion hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	1.77	1.37	13	2.53	2.52
2	1.77	1.37	14	2.53	2.52
3	1.77	1.37	15	2.53	3.20
4	1.52	1.14	16	3.80	4.58
5	2.03	1.83	17	5.57	6.41
6	1.52	1.37	18	8.86	8.92
7	2.03	1.60	19	10.89	11.21
8	2.53	1.83	20	11.14	11.67
9	2.53	2.06	21	11.14	11.44
10	2.53	2.29	22	8.86	8.70
11	2.53	2.75	23	4.56	5.26
12	2.53	2.52	24	2.53	2.06

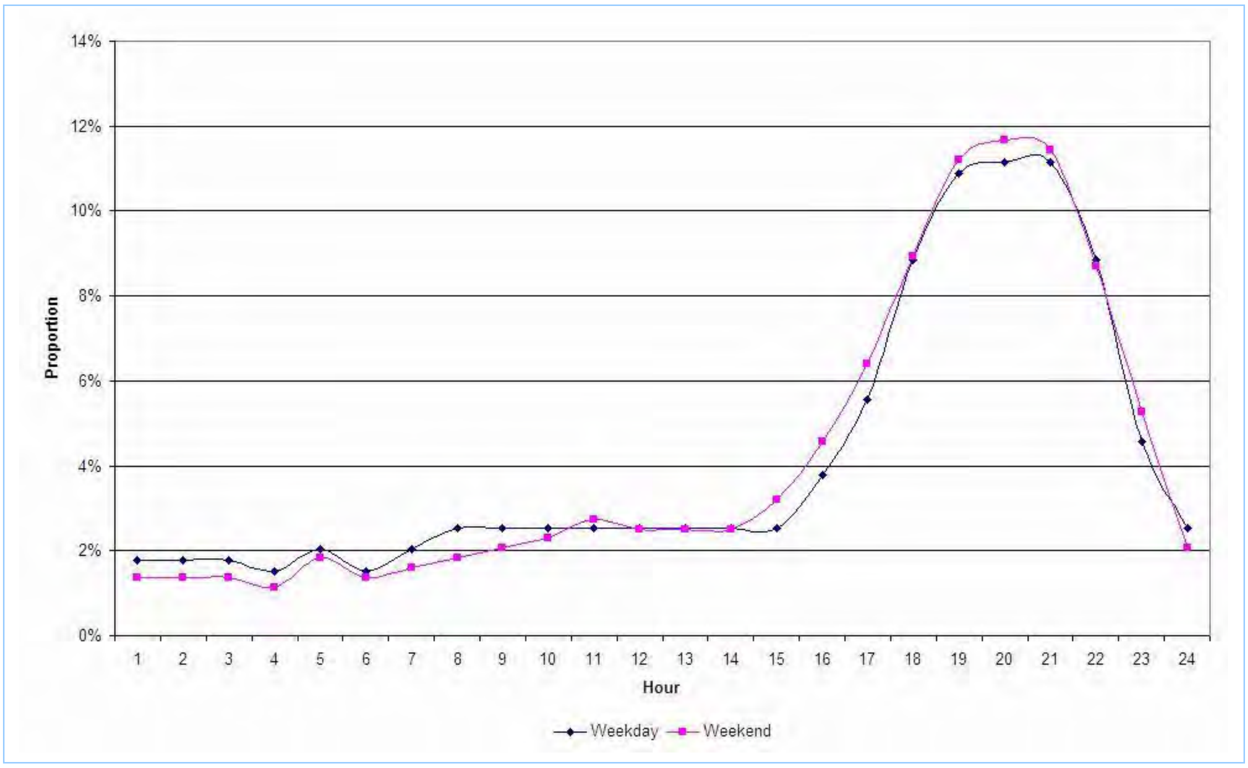

Figure 3-100: Solid fuel combustion hourly temporal profile

Daily temporal variation profiles are presented in Table 3-230 and shown in Figure 3-101.

Table 3-230: Solid fuel combustion daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.11	14.11	14.11	14.11	14.11	14.73	14.73

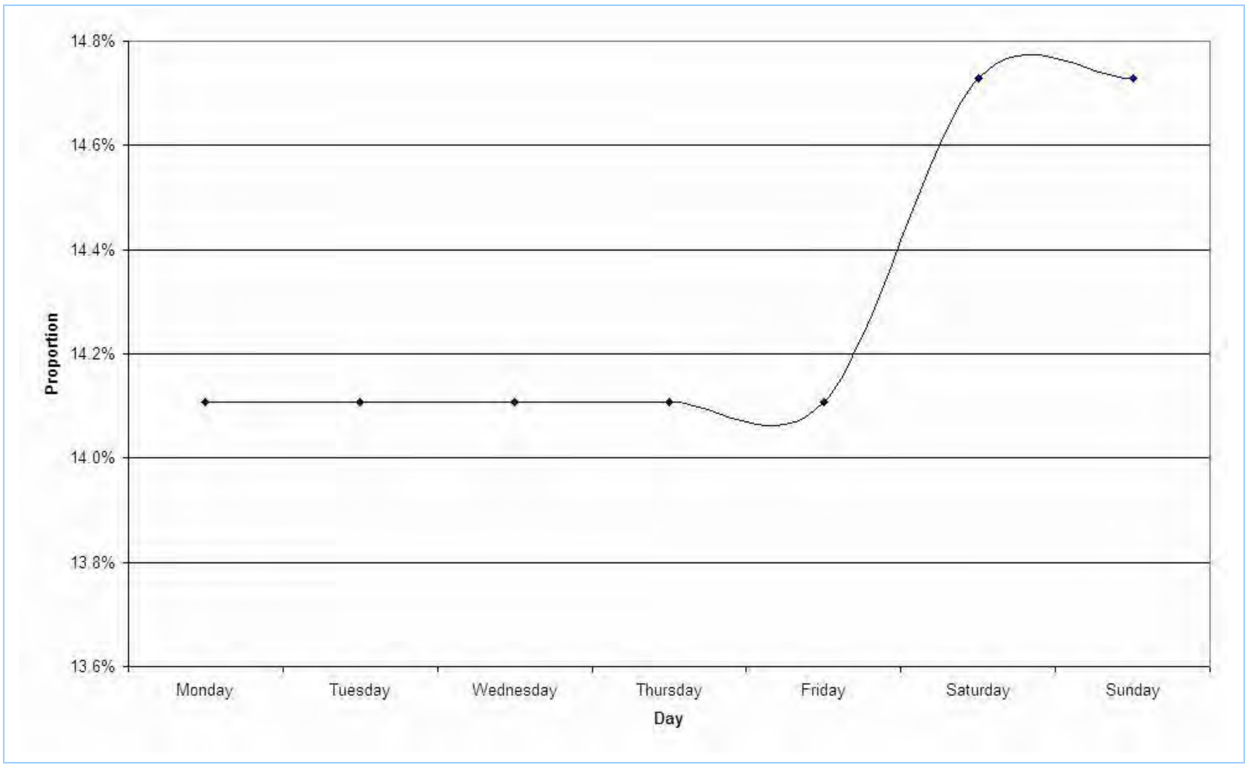

Figure 3-101: Solid fuel combustion daily temporal profile

Monthly temporal variation profiles are presented in Table 3-231 and shown in Figure 3-102.

Table 3-231: Solid fuel combustion monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	-	July	25.47
February	-	August	20.75
March	-	September	10.38
April	3.30	October	4.72
May	12.74	November	0.47
June	22.17	December	-

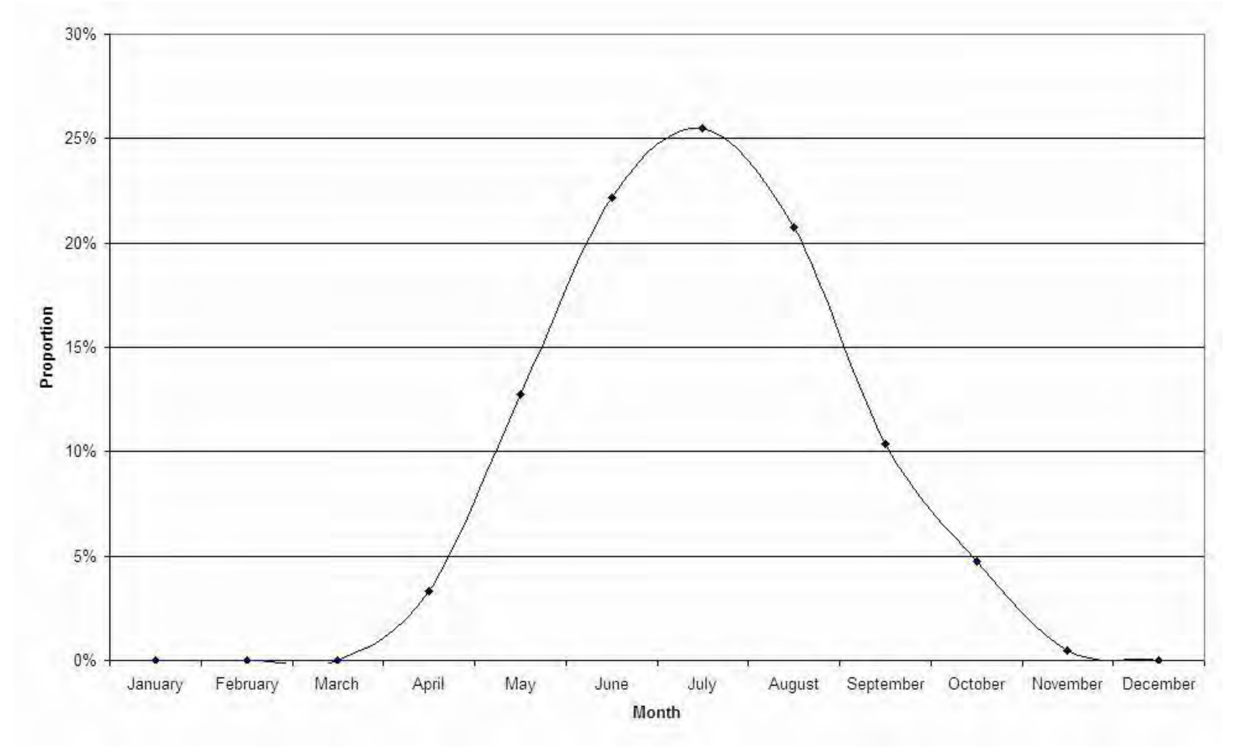

Figure 3-102: Solid fuel combustion monthly temporal profile

3.12.7 Emission Estimates

Table 3-232 presents annual emissions of selected substances from solid fuel combustion by activity.

Table 3-232: Solid fuel combustion emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Solid Fuel Combustion	1,3-BUTADIENE	4,547	11,412	54,414	3,003	73,376
	ACETALDEHYDE	15,051	37,777	180,119	9,940	242,887
	BENZENE	22,873	57,407	273,716	15,105	369,101
	CARBON MONOXIDE	3,345,408	8,396,465	40,034,232	2,209,253	53,985,358
	FORMALDEHYDE	37,945	95,237	454,091	25,059	612,332
	ISOMERS OF XYLENE	3,529	8,856	42,227	2,330	56,942
	LEAD & COMPOUNDS	48	120	573	32	773
	OXIDES OF NITROGEN	50,247	126,112	601,301	33,182	810,843
	PARTICULATE MATTER ≤ 10 µm	473,730	1,188,991	5,669,095	312,844	7,644,661
	PARTICULATE MATTER ≤ 2.5 µm	456,048	1,144,611	5,457,489	301,167	7,359,314
	POLYCYCLIC AROMATIC HYDROCARBONS	8,378	21,028	100,261	5,533	135,200
	SULFUR DIOXIDE	8,013	20,111	95,888	5,292	129,303
	TOLUENE	6,359	15,961	76,100	4,199	102,619

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL SUSPENDED PARTICULATE	506,714	1,271,776	6,063,809	334,626	8,176,925
	TOTAL VOLATILE ORGANIC COMPOUNDS	497,401	1,248,401	5,952,358	328,476	8,026,635

Table 3-233 presents annual emissions of selected substances from solid fuel combustion by source type.

Table 3-233: Solid fuel combustion emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Slow Combustion Heater with AS[70]	1,3-BUTADIENE	1,586	3,980	18,976	1,047	25,588
	ACETALDEHYDE	5,727	14,373	68,529	3,782	92,410
	BENZENE	8,689	21,809	103,986	5,738	140,223
	CARBON MONOXIDE	1,275,779	3,202,012	15,267,149	842,504	20,587,444
	FORMALDEHYDE	20,115	50,486	240,718	13,284	324,603
	ISOMERS OF XYLENE	618	1,550	7,392	408	9,967
	LEAD & COMPOUNDS	18	45	215	12	290
	OXIDES OF NITROGEN	20,659	51,851	247,224	13,643	333,376
	PARTICULATE MATTER ≤ 10 µm	177,594	445,735	2,125,257	117,280	2,865,866
	PARTICULATE MATTER ≤ 2.5 µm	170,965	429,097	2,045,929	112,903	2,758,894
	POLYCYCLIC AROMATIC HYDROCARBONS	1,838	4,614	21,999	1,214	29,666
	SULFUR DIOXIDE	3,624	9,097	43,373	2,393	58,487
	TOLUENE	1,250	3,136	14,953	825	20,164
	TOTAL SUSPENDED PARTICULATE	189,959	476,769	2,273,229	125,446	3,065,404
	TOTAL VOLATILE ORGANIC COMPOUNDS	108,731	272,899	1,301,177	71,804	1,754,612
Slow Combustion Heater without AS	1,3-BUTADIENE	1,538	3,861	18,411	1,016	24,826
	ACETALDEHYDE	2,430	6,099	29,079	1,605	39,213
	BENZENE	7,645	19,188	91,486	5,049	123,367
	CARBON MONOXIDE	910,447	2,285,083	10,895,243	601,244	14,692,017
	FORMALDEHYDE	5,720	14,356	68,449	3,777	92,303

[70] Appliances certified in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b).

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	ISOMERS OF XYLENE	1,709	4,290	20,455	1,129	27,583
	LEAD & COMPOUNDS	12	31	146	8.06	197
	OXIDES OF NITROGEN	11,045	27,722	132,178	7,294	178,239
	PARTICULATE MATTER ≤ 10 µm	120,709	302,962	1,444,517	79,714	1,947,902
	PARTICULATE MATTER ≤ 2.5 µm	116,204	291,653	1,390,598	76,739	1,875,194
	POLYCYCLIC AROMATIC HYDROCARBONS	1,790	4,492	21,419	1,182	28,883
	SULFUR DIOXIDE	1,578	3,960	18,883	1,042	25,463
	TOLUENE	2,880	7,228	34,461	1,902	46,470
	TOTAL SUSPENDED PARTICULATE	129,114	324,055	1,545,092	85,265	2,083,526
	TOTAL VOLATILE ORGANIC COMPOUNDS	209,071	524,737	2,501,941	138,067	3,373,817
Open Fire Place	1,3-BUTADIENE	888	2,228	10,622	586	14,324
	ACETALDEHYDE	6,050	15,183	72,394	3,995	97,622
	BENZENE	3,878	9,734	46,413	2,561	62,588
	CARBON MONOXIDE	842,409	2,114,319	10,081,045	556,313	13,594,087
	FORMALDEHYDE	10,120	25,400	121,108	6,683	163,312
	ISOMERS OF XYLENE	607	1,524	7,264	401	9,795
	LEAD & COMPOUNDS	13	34	161	8.91	218
	OXIDES OF NITROGEN	14,700	36,894	175,911	9,707	237,212
	PARTICULATE MATTER ≤ 10 µm	133,429	334,885	1,596,729	88,114	2,153,157
	PARTICULATE MATTER ≤ 2.5 µm	128,448	322,385	1,537,130	84,825	2,072,788
	POLYCYCLIC AROMATIC HYDROCARBONS	4,127	10,359	49,390	2,726	66,602
	SULFUR DIOXIDE	2,262	5,676	27,063	1,493	36,494
	TOLUENE	1,228	3,082	14,696	811	19,817
	TOTAL SUSPENDED PARTICULATE	142,719	358,202	1,707,903	94,249	2,303,072
	TOTAL VOLATILE ORGANIC COMPOUNDS	106,856	268,192	1,278,737	70,566	1,724,351
Pot Belly Stove	1,3-BUTADIENE	535	1,343	6,406	353	8,638
	ACETALDEHYDE	845	2,122	10,118	558	13,643
	BENZENE	2,660	6,676	31,831	1,757	42,923
	CARBON MONOXIDE	316,773	795,051	3,790,794	209,192	5,111,810
	FORMALDEHYDE	1,990	4,995	23,816	1,314	32,115
	ISOMERS OF XYLENE	595	1,493	7,117	393	9,597
	LEAD & COMPOUNDS	4.25	11	51	2.80	69

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	OXIDES OF NITROGEN	3,843	9,645	45,989	2,538	62,015
	PARTICULATE MATTER ≤ 10 µm	41,998	105,410	502,592	27,735	677,736
	PARTICULATE MATTER ≤ 2.5 µm	40,431	101,475	483,832	26,700	652,438
	POLYCYCLIC AROMATIC HYDROCARBONS	623	1,563	7,452	411	10,049
	SULFUR DIOXIDE	549	1,378	6,570	363	8,859
	TOLUENE	1,002	2,515	11,990	662	16,168
	TOTAL SUSPENDED PARTICULATE	44,923	112,749	537,586	29,666	724,923
	TOTAL VOLATILE ORGANIC COMPOUNDS	72,742	182,572	870,503	48,038	1,173,856

3.12.8 *Emission Projection Methodology*

Table 3-234 summarises the data used to estimate the emission projection factors for solid fuel combustion, while Figure 3-103 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-234: Solid fuel combustion emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from wood fuel combustion in space heaters	Final energy consumption for residential using biomass	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

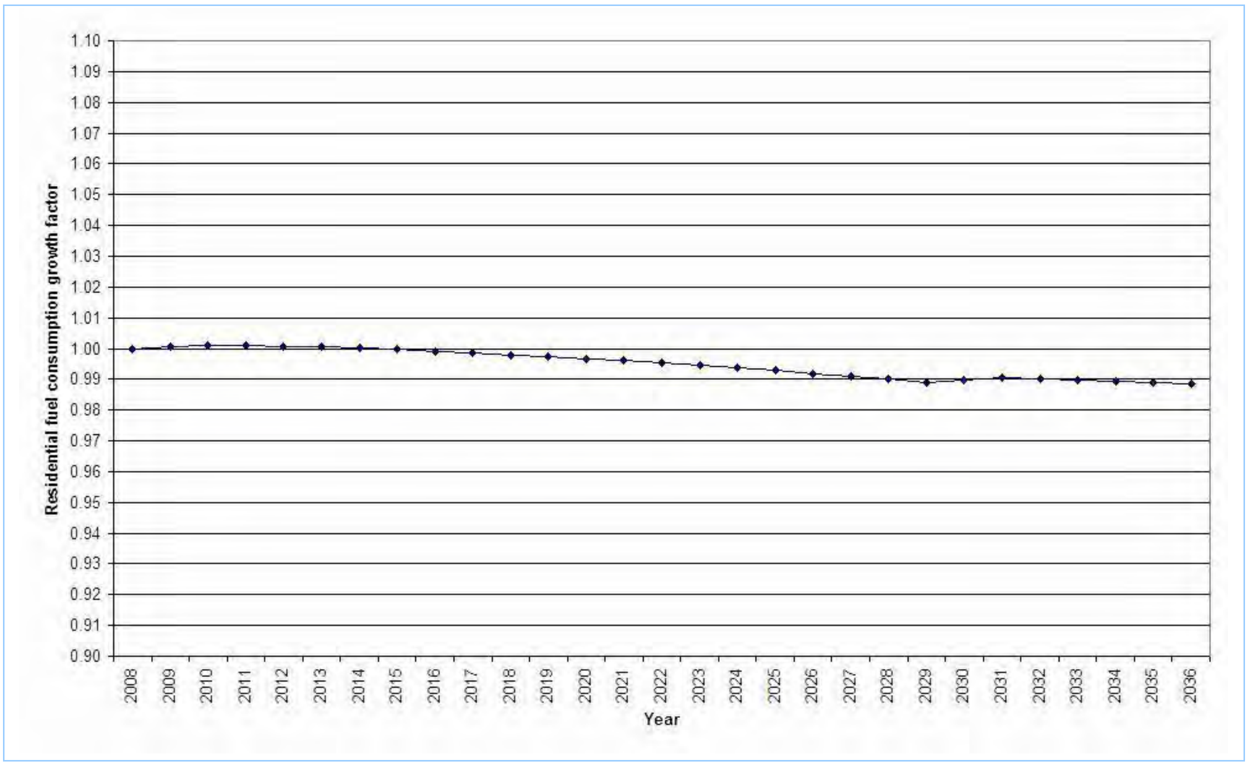

Figure 3-103: Solid fuel combustion emission projection factors

3.13 Surface Coatings

3.13.1 Emission Source Description

The domestic-commercial air emissions inventory includes emissions of evaporative VOC from the application of architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products) surface coatings and thinners.

To estimate emissions from these sources, the following have been considered:

- *Informark Architectural & Decorative Paints & Enamels Industry Aggregate Sales Quantity*

The consumption of water and solvent based architectural and decorative paints, enamels and clears in retail and trade applications in NSW and ACT during 2008 (Informark, 2009a to Informark, 2009d) have been used in combination with NSW, ACT and GMR demographic statistics (ABS, 2009; and TDC, 2009) to estimate total surface coating consumption in the GMR.

The proportion of water and solvent based surface coatings have been derived from an *Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009).

Since the consumption of architectural and decorative thinners is not readily available, the techniques presented in the *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000) have been used to estimate total thinner consumption in the GMR.

- *Informark Architectural & Decorative Woodcare Product Industry Aggregate Sales Quantity*

The consumption of water and solvent based architectural and decorative woodcare products in retail and trade applications in NSW and ACT during 2008 (Informark, 2009e to Informark, 2009h) have been used in combination with NSW, ACT and GMR demographic statistics (ABS, 2009; and TDC, 2009) to estimate total surface coating consumption in the GMR.

The proportion of water and solvent based surface coatings have been derived from an *Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009).

Since the consumption of architectural and decorative thinners is not readily available, the techniques presented in the *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000) have been used to estimate total thinner consumption in the GMR.

- *APMF Quarterly Industrial Sales Statistics Survey and Automotive Refinish Statistics*

The consumption of solvent based industrial paints, enamels, clears, woodcare products and thinners in NSW and ACT during 2008 (APMF, 2009a to APMF, 2009d) have been used to estimate total surface coating and thinner consumption in the GMR.

The consumption of automotive surface coatings and thinners in NSW and ACT during 2008 (APMF, 2009a to APMF, 2009d; and APMF, 2009e to 2009h) have been used in combination with NSW, ACT and GMR demographic statistics (ABS, 2009; and TDC, 2009) to estimate total surface coating and thinner consumption in the GMR.

Automotive surface coating and thinner consumption in the GMR have been subtracted from the total industrial surface coating and thinner consumption.

Emissions of evaporative VOC from commercial businesses within the Smash repairing Australian and New Zealand Standard Industrial Classification (ANZSIC) class (ABS, 1993) are included in the commercial air emissions inventory.

- *Environ VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia Report*

The *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia Report* (Environ, 2009) presents surface coating consumption based emission factors by surface coating type (i.e. architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products)) which have been adopted for the GMR.

- *Surface coating type*

The inventory includes emissions of evaporative VOC from the application of architectural and decorative and industrial surface coatings and thinners as follows:

Architectural & decorative – water based

- *Paving paint;*
- *Roof paint;*
- *Fence paint;*
- *Specialty finishes;*
- *Texture coatings;*
- *Prepcoats;*
- *Ceiling paint / Flat topcoats ;*
- *Door, window, trim topcoats;*
- *Waterbased - interior topcoat;*
- *Waterbased - exterior topcoat; and*
- *Other.*

Architectural & decorative – solvent based

- *Paving paint;*
- *Roof paint;*
- *Metal finishes;*

- *Prepcoats;*
- *Door, Window and Trim topcoats; and*
- *Other.*

Architectural & decorative - water and solvent based timber finishes

- *Decking;*
- *Flooring;*
- *Interior stains;*
- *Exterior stains;*
- *Prepcoats;*
- *Interior clears; and*
- *Exterior clears.*

Architectural & decorative thinners

Industrial surface coatings

- *Protective coatings;*
- *Marine coatings;*
- *Road and runway marking paint;*
- *Can and coil;*
- *Flat board coatings; and*
- *Other.*

Industrial timber finishes

- *Stains;*
- *Clears; and*
- *Solid colours.*

Industrial thinners

3.13.2 Emission Estimation Methodology

Table 3-235 summarises the emission estimation methodologies used for surface coatings.

Table 3-235: Surface coatings emission estimation methodologies

Emission source	Emission estimation methodology source
Evaporative VOC from the application of surface coatings and thinners	- *Area-Wide Source Methodologies, Section 3.5, Coatings and Related Process Solvents Industrial Coatings* (CARB, 1997a) - *Area-Wide Source Methodologies, Section 3.6, Coatings and Related Process Solvents Thinning and Cleaning Solvents* (CARB, 1997b) - *Area-Wide Source Methodologies, Section 6.3, Architectural Coatings* (CARB, 2003) - *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000)

Evaporative VOC emissions from surface coatings and thinners have been estimated using consumption based emission factors combined with activity rates. Activity rates include surface coating and thinner consumption in NSW and ACT (Informark, 2009a to Informark, 2009h; and APMF, 2009a to APMF, 2009h). Architectural and decorative surface coating and thinner consumption in the GMR has been estimated by assuming consumption is proportional to population using NSW, ACT and GMR demographic statistics (ABS, 2009; and TDC, 2009). Industrial surface coating and thinner consumption in NSW and ACT has been used to estimate consumption in the GMR. Automotive surface coating and thinner consumption in the GMR has been subtracted from the total industrial surface coating and thinner consumption. Emissions have been determined using Equation 34 (CARB, 1997a; CARB, 1997b; CARB, 2003; and EC, 2000):

$$E_{VOC,i} = SC_i \times EF_{VOC,i} \ / \ 1000 \qquad \textbf{Equation 34}$$

where:			
$E_{VOC,i}$	=	Emissions of VOC from surface coating and thinner type i	(kg/year)
SC	=	Consumption of surface coating and thinner type i	(L/year)
$EF_{VOC,i}$	=	Emission factor for VOC from surface coating and thinner type i	(g/L)
i	=	Surface coating and thinner type (either "architectural and decorative (i.e. paints, enamels, clears, woodcare products and thinners)" or "industrial (i.e. protective, marine, road and runway, can and coil, flatboard, woodcare products and thinners)"	
1000	=	Conversion factor	(g/kg)

3.13.3 Activity Data

Table 3-236 summarises the activity data used for surface coatings.

Table 3-236: Surface coatings activity data

Activity data	Activity data source
Surface coating consumption	- *Quarterly Industrial Sales Statistics Survey 2008* (APMF, 2009a to 2009d) - *Quarterly Automotive Refinish Statistics 2008* (APMF, 2009e to 2009h) - *Quarterly Architectural & Decorative Paints &*

Activity data	Activity data source
	Enamels Sales Quantity 2008 (Informark, 2009a to 2009d) - *Quarterly Woodcare Products Sales Quantity 2008* (Informark, 2009e to 2009h)
NSW total and gridded 1 km x 1 km population estimates required to scale surface coating consumption from NSW to GMR	NSW: - *83101.0 - Australian Demographic Statistics, Dec 2008* (ABS, 2009) GMR: - *Forecasts for Population from 2006 to 2036* (TDC, 2009)

Table 3-237 presents the consumption of architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products) surface coatings and thinners in the GMR by surface coating category and surface coating type (Informark, 2009a to Informark, 2009h; and APMF, 2009a to APMF, 2009h). Architectural and decorative surface coating and thinner consumption in the GMR has been estimated by assuming consumption is proportional to population using NSW, ACT and GMR demographic statistics (ABS, 2009; and TDC, 2009). Industrial surface coating and thinner consumption in NSW and ACT has been used to estimate consumption in the GMR. Automotive surface coating and thinner consumption in the GMR has been subtracted from the total industrial surface coating and thinner consumption.

Table 3-237: Surface coatings and thinner consumption in the GMR by surface coating category and surface coating type

Surface coating category	Surface coating type	2008 surface coating consumption (L/year)				
		January to March	April to June	July to September	October to December	Grand Total
Architectural & decorative - water based	Paving Paint	47,545	38,238	40,932	53,166	179,881
	Roof Paint	11,753	13,277	11,876	14,790	51,695
	Fence Paint	35,196	25,577	33,692	40,838	135,304
	Specialty Finishes	126,444	117,048	121,846	132,776	498,114
	Texture Coatings	1,004,026	1,058,222	1,120,413	1,005,252	4,187,912
	Prepcoats	629,895	665,415	704,948	685,130	2,685,388
	Ceiling Paint / Flat Topcoats	954,468	1,023,074	1,035,389	967,369	3,980,301
	Door, Window, Trim Topcoats	86,516	82,095	77,884	93,745	340,240
	Waterbased - Interior Topcoat	2,012,976	1,988,455	2,060,687	2,150,559	8,212,678
	Waterbased - Exterior Topcoat	1,162,008	964,096	1,145,318	1,295,073	4,566,495
	Other	9,747	7,043	5,095	7,171	29,056
Architectural & decorative - water based Grand Total		6,080,574	5,982,540	6,358,080	6,445,868	24,867,062
Architectural & decorative – solvent based	Paving Paint	54,274	43,650	46,725	60,691	205,340
	Roof Paint	3,623	4,093	3,661	4,560	15,938
	Metal Finishes	84,695	81,502	91,131	91,265	348,593
	Prepcoats	134,968	142,579	151,049	146,803	575,398

Surface coating category	Surface coating type	2008 surface coating consumption (L/year)				
		January to March	April to June	July to September	October to December	Grand Total
	Door, Window, Trim Topcoats	268,911	255,170	242,081	291,379	1,057,542
	Other	877	634	458	645	2,614
Architectural & decorative – solvent based Grand Total		547,348	527,628	535,106	595,343	2,205,425
Architectural& decorative – water based timber finishes	Decking	15,359	10,359	19,126	23,700	68,544
	Flooring	5,239	5,898	4,739	5,398	21,274
	Interior Stains	3,882	3,648	3,956	3,694	15,180
	Exterior Stains	17,702	12,341	15,693	21,678	67,415
	Prepcoats	17,335	11,749	18,673	23,949	71,706
	Interior Clears	9,138	8,384	9,303	8,497	35,321
	Exterior Clears	10,990	8,620	11,894	18,804	50,309
Architectural & decorative – water based timber finishes Grand Total		79,645	61,001	83,384	105,720	329,750
Architectural & decorative – solvent based timber finishes	Decking	145,539	98,163	181,230	224,570	649,502
	Flooring	31,513	35,482	28,507	32,472	127,973
	Interior Stains	18,960	17,820	19,322	18,044	74,146
	Exterior Stains	17,900	12,479	15,868	21,920	68,166
	Prepcoats	4,403	2,984	4,743	6,083	18,213
	Interior Clears	32,289	29,623	32,871	30,022	124,804
	Exterior Clears	1,181	926	1,278	2,021	5,406
Architectural & decorative – solvent based timber finishes Grand Total		251,785	197,477	283,818	335,131	1,068,211
Architectural & decorative – thinners	Thinners	186,518	155,517	199,556	225,896	767,487
Architectural & decorative – thinners Grand Total		186,518	155,517	199,556	225,896	767,487
Industrial surface coatings	Protective Coatings	536,222	554,738	607,111	554,352	2,252,423
	Marine Coatings	154,942	72,988	83,223	103,593	414,746
	Road & Runway Marking Paint	534,932	631,572	645,304	621,614	2,433,422
	Can and Coil	2,231,552	2,347,138	2,403,355	1,920,270	8,902,315
	Flat Board Coatings	242,377	281,897	235,344	245,684	1,005,302
	Other	913,353	1,046,693	1,025,076	896,520	3,881,642
Industrial surface coatings Grand Total		4,613,378	4,935,026	4,999,413	4,342,033	18,889,850
Industrial timber finishes	Stains	18,148	19,292	13,503	19,523	70,466
	Clears	88,853	98,491	99,228	98,843	385,415
	Solid Colours	39,517	44,413	41,332	42,283	167,545
Industrial timber finishes Grand Total		146,518	162,196	154,063	160,649	623,426
Industrial thinners	Thinners	426,702	468,419	474,507	431,179	1,800,807
Industrial thinners Grand Total		426,702	468,419	474,507	431,179	1,800,807
Grand Total		12,332,468	12,489,803	13,087,927	12,641,820	50,552,018

Table 3-238 presents the consumption of architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products) surface coatings and thinners in the GMR by surface coating category (Informark, 2009a to Informark, 2009h; and APMF, 2009a to APMF, 2009h).

Table 3-238: Surface coatings and thinner consumption in the GMR by surface coating category

Surface coating category	2008 surface coating consumption (L/year)				
	January to March	April to June	July to September	October to December	Grand Total
Architectural & decorative - water based	6,080,574	5,982,540	6,358,080	6,445,868	24,867,062
Architectural & decorative - solvent based	547,348	527,628	535,106	595,343	2,205,425
Architectural & decorative – water and solvent based timber finishes	331,430	258,477	367,202	440,852	1,397,961
Architectural & decorative - thinners	186,518	155,517	199,556	225,896	767,487
Industrial surface coatings	4,613,378	4,935,026	4,999,413	4,342,033	18,889,850
Industrial timber finishes	146,518	162,196	154,063	160,649	623,426
Industrial thinners	426,702	468,419	474,507	431,179	1,800,807
Grand Total	12,332,468	12,489,803	13,087,927	12,641,820	50,552,018

Figure 3-104 shows surface coating and thinner consumption and VOC content by surface coating category.

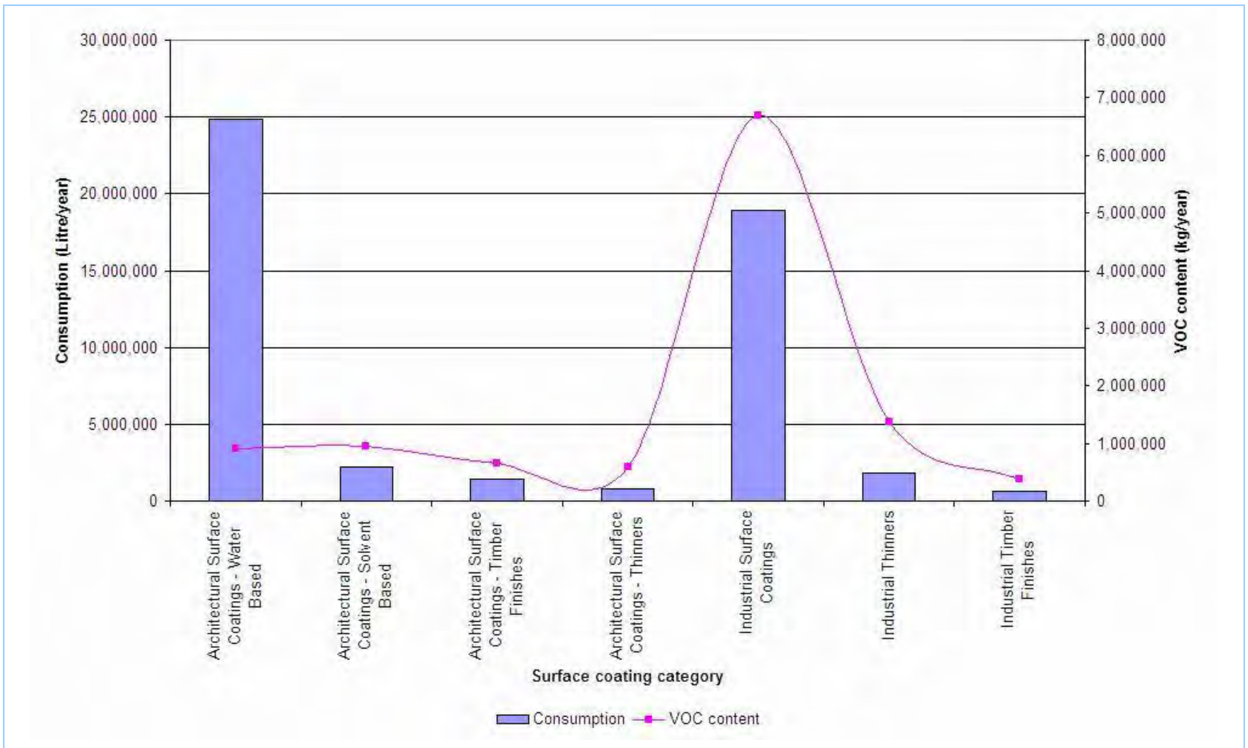

Figure 3-104: Surface coating and thinner consumption and VOC content by surface coating category

Table 3-239 presents the proportion of architectural and decorative surface coatings (i.e. paints, enamels, clears and woodcare products) consumed in retail applications by surface coating category and surface coating type (Informark, 2009a to Informark, 2009h).

Table 3-239: Architectural and decorative surface coatings retail proportion

Surface coating category	Surface coating type	2008 surface coating proportion retail (%)				
		January to March	April to June	July to September	October to December	Grand Total
Architectural& decorative - water and solvent based	Paving Paint	68.66	69.04	70.92	73.94	70.81
	Roof Paint	47.97	48.82	58.53	56.79	53.14
	Fence Paint	98.51	97.90	98.33	98.73	98.42
	Specialty Finishes	79.10	81.17	80.83	80.44	80.37
	Texture Coatings	3.41	1.68	4.53	4.86	3.62
	Metal Finishes	82.94	82.52	84.96	84.65	83.82
	Prepcoats	37.32	31.09	36.77	35.85	35.26
	Ceiling Paint / Flat Topcoats	36.19	30.79	36.29	33.24	34.11
	Door, Window, Trim Topcoats	53.00	47.15	56.55	46.66	50.66
	Waterbased - Interior Topcoat	50.77	42.63	49.06	47.55	47.53
	Waterbased - Exterior Topcoat	50.98	39.93	46.87	49.93	47.32
	Other	4.73	3.88	4.30	3.47	4.13
Architectural & decorative - water and solvent based Grand Total		41.50	34.23	39.90	40.30	39.03
Architectural & decorative – water and solvent based timber finishes	Decking	90.71	88.71	92.31	92.67	91.53
	Flooring	84.66	84.73	81.15	84.00	83.73
	Interior Stains	93.30	92.66	92.41	92.45	92.71
	Exterior Stains	89.48	86.43	85.19	91.33	88.52
	Prepcoats	89.27	86.95	89.42	92.18	89.90
	Interior Clears	79.12	76.84	79.61	79.91	78.90
	Exterior Clears	77.58	75.89	81.12	84.95	80.88
Architectural & decorative – water and solvent based timber finishes Grand Total		88.06	85.86	88.65	90.27	88.51
Grand Total		43.72	36.20	42.37	43.24	41.46

Table 3-240 presents the proportion of architectural and decorative surface coatings (i.e. paints, enamels, clears and woodcare products) consumed in trade applications by surface coating category and surface coating type (Informark, 2009a to Informark, 2009h).

Table 3-240: Architectural and decorative surface coatings trade proportion

Surface coating category	Surface coating type	2008 surface coating proportion trade (%)				
		January to March	April to June	July to September	October to December	Grand Total
Architectural& decorative - water and solvent based	Paving Paint	31.34	30.96	29.08	26.06	29.19
	Roof Paint	52.03	51.18	41.47	43.21	46.86
	Fence Paint	1.49	2.10	1.67	1.27	1.58
	Specialty Finishes	20.90	18.83	19.17	19.56	19.63
	Texture Coatings	96.59	98.32	95.47	95.14	96.38
	Metal Finishes	17.06	17.48	15.04	15.35	16.18
	Prepcoats	62.68	68.91	63.23	64.15	64.74
	Ceiling Paint / Flat Topcoats	63.81	69.21	63.71	66.76	65.89
	Door, Window, Trim Topcoats	47.00	52.85	43.45	53.34	49.34
	Waterbased - Interior Topcoat	49.23	57.37	50.94	52.45	52.47
	Waterbased - Exterior Topcoat	49.02	60.07	53.13	50.07	52.68
	Other	95.27	96.12	95.70	96.53	95.87
Architectural & decorative - water and solvent based Grand Total		58.50	65.77	60.10	59.70	60.97
Architectural & decorative – water and solvent based timber finishes	Decking	9.29	11.29	7.69	7.33	8.47
	Flooring	15.34	15.27	18.85	16.00	16.27
	Interior Stains	6.70	7.34	7.59	7.55	7.29
	Exterior Stains	10.52	13.57	14.81	8.67	11.48
	Prepcoats	10.73	13.05	10.58	7.82	10.10
	Interior Clears	20.88	23.16	20.39	20.09	21.10
	Exterior Clears	22.42	24.11	18.88	15.05	19.12
Architectural & decorative – water and solvent based timber finishes Grand Total		11.94	14.14	11.35	9.73	11.49
Grand Total		56.28	63.80	57.63	56.76	58.54

Since the consumption of architectural and decorative thinners is not readily available, the techniques presented in the *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000) have been used to estimate total thinner consumption in the GMR. Table 3-241 presents the thinner consumption factors by surface coating category (CARB, 2003; EC, 2000; and Environ, 2009).

Table 3-241: Architectural and decorative thinner consumption factors

Surface coating category	VOC thinner kg/VOC surface coating kg[71]			thinner L/surface coating L[72]		
	Retail	Trade	Grand Total	Retail	Trade	Grand Total
Architectural & decorative – solvent based thinners	0.50	0.10	0.32	0.28	0.06	0.18
Architectural & decorative – solvent based timber finishes thinners	0.50	0.10	0.46	0.39	0.07	0.35
Grand Total	0.50	0.10	0.37	0.33	0.06	0.23

3.13.4 Emission and Speciation Factors

Table 3-242 summarises the emission and speciation factors used for surface coatings.

Table 3-242: Surface coatings emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: VOC	Architectural & decorative - water based	- *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009)
	Architectural & decorative - solvent based	- *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009)
	Architectural & decorative – water and solvent based timber finishes	- *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009)
	Architectural & decorative - thinners	- *Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use* (EC, 2000) - *Area-Wide Source Methodologies, Section 6.3, Architectural Coatings* (CARB, 2003)
	Industrial surface coatings	- *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009) - *Area-Wide Source Methodologies, Section 3.5, Coatings and Related Process Solvents Industrial Coatings* (CARB, 1997a)
	Industrial timber finishes	- *VOCs from Surface Coatings – Assessment of the Categorisation, VOC Content and Sales Volumes of Coating Products Sold in Australia* (Environ, 2009) - *Area-Wide Source Methodologies, Section 3.5, Coatings and*

[71] Additional VOC from thinners and cleaning agents expressed as VOC thinner kg/VOC surface coating kg (EC, 2000). The Grand Total is the surface coating type consumption weighted average.
[72] Derived thinners and cleaning agents consumption factors expressed as thinner L/surface coating L (CARB, 2003; and Environ, 2009). The Grand Total is the surface coating type consumption weighted average.

Substance	Emission source	Emission and speciation factor source
		Related Process Solvents Industrial Coatings (CARB, 1997a)
	Industrial thinners	- *Area-Wide Source Methodologies, Section 3.6, Coatings and Related Process Solvents Thinning and Cleaning Solvents* (CARB, 1997b)
Speciated VOC	Architectural & decorative - water based	- *Profile number 3140 Architectural Coatings: Water Borne - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative - solvent based	- *Profile number 3139 Architectural Coatings: Solvent Borne - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative – water and solvent based timber finishes	- *Profile number 2405 Wood Furniture Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative - thinners	- *Profile number 3141 Thinning Solvent/Mineral Spirits - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial surface coatings	- *Profile number 2403 Traffic Markings - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2404 Flat Wood Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2408 Can Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2409 Coil Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2415 Marine Paints - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2418 Industrial Maintenance Coatings - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial timber finishes	- *Profile number 2405 Wood Furniture Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial thinners	- *Profile number 3141 Thinning Solvent/Mineral Spirits - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
Organic air toxics	Architectural & decorative - water based	- *Profile number 3140 Architectural Coatings: Water Borne - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative - solvent based	- *Profile number 3139 Architectural Coatings: Solvent Borne - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative – water and solvent based timber finishes	- *Profile number 2405 Wood Furniture Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Architectural & decorative - thinners	- *Profile number 3141 Thinning Solvent/Mineral Spirits - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial surface coatings	- *Profile number 2403 Traffic Markings - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2404 Flat Wood Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2408 Can Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2409 Coil Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)

Substance	Emission source	Emission and speciation factor source
		- *Profile number 2415 Marine Paints - Speciate 4.2 Database Development Documentation* (Pechan, 2009a) - *Profile number 2418 Industrial Maintenance Coatings - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial timber finishes	- *Profile number 2405 Wood Furniture Coating - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)
	Industrial thinners	- *Profile number 3141 Thinning Solvent/Mineral Spirits - Speciate 4.2 Database Development Documentation* (Pechan, 2009a)

Table 3-243 presents VOC emission factors for architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products) surface coatings (CARB, 1997a; and Environ, 2009) and thinners (CARB, 1997b; and CARB, 2003).

Table 3-243: Surface coatings emission factors

Surface coating category	Surface coating type	Emission factor (g/L)
		VOC
Architectural & decorative - water based	Paving Paint	69.78
	Roof Paint	84.16
	Fence Paint	5.33
	Specialty Finishes	91.38
	Texture Coatings	34.48
	Prepcoats	43.84
	Ceiling Paint / Flat Topcoats	24.28
	Door, Window, Trim Topcoats	70.99
	Waterbased - Interior Topcoat	30.60
	Waterbased - Exterior Topcoat	45.70
	Other	36.48
Architectural & decorative - water based Grand Total		36.48
Architectural & decorative – solvent based	Paving Paint	498.28
	Roof Paint	406.77
	Metal Finishes	462.77
	Prepcoats	461.79
	Door, Window, Trim Topcoats	392.85
	Other	431.85
Architectural & decorative – solvent based Grand Total		431.85
Architectural& decorative – water based timber finishes	Decking	42.99
	Flooring	116.19
	Interior Stains	135.57
	Exterior Stains	96.75
	Prepcoats	50.00
	Interior Clears	135.57
	Exterior Clears	85.16

Surface coating category	Surface coating type	Emission factor (g/L)
		VOC
Architectural & decorative – water based timber finishes Grand Total		80.84
Architectural & decorative – solvent based timber finishes	Decking	634.55
	Flooring	561.79
	Interior Stains	447.51
	Exterior Stains	643.45
	Prepcoats	485.18
	Interior Clears	450.00
	Exterior Clears	424.50
Architectural & decorative – solvent based timber finishes Grand Total		588.25
Architectural & decorative – thinners	Thinners	766.99
Architectural & decorative – thinners Grand Total		766.99
Industrial surface coatings	Protective Coatings	298.69
	Marine Coatings	376.02
	Road & Runway Marking Paint	83.12
	Can and Coil	452.40
	Flat Board Coatings	384.69
	Other	323.39
Industrial surface coatings Grand Total		354.71
Industrial timber finishes	Stains	771.94
	Clears	611.37
	Solid Colours	516.31
Industrial timber finishes Grand Total		603.97
Industrial thinners	Thinners	766.99
Industrial thinners Grand Total		766.99
Grand Total		228.70

3.13.5 *Spatial Distribution of Emissions*

Table 3-244 summarises the data used for spatially allocating emissions from surface coatings.

Table 3-244: Surface coatings spatial data

Emission source	Spatial data	Spatial data source
Evaporative VOC from the application of surface coatings and thinners	Gridded 1 km x 1 km total dwelling estimates	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

Emissions from surface coatings have been spatially distributed according to the proportion of total dwellings in each 1 km by 1 km grid cell (TDC, 2009). The proportion of total dwellings by LGA and region are presented in Table 3-245 and shown in Figure 3-105 .

Table 3-245: Surface coatings spatial distribution of total dwellings by LGA and region

LGA	2008 proportion of total dwellings (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	-	-	0.97	-	0.97
Auburn	-	-	1.13	-	1.13
Bankstown	-	-	3.03	-	3.03
Bathurst Regional	-	2.18×10^{-3}	-	-	2.18×10^{-3}
Baulkham Hills	-	2.39×10^{-3}	2.84	-	2.84
Blacktown	-	-	4.82	-	4.82
Blue Mountains	-	0.56	1.00	-	1.57
Botany Bay	-	-	0.64	-	0.64
Burwood	-	-	0.54	-	0.54
Camden	-	-	0.94	-	0.94
Campbelltown	-	-	2.60	-	2.60
Canada Bay	-	-	1.16	-	1.16
Canterbury	-	-	2.51	-	2.51
Cessnock	3.84×10^{-2}	0.89	-	-	0.93
Dungog	-	0.14	-	-	0.14
Fairfield	-	-	3.01	-	3.01
Gosford	-	0.91	2.45	-	3.36
Goulburn Mulwaree	-	4.14×10^{-3}	-	-	4.14×10^{-3}
Great Lakes	-	6.80×10^{-2}	-	-	6.80×10^{-2}
Hawkesbury	-	2.30×10^{-2}	1.10	-	1.12
Holroyd	-	-	1.74	-	1.74
Hornsby	-	3.62×10^{-3}	2.86	-	2.87
Hunters Hill	-	-	0.16	-	0.16
Hurstville	-	-	1.55	-	1.55
Kiama	-	0.29	-	-	0.29
Kogarah	-	-	1.06	-	1.06
Ku-ring-gai	-	-	1.85	-	1.85
Lake Macquarie	2.00	1.82	-	-	3.82
Lane Cove	-	-	0.57	-	0.57
Leichhardt	-	-	0.89	-	0.89
Lithgow	-	0.36	-	-	0.36
Liverpool	-	-	2.90	-	2.90
Maitland	9.39×10^{-2}	1.15	-	-	1.25
Manly	-	-	0.69	-	0.69
Marrickville	-	-	1.88	-	1.88
Mid-western Regional	-	5.16×10^{-2}	-	-	5.16×10^{-2}
Mosman	-	-	0.68	-	0.68
Muswellbrook	-	0.26	-	-	0.26
N/A	3.05×10^{-2}	5.58×10^{-2}	0.39	7.60×10^{-2}	0.55
Newcastle	3.15	-	-	-	3.15
North Sydney	-	-	1.35	-	1.35
Oberon	-	2.26×10^{-2}	-	-	2.26×10^{-2}
Parramatta	-	-	2.83	-	2.83
Penrith	-	-	3.15	-	3.15
Pittwater	-	-	1.04	-	1.04

LGA	2008 proportion of total dwellings (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Port Stephens	6.97×10^{-2}	1.07	-	-	1.14
Randwick	-	-	2.68	-	2.68
Rockdale	-	-	1.73	-	1.73
Ryde	-	-	2.07	-	2.07
Shellharbour	-	0.89	-	0.31	1.20
Shoalhaven	-	1.50×10^{-3}	-	-	1.50×10^{-3}
Singleton	-	0.37	-	-	0.37
Strathfield	-	-	0.68	-	0.68
Sutherland	-	-	4.08	-	4.08
Sydney	-	-	4.01	-	4.01
Unincorporated	-	-	0.93	-	0.93
Upper Lachlan	-	6.05×10^{-4}	-	-	6.05×10^{-4}
Warringah	-	-	2.73	-	2.73
Waverley	-	-	1.29	-	1.29
Willoughby	-	-	1.39	-	1.39
Wingecarribee	-	0.88	4.72×10^{-3}	1.50×10^{-3}	0.89
Wollondilly	-	1.16×10^{-2}	0.74	3.91×10^{-4}	0.75
Wollongong	-	-	0.27	3.50	3.77
Woollahra	-	-	1.03	-	1.03
Wyong	-	2.96	-	-	2.96
Grand Total	5.38	12.78	77.95	3.89	100.00

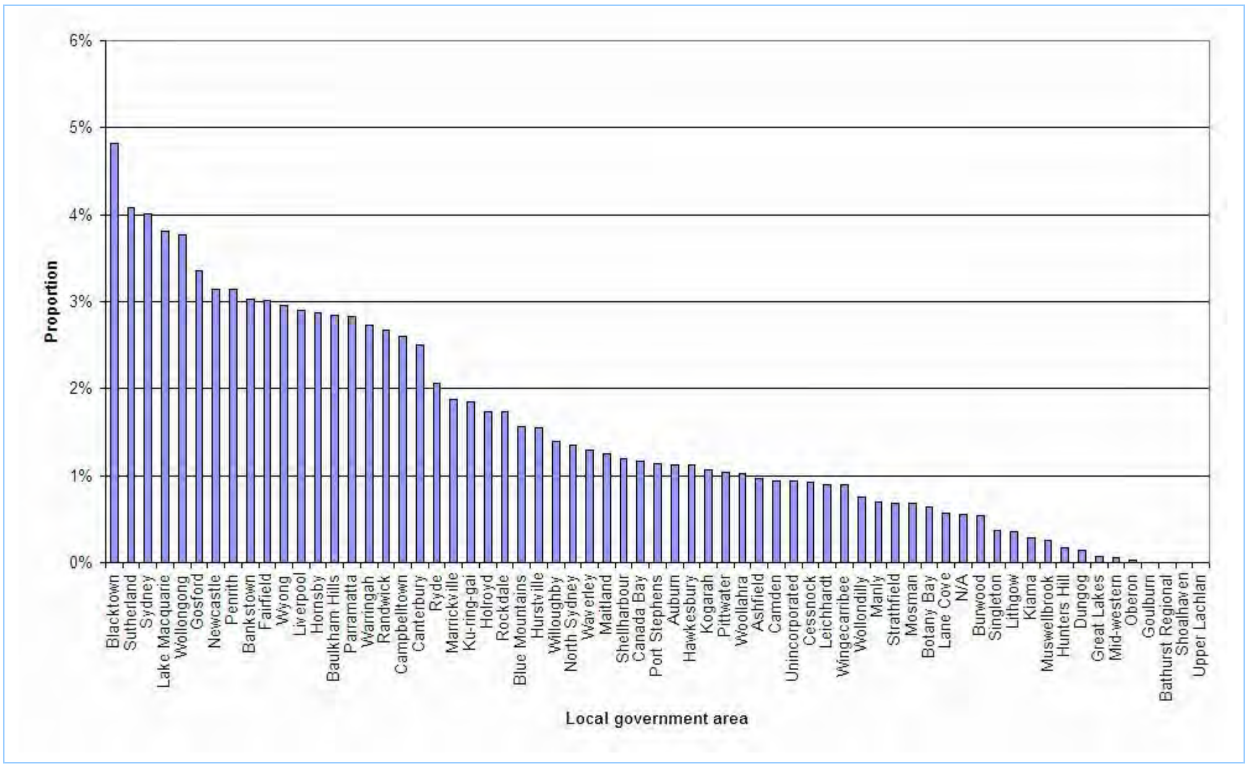

Figure 3-105: Surface coatings spatial distribution of total dwellings by LGA

Figure 3-106 shows the spatial distribution of surface coating emissions.

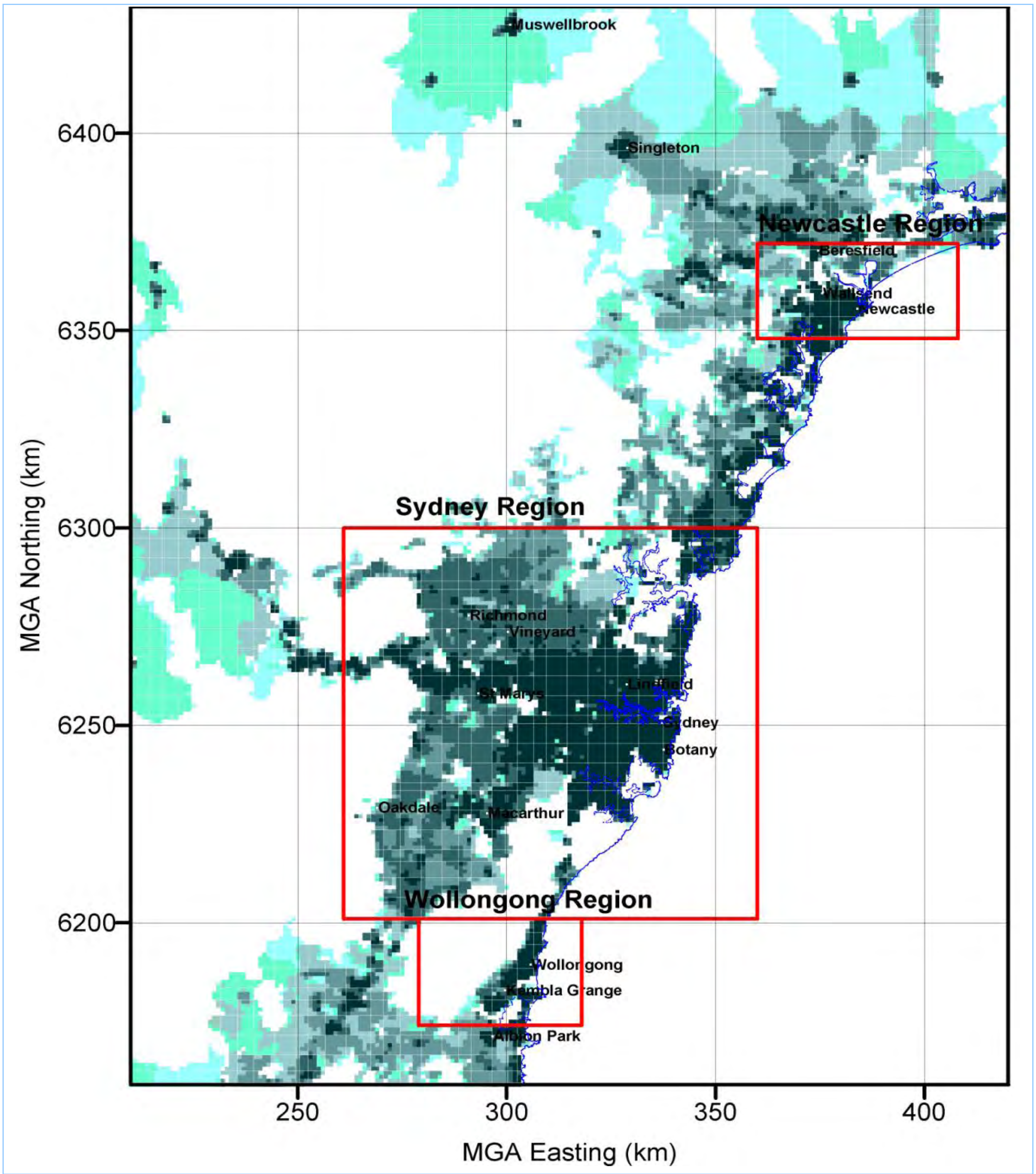

Figure 3-106: Surface coatings spatial distribution of emissions

3.13.6 Temporal Variation of Emissions

Table 3-246 summarises the data used to estimate the temporal variation in emissions from surface coatings.

Table 3-246: Surface coatings temporal data

Emission source	Temporal data	Temporal data source
Evaporative VOC from the application of surface coatings and thinners	Monthly: Surface coating consumption	- *Quarterly Industrial Sales Statistics Survey 2008* (APMF, 2009a to 2009d) - *Quarterly Automotive Refinish Statistics 2008* (APMF, 2009e to 2009h) - *Quarterly Architectural & Decorative Paints & Enamels Sales Quantity 2008* (Informark, 2009a to 2009d) - *Quarterly Woodcare Products Sales Quantity 2008* (Informark, 2009e to 2009h)
	Daily: Source type specific temporal allocation factors	- *Surface Coating /All Surface Coating Categories /Total: All Solvent Types – Weekly profile number 105 - CAIR Platform Temporal Allocation* (USEPA, 2005)
	Hourly: Source type specific temporal allocation factors	- *Surface Coating /All Surface Coating Categories /Total: All Solvent Types – Weekday diurnal profile number 108 and Weekend diurnal profile number 108 - CAIR Platform Temporal Allocation* (USEPA, 2005)

The hourly and daily temporal variation in emissions from surface coatings have been estimated from generic temporal profiles (USEPA, 2005).

The monthly temporal variation emissions from surface coatings have been estimated from architectural and decorative (i.e. paints, enamels, clears and woodcare products) and industrial (i.e. protective, marine, road and runway, can and coil, flatboard and woodcare products) surface coating and thinner consumption (Informark, 2009a to Informark, 2009h; and APMF, 2009a to APMF, 2009h).

Hourly temporal variation profiles are presented in Table 3-247 and shown in Figure 3-107.

Table 3-247: Surface coatings hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	1.00	13	9.00
2	1.00	14	9.00
3	-	15	9.00
4	-	16	9.00
5	-	17	9.00
6	-	18	8.00
7	-	19	1.00
8	3.00	20	1.00
9	9.00	21	1.00
10	9.00	22	1.00
11	9.00	23	1.00
12	9.00	24	1.00

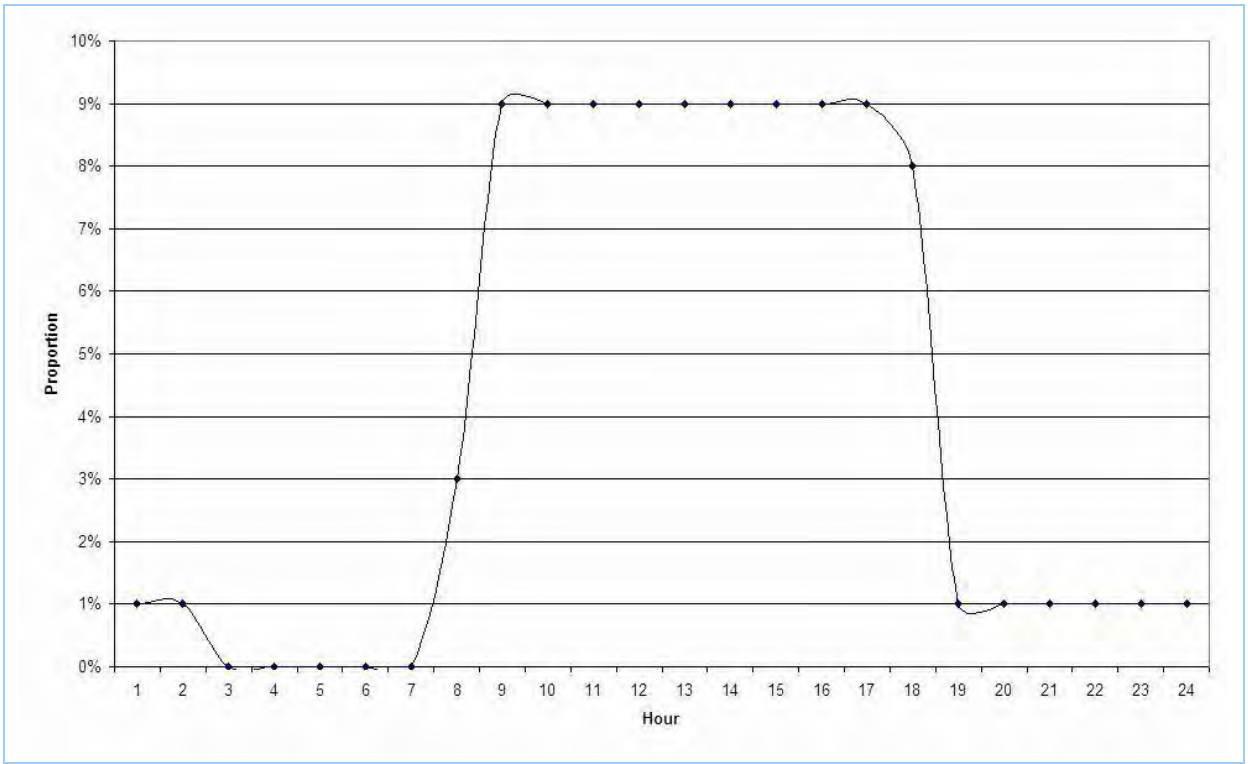

Figure 3-107: Surface coatings hourly temporal profile

Daily temporal variation profiles are presented in Table 3-248 and shown in Figure 3-108.

Table 3-248: Surface coatings daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	19.00	19.00	19.00	19.00	19.00	5.00	0.00

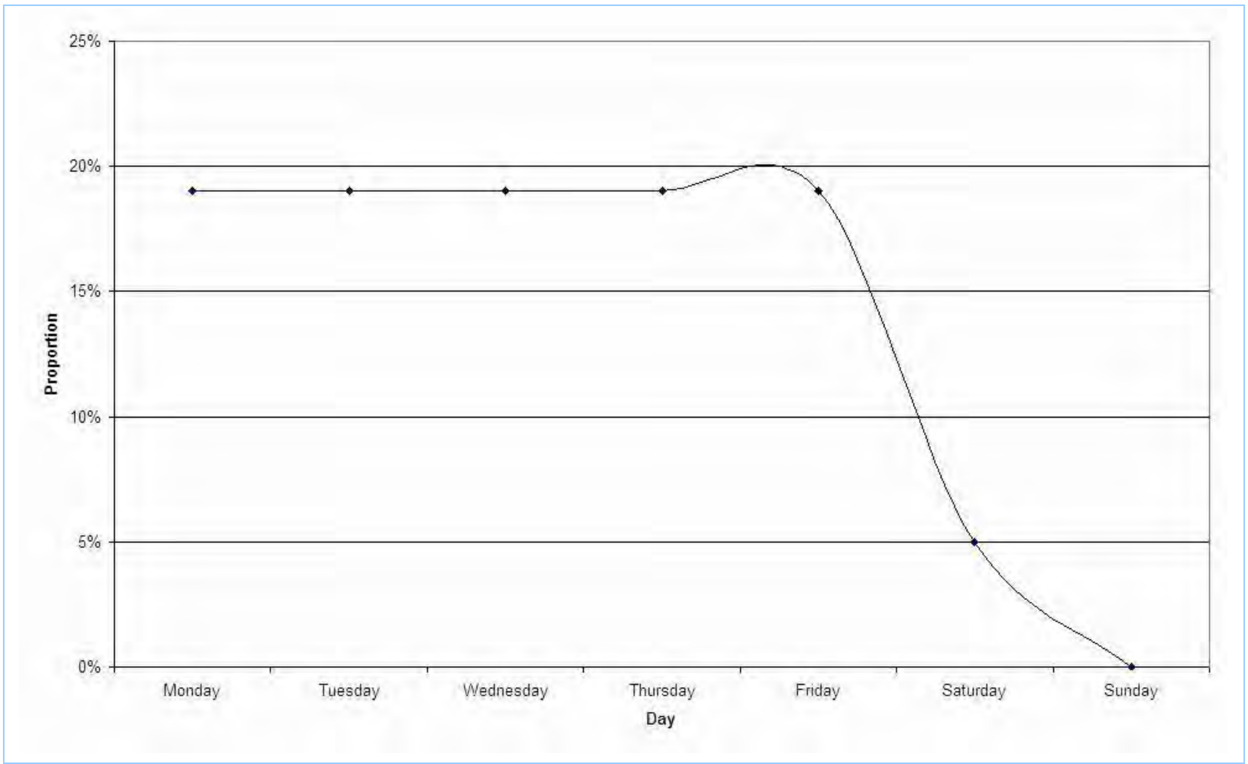

Figure 3-108: Surface coatings daily temporal profile

Monthly temporal variation profiles are presented in Table 3-249 and shown in Figure 3-109.

Table 3-249: Surface coatings monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.72	July	8.05
February	8.21	August	8.65
March	7.57	September	9.44
April	8.91	October	7.65
May	8.23	November	8.20
June	7.88	December	8.49

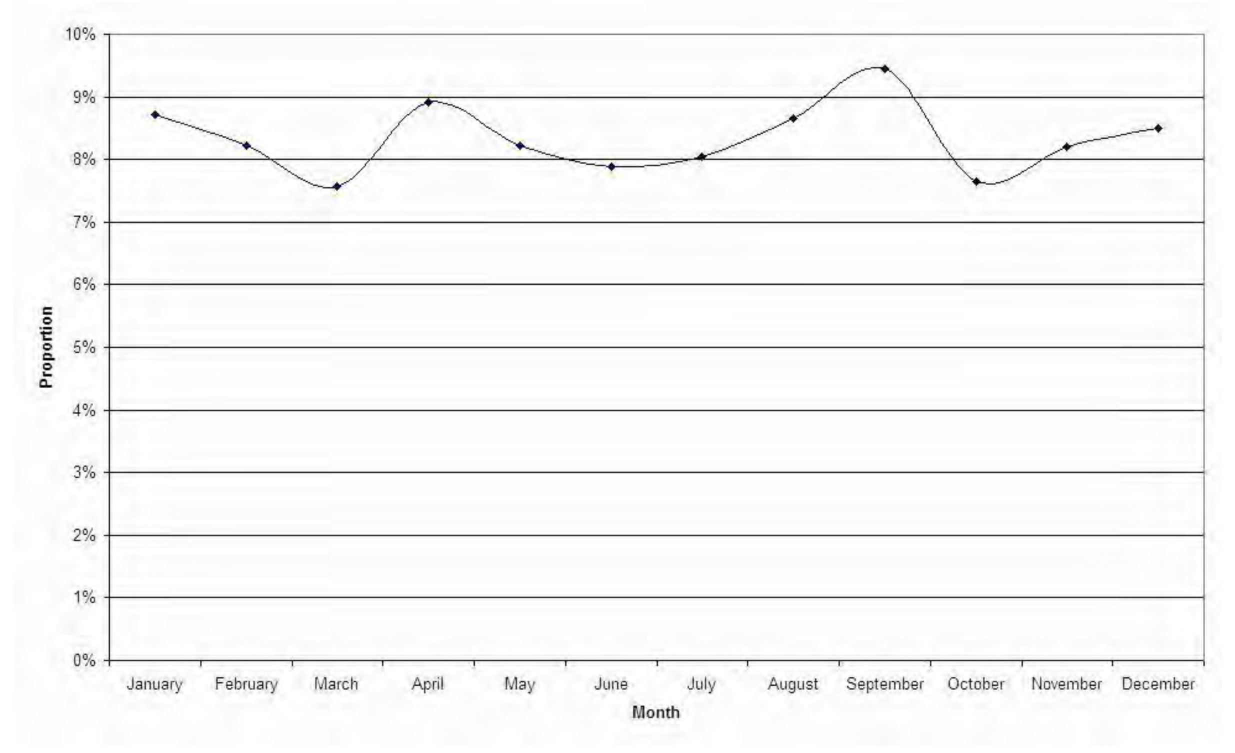

Figure 3-109: Surface coatings monthly temporal profile

3.13.7 Emission Estimates

Table 3-250 presents annual emissions of selected substances from surface coatings by activity.

Table 3-250: Surface coatings emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Surface Coatings	ACETALDEHYDE	15	35	212	11	272
	FORMALDEHYDE	4.88	12	71	3.53	91
	ISOMERS OF XYLENE	75,938	180,499	1,100,548	54,872	1,411,856
	PERCHLOROETHYLENE	5.12	12	74	3.70	95
	POLYCYCLIC AROMATIC HYDROCARBONS	317	755	4,601	229	5,903
	TOLUENE	66,555	158,197	964,570	48,092	1,237,415
	TOTAL VOLATILE ORGANIC COMPOUNDS	621,838	1,478,065	9,012,147	449,334	11,561,384

Table 3-251 presents annual emissions of selected substances from surface coatings by source type.

Table 3-251: Surface coatings emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Architectural and Decorative - Solvent Based	ISOMERS OF XYLENE	2,525	6,003	36,601	1,825	46,954
	PERCHLOROETHYLENE	5.12	12	74	3.70	95
	POLYCYCLIC AROMATIC HYDROCARBONS	10	24	148	7.40	190
	TOLUENE	1,629	3,872	23,609	1,177	30,287
	TOTAL VOLATILE ORGANIC COMPOUNDS	51,226	121,762	742,412	37,016	952,415
Architectural and Decorative - Thinners	ISOMERS OF XYLENE	567	1,347	8,214	410	10,537
	POLYCYCLIC AROMATIC HYDROCARBONS	92	218	1,331	66	1,707
	TOLUENE	1,314	3,123	19,043	949	24,429
	TOTAL VOLATILE ORGANIC COMPOUNDS	31,661	75,256	458,856	22,878	588,651
Architectural and Decorative - Timber Finishes	ISOMERS OF XYLENE	5,253	12,486	76,130	3,796	97,665
	TOLUENE	9,259	22,007	134,185	6,690	172,141
	TOTAL VOLATILE ORGANIC COMPOUNDS	35,231	83,742	510,597	25,458	655,028
Architectural and Decorative - Water Based	ACETALDEHYDE	15	35	212	11	272
	FORMALDEHYDE	4.88	12	71	3.53	91
	ISOMERS OF XYLENE	68	162	990	49	1,270
	TOLUENE	54	128	778	39	998
	TOTAL VOLATILE ORGANIC COMPOUNDS	48,790	115,971	707,104	35,255	907,121
Industrial Surface Coatings	ISOMERS OF XYLENE	63,175	150,162	915,579	45,650	1,174,566
	TOLUENE	45,895	109,088	665,141	33,163	853,287
	TOTAL VOLATILE ORGANIC COMPOUNDS	360,389	856,618	5,223,023	260,413	6,700,443
Industrial Thinners	ISOMERS OF XYLENE	1,330	3,161	19,272	961	24,723
	POLYCYCLIC AROMATIC HYDROCARBONS	215	512	3,122	156	4,005
	TOLUENE	3,083	7,328	44,681	2,228	57,320
	TOTAL VOLATILE ORGANIC COMPOUNDS	74,289	176,579	1,076,646	53,680	1,381,193
Industrial Timber Finishes	ISOMERS OF XYLENE	3,020	7,177	43,762	2,182	56,141
	TOLUENE	5,322	12,651	77,134	3,846	98,953
	TOTAL VOLATILE ORGANIC COMPOUNDS	20,252	48,138	293,509	14,634	376,533

3.13.8 Emission Projection Methodology

Table 3-252 summarises the data used to estimate the emission projection factors for surface coatings, while Figure 3-110 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-252: Surface coatings emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Evaporative VOC from the application of surface coatings and thinners	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

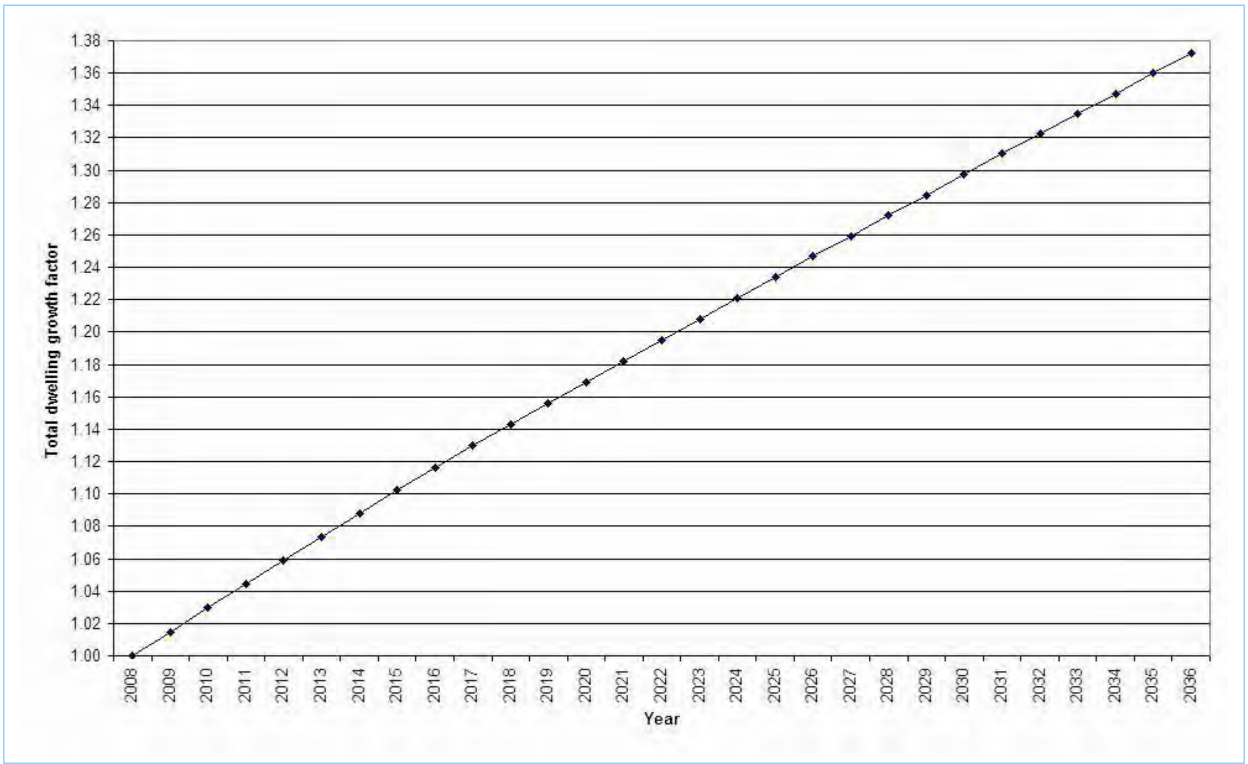

Figure 3-110: Surface coatings emission projection factors

4 EMISSIONS SUMMARY

The domestic-commercial air emissions inventory has been developed for the 2008 calendar year, which incorporates an area covering the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The domestic-commercial air emissions inventory includes emissions from the following sources:

- Aerosols and solvents (domestic and commercial);
- Barbecues (domestic);
- Cutback bitumen;
- Gaseous fuel combustion (domestic and unaccounted);
- Graphic arts (domestic and commercial);
- Lawn mowing and garden equipment (domestic and public open space);
- Liquid fuel combustion (domestic);
- Natural gas leakage;
- Portable fuel containers (domestic and public open space);
- Solid fuel combustion (domestic); and
- Surface coatings (domestic, commercial and industrial).

The pollutants inventoried include criteria pollutants specified in the Ambient Air Quality NEPM (NEPC, 2003), air toxics associated with the National Pollutant Inventory NEPM (NEPC, 2008) and the Air Toxics NEPM (NEPC, 2004) and any other pollutants associated with state specific programs, i.e. Load Based Licensing (i.e. Protection of the Environment Operations (General) Regulation 2009 (PCO, 2010b)) and Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011).

Table 4-1 presents total estimated annual emissions (for selected substances) from all domestic-commercial sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions.

Figure 4-1 shows the proportions of total estimated annual emissions (for selected substances) from all domestic-commercial sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions.

Table 4-1: Total estimated annual emissions from domestic-commercial sources in each region

Substance	Emissions (tonne/year)				
	Newcastle	Non Urban	Sydney	Wollongong	GMR
1,3-BUTADIENE	7.19	18	89	4.81	119
ACETALDEHYDE	18	44	215	12	289
BENZENE	47	116	585	31	779
CARBON MONOXIDE	6,554	16,226	82,186	4,412	109,377
FORMALDEHYDE	43	109	528	29	709
ISOMERS OF XYLENE	187	453	2,657	133	3,430
LEAD & COMPOUNDS	6.79×10^{-2}	0.17	0.83	4.53×10^{-2}	1.12
OXIDES OF NITROGEN	184	445	2,531	130	3,290
PARTICULATE MATTER ≤ 10 µm	504	1,262	6,088	334	8,189
PARTICULATE MATTER ≤ 2.5 µm	485	1,214	5,853	321	7,873
PERCHLOROETHYLENE	4.67	12	73	3.44	92
POLYCYCLIC AROMATIC HYDROCARBONS	14	35	186	9.59	244
SULFUR DIOXIDE	11	26	131	7.07	175
TOLUENE	185	449	2,619	131	3,384
TOTAL SUSPENDED PARTICULATE	539	1,348	6,501	357	8,745
TOTAL VOLATILE ORGANIC COMPOUNDS	3,757	9,213	53,178	2,660	68,809
TRICHLOROETHYLENE	0.28	0.69	4.38	0.21	5.56

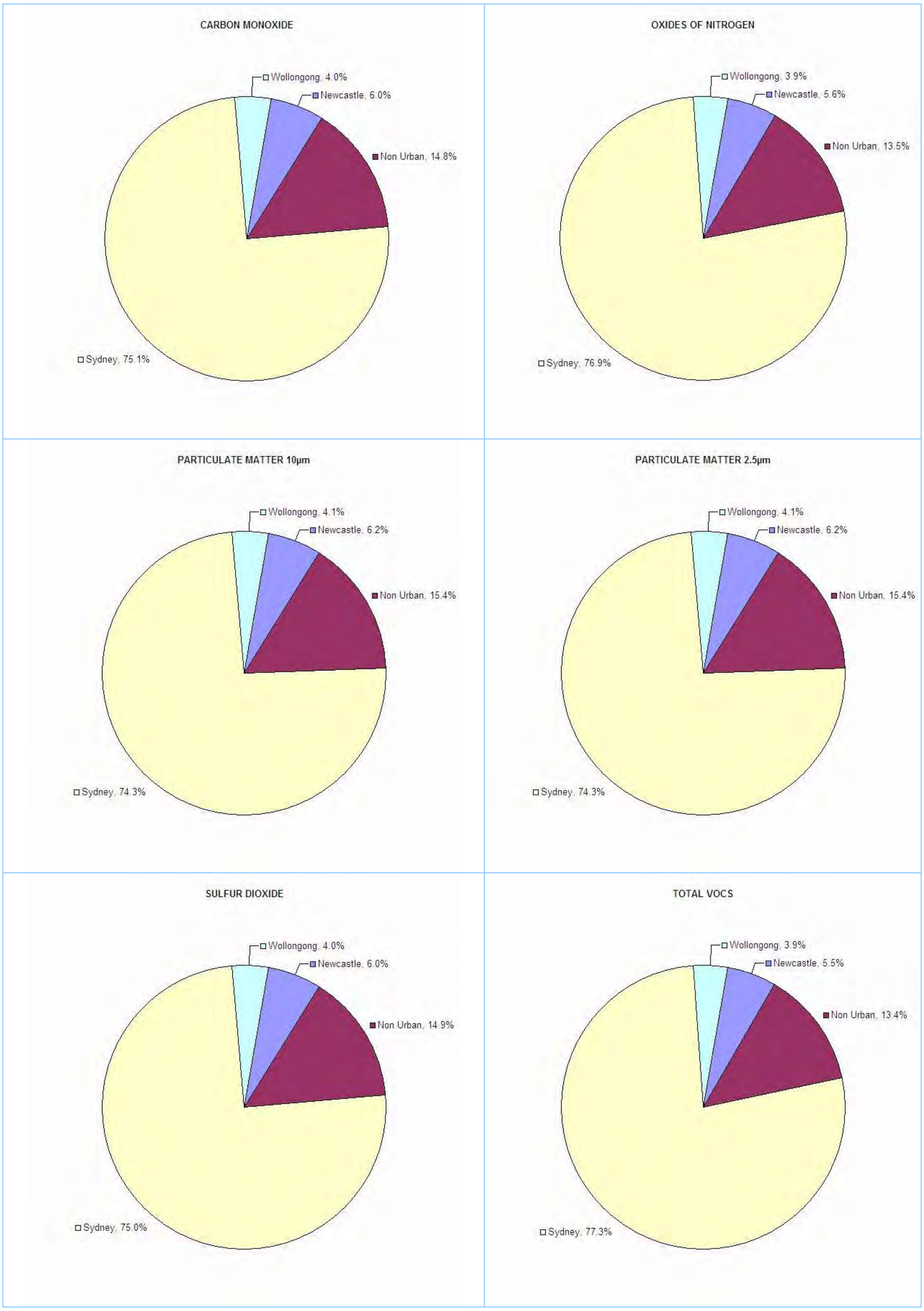

Figure 4-1: Proportions of total estimated annual emissions from domestic-commercial sources in each region

Table 4-2, Table 4-3, Table 4-4, Table 4-5 and Table 4-6 present total estimated annual emissions (for selected substances) from each domestic-commercial source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Figure 4-2, Figure 4-3, Figure 4-4, Figure 4-5 and Figure 4-6 show the proportions of total estimated annual emissions (for selected substances) from each domestic-commercial source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Table 4-2: Total estimated annual emissions by domestic-commercial source type in the GMR

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	1.25	-	-	-	44	-	-	-	73	-	119
ACETALDEHYDE	-	18	-	2.78×10^{-4}	-	27	7.54×10^{-3}	-	-	243	0.27	289
BENZENE	1.13×10^{-2}	4.10	-	4.40×10^{-2}	-	389	3.23×10^{-4}	-	17	369	-	779
CARBON MONOXIDE	-	520	-	861	-	54,003	7.70	-	-	53,985	-	109,377
FORMALDEHYDE	12	13	-	1.57	-	70	5.17×10^{-2}	-	-	612	9.07×10^{-2}	709
ISOMERS OF XYLENE	681	0.84	21	-	80	1,167	1.57×10^{-4}	-	12	57	1,412	3,430
LEAD & COMPOUNDS	-	3.04×10^{-3}	-	1.05×10^{-2}	-	0.33	1.94×10^{-3}	-	-	0.77	-	1.12
OXIDES OF NITROGEN	-	100	-	1,996	-	356	28	-	-	811	-	3,290
PARTICULATE MATTER ≤ 10 µm	-	34	-	159	-	347	3.66	-	-	7,645	-	8,189
PARTICULATE MATTER ≤ 2.5 µm	-	31	-	159	-	320	3.28	-	-	7,359	-	7,873
PERCHLOROETHYLENE	92	4.83×10^{-5}	-	-	-	-	-	-	-	-	9.52×10^{-2}	92
POLYCYCLIC AROMATIC HYDROCARBONS	91	0.47	-	1.46×10^{-2}	7.30	3.53	1.84×10^{-3}	-	-	135	5.90	244
SULFUR DIOXIDE	-	11	-	13	-	10	11	-	-	129	-	175
TOLUENE	846	1.69	11	7.12×10^{-2}	10	1,134	8.91×10^{-3}	-	41	103	1,237	3,384
TOTAL SUSPENDED PARTICULATE	-	46	-	159	-	358	5.08	-	-	8,177	-	8,745
TOTAL VOLATILE ORGANIC COMPOUNDS	25,274	162	169	115	3,475	14,916	1.10	2,973	2,136	8,027	11,561	68,809
TRICHLOROETHYLENE	5.56	-	-	-	-	-	-	-	-	-	-	5.56

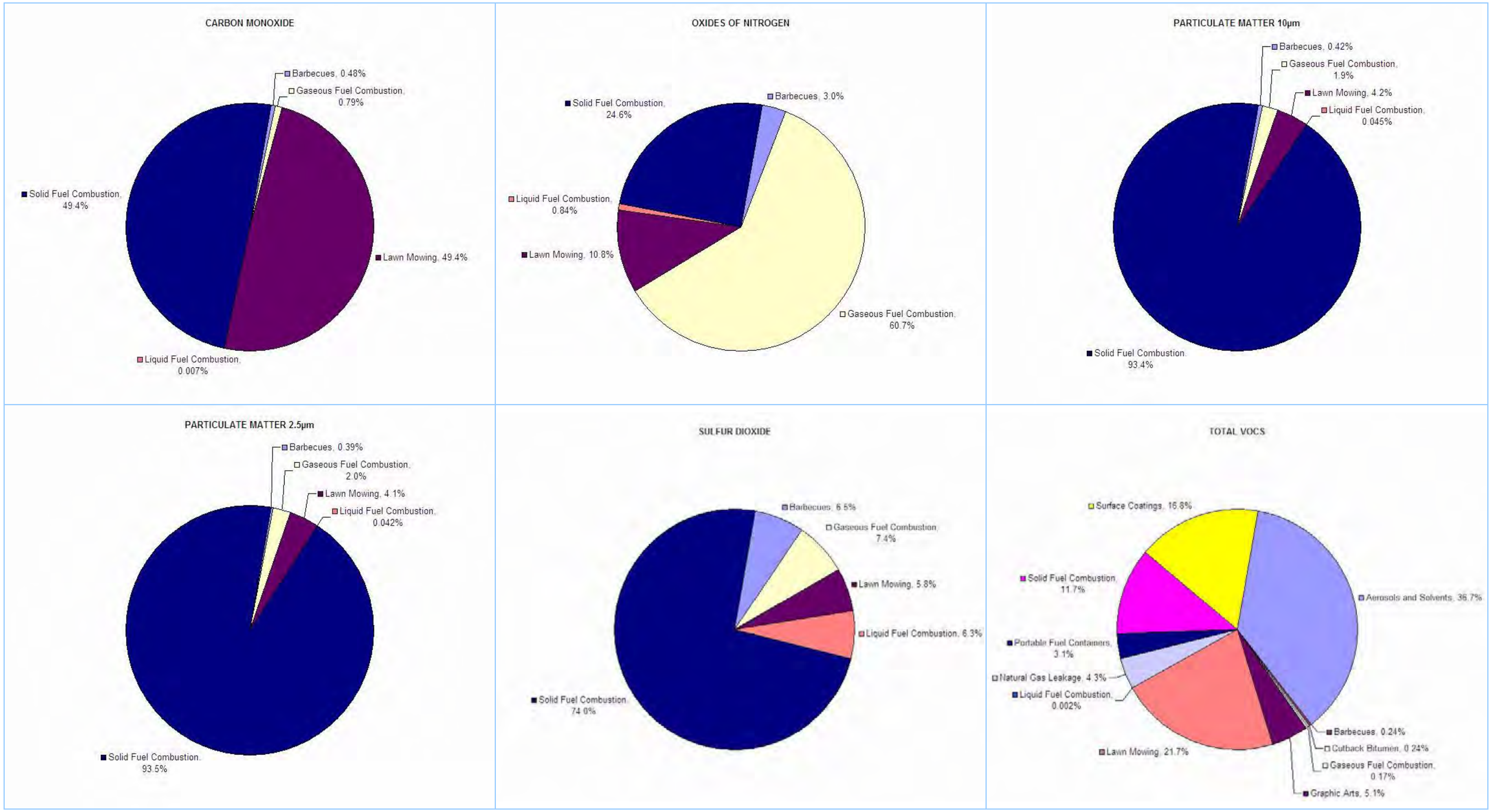

Figure 4-2: Proportions of total estimated annual emissions by domestic-commercial source type in the GMR

Table 4-3: Total estimated annual emissions by domestic-commercial source type in the Sydney region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	0.98	-	-	-	33	-	-	-	54	-	89
ACETALDEHYDE	-	14	-	2.17×10^{-4}	-	21	5.88×10^{-3}	-	-	180	0.21	215
BENZENE	8.91×10^{-3}	3.20	-	3.43×10^{-2}	-	295	2.52×10^{-4}	-	12	274	-	585
CARBON MONOXIDE	-	406	-	671	-	41,069	6.00	-	-	40,034	-	82,186
FORMALDEHYDE	9.08	9.76	-	1.22	-	53	4.03×10^{-2}	-	-	454	7.07×10^{-2}	528
ISOMERS OF XYLENE	536	0.65	16	-	63	890	1.22×10^{-4}	-	8.74	42	1,101	2,657
LEAD & COMPOUNDS	-	2.37×10^{-3}	-	8.16×10^{-3}	-	0.25	1.51×10^{-3}	-	-	0.57	-	0.83
OXIDES OF NITROGEN	-	78	-	1,556	-	275	22	-	-	601	-	2,531
PARTICULATE MATTER ≤ 10 μm	-	27	-	124	-	265	2.86	-	-	5,669	-	6,088
PARTICULATE MATTER ≤ 2.5 μm	-	24	-	124	-	245	2.56	-	-	5,457	-	5,853
PERCHLOROETHYLENE	73	3.77×10^{-5}	-	-	-	-	-	-	-	-	7.42×10^{-2}	73
POLYCYCLIC AROMATIC HYDROCARBONS	72	0.37	-	1.14×10^{-2}	5.75	2.68	1.43×10^{-3}	-	-	100	4.60	186
SULFUR DIOXIDE	-	8.91	-	10	-	7.71	8.52	-	-	96	-	131
TOLUENE	666	1.32	8.48	5.55×10^{-2}	8.21	863	6.95×10^{-3}	-	30	76	965	2,619
TOTAL SUSPENDED PARTICULATE	-	36	-	124	-	273	3.96	-	-	6,064	-	6,501
TOTAL VOLATILE ORGANIC COMPOUNDS	19,905	126	132	90	2,737	11,317	0.86	2,318	1,589	5,952	9,012	53,178
TRICHLOROETHYLENE	4.38	-	-	-	-	-	-	-	-	-	-	4.38

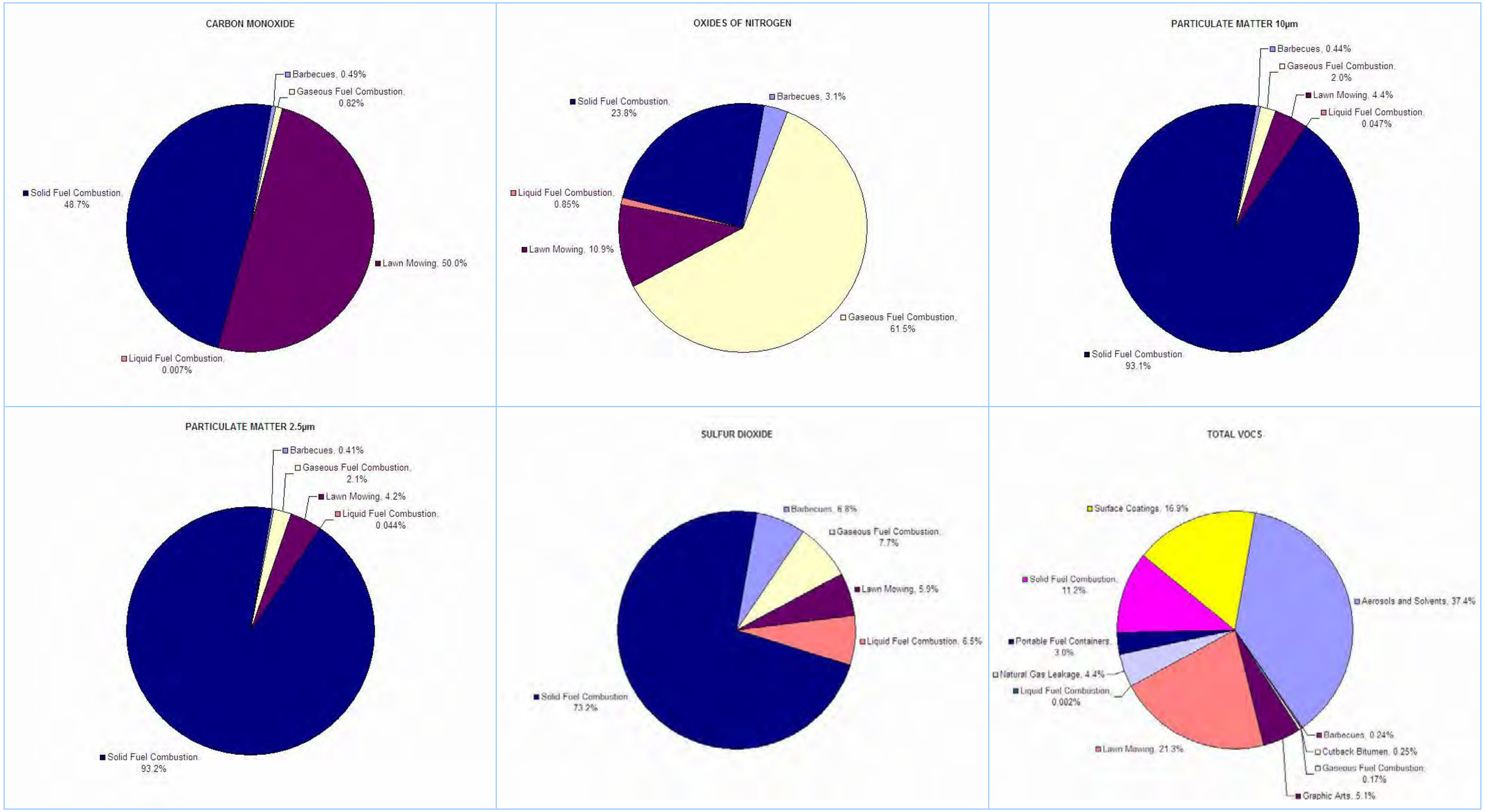

Figure 4-3: Proportions of total estimated annual emissions by domestic-commercial source type in the Sydney region

Table 4-4: Total estimated annual emissions by domestic-commercial source type in the Newcastle region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	6.74×10^{-2}	-	-	-	2.57	-	-	-	4.55	-	7.19
ACETALDEHYDE	-	0.98	-	1.50×10^{-5}	-	1.57	4.06×10^{-4}	-	-	15	1.46×10^{-2}	18
BENZENE	5.71×10^{-4}	0.22	-	2.36×10^{-3}	-	23	1.74×10^{-5}	-	1.02	23	-	47
CARBON MONOXIDE	-	28	-	46	-	3,134	0.41	-	-	3,345	-	6,554
FORMALDEHYDE	0.58	0.67	-	8.45×10^{-2}	-	4.10	2.78×10^{-3}	-	-	38	4.88×10^{-3}	43
ISOMERS OF XYLENE	34	4.50×10^{-2}	1.16	-	4.04	67	8.42×10^{-6}	-	0.72	3.53	76	187
LEAD & COMPOUNDS	-	1.63×10^{-4}	-	5.63×10^{-4}	-	1.92×10^{-2}	1.04×10^{-4}	-	-	4.79×10^{-2}	-	6.79×10^{-2}
OXIDES OF NITROGEN	-	5.35	-	107	-	20	1.49	-	-	50	-	184
PARTICULATE MATTER ≤ 10 µm	-	1.84	-	8.57	-	20	0.20	-	-	474	-	504
PARTICULATE MATTER ≤ 2.5 µm	-	1.65	-	8.57	-	18	0.18	-	-	456	-	485
PERCHLOROETHYLENE	4.66	2.60×10^{-6}	-	-	-	-	-	-	-	-	5.12×10^{-3}	4.67
POLYCYCLIC AROMATIC HYDROCARBONS	4.61	2.53×10^{-2}	-	7.86×10^{-4}	0.37	0.21	9.89×10^{-5}	-	-	8.38	0.32	14
SULFUR DIOXIDE	-	0.61	-	0.69	-	0.60	0.59	-	-	8.01	-	11
TOLUENE	43	9.11×10^{-2}	0.61	3.83×10^{-3}	0.53	66	4.79×10^{-4}	-	2.50	6.36	67	185
TOTAL SUSPENDED PARTICULATE	-	2.46	-	8.57	-	21	0.27	-	-	507	-	539
TOTAL VOLATILE ORGANIC COMPOUNDS	1,276	8.71	9.42	6.19	175	871	5.90×10^{-2}	160	131	497	622	3,757
TRICHLOROETHYLENE	0.28	-	-	-	-	-	-	-	-	-	-	0.28

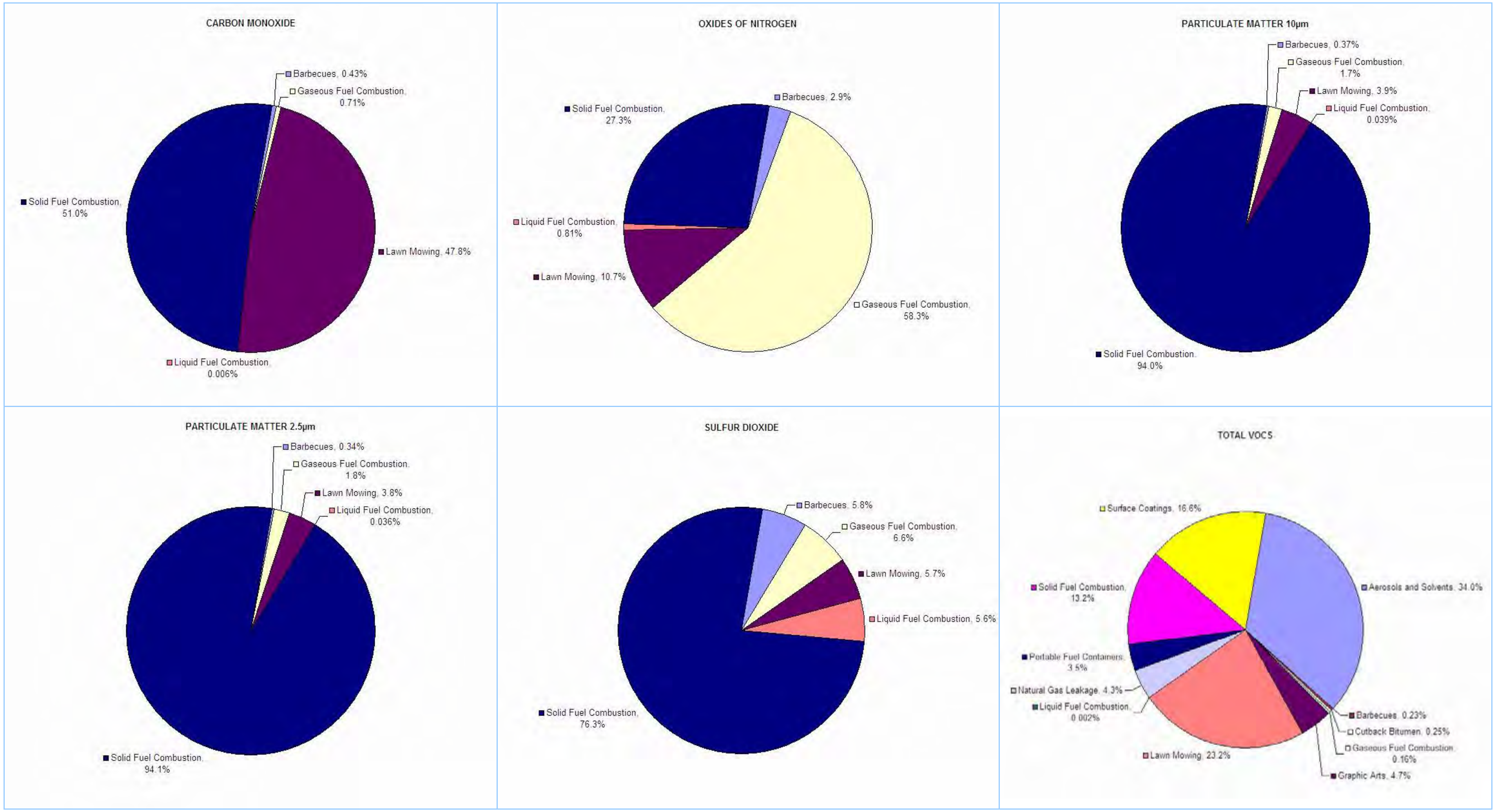

Figure 4-4: Proportions of total estimated annual emissions by domestic-commercial source type in the Newcastle region

Table 4-5: Total estimated annual emissions by domestic-commercial source type in the Wollongong region

Substance	Emissions (tonne/year)										
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	4.87×10^{-2}	-	-	-	1.76	-	-	-	3.00	-	4.81
ACETALDEHYDE	-	0.71	-	1.08×10^{-5}	-	1.08	2.93×10^{-4}	-	-	9.94	1.06×10^{-2}	12
BENZENE	4.21×10^{-4}	0.16	-	1.71×10^{-3}	-	16	1.26×10^{-5}	-	0.68	15	-	31
CARBON MONOXIDE	-	20	-	33	-	2,148	0.30	-	-	2,209	-	4,412
FORMALDEHYDE	0.43	0.49	-	6.10×10^{-2}	-	2.81	2.01×10^{-3}	-	-	25	3.53×10^{-3}	29
ISOMERS OF XYLENE	25	3.25×10^{-2}	0.66	-	2.97	46	6.09×10^{-6}	-	0.48	2.33	55	133
LEAD & COMPOUNDS	-	1.18×10^{-4}	-	4.07×10^{-4}	-	1.31×10^{-2}	7.54×10^{-5}	-	-	3.16×10^{-2}	-	4.53×10^{-2}
OXIDES OF NITROGEN	-	3.87	-	78	-	14	1.08	-	-	33	-	130
PARTICULATE MATTER ≤ 10 µm	-	1.33	-	6.19	-	14	0.14	-	-	313	-	334
PARTICULATE MATTER ≤ 2.5 µm	-	1.19	-	6.19	-	13	0.13	-	-	301	-	321
PERCHLOROETHYLENE	3.43	1.88×10^{-6}	-	-	-	-	-	-	-	-	3.70×10^{-3}	3.44
POLYCYCLIC AROMATIC HYDROCARBONS	3.39	1.83×10^{-2}	-	5.68×10^{-4}	0.27	0.14	7.15×10^{-5}	-	-	5.53	0.23	9.59
SULFUR DIOXIDE	-	0.44	-	0.50	-	0.41	0.42	-	-	5.29	-	7.07
TOLUENE	31	6.58×10^{-2}	0.34	2.77×10^{-3}	0.39	45	3.46×10^{-4}	-	1.66	4.20	48	131
TOTAL SUSPENDED PARTICULATE	-	1.77	-	6.19	-	14	0.20	-	-	335	-	357
TOTAL VOLATILE ORGANIC COMPOUNDS	940	6.29	5.35	4.48	129	595	4.27×10^{-2}	116	87	328	449	2,660
TRICHLOROETHYLENE	0.21	-	-	-	-	-	-	-	-	-	-	0.21

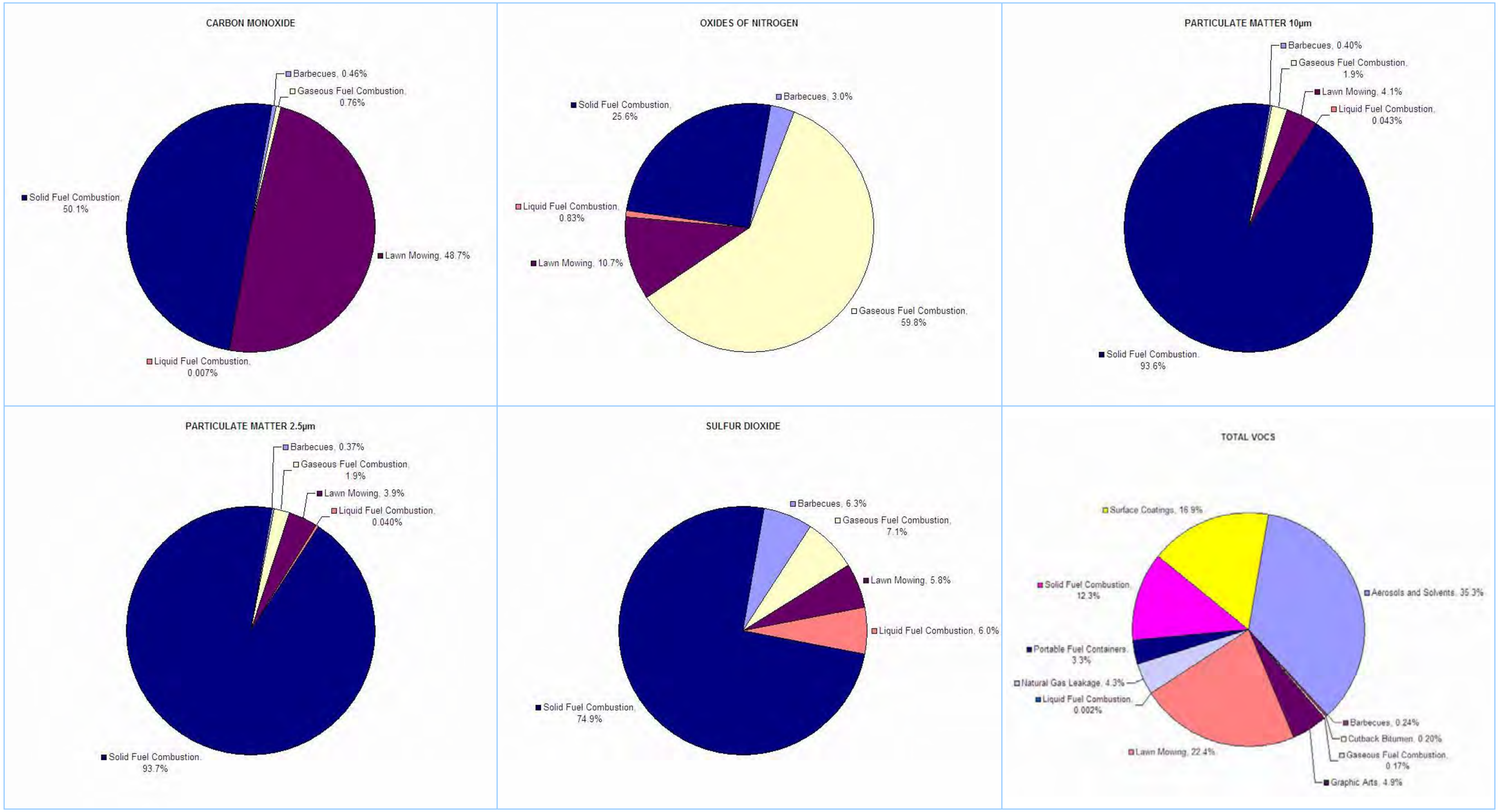

Figure 4-5: Proportions of total estimated annual emissions by domestic-commercial source type in the Wollongong region

Table 4-6: Total estimated annual emissions by domestic-commercial source type in the Non Urban region

Substance	Emissions (tonne/year)											
	Aerosols and solvents	Barbecues	Cutback bitumen	Gaseous fuel combustion	Graphic arts	Lawn mowing	Liquid fuel combustion	Natural gas leakage	Portable fuel containers	Solid fuel combustion	Surface coatings	Domestic-Commercial Total
1,3-BUTADIENE	-	0.16	-	-	-	6.30	-	-	-	11	-	18
ACETALDEHYDE	-	2.33	-	3.56×10^{-5}	-	3.81	9.65×10^{-4}	-	-	38	3.48×10^{-2}	44
BENZENE	1.41×10^{-3}	0.52	-	5.62×10^{-3}	-	55	4.13×10^{-5}	-	2.56	57	-	116
CARBON MONOXIDE	-	67	-	110	-	7,652	0.98	-	-	8,396	-	16,226
FORMALDEHYDE	1.44	1.60	-	0.20	-	10	6.61×10^{-3}	-	-	95	1.16×10^{-2}	109
ISOMERS OF XYLENE	85	0.11	2.73	-	9.98	164	2.0×10^{-5}	-	1.81	8.86	180	453
LEAD & COMPOUNDS	-	3.88×10^{-4}	-	1.34×10^{-3}	-	4.72×10^{-2}	2.48×10^{-4}	-	-	0.12	-	0.17
OXIDES OF NITROGEN	-	13	-	255	-	47	3.54	-	-	126	-	445
PARTICULATE MATTER ≤ 10 µm	-	4.38	-	20	-	48	0.47	-	-	1,189	-	1,262
PARTICULATE MATTER ≤ 2.5 µm	-	3.93	-	20	-	45	0.42	-	-	1,145	-	1,214
PERCHLOROETHYLENE	12	6.18×10^{-6}	-	-	-	-	-	-	-	-	1.22×10^{-2}	12
POLYCYCLIC AROMATIC HYDROCARBONS	11	6.0×10^{-2}	-	1.87×10^{-3}	0.91	0.51	2.35×10^{-4}	-	-	21	0.75	35
SULFUR DIOXIDE	-	1.46	-	1.65	-	1.47	1.40	-	-	20	-	26
TOLUENE	106	0.22	1.43	9.10×10^{-3}	1.30	160	1.14×10^{-3}	-	6.24	16	158	449
TOTAL SUSPENDED PARTICULATE	-	5.84	-	20	-	50	0.65	-	-	1,272	-	1,348
TOTAL VOLATILE ORGANIC COMPOUNDS	3,154	21	22	15	434	2,133	0.14	380	329	1,248	1,478	9,213
TRICHLOROETHYLENE	0.69	-	-	-	-	-	-	-	-	-	-	0.69

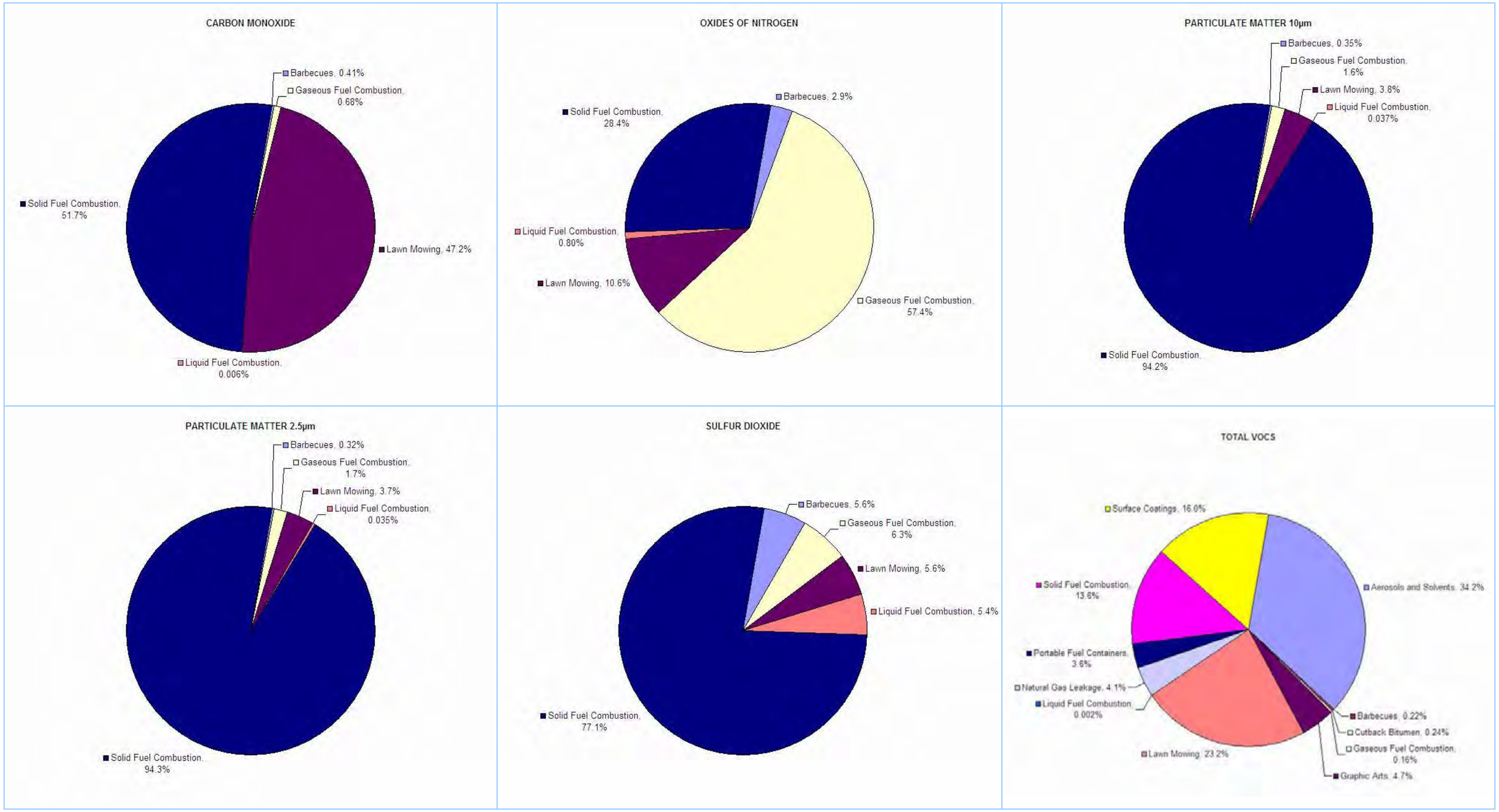

Figure 4-6: Proportions of total estimated annual emissions by domestic-commercial source type in the Non Urban region

Table 4-7 presents total estimated fuel consumption from all domestic-commercial sources in the GMR by volume and energy content.

Table 4-7: Total estimated annual fuel consumption from domestic-commercial sources by volume and energy content in the GMR

Fuel	Annual fuel consumption		
	Volume	Volume units	Energy content (TJ/year)
2-Stroke petrol	25,680	kL/year	878
4-Stroke petrol	39,736		1,359
Diesel	3,336		129
Heating oil	12,848		483
Kerosene	305		11
LPG	99,870		2,547
Natural gas	1,309	Mm^3/year	50,126
Charcoal	2,247	tonne/year	56
Wood	647,802		10,494

Figure 4-7 shows total estimated fuel consumption from all domestic-commercial sources in the GMR by energy content.

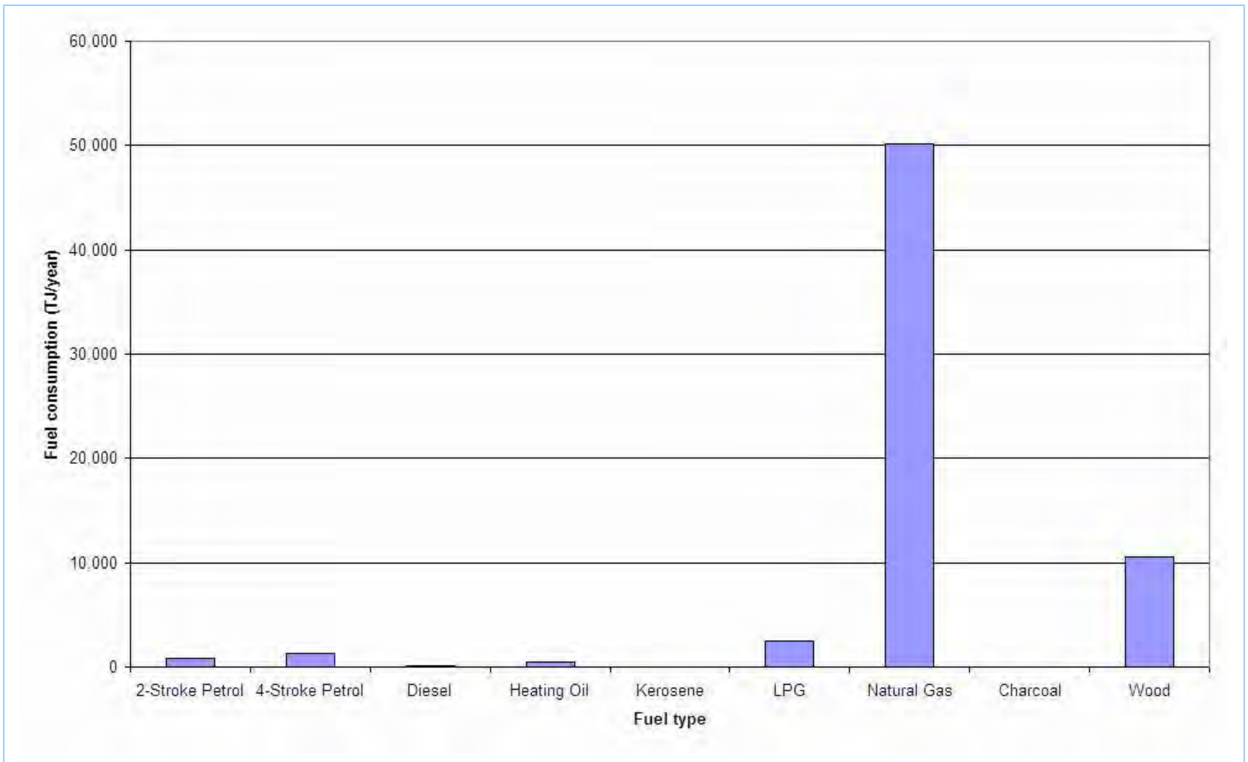

Figure 4-7: Total estimated annual fuel consumption from domestic-commercial sources by energy content in the GMR

Table 4-8 and Table 4-9 present total estimated fuel consumption by domestic-commercial source type in the GMR by volume and energy content, respectively. Figure 4-8 shows total estimated fuel consumption by domestic-commercial source type in the GMR by energy content.

Table 4-8: Total estimated annual fuel consumption by domestic-commercial source type and volume in the GMR

Source type	2-Stroke petrol	4-Stroke petrol	Diesel	Heating oil	Kerosene	LPG	Natural gas	Charcoal	Wood
	kL/year						Mm³/year	tonne/year	
Barbecues – briquettes	-	-	-	-	-	-	-	2,247	-
Barbecues – LPG and butane	-	-	-	-	-	49,885	-	-	-
Barbecues – natural gas	-	-	-	-	-	-	7	-	-
Barbecues – wood	-	-	-	-	-	-	-	-	1,285
Cutback bitumen	-	-	-	-	305	-	-	-	-
Lawn mowing (domestic) – petrol 2 stroke	15,665	-	-	-	-	-	-	-	-
Lawn mowing (domestic) – petrol 4 stroke	-	30,525	-	-	-	-	-	-	-
Lawn mowing (public open space) – diesel	-	-	3,336	-	-	-	-	-	-
Lawn mowing (public open space) – petrol 2 stroke	10,014	-	-	-	-	-	-	-	-
Lawn mowing (public open space) – petrol 4 stroke	-	9,212	-	-	-	-	-	-	-
Liquid fuel combustion (domestic)	-	-	-	12,848	-	-	-	-	-
LPG combustion (domestic)	-	-	-	-	-	49,984	-	-	-
Natural gas combustion (domestic)	-	-	-	-	-	-	508	-	-
Natural gas combustion (unaccounted commercial business equipment)	-	-	-	-	-	-	766	-	-
Natural gas leakage	-	-	-	-	-	-	28	-	-
Wood combustion – open fireplace	-	-	-	-	-	-	-	-	182,471
Wood combustion – pot belly stove	-	-	-	-	-	-	-	-	44,296
Wood combustion – slow combustion heater with AS[73]	-	-	-	-	-	-	-	-	292,435
Wood combustion – slow combustion heater without AS	-	-	-	-	-	-	-	-	127,314
Grand Total	25,680	39,736	3,336	12,848	305	99,870	1,309	2,247	647,802

[73] Appliances certified in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b).

Table 4-9: Total estimated annual fuel consumption by domestic-commercial source type and energy content in the GMR

Source type	Energy content (TJ/year)									
	2-Stroke petrol	4-Stroke petrol	Diesel	Heating oil	Kerosene	LPG	Natural gas	Charcoal	Wood	Grand Total
Barbecues – briquettes	-	-	-	-	-	-	-	56	-	56
Barbecues – LPG and butane	-	-	-	-	-	1,272	-	-	-	1,272
Barbecues - natural gas	-	-	-	-	-	-	252	-	-	252
Barbecues – wood	-	-	-	-	-	-	-	-	21	21
Cutback bitumen	-	-	-	-	11	-	-	-	-	11
Lawn mowing (domestic) - petrol 2 stroke	536	-	-	-	-	-	-	-	-	536
Lawn mowing (domestic) - petrol 4 stroke	-	1,044	-	-	-	-	-	-	-	1,044
Lawn mowing (public open space) – diesel	-	-	129	-	-	-	-	-	-	129
Lawn mowing (public open space) - petrol 2 stroke	342	-	-	-	-	-	-	-	-	342
Lawn mowing (public open space) - petrol 4 stroke	-	315	-	-	-	-	-	-	-	315
Liquid fuel combustion (domestic)	-	-	-	483	-	-	-	-	-	483
LPG combustion (domestic)	-	-	-	-	-	1,275	-	-	-	1,275
Natural gas combustion (domestic)	-	-	-	-	-	-	19,455	-	-	19,455
Natural gas combustion (unaccounted commercial business equipment)	-	-	-	-	-	-	29,332	-	-	29,332
Natural gas leakage	-	-	-	-	-	-	1,087	-	-	1,087
Wood combustion - open fire place	-	-	-	-	-	-	-	-	2,956	2,956
Wood combustion - pot belly stove	-	-	-	-	-	-	-	-	718	718
Wood combustion – slow combustion heater with AS[74]	-	-	-	-	-	-	-	-	4,737	4,737
Wood combustion – slow combustion heater without AS	-	-	-	-	-	-	-	-	2,062	2,062
Grand Total	878	1,359	129	483	11	2,547	50,126	56	10,494	66,084

[74] Appliances certified in accordance with Standards Australia, 1992a and Standards Australia, 1992b or Standards Australia, 1999a and Standards Australia 1999b).

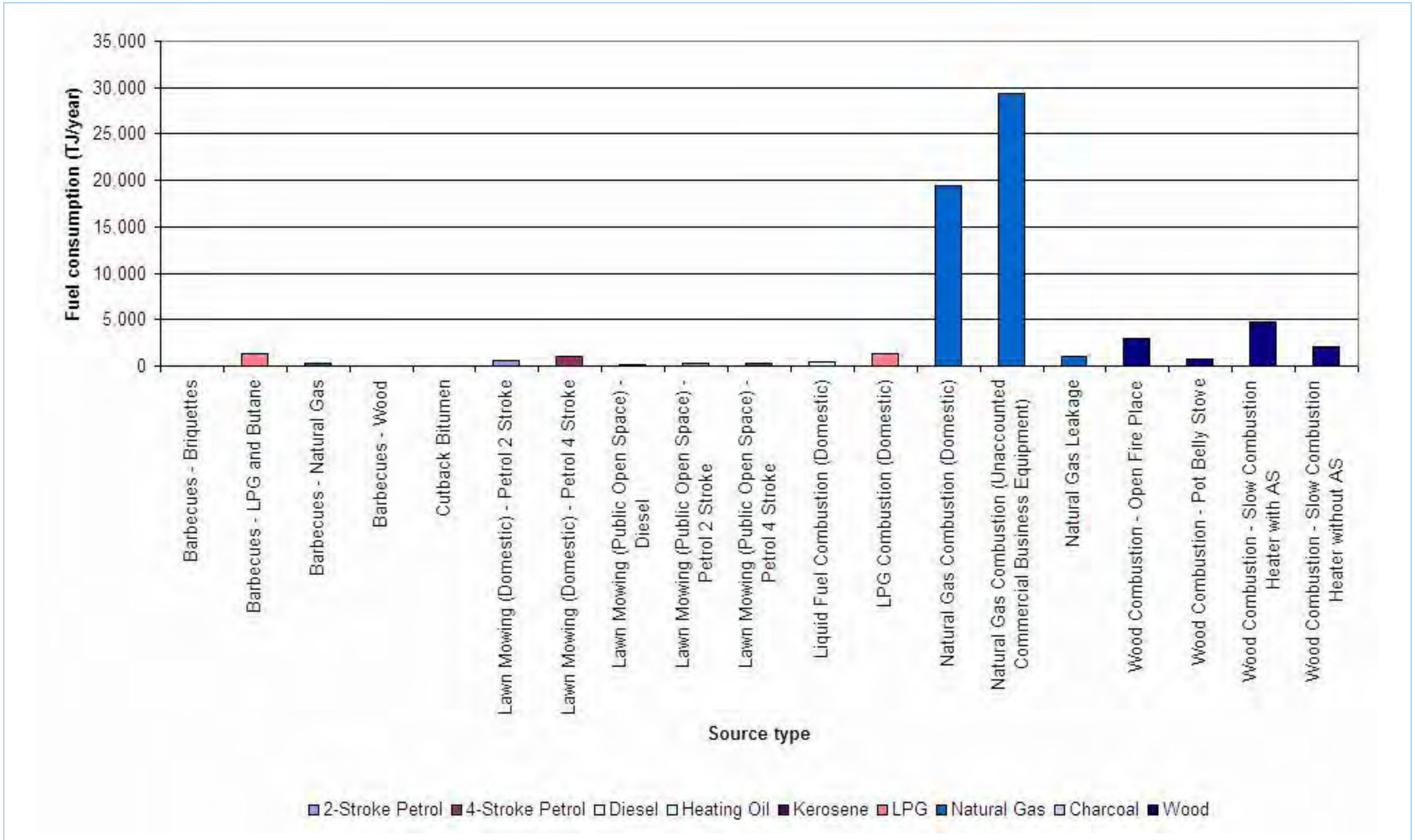

Figure 4-8: Total estimated annual fuel consumption by domestic-commercial source type and energy content in the GMR

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