Technical Report No. 6

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

2008 Calendar Year

Off-Road Mobile Emissions: Results

NSW EPA

ACKNOWLEDGMENTS

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

The 1108 EPA-licensed premises that participated in the industrial survey conducted by the Office of Environment and Heritage are gratefully acknowledged. Their input has enabled a thorough evaluation of industrial sources of air emissions. Data provided by other government departments and service providers, including Airservices Australia, Australian Bureau of Agricultural and Resource Economics and Sciences, Australian Bureau of Statistics, Australian Rail Track Corporation, Bureau of Infrastructure, Transport and Regional Economics, Bureau of Transport Statistics, Department of Resources, Energy and Tourism, Lloyds Register, Newcastle Buses and Ferries, Primary Industries Division of the Department of Trade and Investment, Regional Infrastructure and Services, NSW Maritime, Transport for NSW, Newcastle Port Corporation, Outboard Engine Distributors Association, Pacific National, Port Kembla Port Corporation, RailCorp, Sydney Ports Corporation and Taverner Research, were essential for the completion of this study.

The work of a number of individuals is acknowledged, including Mr Nick Agapides, Manager Major Air Projects and Mr Kelsey Bawden, Senior Technical Policy Advisor, for their efforts in project scoping and management, developing emission estimation methodologies, collecting activity data, developing databases, estimating emissions and preparing this report.

Published by:
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ISBN 978-1-74293-467-9

EPA 2012/0050

August 2012

EXECUTIVE SUMMARY

An air emissions inventory project for off-road mobile sources has take over 2 years to complete. The base year of the off-road mobile 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 off-road mobile air emissions inventory includes emissions from the following sources/activities:

- Aircraft (flight operations);
- Aircraft (ground operations);
- Commercial boats;
- Commercial off-road vehicles and equipment;
- Industrial off-road vehicles and equipment;
- Locomotives;
- Recreational boats; and
- Ships.

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

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 off-road mobile 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 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 off-road mobile sources in each region

Substance	Emissions (tonne/year)				
	Newcastle	Non Urban	Sydney	Wollongong	GMR
1,3-BUTADIENE	2.78	18	18	1.16	40
ACETALDEHYDE	9.97	151	47	4.26	212
BENZENE	31	196	164	13	404
CARBON MONOXIDE	3,343	27,975	20,801	1,698	53,817
FORMALDEHYDE	22	333	113	11	478
ISOMERS OF XYLENE	112	596	602	45	1,356
LEAD & COMPOUNDS	5.85×10^{-2}	0.85	1.28	3.0×10^{-2}	2.22
OXIDES OF NITROGEN	3,548	31,826	16,238	1,598	53,210
PARTICULATE MATTER ≤ 10 µm	284	2,185	1,019	119	3,607
PARTICULATE MATTER ≤ 2.5 µm	266	2,104	952	112	3,433
PERCHLOROETHYLENE	1.77×10^{-5}	6.80×10^{-5}	5.80×10^{-4}	1.24×10^{-4}	7.89×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	0.73	3.18	5.02	0.31	9.24
SULFUR DIOXIDE	1,300	1,246	4,725	553	7,824
TOLUENE	105	566	563	43	1,276
TOTAL SUSPENDED PARTICULATE	294	2,276	1,056	123	3,749
TOTAL VOLATILE ORGANIC COMPOUNDS	1,303	8,715	7,341	591	17,950

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

Figure ES-2: Proportions of total estimated annual emissions from off-road mobile 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 off-road mobile 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 off-road mobile source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Table ES-3: Total estimated annual emissions by off-road mobile source type in the GMR

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	3.86	0.13	12	9.42×10^{-2}	6.48	0.95	16	4.71×10^{-2}	40
ACETALDEHYDE	9.88	3.68	17	1.01	160	6.93	12	1.82	212
BENZENE	3.91	1.60	134	0.65	65	0.80	193	4.60	404
CARBON MONOXIDE	3,128	1,895	12,153	256	20,431	906	14,585	463	53,817
FORMALDEHYDE	29	8.20	33	2.99	366	15	20	3.84	478
ISOMERS OF XYLENE	1.03	0.76	542	0.60	38	1.72	770	2.35	1,356
LEAD & COMPOUNDS	1.71	4.58×10^{-4}	0.17	6.15×10^{-4}	7.32×10^{-2}	2.01×10^{-2}	0.23	2.39×10^{-2}	2.22
OXIDES OF NITROGEN	1,850	265	4,404	162	30,716	6,087	301	9,425	53,210
PARTICULATE MATTER ≤ 10 µm	58	15	193	11	2,094	171	143	922	3,607
PARTICULATE MATTER ≤ 2.5 µm	49	14	182	10	2,031	166	132	849	3,433
PERCHLOROETHYLENE	-	-	-	4.96×10^{-5}	7.39×10^{-4}	-	-	-	7.89×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	2.80	1.52×10^{-2}	0.37	1.73×10^{-2}	2.28	0.45	0.34	2.95	9.24
SULFUR DIOXIDE	167	1.97	15	0.41	64	11	7.46	7,557	7,824
TOLUENE	1.44	1.20	496	0.69	51	1.14	720	4.45	1,276
TOTAL SUSPENDED PARTICULATE	60	15	200	11	2,181	183	148	951	3,749
TOTAL VOLATILE ORGANIC COMPOUNDS	274	113	5,299	32	3,195	358	8,476	204	17,950

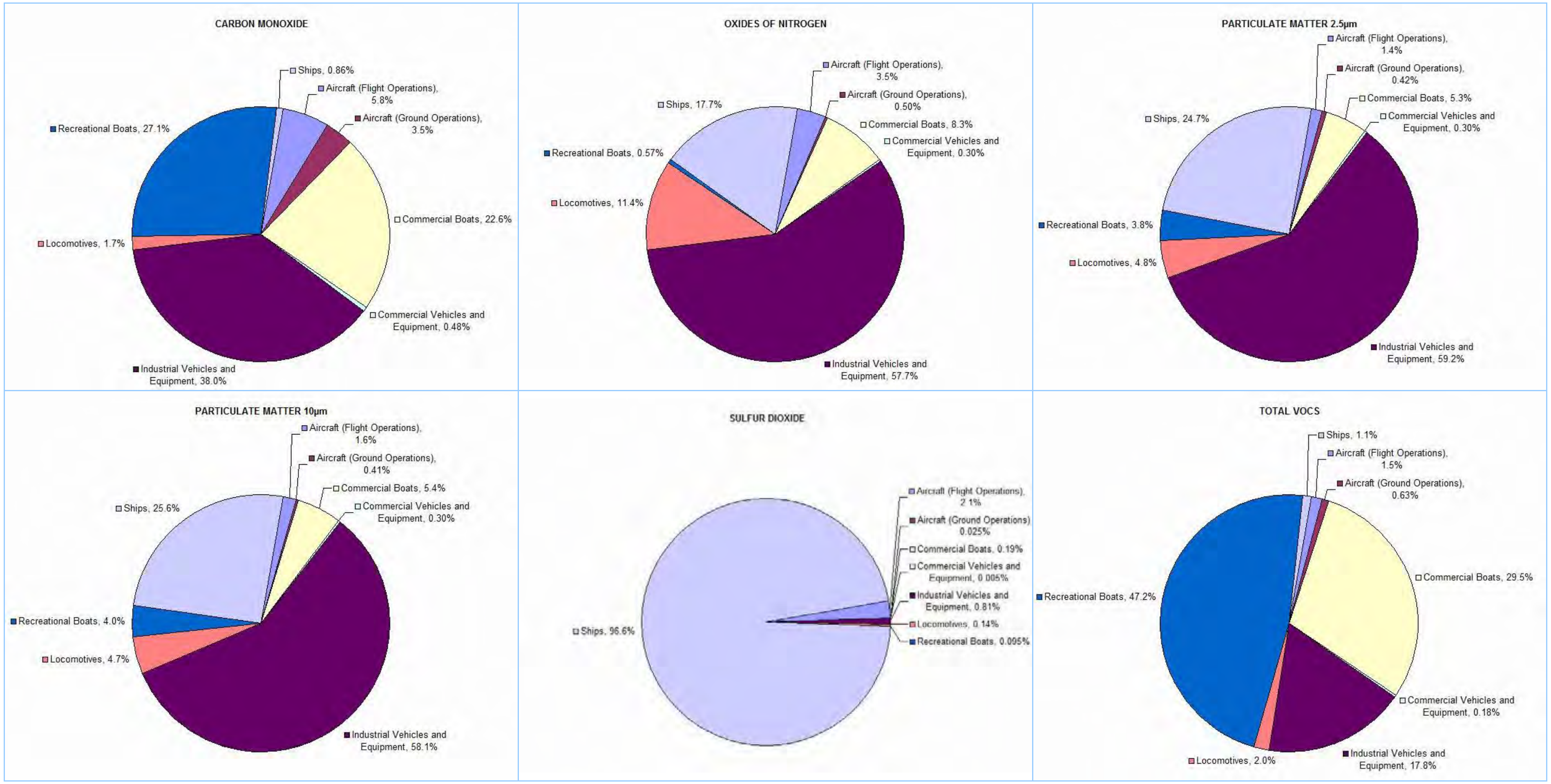

Figure ES-3: Proportions of total estimated annual emissions by off-road mobile source type in the GMR

Table ES-4: Total estimated annual emissions by off-road mobile source type in the Sydney region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	3.54	0.12	5.14	2.93×10^{-2}	0.95	0.46	7.64	2.83×10^{-2}	18
ACETALDEHYDE	9.02	3.54	10	0.51	13	3.33	5.83	1.09	47
BENZENE	3.56	1.47	58	0.23	7.13	0.38	91	2.63	164
CARBON MONOXIDE	2,407	1,823	5,332	136	3,484	436	6,912	271	20,801
FORMALDEHYDE	26	7.89	21	1.57	37	7.02	9.51	2.30	113
ISOMERS OF XYLENE	0.94	0.72	227	0.17	5.84	0.83	365	1.34	602
LEAD & COMPOUNDS	1.07	4.41×10^{-4}	7.03×10^{-2}	2.19×10^{-4}	1.03×10^{-2}	9.65×10^{-3}	0.11	1.44×10^{-2}	1.28
OXIDES OF NITROGEN	1,771	255	3,319	84	2,600	2,927	143	5,138	16,238
PARTICULATE MATTER ≤ 10 µm	46	14	114	5.34	150	82	68	539	1,019
PARTICULATE MATTER ≤ 2.5 µm	41	14	108	5.18	146	80	62	496	952
PERCHLOROETHYLENE	-	-	-	3.0×10^{-5}	5.50×10^{-4}	-	-	-	5.80×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	2.46	1.46×10^{-2}	0.19	8.76×10^{-3}	0.23	0.22	0.16	1.73	5.02
SULFUR DIOXIDE	160	1.89	9.89	0.21	6.10	5.10	3.54	4,538	4,725
TOLUENE	1.33	1.09	209	0.21	7.02	0.55	341	2.55	563
TOTAL SUSPENDED PARTICULATE	47	15	118	5.55	156	88	70	556	1,056
TOTAL VOLATILE ORGANIC COMPOUNDS	253	99	2,296	15	372	172	4,016	117	7,341

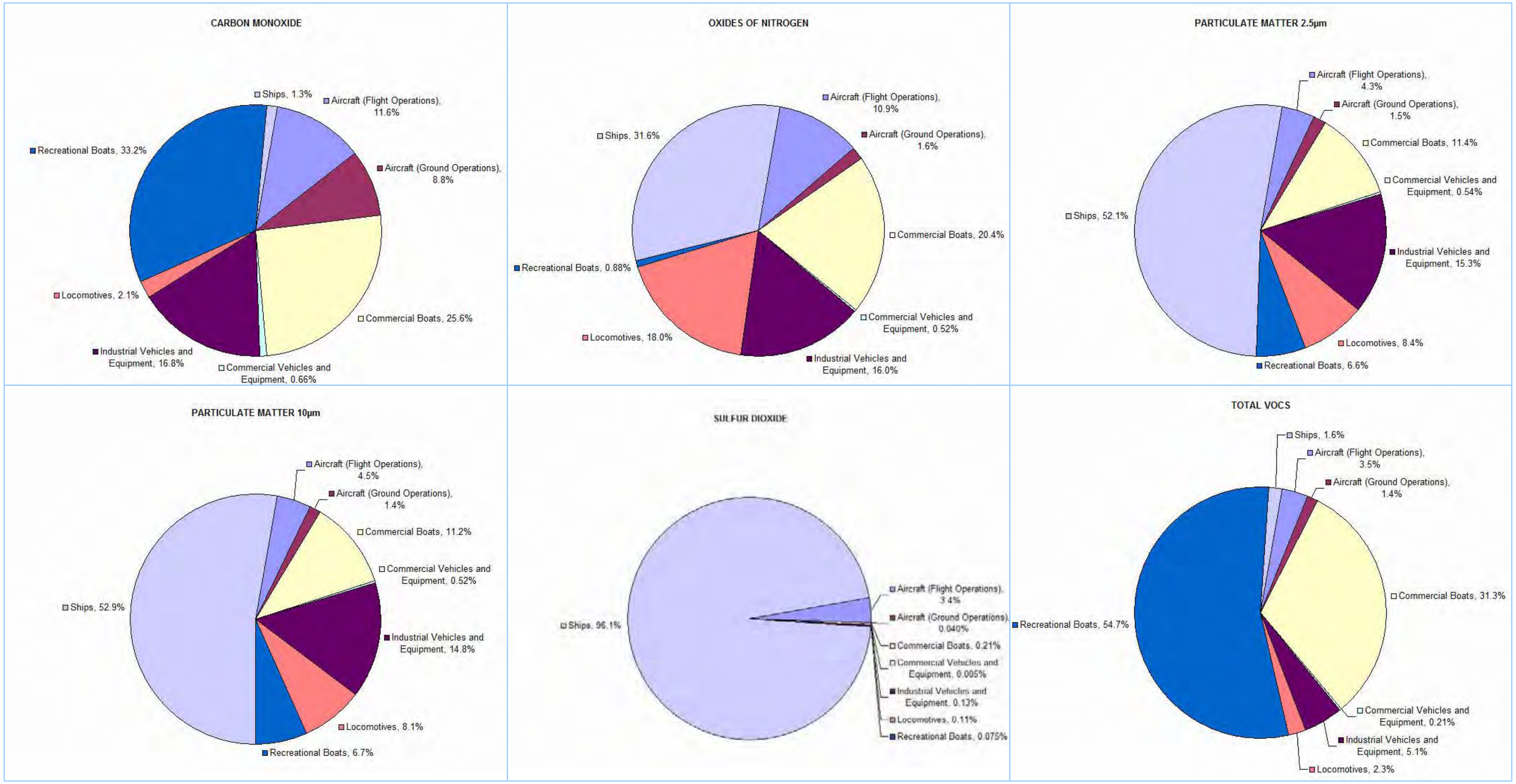

Figure ES-4: Proportions of total estimated annual emissions by off-road mobile source type in the Sydney region

Table ES-5: Total estimated annual emissions by off-road mobile source type in the Newcastle region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	6.34×10^{-2}	4.10×10^{-3}	1.59	2.60×10^{-3}	0.27	4.77×10^{-2}	0.79	8.04×10^{-3}	2.78
ACETALDEHYDE	0.16	0.12	1.56	7.38×10^{-2}	6.79	0.35	0.61	0.31	9.97
BENZENE	6.37×10^{-2}	4.74×10^{-2}	18	2.42×10^{-2}	2.77	4.01×10^{-2}	9.49	0.79	31
CARBON MONOXIDE	41	60	1,566	18	816	46	717	79	3,343
FORMALDEHYDE	0.47	0.26	2.84	0.22	15	0.73	0.99	0.66	22
ISOMERS OF XYLENE	1.69×10^{-2}	2.37×10^{-2}	72	1.28×10^{-2}	1.59	8.63×10^{-2}	38	0.40	112
LEAD & COMPOUNDS	1.70×10^{-2}	1.45×10^{-5}	2.19×10^{-2}	2.45×10^{-5}	3.09×10^{-3}	1.01×10^{-3}	1.14×10^{-2}	4.09×10^{-3}	5.85×10^{-2}
OXIDES OF NITROGEN	32	8.42	227	12	1,305	306	15	1,643	3,548
PARTICULATE MATTER ≤ 10 µm	0.80	0.47	18	0.79	90	8.59	7.04	159	284
PARTICULATE MATTER ≤ 2.5 µm	0.71	0.46	17	0.77	87	8.33	6.48	146	266
PERCHLOROETHYLENE	-	-	-	3.88×10^{-6}	1.38×10^{-5}	-	-	-	1.77×10^{-5}
POLYCYCLIC AROMATIC HYDROCARBONS	4.36×10^{-2}	4.82×10^{-4}	4.17×10^{-2}	1.21×10^{-3}	9.60×10^{-2}	2.28×10^{-2}	1.68×10^{-2}	0.51	0.73
SULFUR DIOXIDE	2.88	6.25×10^{-2}	1.16	2.99×10^{-2}	2.68	0.53	0.37	1,292	1,300
TOLUENE	2.38×10^{-2}	3.52×10^{-2}	66	1.82×10^{-2}	2.16	5.75×10^{-2}	35	0.77	105
TOTAL SUSPENDED PARTICULATE	0.82	0.48	18	0.82	94	9.21	7.26	164	294
TOTAL VOLATILE ORGANIC COMPOUNDS	4.55	3.05	690	1.97	133	18	417	35	1,303

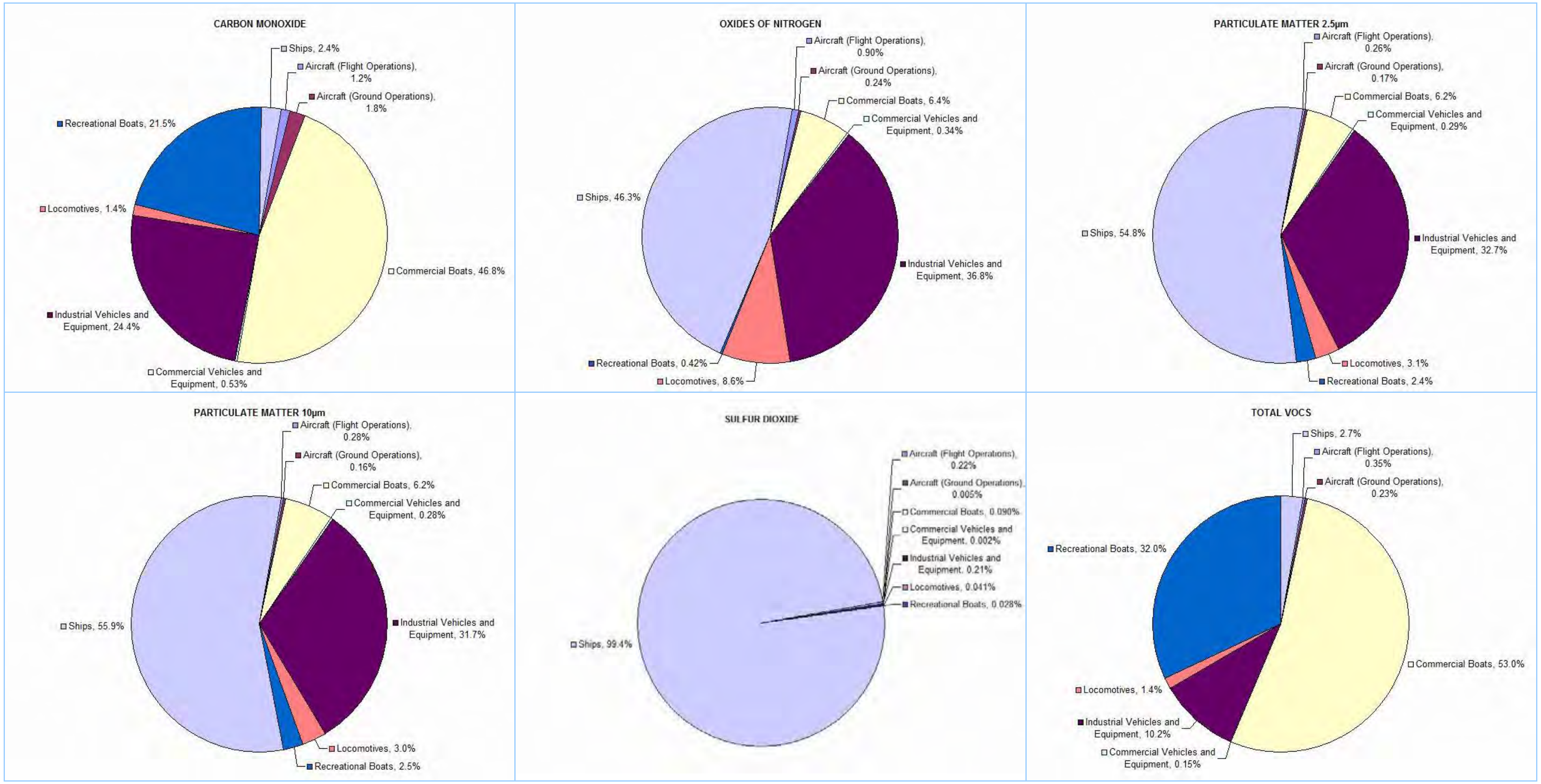

Figure ES-5: Proportions of total estimated annual emissions by off-road mobile source type in the Newcastle region

Table ES-6: Total estimated annual emissions by off-road mobile source type in the Wollongong region

Substance	Emissions (tonne/year)							
	Aircraft (flight operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	4.53×10^{-3}	7.77×10^{-2}	4.33×10^{-4}	0.19	3.92×10^{-2}	0.84	3.77×10^{-3}	1.16
ACETALDEHYDE	1.22×10^{-2}	8.64×10^{-2}	1.23×10^{-2}	3.07	0.29	0.64	0.15	4.26
BENZENE	5.02×10^{-3}	0.87	4.65×10^{-3}	1.50	3.30×10^{-2}	10	0.35	13
CARBON MONOXIDE	13	77	1.38	770	37	762	37	1,698
FORMALDEHYDE	3.90×10^{-2}	0.16	2.83×10^{-2}	8.62	0.60	1.05	0.31	11
ISOMERS OF XYLENE	1.25×10^{-3}	3.53	2.43×10^{-3}	1.15	7.10×10^{-2}	40	0.18	45
LEAD & COMPOUNDS	1.22×10^{-2}	1.07×10^{-3}	4.84×10^{-6}	2.05×10^{-3}	8.30×10^{-4}	1.21×10^{-2}	1.75×10^{-3}	3.0×10^{-2}
OXIDES OF NITROGEN	0.57	16	1.85	607	252	16	706	1,598
PARTICULATE MATTER ≤ 10 µm	0.22	0.98	0.15	35	7.06	7.48	68	119
PARTICULATE MATTER ≤ 2.5 µm	0.15	0.91	0.15	34	6.85	6.89	62	112
PERCHLOROETHYLENE	-	-	6.91×10^{-8}	1.24×10^{-4}	-	-	-	1.24×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	5.43×10^{-3}	2.15×10^{-3}	1.67×10^{-4}	5.33×10^{-2}	1.87×10^{-2}	1.79×10^{-2}	0.22	0.31
SULFUR DIOXIDE	6.15×10^{-2}	6.87×10^{-2}	3.99×10^{-3}	1.41	0.44	0.39	551	553
TOLUENE	1.48×10^{-3}	3.23	3.43×10^{-3}	1.41	4.73×10^{-2}	38	0.34	43
TOTAL SUSPENDED PARTICULATE	0.22	1.01	0.16	37	7.58	7.72	70	123
TOTAL VOLATILE ORGANIC COMPOUNDS	0.26	34	0.24	83	15	443	16	591

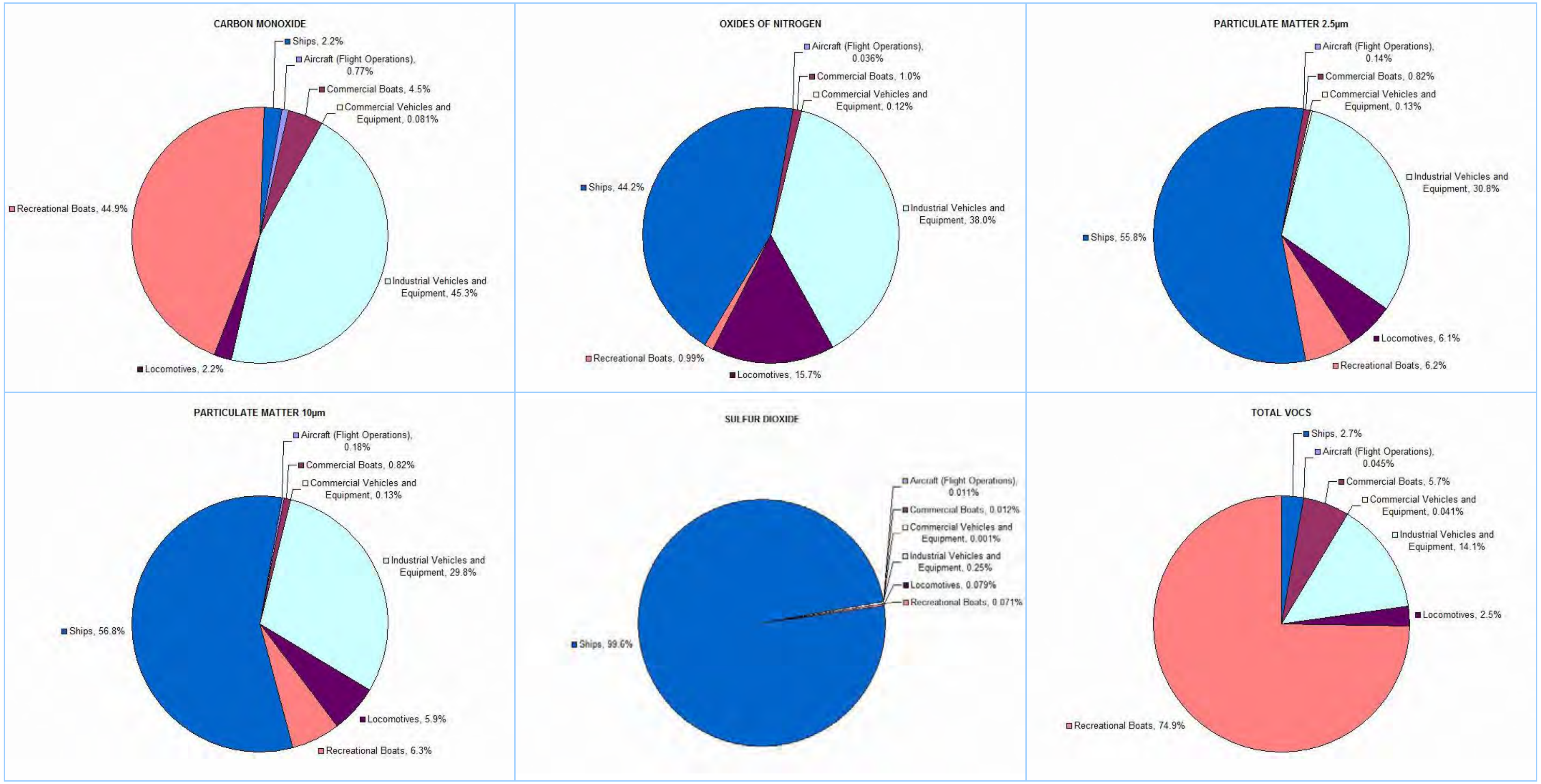

Figure ES-6: Proportions of total estimated annual emissions by off-road mobile source type in the Wollongong region

Table ES-7: Total estimated annual emissions by off-road mobile source type in the Non Urban region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	0.26	7.79×10^{-4}	5.24	6.19×10^{-2}	5.06	0.41	6.84	7.05×10^{-3}	18
ACETALDEHYDE	0.69	2.22×10^{-2}	5.35	0.41	137	2.96	5.23	0.27	151
BENZENE	0.28	8.32×10^{-2}	58	0.40	54	0.34	82	0.82	196
CARBON MONOXIDE	667	11	5,178	100	15,361	387	6,194	76	27,975
FORMALDEHYDE	2.18	4.94×10^{-2}	9.79	1.18	305	6.24	8.52	0.58	333
ISOMERS OF XYLENE	7.09×10^{-2}	1.48×10^{-2}	239	0.41	29	0.73	327	0.42	596
LEAD & COMPOUNDS	0.61	2.76×10^{-6}	7.24×10^{-2}	3.66×10^{-4}	5.78×10^{-2}	8.58×10^{-3}	9.80×10^{-2}	3.67×10^{-3}	0.85
OXIDES OF NITROGEN	46	1.60	843	64	26,204	2,602	128	1,938	31,826
PARTICULATE MATTER ≤ 10 µm	11	8.84×10^{-2}	61	4.42	1,818	73	61	157	2,185
PARTICULATE MATTER ≤ 2.5 µm	7.87	8.68×10^{-2}	57	4.29	1,764	71	56	145	2,104
PERCHLOROETHYLENE	-	-	-	1.56×10^{-5}	5.23×10^{-5}	-	-	-	6.80×10^{-5}
POLYCYCLIC AROMATIC HYDROCARBONS	0.29	9.15×10^{-5}	0.14	7.19×10^{-3}	1.90	0.19	0.15	0.50	3.18
SULFUR DIOXIDE	4.62	1.19×10^{-2}	4.07	0.16	53	4.54	3.17	1,176	1,246
TOLUENE	8.61×10^{-2}	7.05×10^{-2}	218	0.46	41	0.49	306	0.79	566
TOTAL SUSPENDED PARTICULATE	11	9.21×10^{-2}	63	4.60	1,894	78	63	162	2,276
TOTAL VOLATILE ORGANIC COMPOUNDS	16	11	2,279	15	2,607	153	3,599	36	8,715

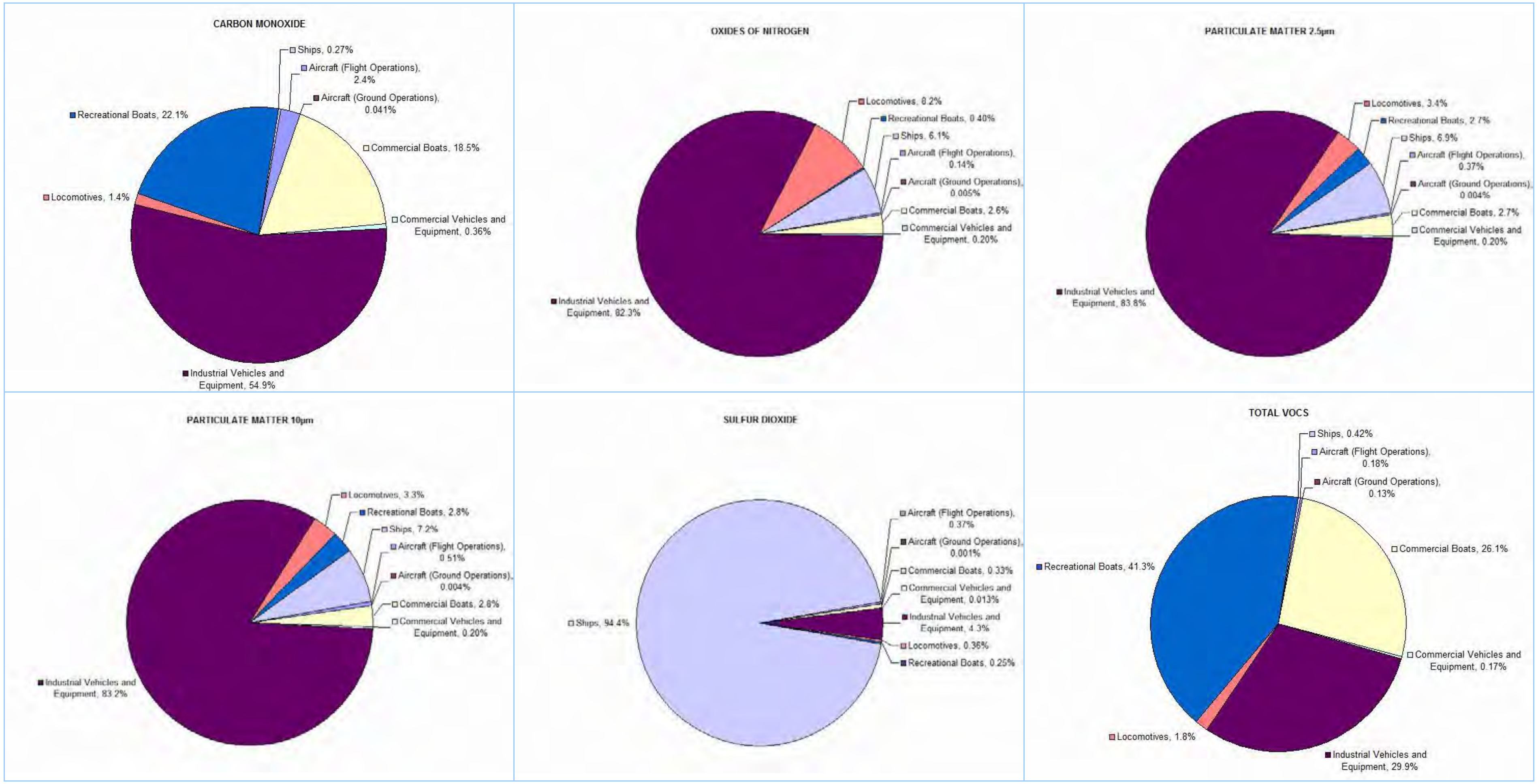

Figure ES-7: Proportions of total estimated annual emissions by off-road mobile source type in the Non Urban region

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

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

Fuel	Annual fuel consumption	
	Volume (kL/year)	Energy content (TJ/year)
2-Stroke petrol	63,776	2,181
4-Stroke petrol	17,090	584
Avgas	2,009	66
Avtur	178,129	6,555
Diesel	1,014,171	39,147
LPG	21,780	555
Marine diesel oil	18,589	706
Marine gas oil	3,053	111
Residual oil	145,424	5,748
Grand Total	1,464,021	55,655

Figure ES-8 and Figure ES-9 show total estimated fuel consumption from all off-road mobile sources in the GMR by volume and energy content, respectively.

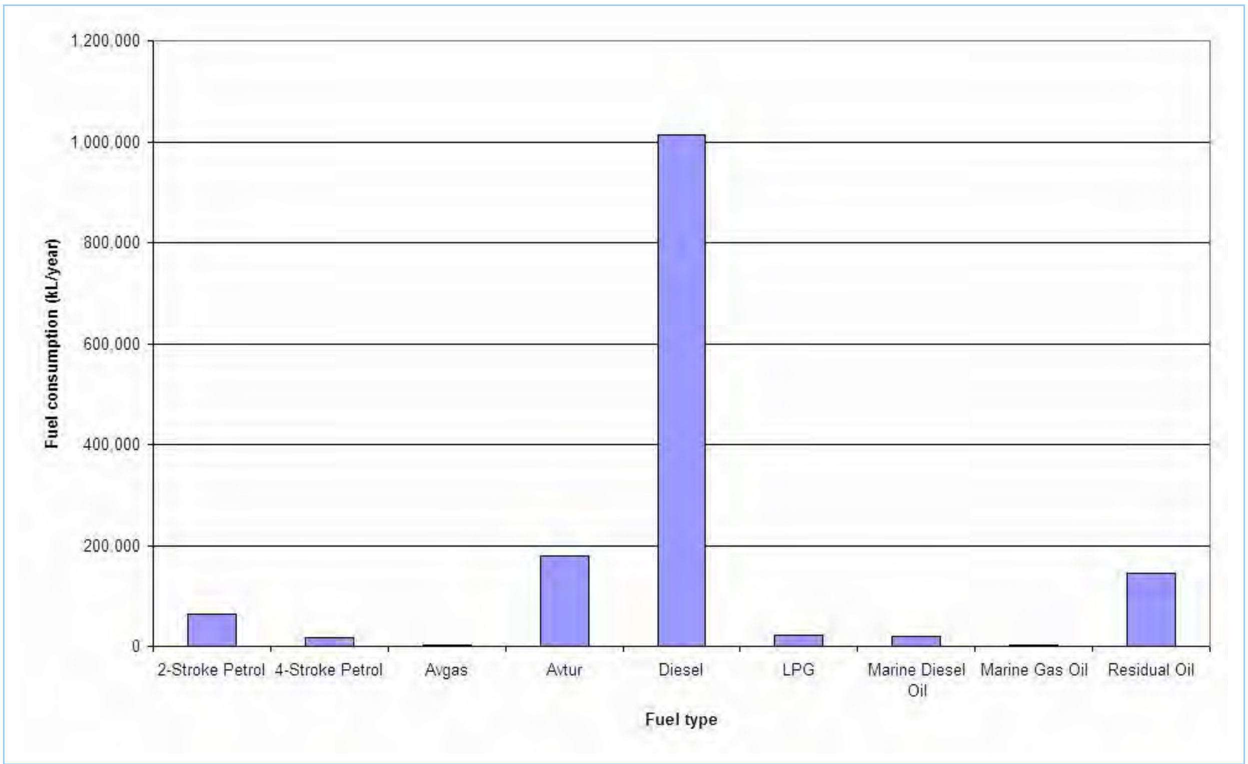

Figure ES-8: Total estimated annual fuel consumption from off-road mobile sources by volume in the GMR

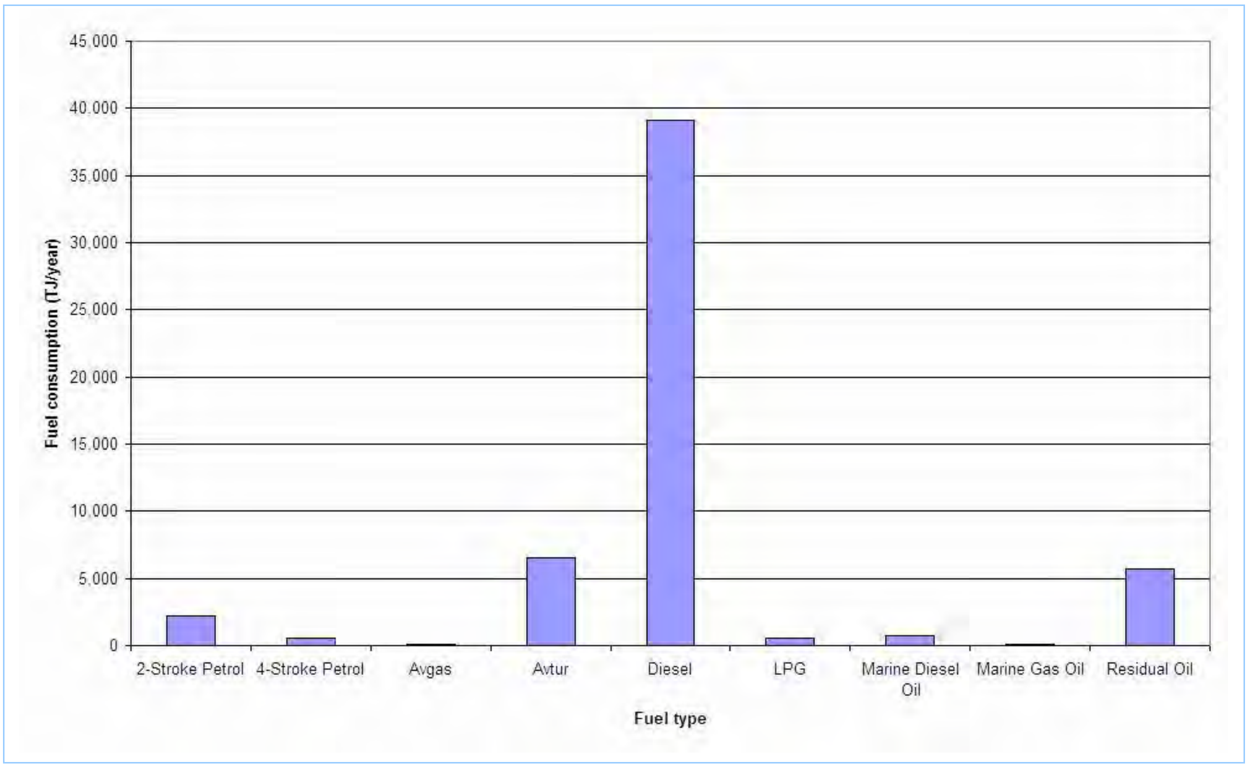

Figure ES-9: Total estimated annual fuel consumption from off-road mobile sources by energy content in the GMR

Table ES-9 and Table ES-10 present total estimated fuel consumption by off-road mobile source type in the GMR by volume and energy content, respectively.

Figure ES-10 and Figure ES-11 show total estimated fuel consumption by off-road mobile source type in the GMR by volume and energy content, respectively.

Table ES-9: Total estimated annual fuel consumption by off-road mobile source type and volume in the GMR

Source type	Volume (kL/year)									
	2-Stroke petrol	4-Stroke petrol	Avgas	Avtur	Diesel	LPG	Marine diesel oil	Marine gas oil	Residual oil	Grand Total
Aircraft ground operations – diesel	-	-	-	-	23,858	-	-	-	-	23,858
Aircraft flight operations – avgas	-	-	2,009	-	-	-	-	-	-	2,009
Aircraft flight operations – avtur	-	-	-	178,129	-	-	-	-	-	178,129
Commercial boats – diesel	-	-	-	-	120,180	-	-	-	-	120,180
Commercial boats - petrol 2 stroke	25,501	-	-	-	-	-	-	-	-	25,501
Commercial boats - petrol 4 stroke	-	7,070	-	-	-	-	-	-	-	7,070
Commercial vehicles and equipment – diesel	-	-	-	-	3,128	-	-	-	-	3,128
Commercial vehicles and equipment – gas	-	-	-	-	-	1,332	-	-	-	1,332
Commercial vehicles and equipment – petrol	-	57	-	-	-	-	-	-	-	57
Industrial vehicles and equipment – diesel	-	-	-	-	737,337	-	-	-	-	737,337
Industrial vehicles and equipment – gas	-	-	-	-	-	20,448	-	-	-	20,448
Industrial vehicles and equipment – petrol	-	2,092	-	-	-	-	-	-	-	2,092
Locomotives – line haul	-	-	-	-	114,170	-	-	-	-	114,170
Locomotives – passenger	-	-	-	-	14,666	-	-	-	-	14,666
Recreational boats – diesel	-	-	-	-	831	-	-	-	-	831
Recreational boats – petrol 2 stroke	38,275	-	-	-	-	-	-	-	-	38,275
Recreational boats – petrol 4 stroke	-	7,871	-	-	-	-	-	-	-	7,871
Ships auxiliary boiler – diesel oil	-	-	-	-	-	-	5,881	-	-	5,881
Ships auxiliary boiler – gas oil	-	-	-	-	-	-	-	843	-	843
Ships auxiliary boiler – residual oil	-	-	-	-	-	-	-	-	37,264	37,264
Ships auxiliary engine – diesel oil	-	-	-	-	-	-	6,396	-	-	6,396
Ships auxiliary engine – gas oil	-	-	-	-	-	-	-	845	-	845
Ships auxiliary engine – residual oil	-	-	-	-	-	-	-	-	37,921	37,921
Ships main engine – diesel oil	-	-	-	-	-	-	6,313	-	-	6,313
Ships main engine – gas oil	-	-	-	-	-	-	-	1,365	-	1,365
Ships main engine – residual oil	-	-	-	-	-	-	-	-	70,239	70,239
Grand Total	63,776	17,090	2,009	178,129	1,014,171	21,780	18,589	3,053	145,424	1,464,021

Table ES-10: Total estimated annual fuel consumption by off-road mobile source type and energy content in the GMR

Source type	Energy content (TJ/year)									
	2-Stroke petrol	4-Stroke petrol	Avgas	Avtur	Diesel	LPG	Marine diesel oil	Marine gas oil	Residual oil	Grand Total
Aircraft ground operations – diesel	-	-	-	-	921	-	-	-	-	921
Aircraft flight operations – avgas	-	-	66	-	-	-	-	-	-	66
Aircraft flight operations – avtur	-	-	-	6,555	-	-	-	-	-	6,555
Commercial boats – diesel	-	-	-	-	4,639	-	-	-	-	4,639
Commercial boats – petrol 2 stroke	872	-	-	-	-	-	-	-	-	872
Commercial boats – petrol 4 stroke	-	242	-	-	-	-	-	-	-	242
Commercial vehicles and equipment – diesel	-	-	-	-	121	-	-	-	-	121
Commercial vehicles and equipment – gas	-	-	-	-	-	34	-	-	-	34
Commercial vehicles and equipment – petrol	-	2	-	-	-	-	-	-	-	2
Industrial vehicles and equipment – diesel	-	-	-	-	28,461	-	-	-	-	28,461
Industrial vehicles and equipment – gas	-	-	-	-	-	521	-	-	-	521
Industrial vehicles and equipment – petrol	-	72	-	-	-	-	-	-	-	72
Locomotives – line haul	-	-	-	-	4,407	-	-	-	-	4,407
Locomotives – passenger	-	-	-	-	566	-	-	-	-	566
Recreational boats – diesel	-	-	-	-	32	-	-	-	-	32
Recreational boats – petrol 2 stroke	1,309	-	-	-	-	-	-	-	-	1,309
Recreational boats – petrol 4 stroke	-	269	-	-	-	-	-	-	-	269
Ships auxiliary boiler – diesel oil	-	-	-	-	-	-	223	-	-	223
Ships auxiliary boiler – gas oil	-	-	-	-	-	-	-	31	-	31
Ships auxiliary boiler – residual oil	-	-	-	-	-	-	-	-	1,473	1,473
Ships auxiliary engine – diesel oil	-	-	-	-	-	-	243	-	-	243
Ships auxiliary engine – gas oil	-	-	-	-	-	-	-	31	-	31
Ships auxiliary engine – residual oil	-	-	-	-	-	-	-	-	1,499	1,499
Ships main engine – diesel oil	-	-	-	-	-	-	240	-	-	240
Ships main engine – gas oil	-	-	-	-	-	-	-	50	-	50
Ships main engine – residual oil	-	-	-	-	-	-	-	-	2,776	2,776
Grand Total	2,181	584	66	6,555	39,147	555	706	111	5,748	55,655

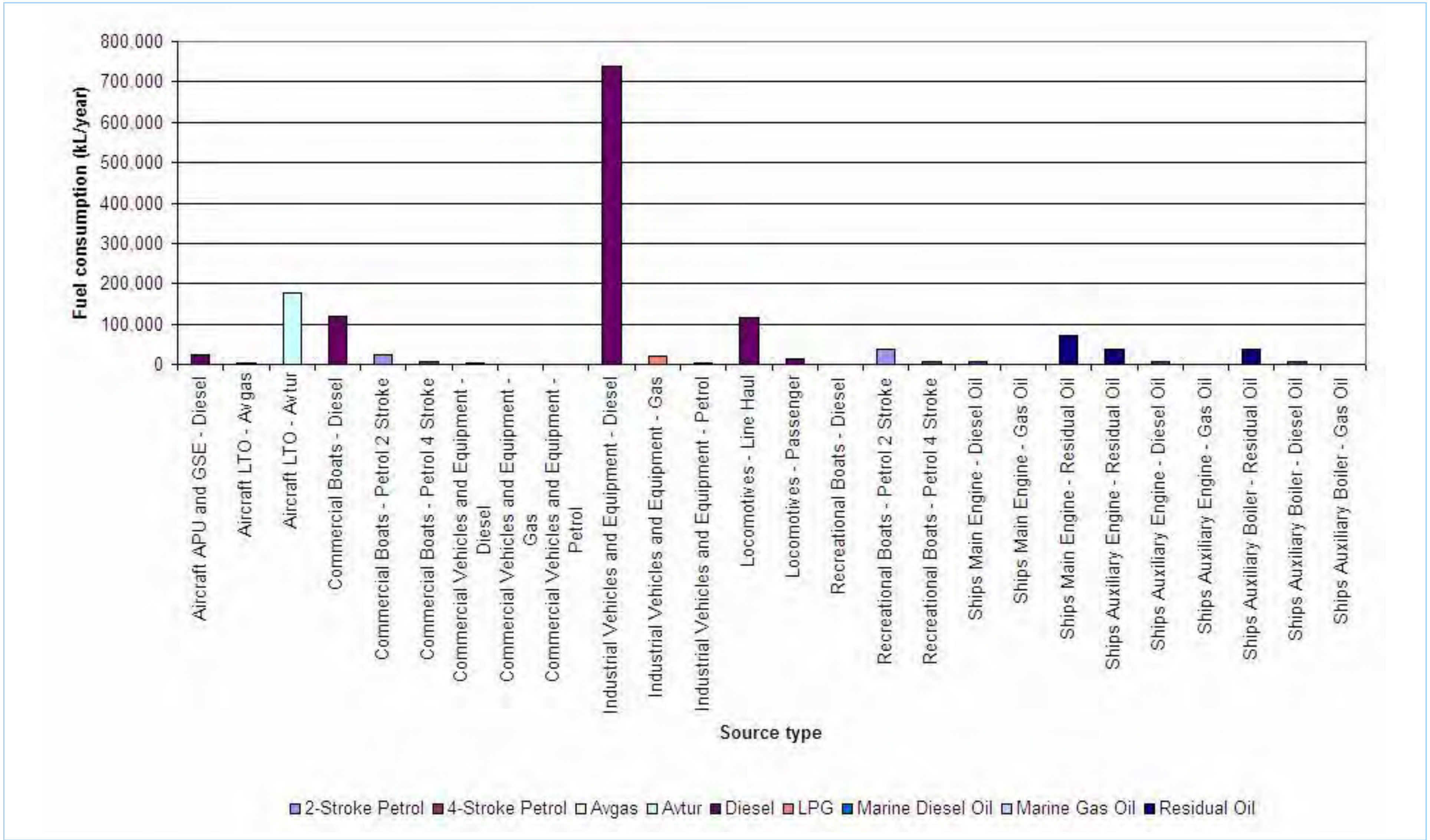

Figure ES-10: Total estimated annual fuel consumption by off-road mobile source type and volume in the GMR

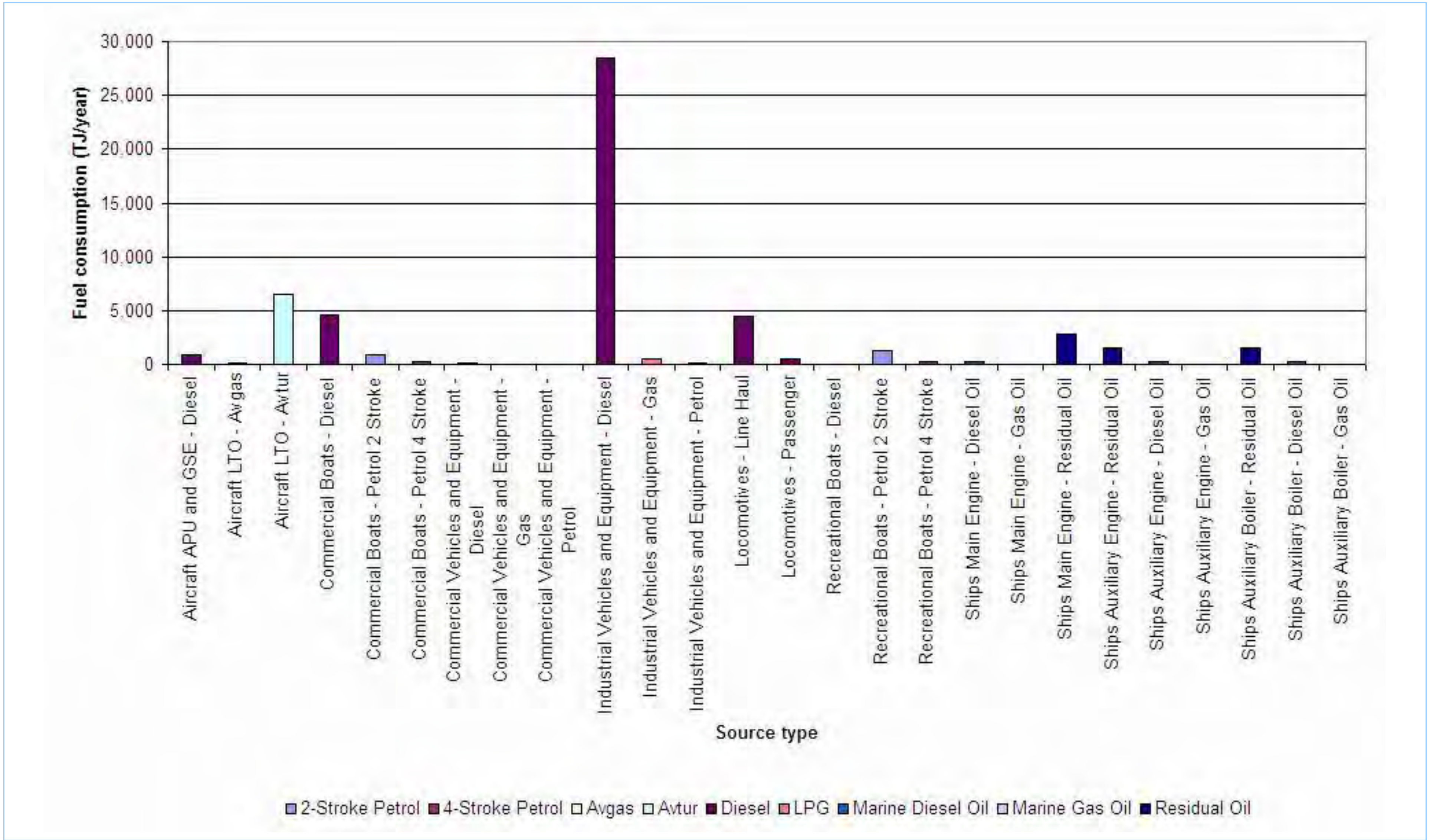

Figure ES-11: Total estimated annual fuel consumption by off-road mobile source type and energy content in the GMR

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1 INTRODUCTION

An air emissions inventory project for off-road mobile sources has taken over 2 years to complete. The base year of the off-road mobile 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 off-road mobile air emissions inventory. The information is structured as follows:

- A description of the off-road mobile 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 off-road mobile source type (Section 3).
- An emission summary (for selected substances) presented by off-road mobile 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 off-road mobile sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions (Section 4).
- A complete list of references (Section 5).
- Total off-road mobile 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 Off-Road Mobile Sources).
- Industrial survey questionnaire form used to obtain activity data for industrial off-road vehicles and equipment (Appendix B. Industrial Survey Questionnaire Form).
- Domestic survey questionnaire form used to obtain activity data for recreational boats (Appendix C. Domestic Survey Questionnaire Form).

2 INVENTORY SPECIFICATIONS

2.1 The Inventory Year

The off-road mobile 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[2] 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

[2] 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 off-road mobile 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.

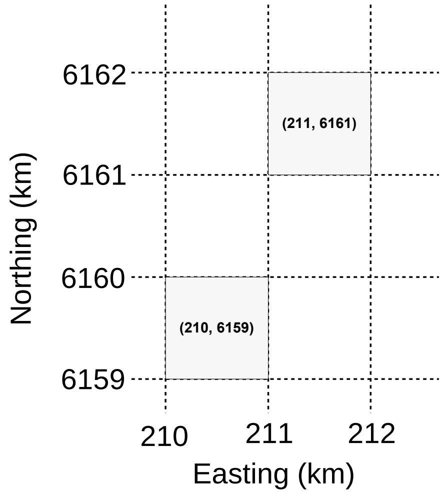

Figure 2-2: Grid coordinate system

2.4 Emission Sources Considered

The off-road mobile air emissions inventory includes emissions from the following sources/activities:

- Aircraft (flight operations);
- Aircraft (ground operations);
- Commercial boats;
- Commercial off-road vehicles and equipment;
- Industrial off-road vehicles and equipment;
- Locomotives;
- Recreational boats; and
- Ships.

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)[3];
- 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, 2010);
- 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 off-road mobile air emissions inventory, while specific details are provided in Section 3.

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

The methodology used to develop the off-road mobile air emissions inventory involves the following steps:

2.6.1 Identify Sources

Off-road mobile sources considered in this report include all sources defined in Section 2.4 with the potential for air emissions in the GMR.

Off-road mobile 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, 1995);
- *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 presented in Table 2-2.

Table 2-2: Off-road mobile estimation methodologies and emission factors

Source type	Methodology or substance	Estimation methodologies and emission factors source
Aircraft (flight operations)	Methodology	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009) - *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	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 &*

Source type	Methodology or substance	Estimation methodologies and emission factors source
		Emissions Factors (USEPA, 2003)
	Speciated VOC	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Organic air toxics	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Metal air toxics	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *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	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)
Aircraft (ground operations)	Methodology	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009) - *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)
	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,*

Source type	Methodology or substance	Estimation methodologies and emission factors source
		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) - *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	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) - *Air Emissions Inventory for the Greater Metropolitan Region in NSW, Commercial Emissions Module: Results* (DECC, 2007a)
	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, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)
Commercial boats	Methodology	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *NONROAD2008a Model* (USEPA, 2009a)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009a)
	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*

Source type	Methodology or substance	Estimation methodologies and emission factors source
		(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 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, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)
Commercial off-road vehicles and equipment	Methodology	- *Documentation for the 2008 Mobile Source National Emissions Inventory* (Pechan, 2011) - *NONROAD2008a Model* (USEPA, 2009a)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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 factors source
		- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *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	- *NONROAD2008a Model* (USEPA, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998)
Industrial off-road vehicles and equipment	Methodology	- *Documentation for the 2008 Mobile Source National Emissions Inventory* (Pechan, 2011) - *NONROAD2008a Model* (USEPA, 2009a)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009a)
	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)

Source type	Methodology or substance	Estimation methodologies and emission factors source
		- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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) - *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	- *NONROAD2008a Model* (USEPA, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a) - *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998)
Locomotives	Methodology	- *Documentation for Locomotive Component of the National Emissions Inventory Methodology* (ERG, 2011b)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Emission Factors for Locomotives* (USEPA, 2009b) - *NONROAD2008a Model* (USEPA, 2009a)
	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)

Source type	Methodology or substance	Estimation methodologies and emission factors source
	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 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, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)
Recreational boats	Methodology	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *NONROAD2008a Model* (USEPA, 2009a)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *NONROAD2008a Model* (USEPA, 2009a)
	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*

Source type	Methodology or substance	Estimation methodologies and emission factors source
		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 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, 2009a) - *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)
Ships	Methodology	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)
	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community* (Entec, 2002) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)
	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	- *California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Organic air toxics	- *California Emission Inventory and Reporting System*

Source type	Methodology or substance	Estimation methodologies and emission factors source
		(CEIDARS), Organic Gas Speciation Profiles (CARB, 2005)
	Metal air toxics	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	Polycyclic aromatic hydrocarbons: PAH	- *Exhaust Emissions from High Speed Passenger Ferries* (Cooper, 2001) - *Exhaust Emissions from Ships at Berth* (Cooper, 2003) - *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
	Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	- *HCB, PCB, PCDD and PCDF Emissions from Ships* (Cooper, 2004)
	Ammonia	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
	Greenhouse gases: CH_4, CO_2 and N_2O	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009)

Detailed emission estimation methodologies for each off-road mobile 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 presented in Table 2-3, Table 2-4 and Table 2-5.

Table 2-3: Off-road mobile activity data

Source type	Activity data	Activity data source
Aircraft (flight operations)	Landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports to estimate aircraft emissions	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Aircraft (ground operations)	Landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports to estimate ground support equipment (GSE) and auxiliary	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b)

Source type	Activity data	Activity data source
	power unit (APU) emissions	- *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
	Avgas and Avtur sales data to estimate storage, transfer and refuelling emissions	- *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)
Commercial boats	Commercial boat type, number and fleet composition	Schedule ferry services - *Our Fleet, Central Coast Ferries Pty* Ltd (CCF, 2010) - *About the Ferries, Church Point Ferry Service* (CPFS, 2010) - *Ferries to Bundeena, Cronulla Ferries* (CF, 2010) - *Australia's Last Riverboat Postman, Hawkesbury River Tourist Services Pty Ltd* (HRTS, 2010) - *Charter Vessels - Bass and Flinders, Bass and Flinders Cruises* (BFC, 2010) - *The Fleet, Matilda Cruises* (MC, 2010) - *Our Fleet, Fantasea Palm Beach* (FPB, 2010) - *Fleet Facts, Sydney Ferries* (SF, 2010) Commercial fishing boats - *Commercial Catch Records, NSW DPI ComCatch & LobCatch 18-07-05 Extraction* (NSW DPI, 2005) - *NSW Maritime 2008 Annual Report* (NSW Maritime, 2008) - *NSW Maritime 2009 Annual Report* (NSW Maritime, 2009) - *The Outboard Motor Market in NSW, Actual Sales Data 2003 to 2005 and Projected Sales Data 2006 to 2010 for NSW and the GMR* (OEDA, 2005) Other commercial boats - *Vessels that have Certificates of Survey within NSW* (NSW Maritime, 2005) - *NSW Maritime 2008 Annual*

Source type	Activity data	Activity data source
		Report (NSW Maritime, 2008) - *NSW Maritime 2009 Annual Report* (NSW Maritime, 2009)
	Commercial boat operating frequency and duration	Schedule ferry services - *Ferry Timetables, NSW Transport and Infrastructure* (TI, 2010) - *Timetables and Maps, Newcastle Buses and Ferries* (NBF, 2010) Commercial fishing boats - *Commercial Catch Records, NSW DPI ComCatch & LobCatch 18-07-05 Extraction* (NSW DPI, 2005) Other commercial boats - *Puget Sound Maritime Air Forum Maritime Air Emissions Inventory* (SCG, 2007) - *The Port of San Diego 2006 Emissions Inventory* (SCG , 2008) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b)
Commercial off-road vehicles and equipment	Commercial off-road vehicles and equipment type, number and fleet composition	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)
	Commercial off-road vehicles and equipment operating frequency and duration	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)
Industrial off-road vehicles and equipment	Industrial off-road vehicles and equipment type, number and fleet composition	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)
	Industrial off-road vehicles and equipment operating frequency and duration	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)
Locomotives	Large line-haul and passenger gross tonne kilometre (GTK) data for GMR and NSW	- *GMR and NSW GTK 2008* (ARTC, 2009)
	Large line-haul and passenger diesel consumption data for NSW	- *Energy Update 2009* (ABARE, 2009a)
	Passenger diesel consumption data for NSW	- *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel*

Source type	Activity data	Activity data source
		Consumption 2007-2008 (RailCorp, 2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2008-2009* (RailCorp, 2009b)
Recreational boats	Recreational boat type/number and monthly usage frequency/duration/location	- *Recreational Boat 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)
	Recreational boat fleet composition	- *The Outboard Motor Market in NSW, Actual Sales Data 2003 to 2005 and Projected Sales Data 2006 to 2010 for NSW and the GMR* (OEDA, 2005)
Ships	Ship logs and pilot data for Botany, Newcastle, Sydney and Kembla ports	- *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009)
	Main engine, auxiliary engine and auxiliary boiler specification and fuel type	- *LRF Bespoke Data Catalogue (APS)* (LR, 2010) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b)
	Gas oil, intermediate fuel oil, marine diesel oil and residual oil sales data to estimate refuelling emissions	- *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)

Table 2-4: Off-road mobile spatial data

Source type	Spatial data	Spatial data source
Aircraft (flight operations)	Gridded 1 km x 1 km Avgas and Avtur consumption estimates allocated to airport locations and flight paths	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
Aircraft (ground operations)	Gridded 1 km x 1 km diesel consumption estimates allocated to airport locations	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and*

Source type	Spatial data	Spatial data source
		Wollongong Aero Data 2008 (BITRE, 2010) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Gridded 1 km x 1 km Avgas and Avtur consumption estimates allocated to airport locations	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010) - *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)
Commercial boats	Gridded 1 km x 1 km fuel consumption estimates allocated to water bodies	Scheduled ferry services: diesel - *Central Coast, Church Point, Cronulla, Dangar Island, Manly, Newcastle, Palm Beach and Sydney Harbour water bodies* (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) - *NONROAD2008a Model* (USEPA, 2009a) Commercial fishing boats: 2-stroke petrol, 4-stroke petrol and diesel - *Avoca Lake, Benson's Creek, Botany Bay, Brisbane Water, Broken Bay, Budgewoi, Cockrone Lake, Curl Curl Lagoon, Dee Why Lagoon, Georges River, Hawkesbury River, Hunter River, Karuah River, Kiama, Lake Illawarra, Lake Macquarie, Larpent River, Manly Lagoon, Minnamurra River, Munmorah, Myall Lakes, Myall River, Myall River, Narrabeen Lagoon, Narrabeen Lake, Parramatta River, Patonga, Pittwater, Port Hacking, Port Kembla, Port Stephens, Spring Creek, Sydney Harbour, Tea Gardens, Terrigal Lake, Towradgie Creek, Tuggerah Lakes, Wamberal Lagoon and Wollongong water bodies* (NSW DPI, 2005) - *NONROAD2008a Model* (USEPA, 2009a) Other commercial boats: 2-stroke petrol, 4-stroke petrol and diesel - *Botany Bay, Brisbane Water, Cowan Creek, Fern Bay, Georges River, Hawks Nest, Hawkesbury River, Kiama, Lake Illawarra, Lake Macquarie, Lemon Tree Passage, Patonga, Pittwater, Port Hacking, Port Hunter, Port Jackson, Port Kembla, Shoal Bay to Soldiers Point, Stockton, Tea Gardens, Terrigal, Tuggerah Lakes and Wollongong water bodies* (NSW Maritime, 2005) - *NONROAD2008a Model* (USEPA, 2009a)
Commercial off-road vehicles and equipment	Gridded 1 km x 1 km site-specific petrol, diesel and gas consumption estimates	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a) - *NONROAD2008a Model* (USEPA, 2009a)
Industrial off-road vehicles and equipment	Gridded 1 km x 1 km site-specific petrol, diesel and gas consumption estimates	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009) - *NONROAD2008a Model* (USEPA, 2009a)
Locomotives	Gridded 1 km x 1 km diesel consumption estimates allocated to rail network	- *GMR and NSW GTK 2008* (ARTC, 2009) - *Energy Update 2009* (ABARE, 2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2007-2008* (RailCorp,

Source type	Spatial data	Spatial data source
		2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2008-2009* (RailCorp, 2009b) - *Rail Movement Data in NSW Broken Down by Region 2003* (Pacific National, 2005)
Recreational boats	Gridded 1 km x 1 km petrol and diesel consumption estimates allocated to water bodies	- *Recreational Boat Pollution Survey* (TR, 2009) - *NONROAD2008a Model* (USEPA, 2009a)
Ships	Gridded 1 km x 1 km main engine, auxiliary engine and auxiliary boiler gas oil, intermediate fuel oil, marine diesel oil and residual oil consumption and fuel loaded estimates allocated to port locations and water bodies	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community* (Entec, 2002) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b) - *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009) - *LRF Bespoke Data Catalogue (APS)* (LR, 2010) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b) - *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009) - *Geospatial Analysis, A Comprehensive Guide to Principles, Techniques and Software Tools, Third Edition* (De Smith et. al., 2009)

Table 2-5: Off-road mobile temporal data

Source type	Temporal data	Temporal data source
Aircraft (flight operations)	Monthly, daily and hourly: Derived from landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Aircraft (ground operations)	Monthly, daily and hourly: Derived from landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b)

Source type	Temporal data	Temporal data source
		- *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Commercial boats	Monthly, daily and hourly: Derived from Newcastle and Sydney Ferries timetables	- *Ferry Timetables, NSW Transport and Infrastructure* (TI, 2010) - *Timetables and Maps, Newcastle Buses and Ferries* (NBF, 2010)
Commercial off-road vehicles and equipment	Monthly, daily and hourly: Derived from commercial off-road vehicles and equipment pollution survey	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)
Industrial off-road vehicles and equipment	Monthly, daily and hourly: Derived from industrial off-road vehicles and equipment pollution survey	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)
Locomotives	Monthly: Derived from Australian Rail Track Corporation gross tonne kilometre data for the GMR	- *GMR and NSW GTK 2008* (ARTC, 2009)
	Daily: Derived from Pacific National gross tonne kilometre data by NSW region	- *Rail Movement Data in NSW Broken Down by Region 2003* (Pacific National, 2005)
	Hourly: Derived from inverse of hourly passenger train volumes	- *Analysis of Peak Hour Travel Using the Sydney Household Travel Survey Data* (TPDC, 2006)
Recreational boats	Monthly, daily and hourly: Derived from domestic survey	- *Recreational Boat Pollution Survey* (TR, 2009)
Ships	Monthly, daily and hourly: Derived from ship logs	- *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009)

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

2.6.4 *Design and Implement Emission Estimation Techniques*

All emissions have been calculated within the Off-Road Mobile 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 off-road mobile 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 Off-Road Mobile Emissions Data Management System v1.0 start-up form is shown in Figure 2-3.

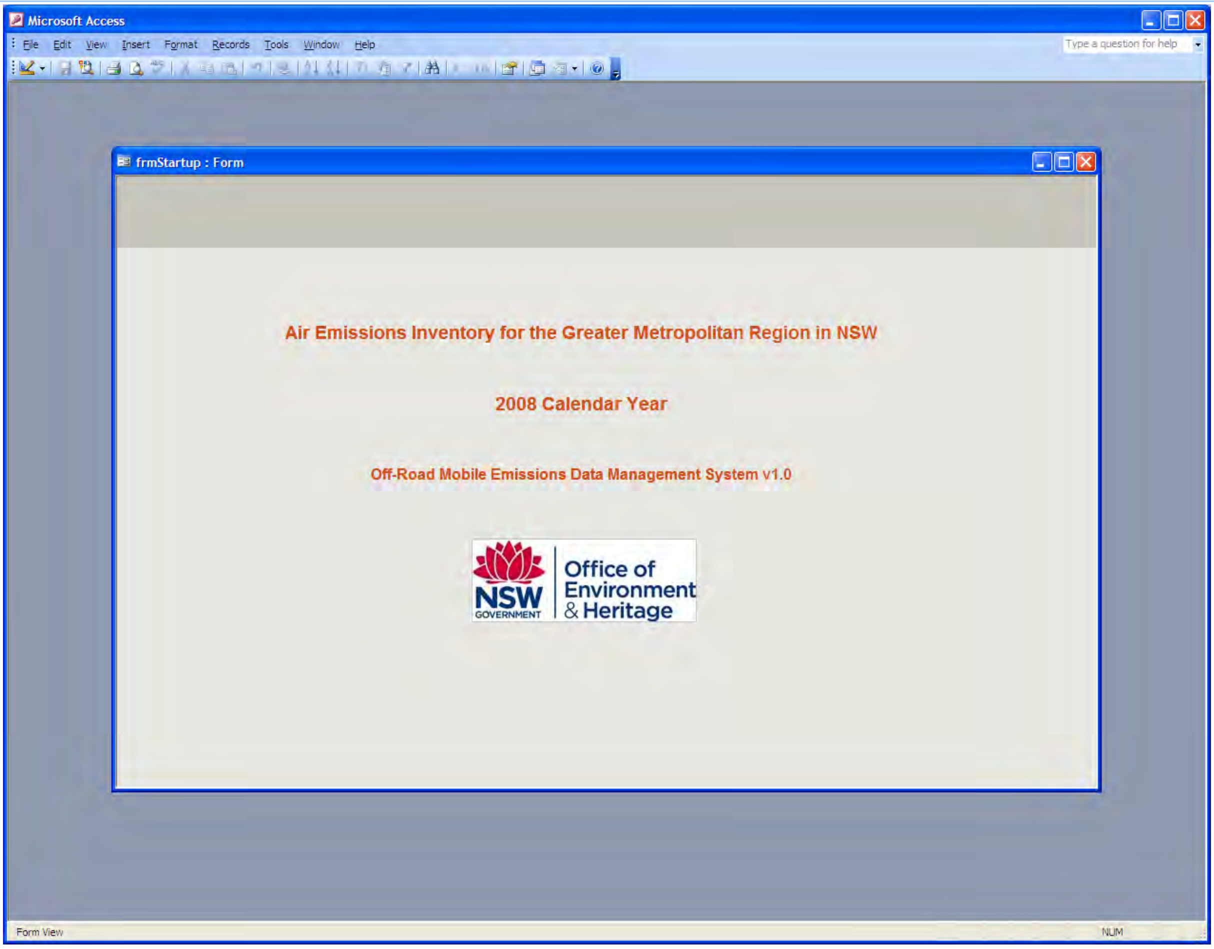

Figure 2-3: Off-Road Mobile Emissions Data Management System v1.0 start-up form

In general, emissions have been estimated using Equation 1:

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

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 off-road mobile 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); and
- Total dwelling 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:

$$\mathbf{E_{i,j,n} = E_{i,j,2008} \times PF_{j,n}} \qquad \textbf{Equation 2}$$

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: Off-road mobile projection factors

Source type	Projection factor surrogate	Projection factor source
Aircraft (flight operations)	Final energy consumption for air transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Aircraft (ground operations)	Final energy consumption for air transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Commercial boats	Final energy consumption for agriculture, commercial & services and domestic water transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Commercial off-road vehicles and equipment	Final energy consumption for agriculture, manufacturing & construction and mining using liquid petroleum gas, petroleum and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Industrial off-road vehicles and equipment	Final energy consumption for manufacturing & construction and mining using liquid petroleum gas, petroleum and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Locomotives	Final energy consumption for rail transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Recreational boats	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)
Ships	Final energy consumption for international water transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

Detailed emission projection factors for each off-road mobile source are presented in Section 3.

3 DATA SOURCES AND RESULTS

This section presents the: detailed emission estimation methodologies; activity, spatial and temporal data sources used; and the associated emission estimates for the 2008 calendar year for the following off-road mobile sources:

- Aircraft (flight operations);
- Aircraft (ground operations);
- Commercial boats;
- Commercial off-road vehicles and equipment;
- Industrial off-road vehicles and equipment;
- Locomotives;
- Recreational boats; and
- Ships.

For each off-road mobile 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.

Off-road mobile 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 Off-Road Mobile 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 off-road mobile 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 off-road mobile 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)

These substances were selected since they are:

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

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

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

Total off-road mobile 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 Off-Road Mobile Sources.

3.1 Aircraft (flight operations) and aircraft (ground operations)

3.1.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from:
    - Aircraft engines during the LTO cycle; and
    - Ground support equipment (GSE) and auxiliary power unit (APU) engines.
- Evaporative VOC from the transfer of fuel to:
    - On-site storage tanks;
    - Tankers; and
    - Aircraft.

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

- *Airport location, aircraft schedules, BADA and ICAO aircraft and engine data*

There are nine airports considered in this inventory, including Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong.

Aircraft schedules have been obtained from Airservices Australia (ASA) and Bureau of Infrastructure, Transport and Regional Economics (BITRE), which contain amongst other data, airport code, unique flight key, aircraft type code and time and date of arrival and departure (ASA, 2009a; ASA, 2009b; and BITRE, 2010).

The aircraft schedules have been used to establish the number of arrivals and departures of each aircraft type from each airport and the hourly, daily and monthly temporal variation in flights.

Each aircraft listed in the aircraft schedules has been matched with data from the Eurocontrol Base of Aircraft Data (BADA, 2009) and the International Civil Aviation Organization (ICAO, 2010) to establish detailed aircraft type, engine and fuel characteristics (FAA, 2009).

Figure 3-1 shows how aircraft schedules, BADA/ICAO aircraft and activity data have been combined with emission factor data to develop an inventory of aircraft emissions (FAA, 2009).

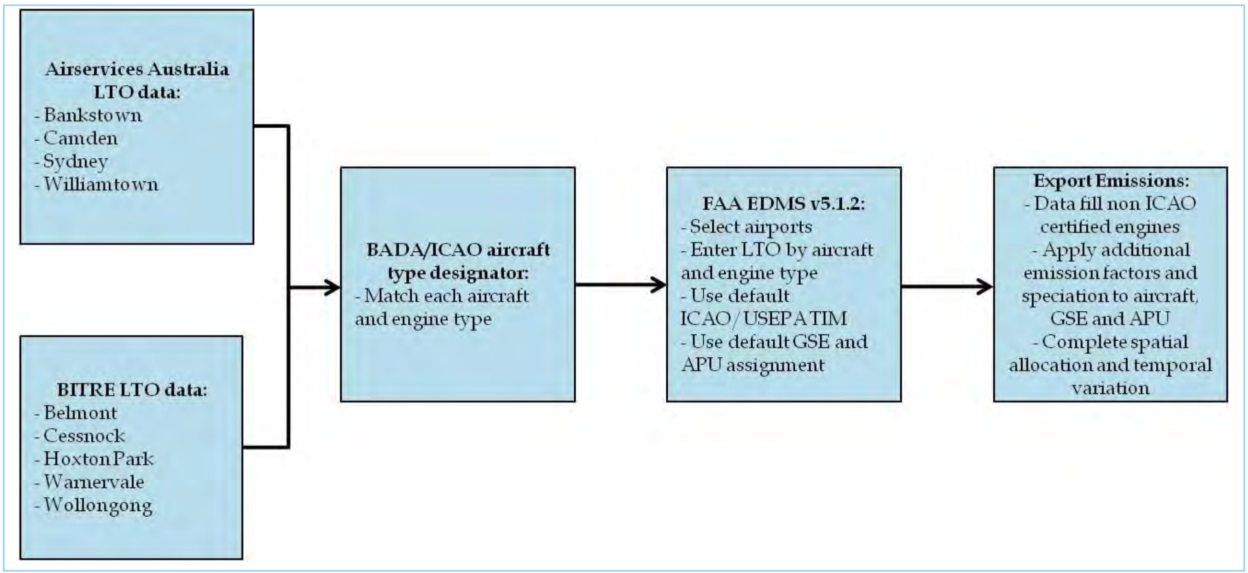

Figure 3-1: Aircraft – use of aircraft schedules, BADA and ICAO data

- *Aircraft type*

The inventory includes all aircraft types used for public, private, and military purposes. This includes four types of aircraft:

- *Air taxi* – used for transporting passengers and/or freight. They tend to be smaller aircraft powered by either jet or piston engines. These aircraft are only used for domestic travel;
- *Commercial* - used for transporting passengers and/or freight. They tend to be larger aircraft powered by jet engines and operate through larger airports. These aircraft are used for domestic and international travel;
- *General aviation* - used for recreational flying, personal transportation and unscheduled business transportation. They tend to be smaller aircraft powered by piston engines, although some smaller unscheduled business aircraft are powered by jet engines; and
- *Military* – used for military purposes only. They include a wide variety such as trainer, fighter and helicopter aircraft, which are powered by either jet or piston engines.

Aircraft can be categorised in a number of ways, either by size, designation, engine type, usage or European category (BADA, 2009; ICAO, 2010; and FAA, 2009).

Table 3-1 presents the various aircraft included in the inventory by category, type and code for the nine airports considered (ASA, 2009a; ASA, 2009b; and BITRE, 2010).

Table 3-1: Aircraft category, type and code

Aircraft category	Aircraft type	Aircraft code
Size	Heavy (MTOW[4] over 255,000 lb)	H
	Large (MTOW 41,001 to 255,000 lb)	L
	Small (MTOW 41,000 lb or less)	S
Designation	Civil	C
	Military	M
	General Aviation	G
Engine Type	Jet	J
	Turboprop/Turboshaft	T
	Piston	P
Usage	Passenger or VIP Transport	P
	Cargo or General Transport	C
	Business	B
	Helicopter	H
	Combat or Attack	A
	Other	O
European Category	Light Helicopter	H1
	Heavy Helicopter	H2
	Business Jet	JB
	Large Jet	JL
	Medium Jet	JM
	Regional Jet	JR
	Small Jet	JS
	Propeller	PP
	Supersonic	SS
	Turboprop	TP

➢ *Ground support equipment (GSE) and auxiliary power unit (APU) type*

Ground support equipment and APU are used while the aircraft is stationary at the gate.

When the aircraft arrives at the gate, GSE are used to unload baggage and service the lavatory and cabin. While the aircraft is parked at the gate, mobile generators and air conditioning units are used to provide electricity and air conditioning. Prior to aircraft departure, GSE are used to load baggage, food and fuel. When an aircraft departs from the gate, a tug is used to push or tow the aircraft to the taxiway.

[4] Maximum take-off weight.

Auxiliary power units are mainly on-board generators that provide electrical power to the aircraft while its engines are shut down. While some pilots start the on-board APU while taxiing to the gate, they are mainly started when the aircraft reaches the gate. The inventory includes the following types of GSE and APU:

- *Air conditioner;*
- *Air start;*
- *Aircraft tractor;*
- *Baggage tractor;*
- *Belt loader;*
- *Bobtail;*
- *Cabin service truck;*
- *Cargo loader;*
- *Cargo tractor;*
- *Cart;*
- *Catering truck;*
- *De-icer;*
- *Fork lift;*
- *Fuel truck;*
- *Generator;*
- *Ground power unit;*
- *Hydrant truck;*
- *Lavatory truck;*
- *Lift;*
- *Passenger stand;*
- *Service truck;*
- *Sweeper; and*
- *Water service.*

- *Aircraft engine type*

The inventory includes all engine types used for public, private, and military purposes. This includes two major types of engine:

  - *Reciprocating piston* – the fuel and air mixture is burned in the combustion chamber and the energy is transferred by a piston and crank mechanism to the propeller; and

  - *Gas turbine* – these can be grouped into three types including, turbofan, turboprop and turbojet. A gas turbine engine consists of three major components including, compressor, combustion chamber and turbine. In all three types of gas turbine engine, air enters the front of the engine, is compressed and the fuel and air mixture is then burned in the combustion chamber. In turbofan and turboprop engines, the energy generated in the combustion chamber is used to drive the turbine for propulsion. In turbojet engines, the expanding exhaust gases are used for propulsion and energy from the turbine only drives the compressor.

Commercial and military aircraft are dominated by gas turbine engines, while civilian aircraft have a larger proportion of piston engines compared with gas turbine engines.

Piston engines use gasoline-like fuel or "Avgas" while gas turbine engines use a kerosene-like fuel or "Avtur".

There is a wide variety of engine models in each engine type. Many aircraft use only a single engine model, while others may use two or three different engine models. Air pollutant emissions are dependent upon the engine type, engine model and aircraft type (FAA, 2009).

- *Ground support equipment (GSE) and auxiliary power unit (APU) engine type*

The inventory includes GSE and APU powered by diesel compression ignition (CI) engines.

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

- *Aircraft fuel type*

The inventory includes aircraft that use two fuel types, including gasoline-like "Avgas" and kerosene-like "Avtur". Reciprocating piston engines use Avgas, while gas turbines use Avtur.

Table 3-2 presents the aircraft fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2008a).

Table 3-2: Aircraft (flight operations) fuel type and properties

Fuel type	Lead content (g/L)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Aviation gasoline (Avgas)	0.80	0.708	33.1	85
Aviation turbine fuel (Avtur)	-	0.793	36.8	85

- *Ground support equipment (GSE) and auxiliary power unit (APU) fuel type*

The inventory includes GSE and APU that use automotive diesel oil (ADO).

Table 3-3 presents the GSE and APU fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). The sulfur content in ADO are requirements of the *Fuel Standard (Automotive Diesel) Determination 2001* (Attorney-General's Department, 2009), which are relevant for the 2008 calendar year.

Table 3-3: Aircraft (ground operations) GSE and APU fuel type and properties

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

- *Mode of operation*

Aircraft flight operations are divided into two major parts:

- *Landing/Take-off (LTO) cycle* - includes all activities near the airport that take place below the altitude of 3,000 ft (i.e. 914.4 m). This includes approach, taxi/idle-in, start-up, taxi/idle-out, take-off and climb-out modes of operation; and
- *Cruise cycle* – includes all activities that take place at altitudes above 3,000 ft (i.e. 914.4 m), with no upper limit to the altitude. Cruise includes the climb from the end of climb-out in the LTO cycle to cruise altitude, cruise and descent from cruise altitude to the beginning of descent in the LTO cycle.

The LTO and cruise cycles are shown in Figure 3-2 (EEA, 2010).

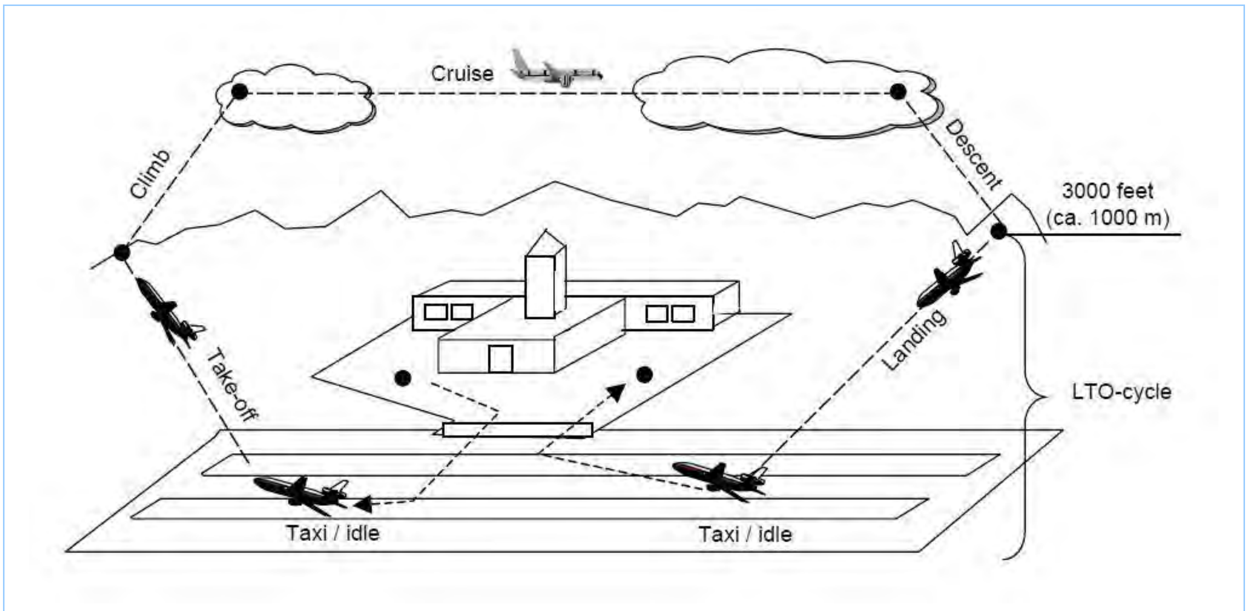

Figure 3-2: Aircraft LTO and cruise cycle

The inventory includes only those activities which take place during the LTO cycle.

The inventory includes aircraft emissions that occur within the mixed layer, which is a vertical column of air that begins at the earth's surface and is equal in depth to the inversion layer. When aircraft operate within the mixed layer, air pollutants are trapped by the inversion layer and impact on ground-level air quality. Conversely, when aircraft operate above the mixed layer, air pollutants have little interaction with the mixed layer and have negligible impacts on ground-level air quality. The aircraft operations which occur within the mixed layer are defined as the Landing/Take-off (LTO) cycle. Each LTO cycle consists of six specific operating modes:

- *Approach* - the aircraft operates in this mode when it approaches the airport on its descent from the mixing height until it lands on the runway. It includes both the descent and landing phases of the LTO cycle;
- *Taxi/idle-in* - the aircraft operates in this mode when it taxis from the runway to the gate;
- *Start-up* – the aircraft operates in this mode at the gate;
- *Taxi/idle-out* - the aircraft operates in this mode when it taxis from the gate to the runway;
- *Take-off* – the aircraft operates in this mode at maximum engine power until it reaches between 500 ft (i.e. 152.4 m) and 1,000 ft (i.e. 304.8 m) above ground level when the engine power is reduced; and
- *Climb-out* – the aircraft operates in this mode after the take-off mode (i.e. between 500 ft (i.e. 152.4 m) and 1,000 ft (i.e. 304.8 m)) until the aircraft reaches 3,000 ft (i.e. 914.4 m).

The LTO cycle is shown in Figure 3-3 (FAA, 2009).

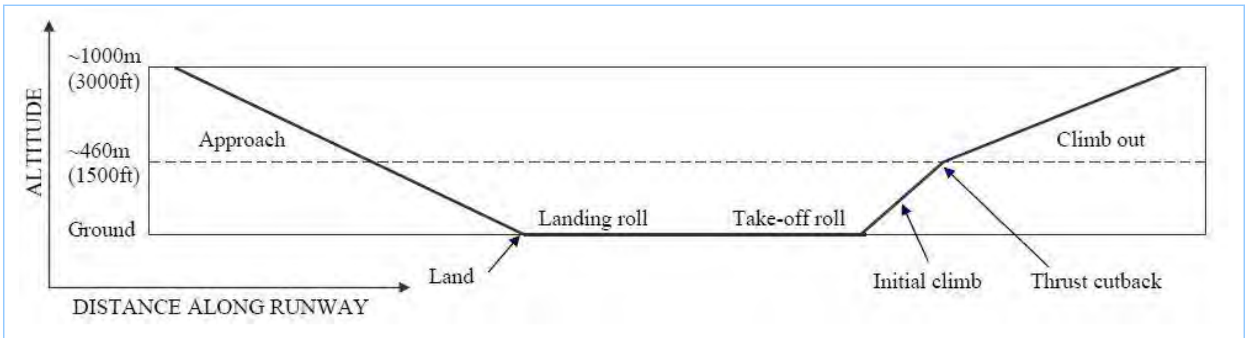

Figure 3-3: Aircraft LTO cycle

The operation time in each of these modes is dependent on the aircraft type, local meteorology and airport procedures. The inventory uses the default ICAO/USEPA LTO cycle time-in-mode (TIM) parameters (FAA, 2009).

3.1.2 *Emission Estimation Methodology*

Table 3-4 summarises the emission estimation methodologies used for aircraft (flight operations) and aircraft (ground operations).

Table 3-4: Aircraft (flight operations) and aircraft (ground operations) emission estimation methodologies

Emission source	Emission estimation methodology source
Flight operations: Exhaust emissions from aircraft	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
Ground operations: Evaporative emissions from the transfer of fuel to on-site storage tanks, tankers and aircraft	- *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)

➢ *Aircraft engine exhaust*

Exhaust emissions from aircraft have been estimated using aircraft type and LTO data in combination with time-in-mode (TIM) and emission factor data within the *FAA EDMS v5.1.2 Model* (FAA, 2009).

Exhaust emissions from aircraft have been estimated using Equation 3 within the *FAA EDMS v5.1.2 Model* (FAA, 2009):

$$\mathbf{E_{i,j,k,l,m,n} = NLTO_{j,k,l,m} \times NE_{j,k} \times TIM_{j,k,n} \times FF_{j,k,n} \times EF_{i,j,k,l,m,n}} \qquad \textbf{Equation 3}$$

where:

$E_{i,j,k,l,m,n}$	=	Emissions of substance i, from aircraft model j, engine model k, aircraft type l and engine type m during mode of operation n	(kg/year)
$NLTO_{j,k,l,m}$	=	Landing/take-off cycles for aircraft model j, engine model k, aircraft type l and engine type m	(number/year)
$NE_{j,k}$	=	Engines for aircraft model j and engine model k	(number)
$TIM_{j,k,n}$	=	Time-in-mode for aircraft model j and engine model k during mode of operation n	(min)
$FF_{j,k,n}$	=	Fuel flowrate for aircraft model j and engine model k during mode of operation n	(kL/min)
$EF_{i,j,k,l,m,n}$	=	Emission factor for substance i, from aircraft model j, engine model k, aircraft type l and engine type m during mode of operation n	(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	=	Aircraft model (e.g. Boeing 737-800 Series)	(-)
k	=	Engine model (e.g. CFM56-7B26 Turbofan)	

where:			
l	=	Aircraft type (either "air taxi", "commercial", "general aviation" or "military")	(-)
m	=	Engine type (either "reciprocating piston using Avgas" or "gas turbine using Avtur")	(-)
n	=	Mode of operation (either "approach", "taxi/idle-in", "start-up", "taxi/idle-out", "take-off" or "climb-out")	(-)

➢ *Ground support equipment (GSE) and auxiliary power unit (APU) exhaust*

Exhaust emissions from GSE and APU have been estimated using the default GSE and APU assignments for population and activity data in combination with emission and load factors within the *FAA EDMS v5.1.2 Model* (FAA, 2009):

Exhaust emission factors have been adjusted according to fuel sulfur content for diesel engines (FAA, 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 (FAA, 2009).

Exhaust emissions from GSE and APU have been estimated using Equation 4 within the *FAA EDMS v5.1.2 Model* (FAA, 2009):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times EF_{i,j,k,l,m} / 1000} \qquad \textbf{Equation 4}$$

where:			
$E_{i,j,k,l,m}$	=	Emissions of substance i from ground support equipment and auxiliary power unit type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of ground support equipment and auxiliary power unit type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of ground support equipment and auxiliary power unit type j, engine type k and engine power range l	(h/year)
$HP_{j,k,l}$	=	Maximum rated power of ground support equipment and auxiliary power unit type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for ground support equipment and auxiliary power unit type j, engine type k and engine power range l	(hp/hp)
$EF_{i,j,k,l,m}$	=	Emission factor for substance i from ground support equipment and auxiliary power unit 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")	(-)

where:			
j	=	Ground support equipment and auxiliary power unit type (either "Air conditioner", "Air start", "Aircraft tractor", "Baggage tractor", "Belt loader", "Bobtail", "Cabin service truck", "Cargo loader", "Cargo tractor", "Cart", "Catering truck", "Deicer", "Fork lift", "Fuel truck", "Generator", "Ground power unit", "Hydrant truck", "Lavatory truck", "Lift", "Passenger stand", "Service truck", "Sweeper" or "Water service")	(-)
k	=	Engine type ("diesel")	(-)
l	=	Engine power range	(hp)
m	=	Source type ("exhaust")	(-)
1000	=	Conversion factor	(g/kg)

➢ *Transfer of fuel to on-site storage tanks, tankers and aircraft*

Evaporative VOC emissions from the transfer of fuel to on-site storage tanks, tankers and aircraft have been estimated using emission factors combined with Avgas and Avtur fuel sales data within Equation 5 (USEPA, 2008b):

$$\mathbf{E_{VOC,i} = EF_{VOC,i} \times A_i} \qquad \textbf{Equation 5}$$

where:			
$E_{VOC,i}$	=	Emissions of VOC from fuel type i	(kg/year)
$EF_{VOC,i}$	=	VOC emission factor for fuel type i (Equation 6)	(kg/kL)
A_i	=	Amount of fuel type i loaded	(kL/year)
i	=	Fuel type (either "Avgas" or "Avtur")	(-)

Emission factors for the transfer of fuels have been estimated using Equation 6 (USEPA, 2008b):

$$\mathbf{EF_{VOC,i} = 12.46 \times \frac{S_j \times P_i \times M_i}{T} \times \left(1 - \frac{eff_j}{100}\right) \times \frac{0.4536}{3.7862}} \qquad \textbf{Equation 6}$$

where:			
$EF_{VOC,i}$	=	VOC emission factor for fuel type i	(kg/kL)
S_j	=	Saturation factor for loading type j (Table 5.2-1; USEPA, 2008b) - 0.6, 0.6 and 1.45 for loading to storage tanks (Submerged loading: dedicated normal service), loading to tankers (Submerged loading: dedicated normal service) and refuelling aircraft (Splash loading of a clean cargo tank), respectively	(-)

where:

P_i	=	True vapour pressure of fuel type i (Table 7.1-2; USEPA, 2006) – 3.5 and 0.0085 for Avgas and Avtur, respectively	(psia)
M_i	=	Molecular weight of vapour for fuel type i (Table 7.1-2; USEPA, 2006) – 68 and 130 for Avgas and Avtur, respectively	(lb/lb.mol)
T	=	Temperature of bulk liquid loaded (Table 7.1-2; USEPA, 2006) – 520	(°R)
f_j	=	Overall reduction efficiency for loading type j – 95.92%[5], 0% and 0% for loading to storage tanks (i.e. stage 1 vapour recovery), loading to tankers and refuelling aircraft, respectively	
i	=	Fuel type (either "Avgas"or "Avtur")	(-)
j	=	Loading type (either "storage tanks", "tankers" or "refuelling aircraft")	(-)
0.4536	=	Conversion factor	(lb/kg)
3.7862	=	Conversion factor	(L/US gal)

3.1.3 *Activity Data*

Table 3-5 summarises the activity data used for aircraft (flight operations) and aircraft (ground operations).

Table 3-5: Aircraft (flight operations) and aircraft (ground operations) activity data

Activity data	Activity data source
Landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports to estimate aircraft emissions	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports to estimate ground support equipment (GSE) and auxiliary power unit (APU) emissions	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Avgas and Avtur sales data to estimate storage, transfer and refuelling emissions	- *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)

[5] Estimated from the Industrial Off-Road Vehicles and Equipment Pollution Survey (DECCW, 2009).

Aircraft schedules have been obtained from Airservices Australia (ASA) and Bureau of Infrastructure, Transport and Regional Economics (BITRE), which contain amongst other data, airport code, unique flight key, aircraft type code and time and date of arrival and departure (ASA, 2009a; ASA, 2009b; and BITRE, 2010).

The aircraft schedules have been used to establish the number of arrivals and departures of each aircraft type from each airport and the hourly, daily and monthly temporal variation in flights.

Each aircraft listed in the aircraft schedules has been matched with data from the Eurocontrol Base of Aircraft Data (BADA, 2009) and the International Civil Aviation Organization (ICAO, 2010) to establish detailed aircraft type, engine and fuel characteristics (FAA, 2009).

Table 3-6 presents arrivals and departure by aircraft model at each of the nine airports in the GMR.

Arrivals and departure by aircraft type at each of the nine airports in the GMR are presented in Table 3-7 and shown in Figure 3-4.

Arrivals and departure by engine type at each of the nine airports in the GMR are presented in Table 3-8 and shown in Figure 3-5.

Arrivals and departure by usage at each of the nine airports in the GMR are presented in Table 3-9 and shown in Figure 3-6.

Arrivals and departure by European category at each of the nine airports in the GMR are presented in Table 3-10 and shown in Figure 3-7.

Table 3-6: Aircraft arrivals and departures by aircraft model

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Aerostar PA-60	249	13	5	32	5	52	12	4	4	375
Agusta A-109	365	8	3	19	3	49	7	12	2	468
Air Tractor 802	2	11	4	25	4	-	9	-	3	58
Air Tractor AT-502	3	-	-	-	-	-	-	-	-	3
Airbus A310-200 Series	-	-	-	-	-	20	-	-	-	20
Airbus A319-100 Series	-	-	-	-	-	13	-	-	-	13
Airbus A320-100 Series	1	-	-	-	-	27,981	-	5,521	-	33,503
Airbus A321-100 Series	1	-	-	-	-	5	-	10	-	16
Airbus A330-200 Series	-	-	-	-	-	5,717	-	-	-	5,717
Airbus A330-300 Series	-	-	-	-	-	7,355	-	-	-	7,355
Airbus A340-200 Series	-	-	-	-	-	291	-	-	-	291
Airbus A340-300 Series	-	-	-	-	-	1,100	-	-	-	1,100
Airbus A340-500 Series	-	-	-	-	-	2,163	-	-	-	2,163
Airbus A340-600 Series	-	-	-	-	-	824	-	-	-	824
Airbus A380-800	-	-	-	-	-	820	-	-	-	820
Antonov 124 Ruslan	-	-	-	-	-	-	-	8	-	8
ATR 42-200	666	-	-	-	-	7	-	-	-	673
Aviat Husky A1B	49	1,092	407	2,573	383	-	950	-	298	5,753
Avro RJ-70	34	1,610	600	3,794	564	-	1,401	-	440	8,443
Ayres S2R-T34 Turbo-Thrush	6	-	-	-	-	-	-	-	-	6
BAE 146-100	1	-	-	-	-	688	-	-	-	689
BAE 146-200	-	-	-	-	-	12	-	-	-	12
BAE 146-300	1	-	-	-	-	1,086	-	-	-	1,087
BAE Jetstream 31	42	-	-	-	-	4,142	-	4,397	-	8,581
BAE Jetstream 41	-	-	-	-	-	4	-	1,021	-	1,025

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Bell 206 JetRanger	6,503	191	71	449	67	5,706	166	90	52	13,294
Bell AH-1J Cobra	2,500	32	12	76	11	46	28	6	9	2,720
Bell UH-1 Iroquois	64	-	-	-	-	1	-	-	-	65
Boeing 707-300 Series	-	-	-	-	-	6	-	2	-	8
Boeing 727-100 Series	-	-	-	-	-	10	-	-	-	10
Boeing 727-200 Series	-	-	-	-	-	474	-	-	-	474
Boeing 737-200 Series	-	-	-	-	-	419	-	108	-	527
Boeing 737-300 Series	180	-	-	-	-	971	-	2	-	1,153
Boeing 737-400 Series	2	-	-	-	-	13,790	-	-	-	13,792
Boeing 737-700 Series	-	3	1	6	1	20,538	2	1,300	1	21,852
Boeing 737-800 Series	-	-	-	-	-	63,546	-	940	-	64,486
Boeing 747-100 Series	-	-	-	-	-	36	-	-	-	36
Boeing 747-200 Series	-	-	-	-	-	190	-	-	-	190
Boeing 747-300 Series	-	-	-	-	-	1,402	-	-	-	1,402
Boeing 747-400 Series	-	-	-	-	-	15,160	-	-	-	15,160
Boeing 747-SP	-	-	-	-	-	4	-	-	-	4
Boeing 757-200 Series	1	-	-	-	-	138	-	-	-	139
Boeing 767-200 Series	1	-	-	-	-	349	-	-	-	350
Boeing 767-300 Series	1	-	-	-	-	29,983	-	-	-	29,984
Boeing 777-200 Series	-	-	-	-	-	4,468	-	-	-	4,468
Boeing 777-200-ER	-	-	-	-	-	240	-	-	-	240
Boeing 777-300 ER	-	-	-	-	-	1,307	-	-	-	1,307
Boeing 777-300 Series	-	-	-	-	-	1,492	-	-	-	1,492
Boeing C-17A	-	-	-	-	-	8	-	58	-	66
Boeing DC-10-10 Series	-	-	-	-	-	2	-	-	-	2
Boeing DC-3	3	-	-	-	-	-	-	-	-	3
Boeing DC-8 Series 60	-	-	-	-	-	2	-	-	-	2

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Boeing F/A-18 Hornet	-	-	-	-	-	-	-	510	-	510
Boeing F-15 Eagle	-	-	-	-	-	-	-	4	-	4
Boeing KC-135 Stratotanker	-	-	-	-	-	2	-	10	-	12
Boeing MD-11	-	-	-	-	-	1,130	-	-	-	1,130
Boeing MD-82	-	-	-	-	-	38	-	-	-	38
Boeing Stearman PT-17 / A75N1	68	759	283	1,789	266	-	661	-	207	4,034
Bombardier Challenger 600	2	-	-	-	-	567	-	71	-	640
Bombardier de Havilland Dash 8 Q100	-	-	-	-	-	1,468	-	139	-	1,607
Bombardier de Havilland Dash 8 Q200	1	-	-	-	-	3,497	-	123	-	3,621
Bombardier de Havilland Dash 8 Q300	2	-	-	-	-	16,427	-	777	-	17,206
Bombardier de Havilland Dash 8 Q400	-	-	-	-	-	10,141	-	-	-	10,141
Bombardier Global Express	6	-	-	-	-	373	-	-	-	379
Bombardier Learjet 35	-	-	-	-	-	164	-	125	-	289
Bombardier Learjet 45	21	-	-	-	-	148	-	6	-	175
Bombardier Learjet 60	-	-	-	-	-	24	-	-	-	24
CASA 212-100 Series	2	-	-	-	-	9	-	-	-	11
CASA C-101 Aviojet	-	-	-	-	-	-	-	22	-	22
Cessna 150 Series	40,381	2,093	780	4,932	734	6	1,821	6	572	51,324
Cessna 172 Skyhawk	7,789	4,167	1,553	9,819	1,460	16	3,626	36	1,138	29,605
Cessna 182	2,526	4,790	1,785	11,286	1,679	1	4,168	2	1,308	27,545
Cessna 206	617	145	54	341	51	-	126	-	40	1,374
Cessna 208 Caravan	933	3	1	6	1	6	2	3	1	956
Cessna 210 Centurion	298	64	24	152	23	-	56	-	18	634
Cessna 310	285	46	17	107	16	49	40	2	12	574
Cessna 337 Skymaster	28	5	2	13	2	-	5	-	1	56
Cessna 340	140	48	18	114	17	2	42	-	13	394
Cessna 402	81	16	6	38	6	-	14	4	4	169

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Cessna 404 Titan II	164	-	-	-	-	302	-	4	-	470
Cessna 414	175	75	28	177	26	6	65	2	21	575
Cessna 421 Golden Eagle	29	-	-	-	-	-	-	-	-	29
Cessna 441 Conquest II	175	5	2	13	2	231	5	10	1	444
Cessna 500 Citation I	58	-	-	-	-	55	-	2	-	115
Cessna 501 Citation ISP	67	3	1	6	1	16	2	4	1	101
Cessna 525 CitationJet	220	5	2	13	2	294	5	8	1	550
Cessna 550 Citation II	274	-	-	-	-	122	-	66	-	462
Cessna 560 Citation Excel	56	-	-	-	-	16	-	-	-	72
Cessna 560 Citation V	257	3	1	6	1	149	2	2	1	422
Cessna 650 Citation III	295	-	-	-	-	309	-	2	-	606
Cessna 680 Citation Sovereign	2	-	-	-	-	41	-	2	-	45
Cessna 750 Citation X	97	-	-	-	-	24	-	-	-	121
Cessna T-37 Tweet	8	-	-	-	-	-	-	-	-	8
Cirrus SR20	30	-	-	-	-	1	-	-	-	31
Cirrus SR22	356	21	8	51	8	8	19	1	6	477
Convair CV-580	207	-	-	-	-	370	-	2	-	579
Dassault Falcon 100	-	-	-	-	-	8	-	-	-	8
Dassault Falcon 2000	-	-	-	-	-	24	-	2	-	26
Dassault Falcon 50	-	-	-	-	-	2	-	-	-	2
Dassault Falcon 900	-	-	-	-	-	153	-	-	-	153
DeHavilland DHC-2 Mk III Beaver	482	83	31	196	29	-	72	-	23	916
DeHavilland DHC-3 Otter	40	-	-	-	-	-	-	-	-	40
DeHavilland DHC-6-100 Twin Otter	4	-	-	-	-	-	-	3	-	7
Dornier 228-100 Series	444	-	-	-	-	4	-	-	-	448
Dornier 328-100 Series	-	-	-	-	-	2	-	-	-	2
EADS Socata TB-10 Tobago	1,698	5	2	13	2	-	5	-	1	1,726

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
EADS Socata TBM-700	22	5	2	13	2	57	5	1	1	108
EADS Socata TBM-850	4	-	-	-	-	16	-	3	-	23
Embraer EMB110 Bandeirante	7	-	-	-	-	536	-	597	-	1,140
Embraer EMB120 Brasilia	29	-	-	-	-	458	-	-	-	487
Embraer ERJ135	-	-	-	-	-	18	-	-	-	18
Embraer ERJ145	-	-	-	-	-	20	-	2	-	22
Embraer ERJ170	1	-	-	-	-	8,704	-	-	-	8,705
Embraer ERJ190	-	-	-	-	-	442	-	2	-	444
Fairchild SA-226-T Merlin III	135	5	2	13	2	118	5	6	1	287
Fairchild SA-227-AC Metro III	2,458	8	3	19	3	2,797	7	1,052	2	6,349
Fokker F100	2	-	-	-	-	34	-	6	-	42
Fokker F28-1000 Series	-	-	-	-	-	2	-	-	-	2
Fokker F50	2	-	-	-	-	-	-	-	-	2
General Dynamics F-111 Raven	-	-	-	-	-	-	-	8	-	8
Grumman G-21G Goose	1	-	-	-	-	-	-	-	-	1
Gulfstream G400	-	-	-	-	-	189	-	4	-	193
Gulfstream G500	-	-	-	-	-	251	-	2	-	253
Gulfstream II	-	-	-	-	-	2	-	-	-	2
Hawker HS-125 Series 700	4	-	-	-	-	289	-	68	-	361
Hawker Hunter	1	-	-	-	-	-	-	256	-	257
Hughes 500D	42	21	8	51	8	-	19	-	6	154
Ilyushin 62 Classic	-	-	-	-	-	2	-	-	-	2
Israel IAI-1124 Westwind I	7	-	-	-	-	459	-	177	-	643
Lancair 360	107	97	36	228	34	-	84	-	26	612
Lockheed C-130 Hercules	-	-	-	-	-	-	-	88	-	88
Lockheed C-5 Galaxy	-	-	-	-	-	-	-	2	-	2
Lockheed L-1011 Tristar	-	-	-	-	-	4	-	-	-	4

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Lockheed P-3 Orion	-	-	-	-	-	-	-	8	-	8
Mitsubishi MU-2	4	-	-	-	-	-	-	-	-	4
Mooney M20-K	218	134	50	316	47	4	117	-	37	923
Partenavia P.68 Victor	775	531	198	1,252	186	2	462	4	145	3,556
Pilatus PC-12	215	-	-	-	-	75	-	4	-	294
Pilatus Turbo Trainer PC-9	8	-	-	-	-	-	-	119	-	127
Piper PA-23 Apache/Aztec	802	27	10	63	9	4	23	8	7	954
Piper PA-24 Comanche	37	21	8	51	8	-	19	2	6	151
Piper PA-27 Aztec	69	-	-	-	-	-	-	4	-	73
Piper PA-28 Cherokee Series	19,880	2,351	876	5,539	824	6	2,045	25	642	32,188
Piper PA-30 Twin Comanche	7,152	1,014	378	2,390	355	26	883	5	277	12,480
Piper PA-31 Navajo	6,709	81	30	190	28	1,718	70	578	22	9,425
Piper PA-31T Cheyenne	2	-	-	-	-	-	-	-	-	2
Piper PA-32 Cherokee Six	387	51	19	120	18	-	44	-	14	653
Piper PA-34 Seneca	186	295	110	696	103	14	257	15	81	1,757
Piper PA-42 Cheyenne Series	35	-	-	-	-	-	-	-	-	35
Piper PA46-TP Meridian	183	5	2	13	2	-	5	-	1	211
Raytheon Beech 1900-C	2	-	-	-	-	2,570	-	4	-	2,576
Raytheon Beech 55 Baron	92	62	23	145	22	44	54	6	17	464
Raytheon Beech 60 Duke	73	-	-	-	-	-	-	-	-	73
Raytheon Beech Baron 58	562	140	52	329	49	47	121	10	38	1,348
Raytheon Beech Bonanza 36	684	217	81	512	76	62	189	-	59	1,881
Raytheon Beechjet 400	20	-	-	-	-	290	-	2	-	312
Raytheon Hawker 1000	-	-	-	-	-	12	-	-	-	12
Raytheon King Air 90	17	343	128	809	120	-	299	-	94	1,811
Raytheon Premier I	38	-	-	-	-	176	-	-	-	214
Raytheon Super King Air 200	339	11	4	25	4	5,880	9	1,481	3	7,756

Aircraft model	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Raytheon Super King Air 300	137	-	-	-	-	148	-	51	-	336
Robin R 2160 Alpha Sport	2,673	11	4	25	4	-	9	-	3	2,729
Robinson R22	6,128	486	181	1,144	170	137	423	5	133	8,807
Rockwell Commander 500	1,567	-	-	-	-	2	-	506	-	2,075
Rockwell Commander 680	33	-	-	-	-	-	-	-	-	33
Rockwell Commander 690	1	-	-	-	-	1	-	-	-	2
Ryan Navion B	2	-	-	-	-	-	-	-	-	2
Saab 340-A	8	-	-	-	-	26,937	-	-	-	26,945
Shorts Skyvan SC7-3-1	26	-	-	-	-	-	-	-	-	26
Sikorsky CH-53 Sea Stallion	7	-	-	-	-	-	-	-	-	7
Sikorsky S-76 Spirit	29	-	-	-	-	236	-	56	-	321
Sikorsky UH-60 Black Hawk	-	-	-	-	-	3	-	3	-	6
Grand Total	120,915	21,215	7,906	49,988	7,435	301,614	18,460	20,599	5,794	553,926

Table 3-7: Aircraft arrivals and departures by aircraft type

Aircraft type	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Air Taxi – Jet	426	12	4	24	4	752	8	18	4	1,252
Air Taxi – Piston	87,596	17,475	6,513	41,182	6,125	122	15,211	593	4,772	179,591
Commercial	4,738	1,637	610	3,857	574	288,953	1,424	17,560	446	319,796
General Aviation – Jet	9,546	594	221	1,396	209	9,327	514	817	162	22,786
General Aviation – Piston	16,029	1,465	546	3,453	512	2,388	1,275	636	401	26,705
Military	2,580	32	12	76	12	72	28	975	9	3,796
Grand Total	120,915	21,215	7,906	49,988	7,435	301,614	18,460	20,599	5,794	553,926

Table 3-8: Aircraft arrivals and departures by engine type

Engine type	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Jet	1,659	1,623	605	3,825	569	217,163	1,413	9,314	443	236,615
Piston	103,625	18,942	7,059	44,633	6,638	2,510	16,482	1,229	5,173	206,292
Turboprop/Turboshaft	15,631	649	242	1,530	228	81,941	565	10,056	177	111,019
Grand Total	120,915	21,215	7,906	49,988	7,435	301,614	18,460	20,599	5,794	553,926

Table 3-9: Aircraft arrivals and departures by usage

Usage	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Business	12,499	1,342	500	3,161	470	5,976	1,167	1,174	366	26,656
Cargo or General Transport	-	-	-	-	-	10	-	166	-	176
Combat or Attack	9	-	-	-	-	-	-	800	-	809
Helicopter	15,638	738	275	1,739	259	6,178	642	172	202	25,842
Other	19	11	4	25	4	-	9	127	3	202
Passenger or VIP Transport	92,750	19,125	7,127	45,063	6,702	289,450	16,641	18,160	5,223	500,241
Grand Total	120,915	21,215	7,906	49,988	7,435	301,614	18,460	20,599	5,794	553,926

Table 3-10: Aircraft arrivals and departures by European category

European category	2008 arrivals and departures									
	Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
Business Jet	1,425	11	4	25	4	3,217	9	750	3	5,448
Heavy Helicopter	2,965	40	15	95	14	335	35	77	11	3,587
Large Jet	6	-	-	-	-	31,006	-	2	-	31,014
Light Helicopter	12,673	698	260	1,644	245	5,843	607	95	191	22,255
Medium Jet	2	-	-	-	-	43,444	-	78	-	43,524
Propeller	97,460	18,456	6,878	43,488	6,468	2,372	16,060	1,224	5,041	197,447
Regional Jet	41	1,610	600	3,794	564	11,573	1,401	81	440	20,104
Small Jet	185	3	1	6	1	127,923	2	7,881	1	136,003
Supersonic	-	-	-	-	-	-	-	522	-	522
Turboprop	6,158	397	148	936	139	75,901	346	9,889	108	94,022
Grand Total	120,915	21,215	7,906	49,988	7,435	301,614	18,460	20,599	5,794	553,926

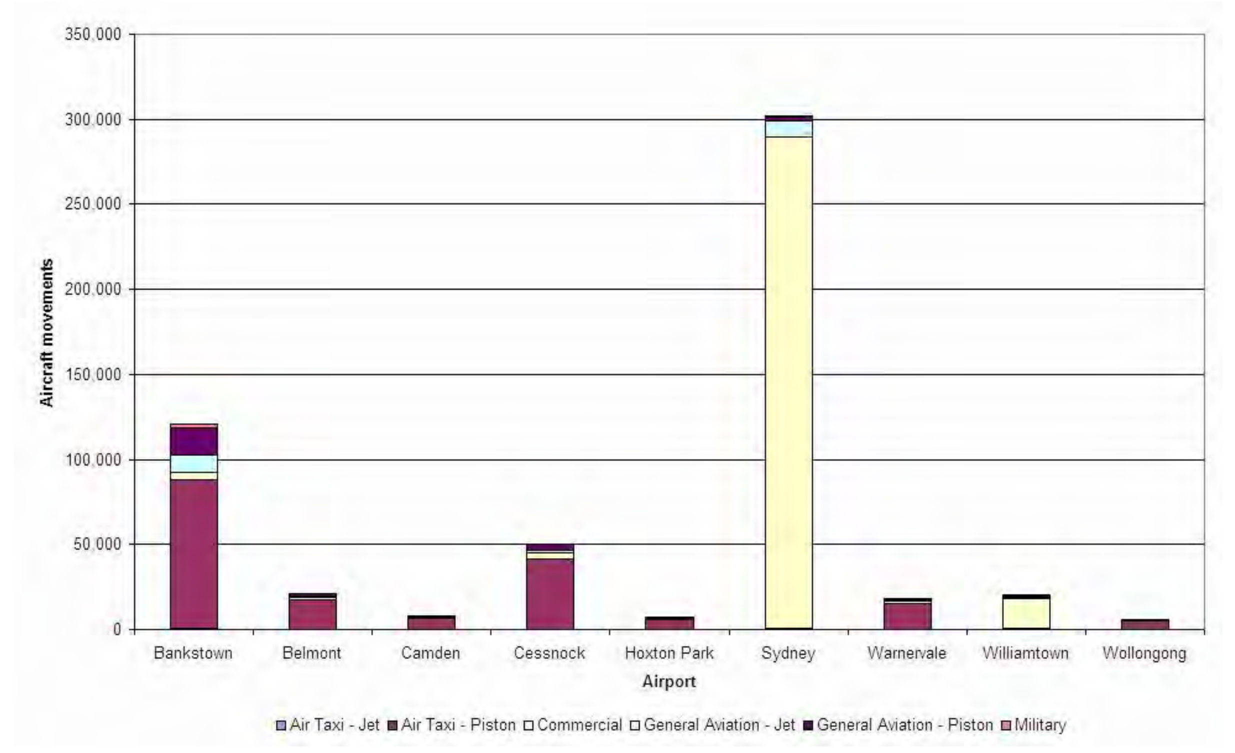

Figure 3-4: Aircraft arrivals and departures by aircraft type

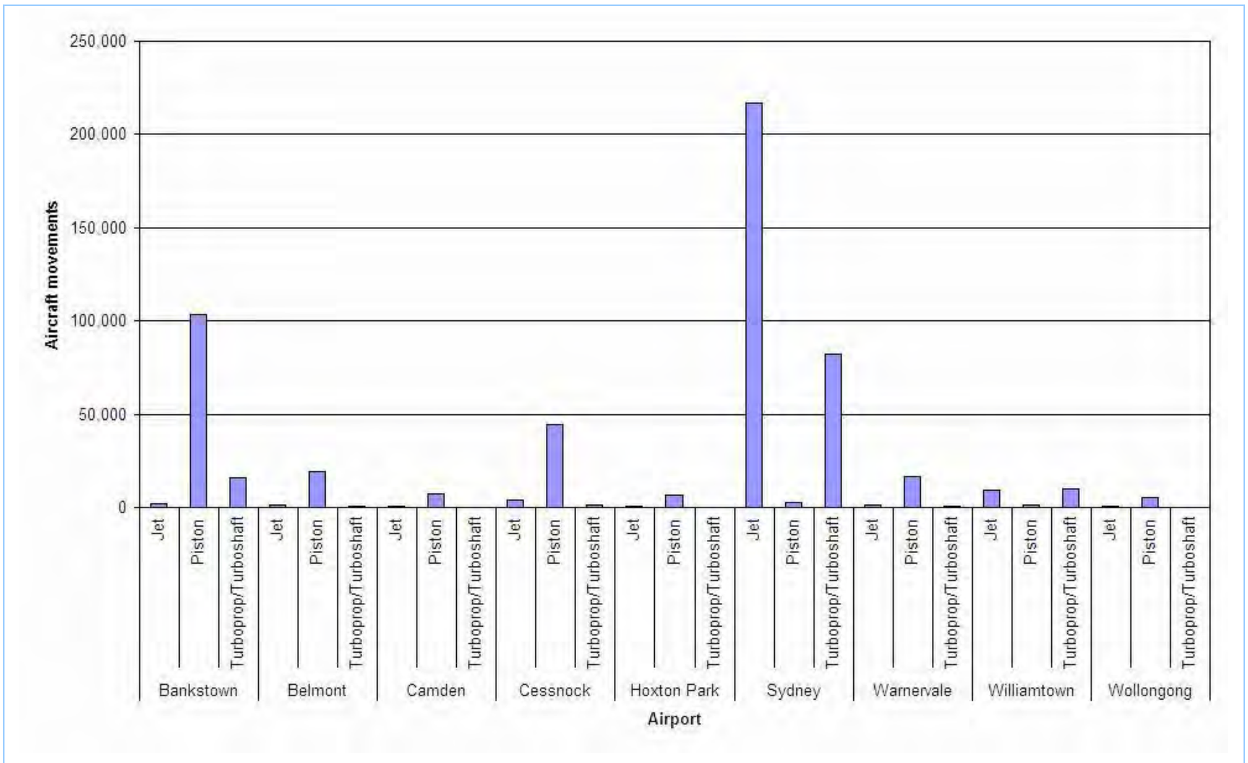

Figure 3-5: Aircraft arrivals and departures by engine type

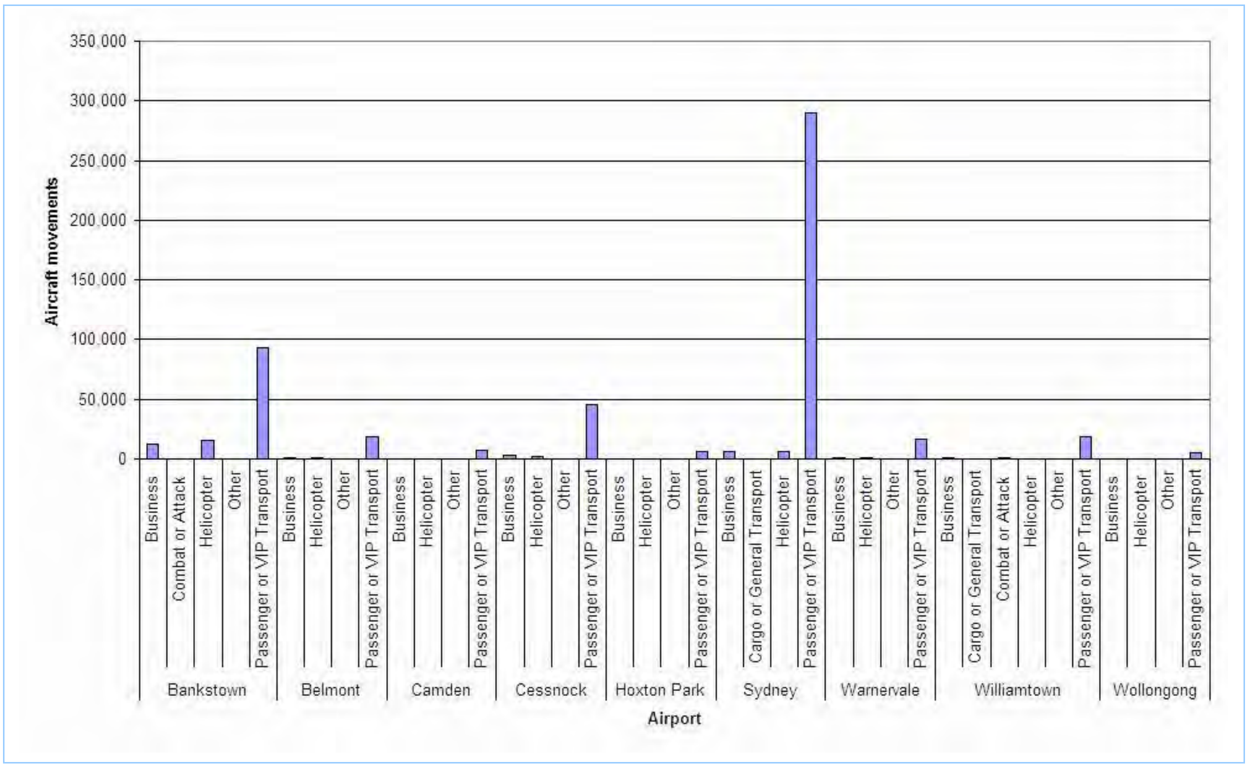

Figure 3-6: Aircraft arrivals and departures by usage

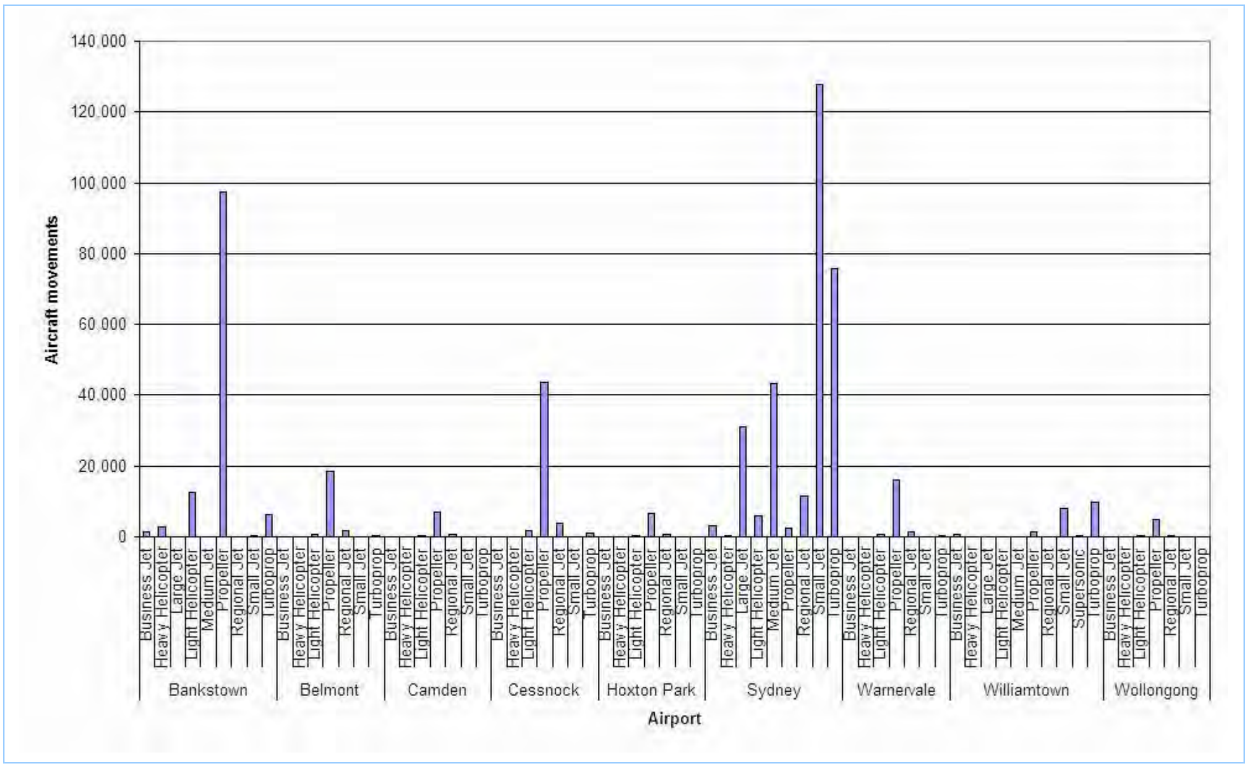

Figure 3-7: Aircraft arrivals and departures by European category

Exhaust emissions from aircraft have been estimated using aircraft type and LTO data in combination with default ICAO/USEPA time-in-mode (TIM) and emission factor data within the *FAA EDMS v5.1.2 Model* (FAA, 2009).

Similarly, exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU) have been estimated using the default GSE and APU assignments for population and activity data in combination with emission and load factors within the *FAA EDMS v5.1.2 Model* (FAA, 2009).

Figure 3-8 shows the EDMS Model study properties selected for the aircraft emission estimation simulation.

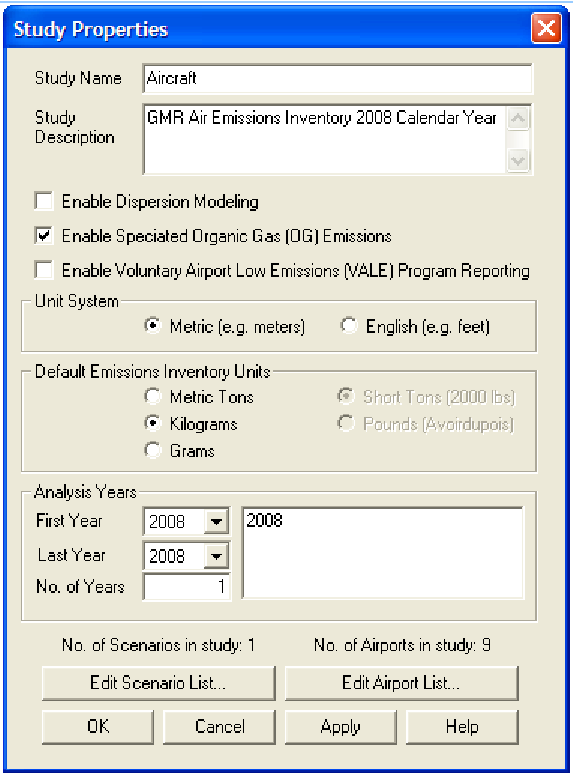

Figure 3-8: Aircraft EDMS Model study properties

Figure 3-9 shows the EDMS Model airports selected for the aircraft emission estimation simulation.

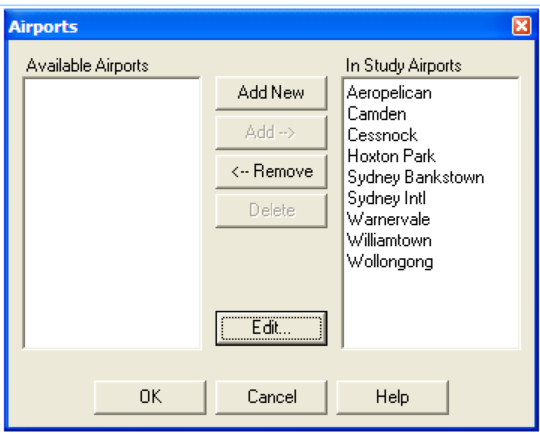

Figure 3-9: Aircraft EDMS Model airports

Figure 3-10 shows the EDMS Model airport properties selected for Sydney airport as part of the aircraft emission estimation simulation.

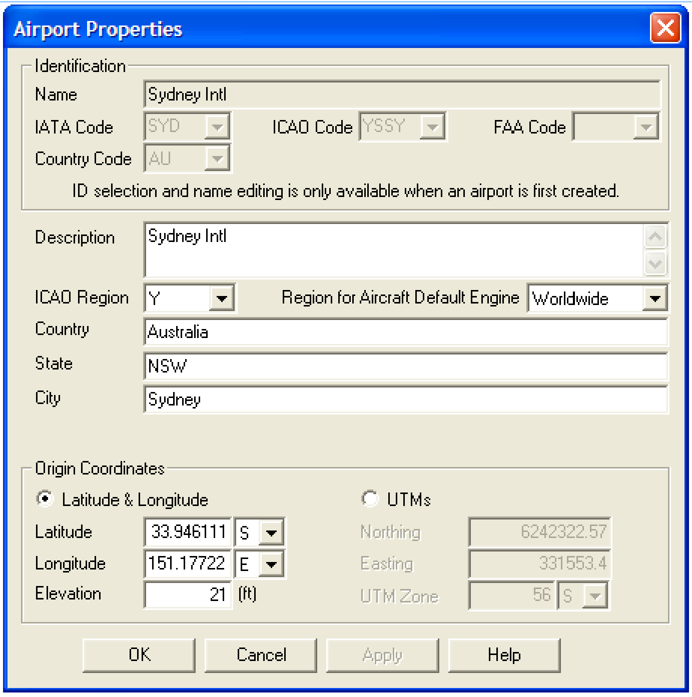

Figure 3-10: Aircraft EDMS Model airport properties

Figure 3-11 shows the EDMS Model aircraft/engine combinations and arrivals/departure data selected for Sydney airport as part of the aircraft emission estimation simulation.

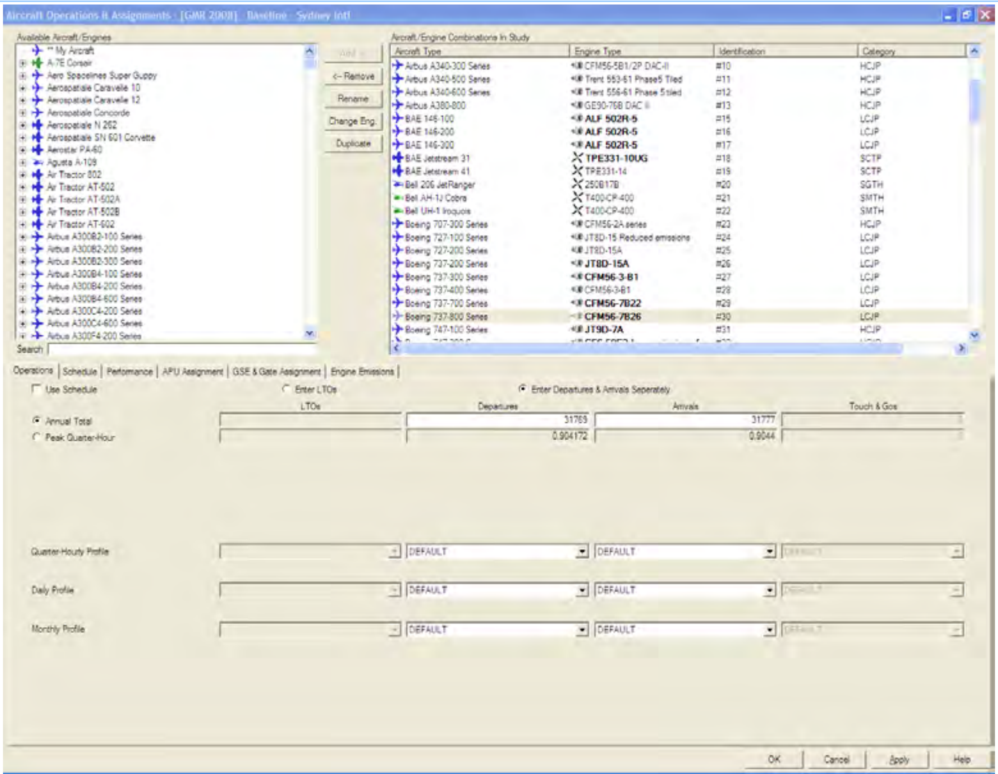

Figure 3-11: Aircraft EDMS Model aircraft/engine combinations and arrivals/departure data

Figure 3-12 shows the EDMS Model time-in-mode data selected for Sydney airport as part of the aircraft emission estimation simulation.

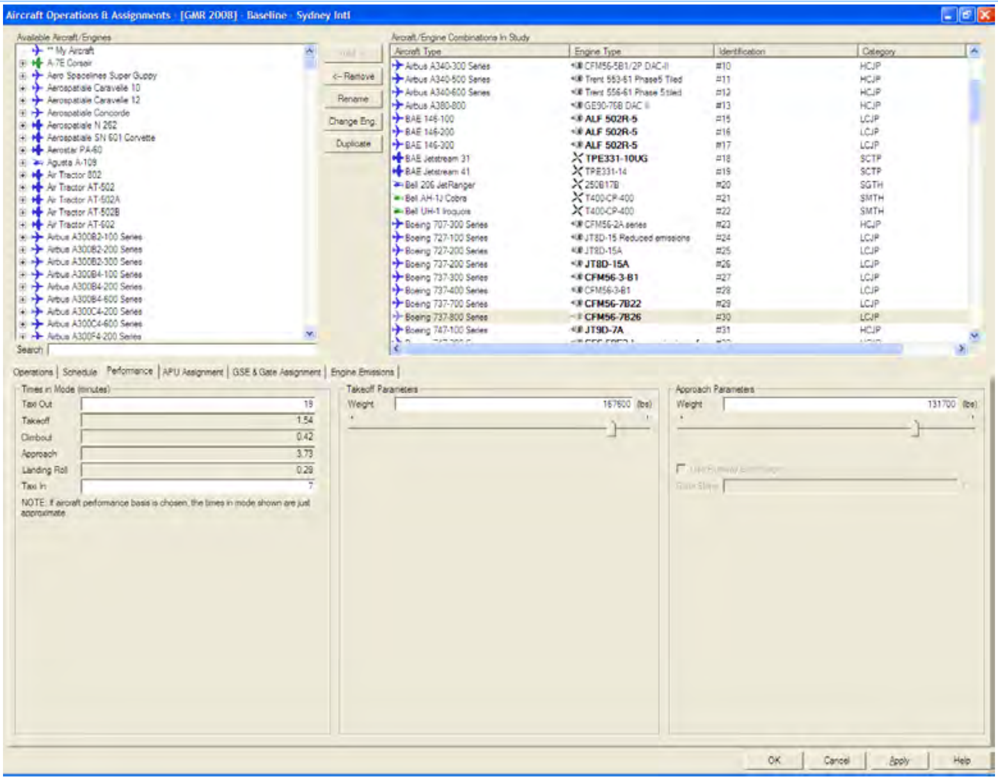

Figure 3-12: Aircraft EDMS Model time-in-mode data

Figure 3-13 shows the EDMS Model GSE assignment data selected for Sydney airport as part of the aircraft emission estimation simulation.

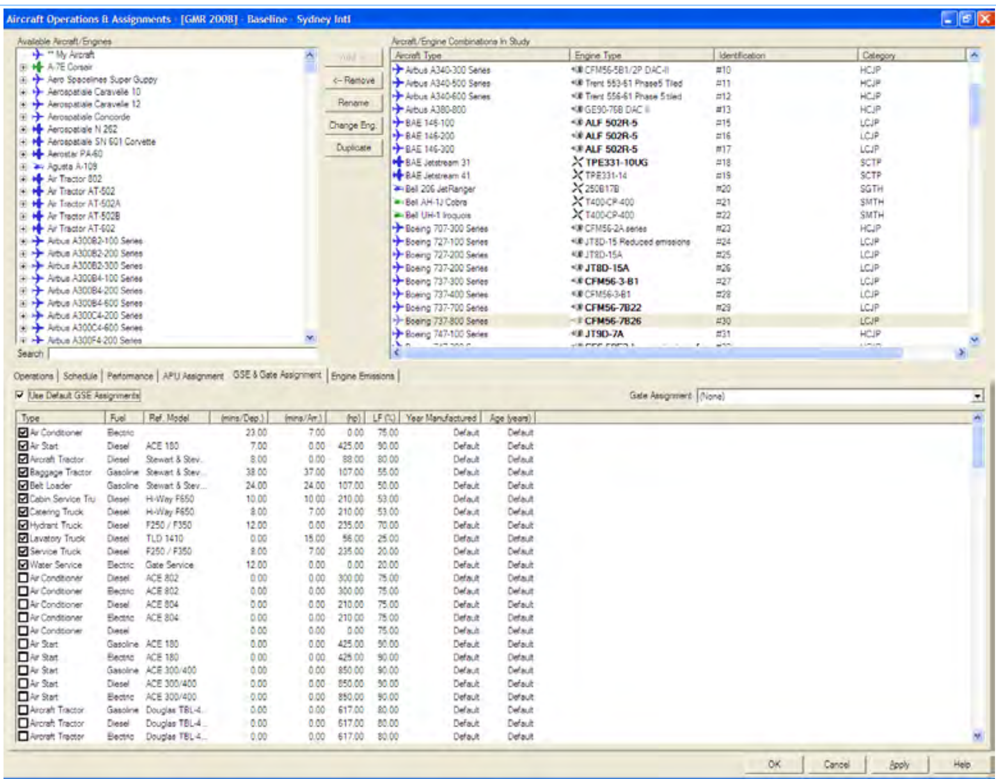

Figure 3-13: Aircraft EDMS Model GSE assignment data

Table 3-11 presents the aircraft LTO cycle fuel consumption estimates from the *FAA EDMS v5.1.2 Model* (FAA, 2009).

Table 3-11: Aircraft (flight operations) LTO cycle EDMS Model fuel consumption in the GMR

Airport	2008 fuel consumption (kL/year)	
	Avgas	Avtur
Bankstown	992	925
Belmont	185	585
Camden	65	217
Cessnock	416	1,368
Hoxton Park	62	204
Sydney	58	169,380
Warnervale	152	502
Williamtown	28	4,789
Wollongong	50	160
Grand Total	2,009	178,129

Table 3-12 presents the GSE and APU diesel consumption estimates from the *FAA EDMS v5.1.2 Model* (FAA, 2009).

Table 3-12: Aircraft (ground operations) GSE and APU EDMS Model diesel consumption in the GMR

Airport	2008 diesel consumption (kL/year)
Bankstown	149
Belmont	32
Camden	12
Cessnock	75
Hoxton Park	11
Sydney	22,785
Warnervale	28
Williamtown	757
Wollongong	9
Grand Total	23,858

Table 3-13 presents the quantity of Avgas and Avtur loaded to aircraft for refuelling (DRET, 2009).

Table 3-13: Aircraft (ground operations) fuel loaded in the GMR

Airport	2008 fuel loaded (kL/year)	
	Avgas	Avtur
Bankstown	9,045	14,197
Belmont	1,689	8,971
Camden	596	3,325

Airport	2008 fuel loaded (kL/year)	
	Avgas	Avtur
Cessnock	3,788	20,987
Hoxton Park	565	3,131
Sydney	530	2,599,255
Warnervale	1,388	7,705
Williamtown	257	73,490
Wollongong	451	2,462
Grand Total	18,308	2,733,523

3.1.4 *Emission and Speciation Factors*

Table 3-14 summarises the emission and speciation factors used for aircraft (flight operations) and aircraft (ground operations).

Table 3-14: Aircraft (flight operations) and aircraft (ground operations) emission and speciation factors

Substance	Emission source	Emission and speciation factor source[6]
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	Flight operations: Exhaust emissions from aircraft	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009) - *Appendix A - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Ground operations: Evaporative emissions from the transfer of fuel to on-site storage tanks, tankers and aircraft	- *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5:*

[6] Where references are marked with an asterisk (i.e. *), reciprocating piston engines use 4-stroke petrol spark ignition (SI) engine emission data, which have been adjusted to Avgas equivalent based on effective heating value of 33.1 MJ/L for aviation gasoline and 34.2 MJ/L for automotive gasoline (ABARE, 2009b). Where references are marked with a hash (i.e. #), gas turbine engines use diesel compression ignition (CI) engine emission data, which have been adjusted to Avtur equivalent based on effective heating value of 36.8 MJ/L for aviation turbine fuel and 38.6 MJ/L for automotive diesel oil (ABARE, 2009b).

Substance	Emission source	Emission and speciation factor source[6]
		Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids (USEPA, 2008b)
Criteria pollutants: TSP	Flight operations: Exhaust emissions from reciprocating piston aircraft	- *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Flight operations: Exhaust emissions from turbofan, turboprop and turbojet aircraft	- *PMPROF 141 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *PMPROF 116 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
Speciated NO_x	Flight operations: Exhaust emissions from aircraft and Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	Flight operations: Exhaust emissions from aircraft	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *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)
	Ground operations: Evaporative emissions from the transfer of Avgas to on-site storage tanks, tankers and aircraft	- *ORGPROF 708 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Ground operations: Evaporative emissions from the transfer of Avtur to on-site storage tanks, tankers and aircraft	- *ORGPROF 100 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Organic air toxics	Flight operations: Exhaust emissions from aircraft	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *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)
	Ground operations: Evaporative emissions from the transfer of Avgas to on-site storage tanks, tankers and aircraft	- *ORGPROF 708 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Ground operations: Evaporative	- *ORGPROF 100 - California Emission Inventory*

Substance	Emission source	Emission and speciation factor source[6]
	emissions from the transfer of Avtur to on-site storage tanks, tankers and aircraft	*and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Metal air toxics	Flight operations: Exhaust emissions from reciprocating piston aircraft	- *Documentation for Aircraft Component of the National Emissions Inventory Methodology* (ERG, 2011a) - *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)
	Flight operations: Exhaust emissions from turbofan, turboprop and turbojet aircraft	- *PMPROF 141 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *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	Flight operations: Exhaust emissions from aircraft	- *Appendix A - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *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 and Polychlorinated dibenzofurans: PCDD and PCDF	Flight operations: Exhaust emissions from reciprocating piston aircraft	- *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)*
	Flight operations: Exhaust emissions from turbofan, turboprop and turbojet aircraft	- *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)#
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *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	Flight operations: Exhaust emissions	- *Table III-6 - Estimating Ammonia Emissions from*

Substance	Emission source	Emission and speciation factor source[6]
	from reciprocating piston aircraft	*Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)*
	Flight operations: Exhaust emissions from turbofan, turboprop and turbojet aircraft	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)#
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
Greenhouse gases: CH_4	Flight operations: Exhaust emissions from aircraft	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)
Greenhouse gases: CO_2	Flight operations: Exhaust emissions from aircraft	- *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Table 5 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)
Greenhouse gases: N_2O	Flight operations: Exhaust emissions from aircraft	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)
	Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008b)

Table 3-15 presents average activity weighted aircraft, GSE and APU exhaust and evaporative emission factors for aircraft (flight operations) and aircraft (ground operations).

Table 3-15: Aircraft (flight operations) and aircraft (ground operations) emission factors

Source category	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
Flight operations	Reciprocating piston engine (i.e. Avgas fuelled) exhaust	1.88	0.028	0.028	0.829	12.95	8.93	11.98	1.585	791.18	2,234.42	0.2990	3.19×10^{-12}
	Gas turbine engine (i.e. Avtur fuelled) exhaust	10.36	0.079	0.021	0.929	0.18	0.18	1.40	0.069	8.64	2,501.98	0.0124	4.36×10^{-9}
Ground operations	Ground support equipment (GSE) and auxiliary power units (APU) engine (i.e. Diesel fuelled) exhaust	11.12	0.068	0.022	0.082	0.61	0.60	2.91	0.152	79.41	2,680.76	0.0006	4.57×10^{-9}
	Loading Avgas to storage tanks	-	-	-	-	-	-	1.67×10^{-2}	-	-	-	-	-
	Loading Avgas to tankers	-	-	-	-	-	-	0.41	-	-	-	-	-
	Refuelling aircraft with Avgas	-	-	-	-	-	-	0.99	-	-	-	-	-
	Loading Avtur to storage tanks	-	-	-	-	-	-	7.77×10^{-5}	-	-	-	-	-
	Loading Avtur to tankers	-	-	-	-	-	-	1.90×10^{-3}	-	-	-	-	-
	Refuelling aircraft with Avtur	-	-	-	-	-	-	4.60×10^{-3}	-	-	-	-	-

3.1.5 Spatial Distribution of Emissions

Table 3-16 summarises the data used for spatially allocating emissions from aircraft (flight operations) and aircraft (ground operations).

Table 3-16: Aircraft (flight operations) and aircraft (ground operations) spatial data

Emission source	Spatial data	Spatial data source
Flight operations: Exhaust emissions from aircraft	Gridded 1 km x 1 km Avgas and Avtur consumption estimates allocated to airport locations and flight paths	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)	Gridded 1 km x 1 km diesel consumption estimates allocated to airport locations	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010) - *Emissions and Dispersion Modeling System (EDMS) v5.1.2* (FAA, 2009)
Ground operations: Evaporative emissions from the transfer of Avgas to on-site storage tanks, tankers and aircraft	Gridded 1 km x 1 km Avgas and Avtur consumption estimates allocated to airport locations	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010) - *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)

Emissions from aircraft (flight operations) and aircraft (ground operations) have been spatially distributed according to Avgas, Avtur and diesel consumption at each on the nine airports in the GMR.

Avtur and Avgas consumption from aircraft have been estimated using aircraft type and LTO data (ASA, 2009a; ASA, 2009b; and BITRE, 2010) in combination with time-in-mode (TIM) and fuel factor data within the *FAA EDMS v5.1.2 Model* (FAA, 2009). The estimated Avgas and Avtur consumption at each of the nine airports have been allocated to the 1 km by 1 km grid cells which correspond to the runway orientation and flight paths used during the LTO cycle (ASA, 2009a; ASA, 2009b; and BITRE, 2010) according to the method shown in Figure 3-14.

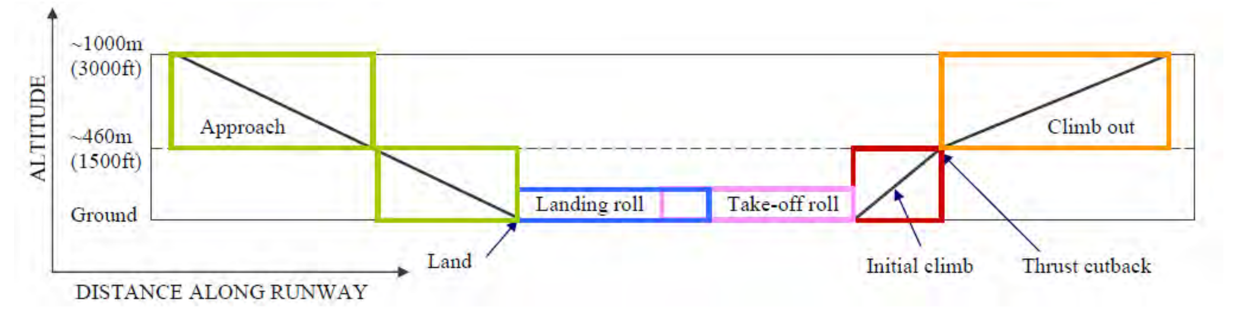

Figure 3-14: Aircraft (flight operations) LTO cycle spatial allocation

Aircraft Avgas and Avtur consumption by region and airport is presented in Table 3-17 and shown in Figure 3-15 and Figure 3-16.

Table 3-17: Aircraft (flight operations) LTO cycle Avgas and Avtur consumption by region and airport

Fuel	Airport	2008 fuel consumption (kL/year)				
		Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Avgas	Bankstown	-	-	992.37	-	992.37
	Belmont	-	185.28	-	-	185.28
	Camden	-	-	65.36	-	65.36
	Cessnock	-	415.58	-	-	415.58
	Hoxton Park	-	-	61.99	-	61.99
	Sydney	-	-	58.11	-	58.11
	Warnervale	-	152.27	-	-	152.27
	Williamtown	18.22	10.02	-	-	28.23
	Wollongong	-	33.50	-	16.02	49.53
Total Avgas		18.22	796.65	1,177.82	16.02	2,008.71
Avtur	Bankstown	-	-	925.13	-	925.13
	Belmont	-	584.58	-	-	584.58
	Camden	-	-	216.65	-	216.65
	Cessnock	-	1,367.60	-	-	1,367.60
	Hoxton Park	-	-	204.05	-	204.05
	Sydney	-	-	169,379.63	-	169,379.63
	Warnervale	-	502.09	-	-	502.09
	Williamtown	3,089.66	1,699.32	-	-	4,788.98
	Wollongong	-	108.53	-	51.90	160.43
Total Avtur		3,089.66	4,262.11	170,725.46	51.90	178,129.14

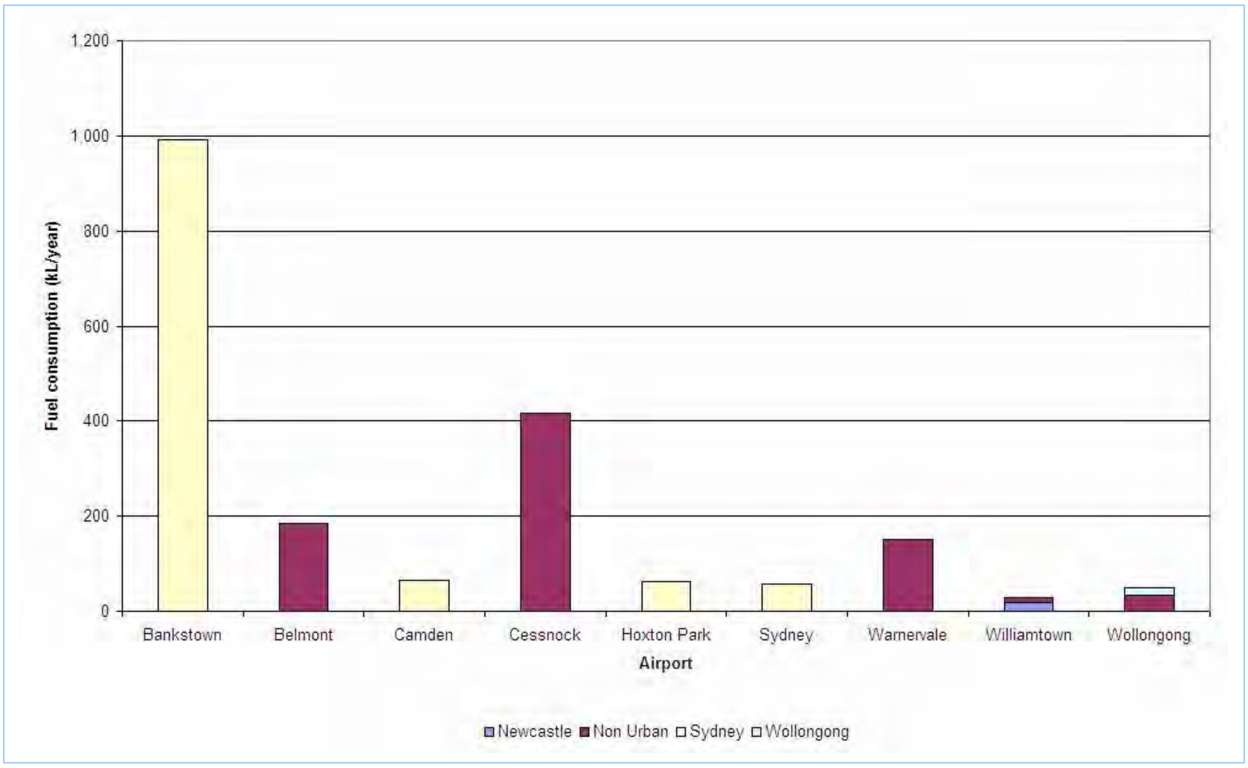

Figure 3-15: Aircraft (flight operations) LTO cycle Avgas consumption by region and airport

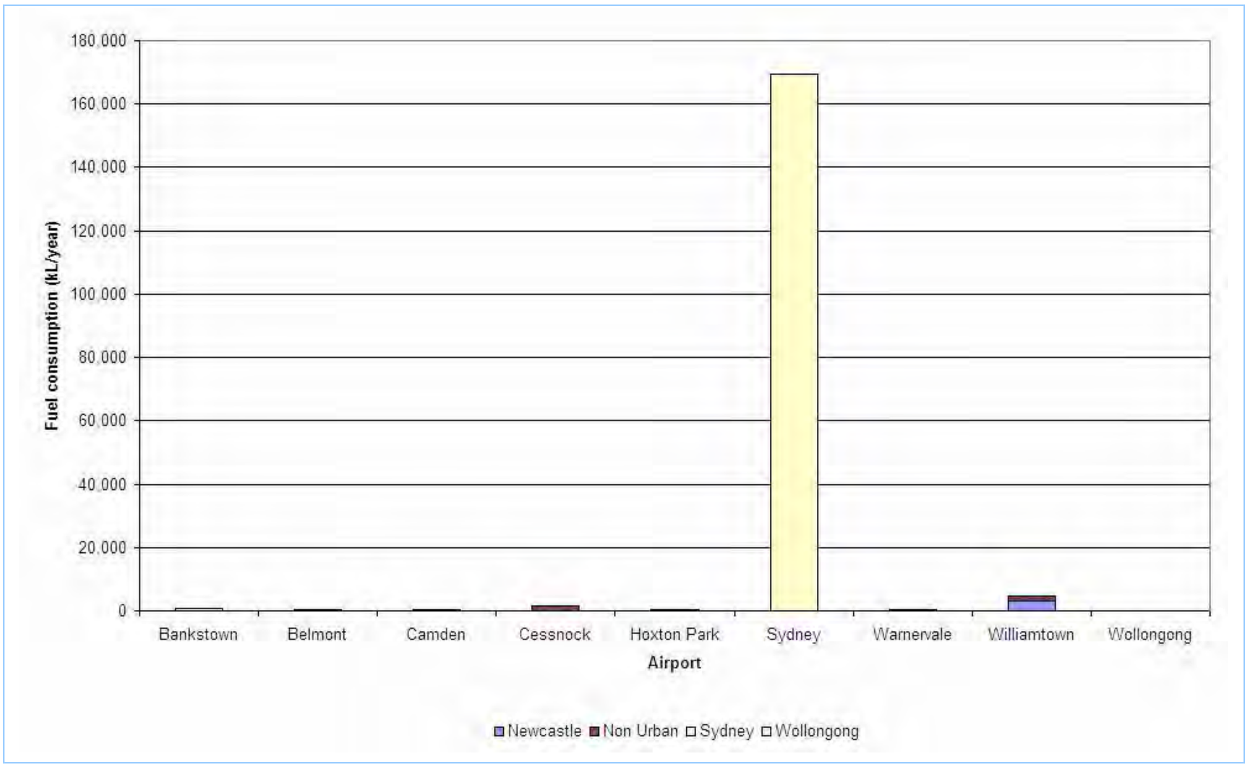

Figure 3-16: Aircraft (flight operations) LTO cycle Avtur consumption by region and airport

Diesel consumption from GSE and APU have been estimated using the default GSE and APU assignments for population and activity data in combination with fuel and load factors within the *FAA EDMS v5.1.2 Model* (FAA, 2009). The estimated diesel consumption at each of the nine airports has been allocated to the 1 km by 1 km grid cells which correspond to ground operations (ASA, 2009a; ASA, 2009b; and BITRE, 2010).

Ground support equipment and APU diesel consumption by region and airport is presented in Table 3-18 and shown in Figure 3-17.

Table 3-18: Aircraft (ground operations) GSE and APU diesel consumption by region and airport

Airport	2008 diesel consumption (kL/year)			
	Newcastle	Non Urban	Sydney	Grand Total
Bankstown	-	-	149.42	149.42
Belmont	-	32.01	-	32.01
Camden	-	-	11.91	11.91
Cessnock	-	75.28	-	75.28
Hoxton Park	-	-	11.22	11.22
Sydney	-	-	22,784.63	22,784.63
Warnervale	-	27.76	-	27.76
Williamtown	757.26	-	-	757.26
Wollongong	-	8.75	-	8.75
Grand Total	757.26	143.80	22,957.17	23,858.23

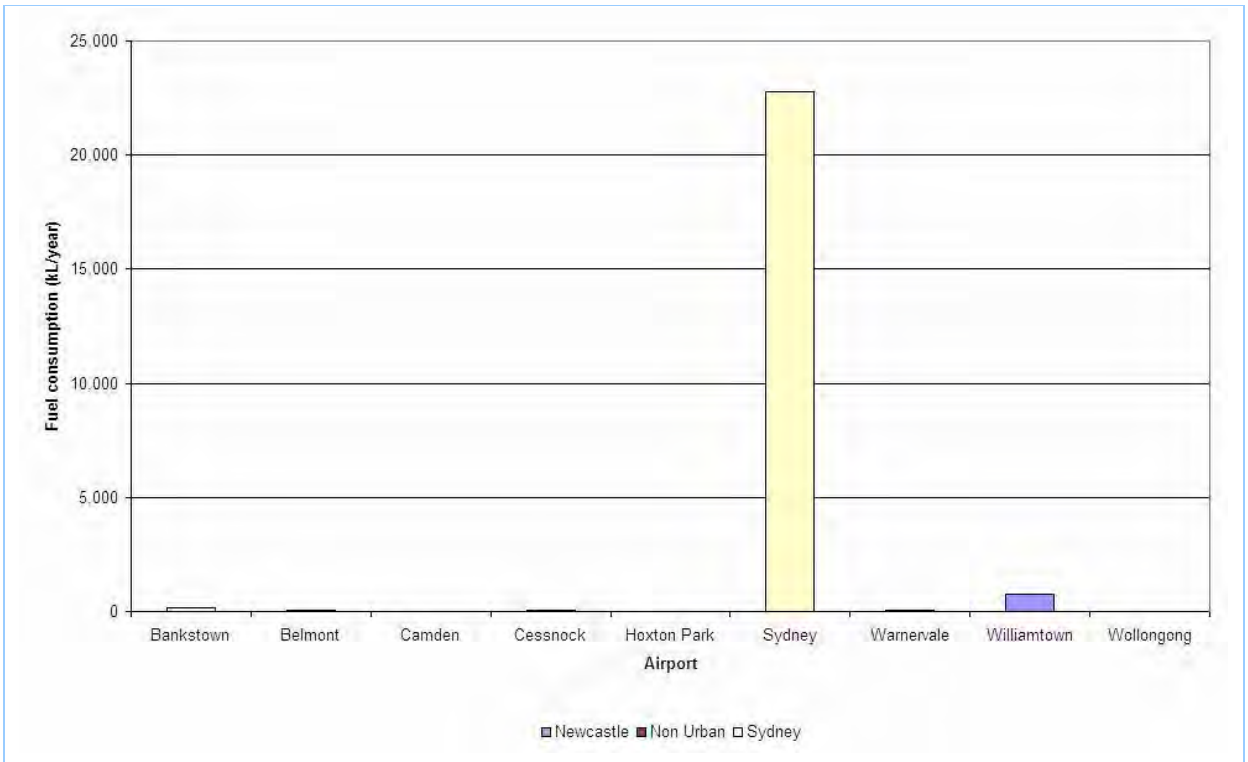

Figure 3-17: Aircraft (ground operations) GSE and APU diesel consumption by region and airport

Avgas and Avtur transferred to on-site storage tanks, tankers and aircraft have been estimated using fuel sales data (DRET, 2009). The estimated Avgas and Avtur transferred at each of the nine airports have been allocated to the 1 km by 1 km grid cells which correspond to ground operations (ASA, 2009a; ASA, 2009b; and BITRE, 2010).

Avgas and Avtur transferred by region and airport is presented in Table 3-19 and shown in Figure 3-18 and Figure 3-19.

Table 3-19: Aircraft (ground operations) Avgas and Avtur transferred to on-site storage tanks, tankers and aircraft by region and airport

Fuel	Airport	2008 fuel loaded (kL/year)			
		Newcastle	Non Urban	Sydney	Grand Total
Avgas	Bankstown	-	-	9,044.75	9,044.75
	Belmont	-	1,688.69	-	1,688.69
	Camden	-	-	595.72	595.72
	Cessnock	-	3,787.68	-	3,787.68
	Hoxton Park	-	-	564.97	564.97
	Sydney	-	-	529.61	529.61
	Warnervale	-	1,387.83	-	1,387.83
	Williamtown	257.34	-	-	257.34
	Wollongong	-	451.41	-	451.41
Total Avgas		257.34	7,315.61	10,735.04	18,308.00
Avtur	Bankstown	-	-	14,196.76	14,196.76
	Belmont	-	8,970.79	-	8,970.79
	Camden	-	-	3,324.65	3,324.65
	Cessnock	-	20,986.76	-	20,986.76
	Hoxton Park	-	-	3,131.35	3,131.35
	Sydney	-	-	2,599,255.37	2,599,255.37
	Warnervale	-	7,704.94	-	7,704.94
	Williamtown	73,490.41	-	-	73,490.41
	Wollongong	-	2,461.96	-	2,461.96
Total Avtur		73,490.41	40,124.45	2,619,908.14	2,733,523.00

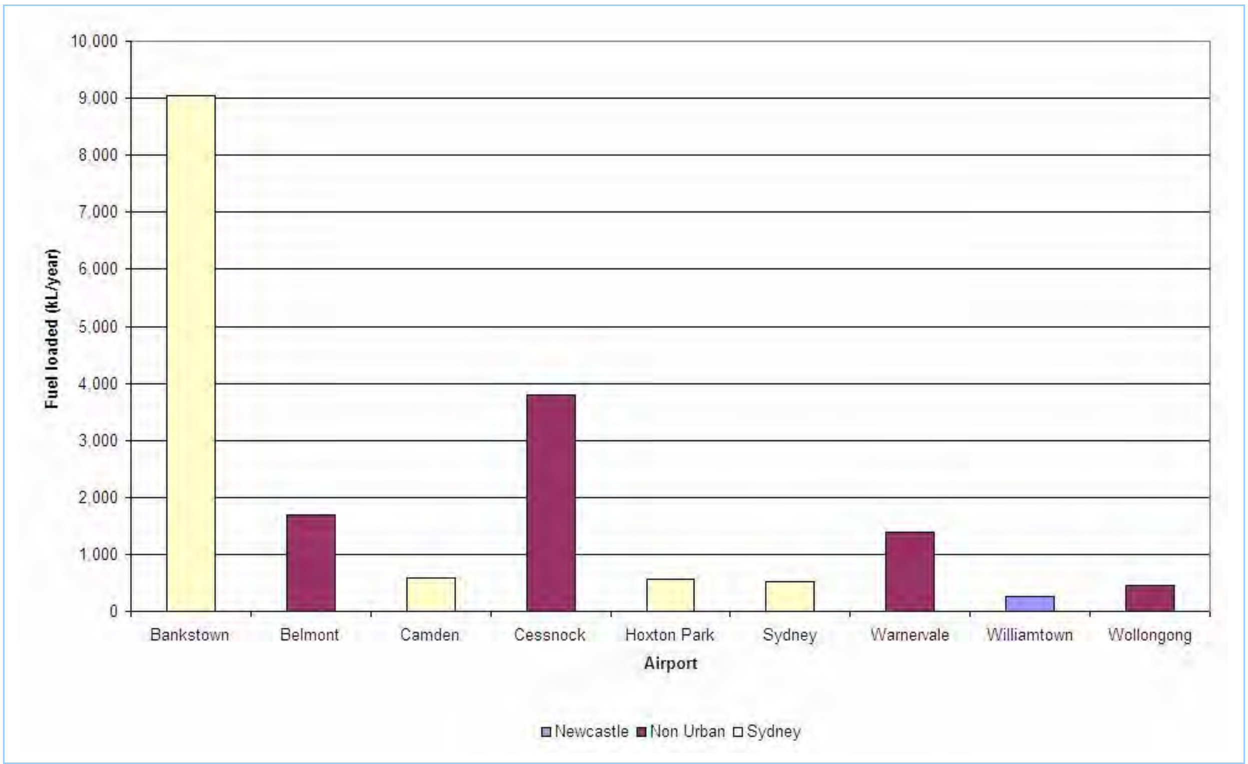

Figure 3-18: Aircraft (ground operations) Avgas transferred to on-site storage tanks, tankers and aircraft by region and airport

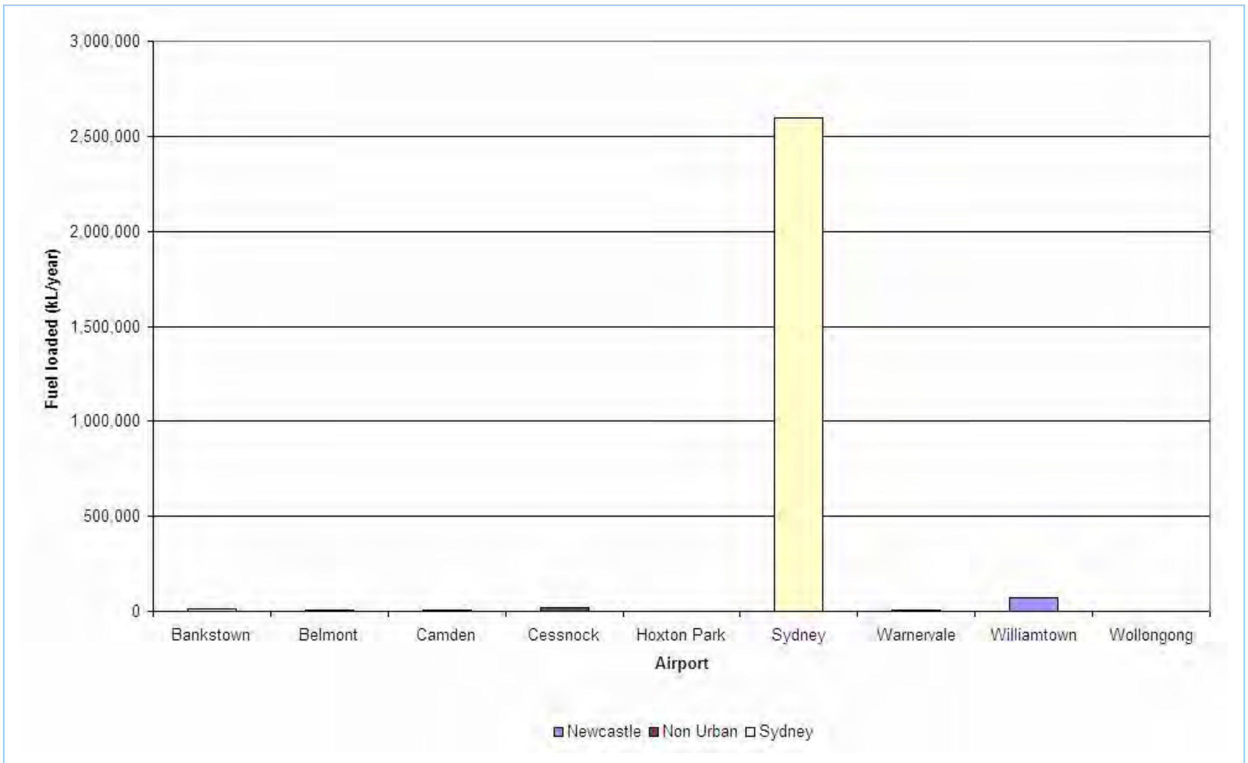

Figure 3-19: Aircraft (ground operations) Avtur transferred to on-site storage tanks, tankers and aircraft by region and airport

Figure 3-20, Figure 3-21, Figure 3-22, Figure 3-23 and Figure 3-24 show the spatial distribution of aircraft (flight operations) and aircraft (ground operations) emissions.

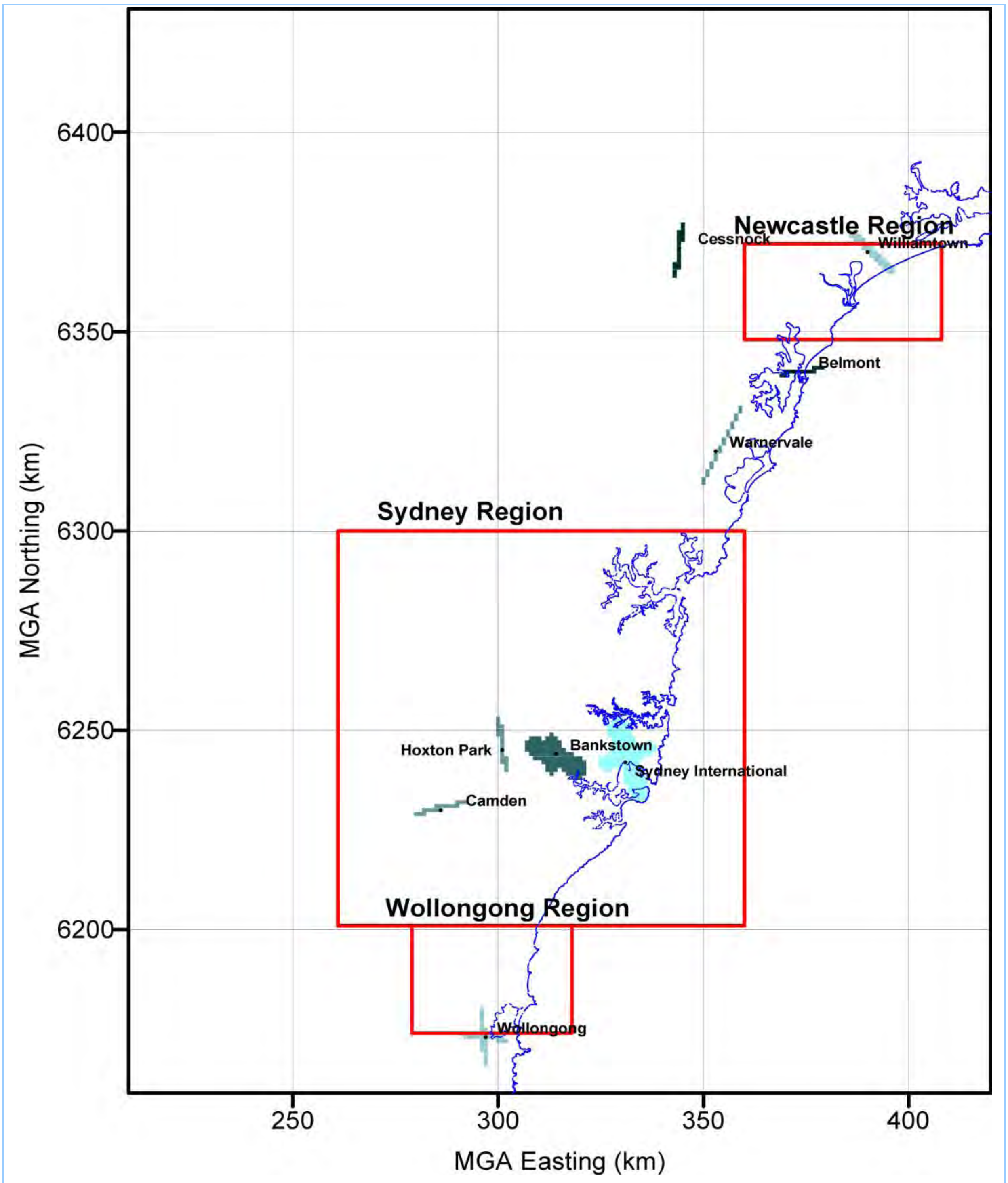

Figure 3-20: Aircraft (flight operations) LTO cycle spatial distribution of reciprocating piston engine emissions

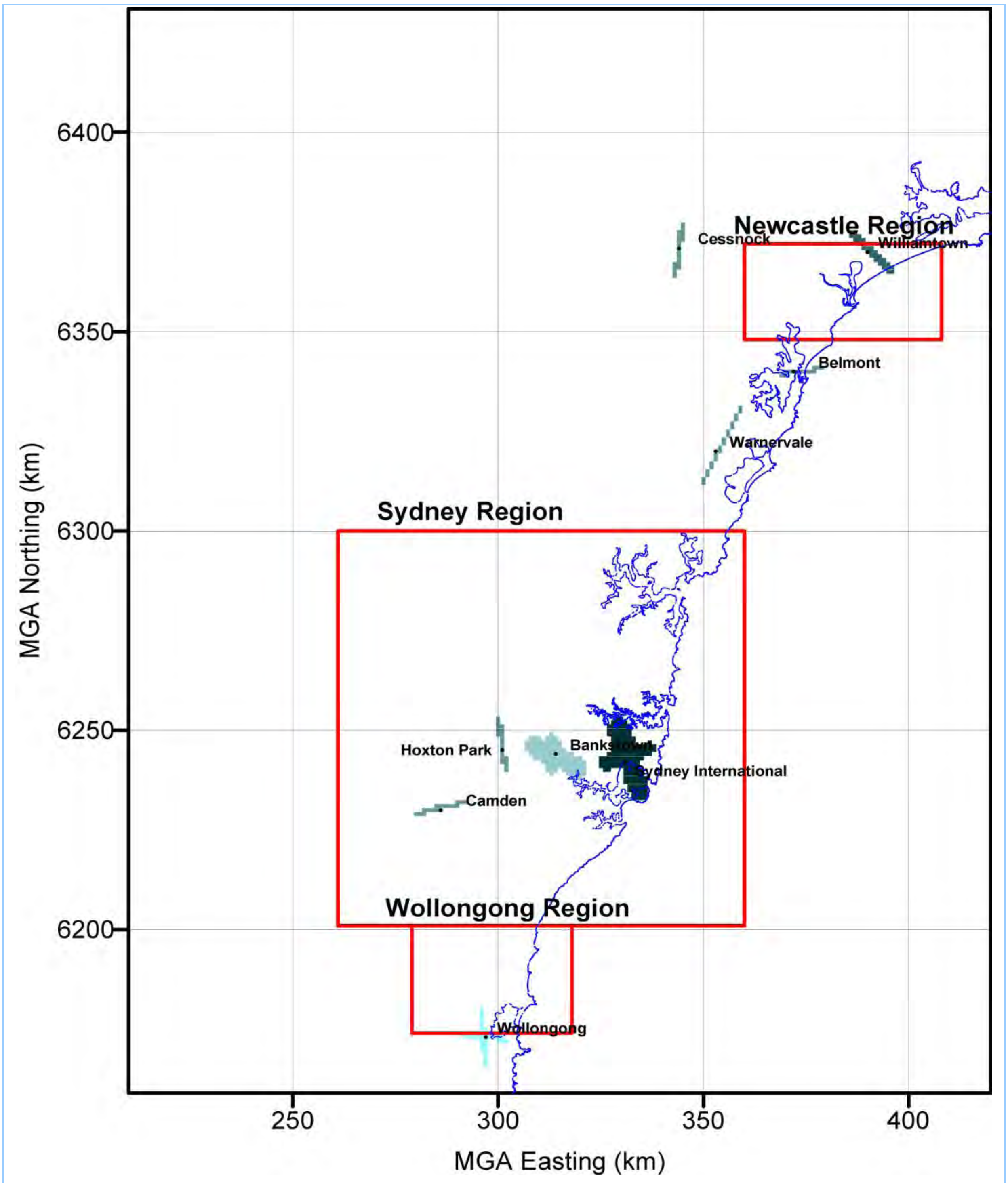

Figure 3-21: Aircraft (flight operations) LTO cycle spatial distribution of gas turbine engine emissions

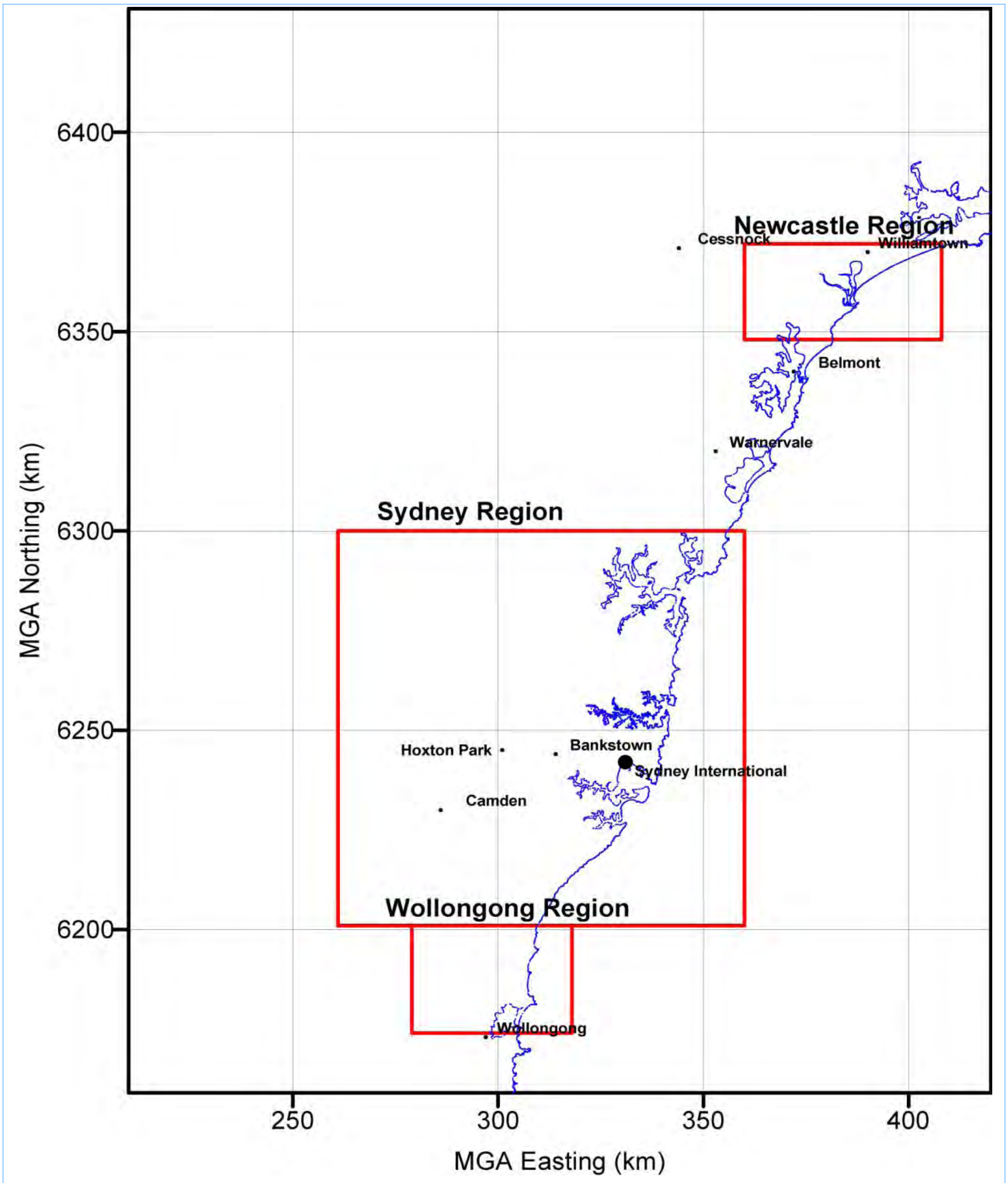

Figure 3-22: Aircraft (ground operations) spatial distribution of GSE and APU emissions

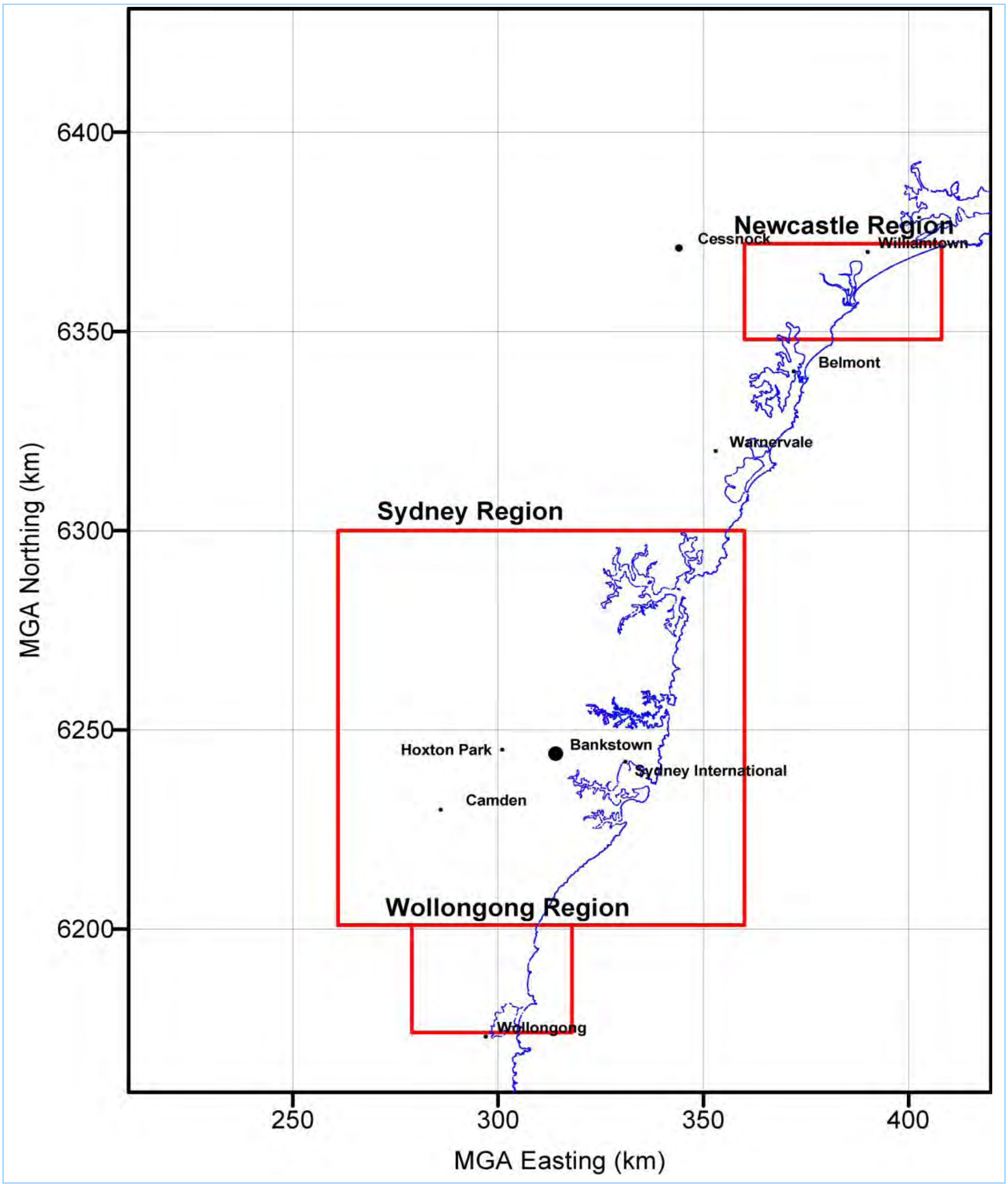

Figure 3-23: Aircraft (ground operations) spatial distribution of Avgas evaporative emissions

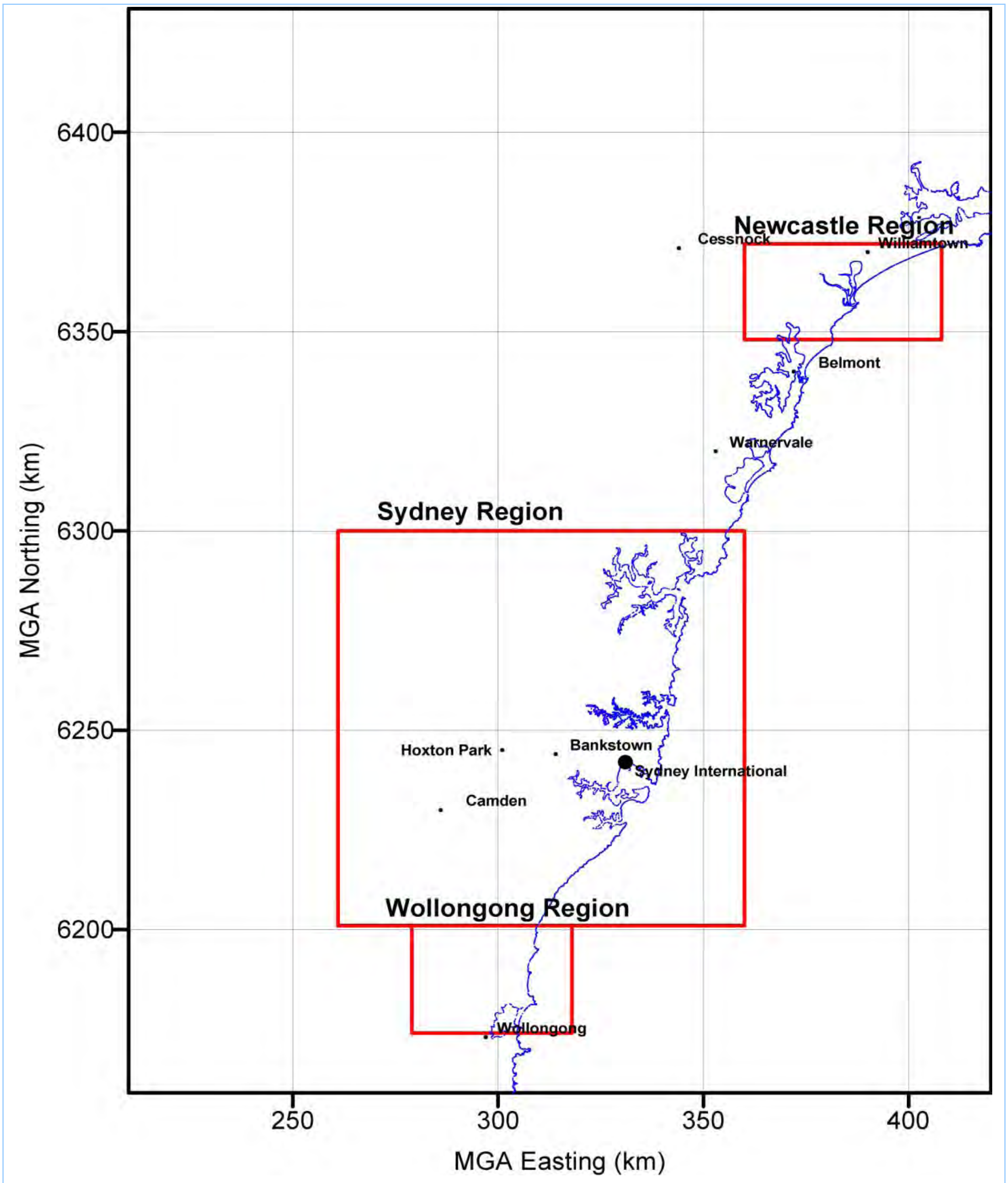

Figure 3-24: Aircraft (ground operations) spatial distribution of Avtur evaporative emissions

3.1.6 *Temporal Variation of Emissions*

Table 3-20 summarises the data used to estimate the temporal variation in emissions from aircraft (flight operations) and aircraft (ground operations).

Table 3-20: Aircraft (flight operations) and aircraft (ground operations) temporal data

Emission source	Temporal data	Temporal data source
Flight operations: Exhaust emissions from aircraft	Monthly, daily and hourly: Derived from landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports	- *Camden and Williamtown Aero Data 2008* (ASA, 2009a) - *Bankstown and Sydney Aero Data 2008* (ASA, 2009b) - *Belmont, Cessnock, Hoxton Park, Warnervale and Wollongong Aero Data 2008* (BITRE, 2010)
Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)		
Ground operations: Evaporative emissions from the transfer of Avgas to on-site storage tanks, tankers and aircraft		

The temporal variation in exhaust and evaporative emissions from aircraft (flight operations) and aircraft (ground operations) have been estimated using landing-takeoff cycle (LTO) data for Bankstown, Belmont, Camden, Cessnock, Hoxton Park, Sydney, Warnervale, Williamtown and Wollongong airports (ASA, 2009a; ASA, 2009b; and BITRE, 2010). While the temporal variation in emissions is different for each of the nine airports, activity weighted hourly, daily and monthly variation in fuel consumption or fuel loaded for all nine airports in the GMR have been estimated.

Hourly temporal variation profiles for aircraft (flight operations) and aircraft (ground operations) emissions are presented in Table 3-21 and shown in Figure 3-25.

Table 3-21: Aircraft (flight operations) and aircraft (ground operations) hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	0.55	0.13	13	6.87	8.11
2	0.27	0.10	14	5.59	6.92
3	0.18	0.11	15	6.20	7.36
4	0.25	0.11	16	6.83	7.85
5	0.18	0.07	17	6.70	7.10
6	0.42	0.20	18	6.01	5.61
7	3.49	2.30	19	6.67	5.34
8	6.00	5.07	20	5.68	4.66
9	7.13	6.77	21	3.87	3.19
10	7.16	7.93	22	2.99	2.36
11	6.98	8.52	23	2.38	1.70
12	6.93	8.34	24	0.67	0.16

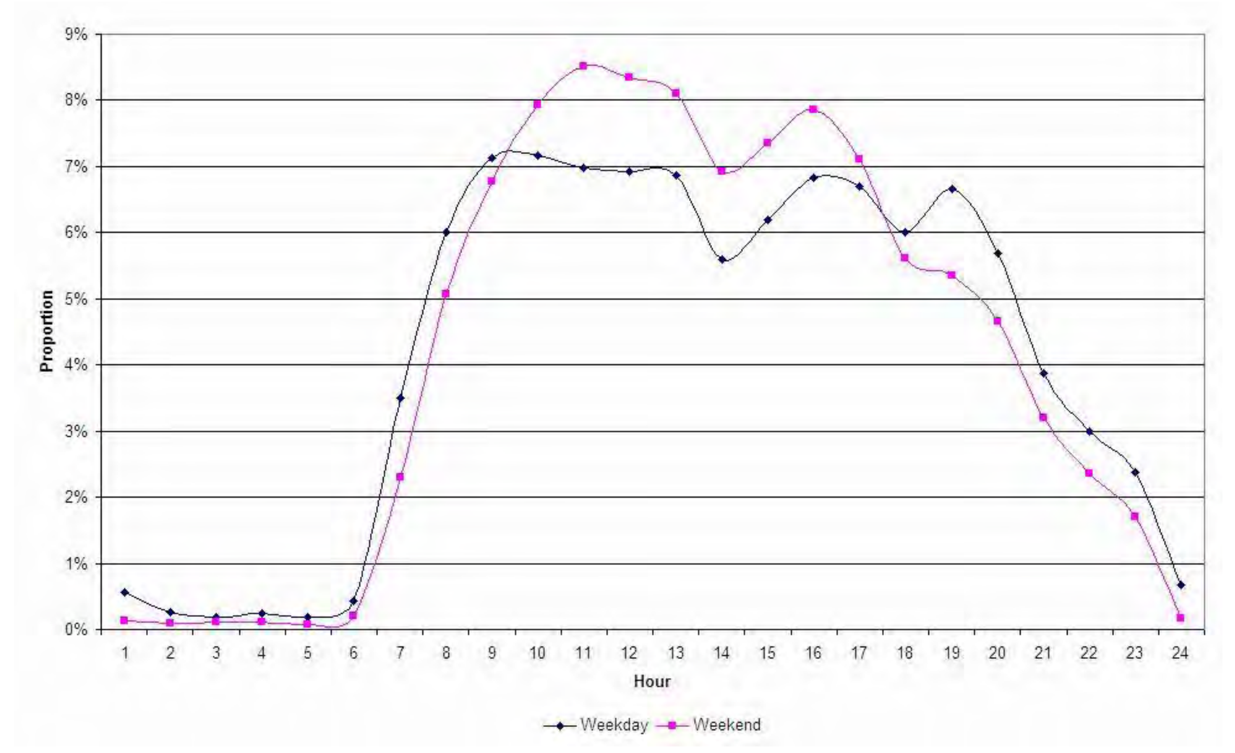

Figure 3-25: Aircraft (flight operations) and aircraft (ground operations) hourly temporal profile

Daily temporal variation profiles for aircraft (flight operations) and aircraft (ground operations) emissions are presented in Table 3-22 and shown in Figure 3-26.

Table 3-22: Aircraft (flight operations) and aircraft (ground operations) daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.11	14.98	15.30	15.03	14.83	12.71	13.04

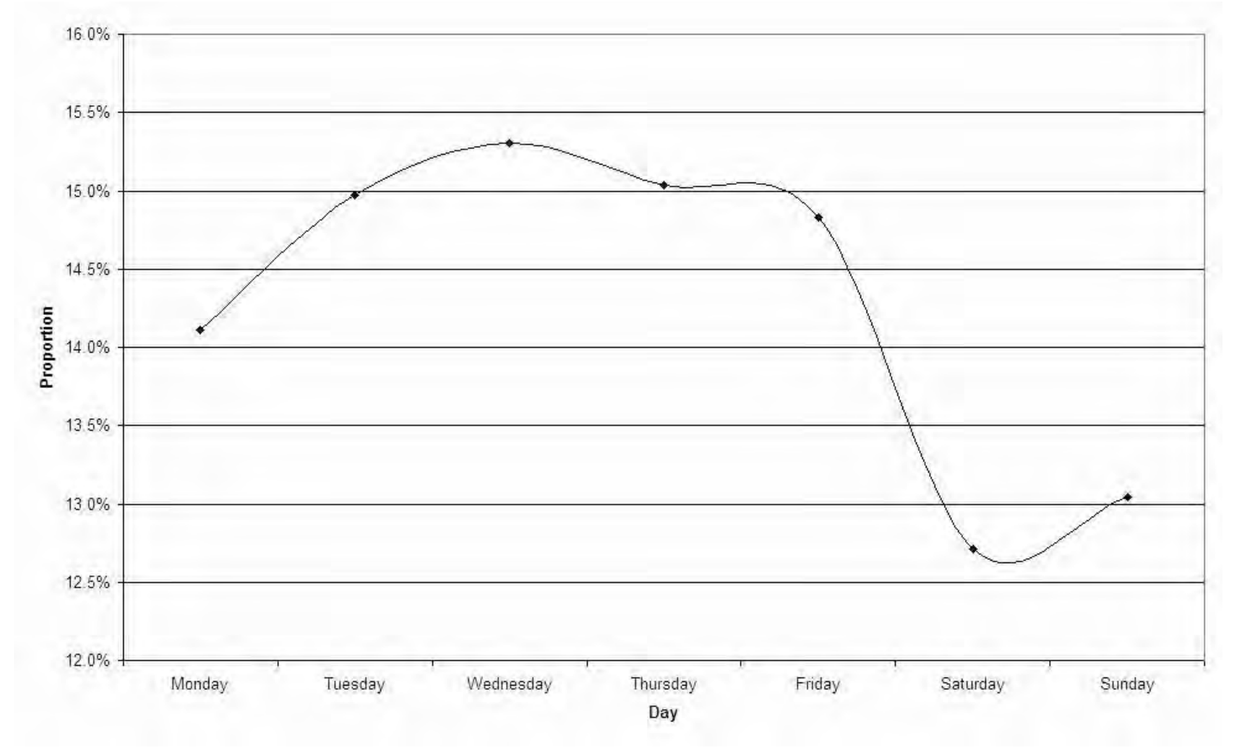

Figure 3-26: Aircraft (flight operations) and aircraft (ground operations) daily temporal profile

Monthly temporal variation profiles for aircraft (flight operations) and aircraft (ground operations) emissions are presented in Table 3-23 and shown in Figure 3-27.

Table 3-23: Aircraft (flight operations) and aircraft (ground operations) monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.10	July	8.69
February	8.08	August	8.41
March	8.90	September	8.11
April	8.19	October	8.51
May	9.02	November	8.25
June	7.78	December	7.96

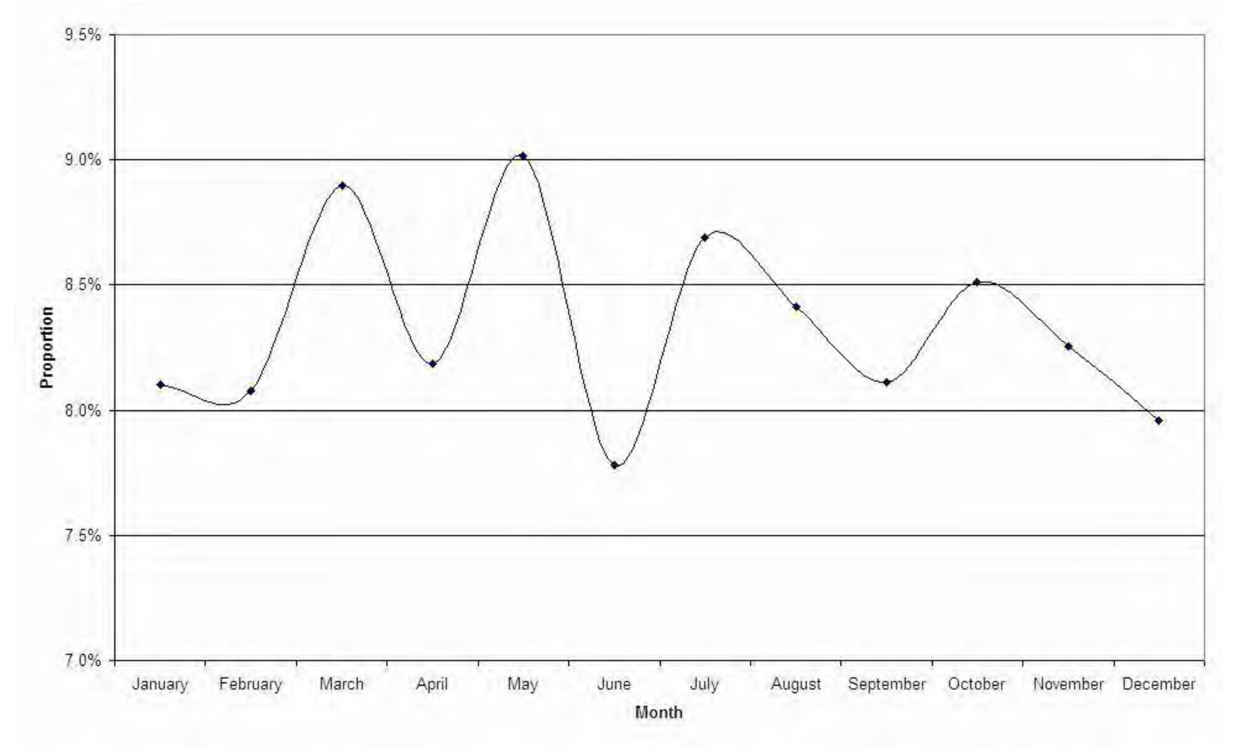

Figure 3-27: Aircraft (flight operations) and aircraft (ground operations) monthly temporal profile

3.1.7 Emission Estimates

Table 3-24 presents annual emissions of selected substances from aircraft (flight operations) and aircraft (ground operations) by activity.

Table 3-24: Aircraft (flight operations) and aircraft (ground operations) emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Aircraft (Flight Operations)	1,3-BUTADIENE	63	258	3,539	4.53	3,864
	ACETALDEHYDE	161	690	9,017	12	9,881
	BENZENE	64	282	3,563	5.02	3,913
	CARBON MONOXIDE	41,108	667,116	2,406,987	13,126	3,128,337
	FORMALDEHYDE	469	2,177	26,260	39	28,945
	ISOMERS OF XYLENE	17	71	943	1.25	1,033
	LEAD & COMPOUNDS	17	610	1,070	12	1,709
	OXIDES OF NITROGEN	32,051	45,666	1,771,391	568	1,849,676
	PARTICULATE MATTER ≤ 10 µm	797	11,088	46,250	217	58,352
	PARTICULATE MATTER ≤ 2.5 µm	706	7,866	40,515	152	49,238
	POLYCYCLIC AROMATIC HYDROCARBONS	44	291	2,461	5.43	2,801
	SULFUR DIOXIDE	2,885	4,619	159,544	61	167,110

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOLUENE	24	86	1,329	1.48	1,440
	TOTAL SUSPENDED PARTICULATE	818	11,426	47,484	224	59,952
	TOTAL VOLATILE ORGANIC COMPOUNDS	4,550	15,516	253,460	265	273,790
Aircraft (Ground Operations)	1,3-BUTADIENE	4.10	0.78	124	-	129
	ACETALDEHYDE	117	22	3,544	-	3,683
	BENZENE	47	83	1,468	-	1,598
	CARBON MONOXIDE	60,133	11,419	1,823,021	-	1,894,573
	FORMALDEHYDE	260	49	7,888	-	8,198
	ISOMERS OF XYLENE	24	15	722	-	760
	LEAD & COMPOUNDS	1.45×10^{-2}	2.76×10^{-3}	0.44	-	0.46
	OXIDES OF NITROGEN	8,418	1,599	255,207	-	265,224
	PARTICULATE MATTER ≤ 10 µm	465	88	14,112	-	14,666
	PARTICULATE MATTER ≤ 2.5 µm	457	87	13,862	-	14,406
	POLYCYCLIC AROMATIC HYDROCARBONS	0.48	9.15×10^{-2}	15	-	15
	SULFUR DIOXIDE	62	12	1,894	-	1,968
	TOLUENE	35	71	1,094	-	1,199
	TOTAL SUSPENDED PARTICULATE	485	92	14,700	-	15,277
	TOTAL VOLATILE ORGANIC COMPOUNDS	3,051	11,051	99,218	-	113,319

Table 3-25 presents annual emissions of selected substances from aircraft (flight operations) and aircraft (ground operations) by source type.

Table 3-25: Aircraft (flight operations) and aircraft (ground operations) emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
LTO – Avgas	1,3-BUTADIENE	4.02	176	260	3.53	443
	ACETALDEHYDE	11	483	714	9.71	1,218
	BENZENE	4.57	200	296	4.02	504
	CARBON MONOXIDE	14,412	630,290	931,868	12,678	1,589,247
	FORMALDEHYDE	36	1,579	2,335	32	3,982
	ISOMERS OF XYLENE	1.13	49	73	0.99	124
	LEAD & COMPOUNDS	14	605	895	12	1,527
	OXIDES OF NITROGEN	34	1,499	2,216	30	3,780
	PARTICULATE MATTER ≤ 10 µm	236	10,314	15,249	207	26,007

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	PARTICULATE MATTER ≤ 2.5 µm	163	7,117	10,522	143	17,945
	POLYCYCLIC AROMATIC HYDROCARBONS	5.45	238	352	4.79	601
	SULFUR DIOXIDE	15	661	977	13	1,666
	TOLUENE	1.26	55	81	1.10	139
	TOTAL SUSPENDED PARTICULATE	243	10,633	15,721	214	26,811
	TOTAL VOLATILE ORGANIC COMPOUNDS	218	9,541	14,106	192	24,057
LTO – Avtur	1,3-BUTADIENE	59	82	3,279	1.00	3,421
	ACETALDEHYDE	150	207	8,303	2.52	8,663
	BENZENE	59	82	3,267	0.99	3,409
	CARBON MONOXIDE	26,696	36,826	1,475,119	448	1,539,089
	FORMALDEHYDE	433	597	23,925	7.27	24,963
	ISOMERS OF XYLENE	16	22	871	0.26	908
	LEAD & COMPOUNDS	3.16	4.36	175	5.31×10^{-2}	182
	OXIDES OF NITROGEN	32,017	44,167	1,769,174	538	1,845,896
	PARTICULATE MATTER ≤ 10 µm	561	774	31,001	9.43	32,345
	PARTICULATE MATTER ≤ 2.5 µm	543	749	29,993	9.12	31,293
	POLYCYCLIC AROMATIC HYDROCARBONS	38	53	2,109	0.64	2,200
	SULFUR DIOXIDE	2,870	3,959	158,568	48	165,444
	TOLUENE	23	31	1,248	0.38	1,302
	TOTAL SUSPENDED PARTICULATE	575	793	31,763	9.66	33,141
	TOTAL VOLATILE ORGANIC COMPOUNDS	4,332	5,975	239,354	73	249,734
APU and GSE – Diesel	1,3-BUTADIENE	4.10	0.78	124	-	129
	ACETALDEHYDE	117	22	3,544	-	3,683
	BENZENE	45	8.51	1,358	-	1,412
	CARBON MONOXIDE	60,133	11,419	1,823,021	-	1,894,573
	FORMALDEHYDE	260	49	7,888	-	8,198
	ISOMERS OF XYLENE	23	4.43	706	-	734
	LEAD & COMPOUNDS	1.45×10^{-2}	2.76×10^{-3}	0.44	-	0.46
	OXIDES OF NITROGEN	8,418	1,599	255,207	-	265,224
	PARTICULATE MATTER ≤ 10 µm	465	88	14,112	-	14,666
	PARTICULATE MATTER ≤ 2.5 µm	457	87	13,862	-	14,406
	POLYCYCLIC AROMATIC HYDROCARBONS	0.48	9.15×10^{-2}	15	-	15
	SULFUR DIOXIDE	62	12	1,894	-	1,968
	TOLUENE	33	6.26	999	-	1,038

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL SUSPENDED PARTICULATE	485	92	14,700	-	15,277
	TOTAL VOLATILE ORGANIC COMPOUNDS	2,202	418	66,763	-	69,384
Evaporative – Avgas	BENZENE	2.63	75	110	-	187
	ISOMERS OF XYLENE	0.36	10	15	-	26
	TOLUENE	2.26	64	94	-	161
	TOTAL VOLATILE ORGANIC COMPOUNDS	365	10,368	15,215	-	25,948
Evaporative – Avtur	TOTAL VOLATILE ORGANIC COMPOUNDS	484	264	17,240	-	17,987

Table 3-26 presents annual emissions of selected substances from aircraft (flight operations) and aircraft (ground operations) by airport.

Table 3-26: Aircraft (flight operations) and aircraft (ground operations) emissions by airport

Source type	Substance	Emissions (kg/year)									
		Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
LTO – Avgas	CARBON MONOXIDE	767,972	147,265	51,111	327,208	48,481	59,697	120,375	28,768	38,371	1,589,248
	OXIDES OF NITROGEN	1,920	362	130	820	123	14	302	7.74	100	3,780
	PARTICULATE MATTER ≤ 10 µm	12,846	2,470	920	5,820	866	145	2,150	115	674	26,007
	PARTICULATE MATTER ≤ 2.5 µm	8,864	1,704	635	4,016	598	100	1,483	80	465	17,945
	SULFUR DIOXIDE	823	154	54	345	51	48	126	23	41	1,666
	TOTAL VOLATILE ORGANIC COMPOUNDS	12,562	1,958	697	4,443	660	1,060	1,635	523	520	24,057
LTO – Avtur	CARBON MONOXIDE	22,209	9,247	3,452	21,791	3,248	1,410,121	8,019	58,466	2,537	1,539,089
	OXIDES OF NITROGEN	3,809	2,937	1,106	6,941	1,039	1,786,558	2,588	40,103	817	1,845,896
	PARTICULATE MATTER ≤ 10 µm	2,005	94	35	221	33	26,927	81	2,923	26	32,345
	PARTICULATE MATTER ≤ 2.5 µm	1,710	83	31	194	29	26,339	71	2,814	23	31,293
	SULFUR DIOXIDE	859	543	201	1,270	190	157,318	466	4,448	149	165,444
	TOTAL VOLATILE ORGANIC COMPOUNDS	8,060	1,555	578	3,646	545	221,307	1,339	12,275	429	249,734
APU and GSE – Diesel	CARBON MONOXIDE	18,297	4,274	1,590	10,052	1,496	1,778,010	3,708	75,980	1,167	1,894,573
	OXIDES OF	2,603	558	208	1,312	195	249,537	484	10,173	152	265,224

Source type	Substance	Emissions (kg/year)									
		Bankstown	Belmont	Camden	Cessnock	Hoxton Park	Sydney	Warnervale	Williamtown	Wollongong	Grand Total
	NITROGEN										
	PARTICULATE MATTER ≤ 10 µm	73	15	5.58	35	5.25	14,145	13	369	4.10	14,666
	PARTICULATE MATTER ≤ 2.5 µm	71	14	5.36	34	5.04	13,901	12	360	3.94	14,406
	SULFUR DIOXIDE	12	2.64	0.98	6.21	0.93	1,879	2.29	62	0.72	1,968
	TOTAL VOLATILE ORGANIC COMPOUNDS	691	157	58	370	55	65,235	136	2,638	43	69,384
Evaporative – Avgas	TOTAL VOLATILE ORGANIC COMPOUNDS	12,819	2,393	844	5,368	801	751	1,967	365	640	25,948
Evaporative – Avtur	TOTAL VOLATILE ORGANIC COMPOUNDS	93	59	22	138	21	17,104	51	484	16	17,987

3.1.8 *Emission Projection Methodology*

Table 3-27 summarises the data used to estimate the emission projection factors for aircraft (flight operations) and aircraft (ground operations), while Figure 3-28 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-27: Aircraft (flight operations) and aircraft (ground operations) emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Flight operations: Exhaust emissions from aircraft	Final energy consumption for air transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)
Ground operations: Exhaust emissions from ground support equipment (GSE) and auxiliary power units (APU)		
Ground operations: Evaporative emissions from the transfer of Avgas to on-site storage tanks, tankers and aircraft		

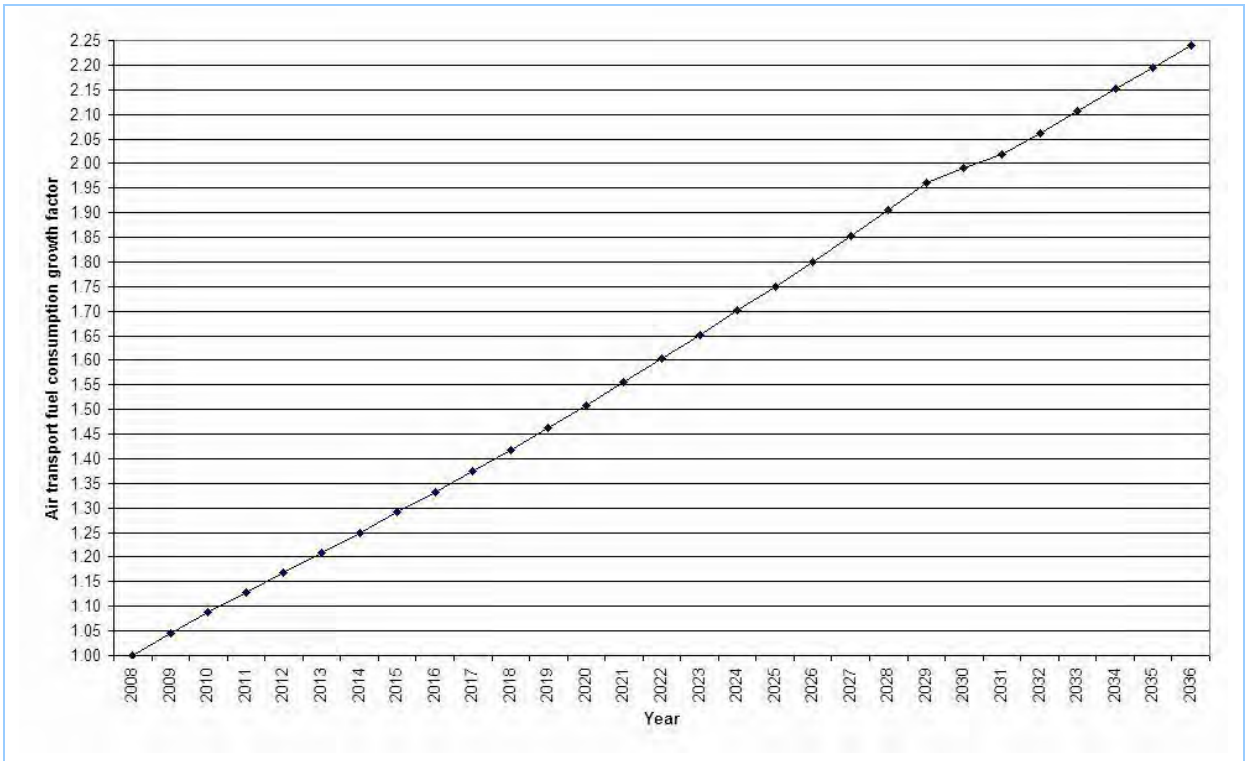

Figure 3-28: Aircraft (flight operations) and aircraft (ground operations) emission projection factors

3.2 Commercial Boats

3.2.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from commercial boat (i.e. harbour vessels) 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 boat operating area and survey data*

The inventory includes commercial boats that operate within estuaries, ports or harbours, which are located in the GMR.

Commercial boat operating areas include:

- *Scheduled ferry services* - Central Coast, Church Point, Cronulla, Dangar Island, Manly, Newcastle, Palm Beach and Sydney Harbour (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010);
- *Commercial fishing boats* - Avoca Lake, Benson's Creek, Botany Bay, Brisbane Water, Broken Bay, Budgewoi, Cockrone Lake, Curl Curl Lagoon, Dee Why Lagoon, Georges River, Hawkesbury River, Hunter River, Karuah River, Kiama, Lake Illawarra, Lake Macquarie, Larpent River, Manly Lagoon, Minnamurra River, Munmorah, Myall Lakes, Myall River, Myall River, Narrabeen Lagoon, Narrabeen Lake, Parramatta River, Patonga, Pittwater, Port Hacking, Port Kembla, Port Stephens, Spring Creek, Sydney Harbour, Tea Gardens, Terrigal Lake, Towradgie Creek, Tuggerah Lakes, Wamberal Lagoon and Wollongong (NSW DPI, 2005); and
- *Other commercial boats* (e.g. assist tugboat, crew boat, dredge and dredging support boat, excursion boat, government boat, towboat/pushboat/tugboat and work boat) - Botany Bay, Brisbane Water, Cowan Creek, Fern Bay, Georges River, Hawks Nest, Hawkesbury River, Kiama, Lake Illawarra, Lake Macquarie, Lemon Tree Passage, Patonga, Pittwater, Port Hacking, Port Hunter, Port Jackson, Port Kembla, Shoal Bay to Soldiers Point, Stockton, Tea Gardens, Terrigal, Tuggerah Lakes and Wollongong (NSW Maritime, 2005).

Commercial boat survey data include:

- *Scheduled ferry services* – vessel number, engine type, number and power (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) and operating hours (TI, 2010; and NBF, 2010);
- *Commercial fishing boats* – vessel number, engine type, number and power (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (NSW DPI, 2005); and
- *Other commercial boats* – vessel number, engine type, number and power (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b).

Figure 3-29 shows how the commercial boat survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009a) to develop an inventory of commercial boat emissions.

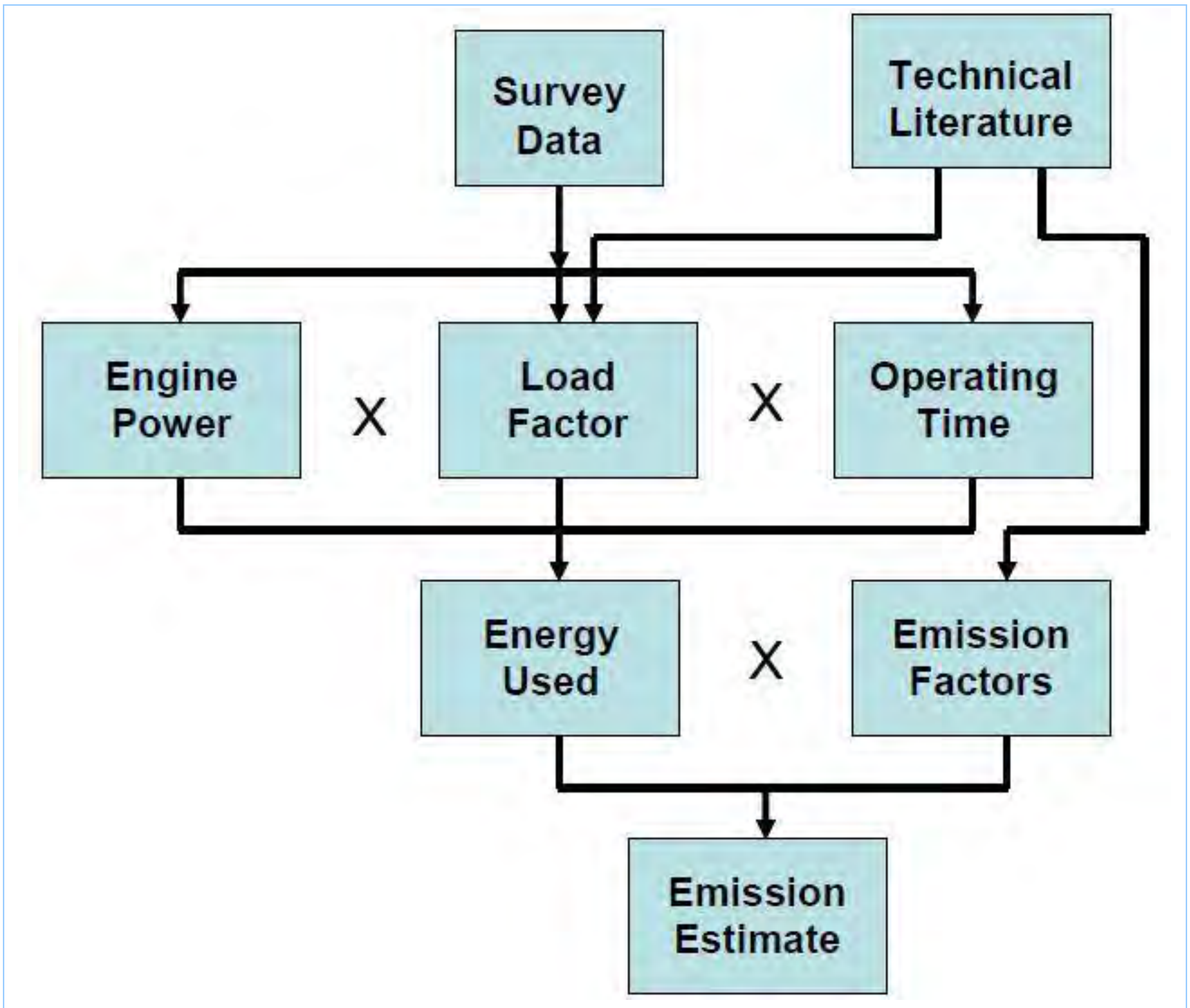

Figure 3-29: Commercial boats – use of survey data

➢ *Commercial boat type*

The inventory includes commercial boats as follows:

- *Scheduled ferry service;*
- *Commercial fishing boat; and*
- *Other commercial boat.*

Table 3-28 presents a description of each commercial boat type (ICF, 2009).

Table 3-28: Commercial boats type and description

Commercial boat type	Description
Assist tugboats	Assist ocean going vessels (OGV) manoeuvre in the harbour during arrival and departure and shifts to and from the pier/wharf/dock (PWD). Provide tugboat escort for tankers. Vessels with a dead weight tonnage (DWT) of ~20,000 tonnes or less generally use one tugboat, while those greater than ~20,000 tonnes use two or more tugboats
Commercial fishing boats	Used for commercial fishing
Crew boats	Carry personnel and supplies to and from in harbour or off-shore locations
Dredges and dredging support boats	Perform or assist in performing dredging activities in the harbour
Ferries and excursion boats	Ferries transport people and property, while excursion boats provide recreational activities such as harbour cruises and whale watching
Government boats	Typically include coast guard, customs, navy, fishing authority, fire, maritime authority and police boats
Towboats/pushboats/tugboats	Self propelled vessels that tow or push barges in harbour or off-shore locations
Work boats	Include utility, inspection, survey, spill/response, research, mining, training and construction boats

➢ *Engine type*

The inventory includes commercial boats powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines and diesel compression ignition (CI) engines. 2-stroke petrol engines are all outboard and range from 1 to 300 horsepower (hp)[7] for commercial fishing boats and other commercial boats. 4-stroke petrol engines are either inboard or outboard and range from 3 to 300 hp for commercial fishing boats and 3 to 750 hp for other commercial boats. All diesel engines are inboard and range from 50 to

[7] 1 horsepower (hp) is equivalent to 0.7457 kilowatts (kW) (USEPA, 1995a).

3,000 hp for scheduled ferry services, 6 to 750 hp for commercial fishing boats and 6 to 3,000 hp for other commercial boats.

Since there are no NSW or Australian emission standards, the inventory considers all commercial boats have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009a).

➢ *Fuel type*

The inventory includes commercial boats that use automotive gasoline (petrol) and automotive diesel oil (ADO).

Table 3-29 presents the commercial boat fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). 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.

Table 3-29: Commercial boats 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[8]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[9]	2.84 – Weighted average[10]			
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

➢ *Source type*

The inventory includes emissions of combustion products and evaporation from commercial boat engines.

[8] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[9] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[10] 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 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
- *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).

3.2.2 *Emission Estimation Methodology*

Table 3-30 summarises the emission estimation methodologies used for commercial boats.

Table 3-30: Commercial boats emission estimation methodologies

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from commercial boats	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *NONROAD2008a Model* (USEPA, 2009a)

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

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, 2009a).

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, 2009a).

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, 2009a).

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, 2009a).

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, 2009a).

Engine population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and monthly basis. Engine population and activity rates have been derived from commercial boat survey data (scheduled ferry services - CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; SF, 2010; TI, 2010; and NBF, 2010; commercial fishing boats - NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009; and other commercial boats - NSW Maritime, 2005; NSW Maritime, 2008; NSW Maritime, 2009; SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b) and sales data (OEDA, 2005). Emissions have been determined using Equation 7 within the *NONROAD2008a Model* (USEPA, 2009a):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times TAF_{j,k,l} \times DF_{j,k,l} \times EF_{i,j,k,l,m} / 1000} \qquad \textbf{Equation 7}$$

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

where:			
$DF_{j,k,l}$	=	Fractional deterioration factor for commercial boat 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 commercial boat 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	=	Commercial boat type (either "assist tugboat", "crew boat", "dredge and dredging support boat", "excursion boat", "ferry", "fishing boat", "government boat", "towboat/pushboat/tugboat" or "work boat")	(-)
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)

3.2.3 *Activity Data*

Table 3-31 summarises the activity data used for commercial boats.

Table 3-31: Commercial boats activity data

Activity data	Activity data source
Commercial boat type, number and fleet composition	Scheduled ferry services - *Our Fleet, Central Coast Ferries Pty* Ltd (CCF, 2010) - *About the Ferries, Church Point Ferry Service* (CPFS, 2010) - *Ferries to Bundeena, Cronulla Ferries* (CF, 2010) - *Australia's Last Riverboat Postman, Hawkesbury River Tourist Services Pty Ltd* (HRTS, 2010) - *Charter Vessels - Bass and Flinders, Bass and Flinders Cruises* (BFC, 2010) - *The Fleet, Matilda Cruises* (MC, 2010) - *Our Fleet, Fantasea Palm Beach* (FPB, 2010) - *Fleet Facts, Sydney Ferries* (SF, 2010) Commercial fishing boats - *Commercial Catch Records, NSW DPI ComCatch & LobCatch 18-07-05 Extraction* (NSW DPI, 2005) - *NSW Maritime 2008 Annual Report* (NSW Maritime, 2008) - *NSW Maritime 2009 Annual Report* (NSW Maritime, 2009) - *The Outboard Motor Market in NSW, Actual Sales Data 2003 to 2005 and Projected Sales Data 2006 to 2010 for NSW and the GMR* (OEDA, 2005) Other commercial boats - *Vessels that have Certificates of Survey within NSW* (NSW Maritime, 2005) - *NSW Maritime 2008 Annual Report* (NSW Maritime, 2008) - *NSW Maritime 2009 Annual Report* (NSW Maritime, 2009)
Commercial boat operating frequency and duration	Scheduled ferry services - *Ferry Timetables, NSW Transport and Infrastructure* (TI, 2010) - *Timetables and Maps, Newcastle Buses and Ferries* (NBF, 2010) Commercial fishing boats

Activity data	Activity data source
	- *Commercial Catch Records, NSW DPI ComCatch & LobCatch 18-07-05 Extraction* (NSW DPI, 2005) Other commercial boats - *Puget Sound Maritime Air Forum Maritime Air Emissions Inventory* (SCG, 2007) - *The Port of San Diego 2006 Emissions Inventory* (SCG , 2008) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b)

Activity data has been obtained for scheduled ferry services, including vessel number, engine type, number and power (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) and operating hours (TI, 2010; and NBF, 2010) for Central Coast, Church Point, Cronulla, Dangar Island, Manly, Newcastle, Palm Beach and Sydney Harbour. Table 3-32 presents scheduled ferry service engine and vessel population and power by ferry class in the GMR. Scheduled ferry service vessels are powered by diesel compression ignition (CI) engines. All diesel engines are inboard.

Table 3-32: Scheduled ferry service engine and vessel population and power by ferry class in the GMR

Ferry class	Vessel name	2008 engine population	Average engine power (hp)	2008 vessel population	Average vessel power (hp)
Central Coast	Codock II	1	70	1	70
	MV Saratoga	2	225	1	451
Central Coast Total		3	174	2	260
Church Point	Amelia K	2	225	1	451
	Curlew	1	70	1	70
	Elvina	1	70	1	70
Church Point Total		4	148	3	197
Cronulla	MV Curranulla	1	78	1	78
Cronulla Total		1	78	1	78
Dangar Island	MV Hawkesbury	2	409	1	818
Dangar Island Total		2	409	1	818
First Fleet/HarbourCat	Alexander	2	388	1	775
	Anne Sargeant	2	409	1	818
	Borrowdale	2	388	1	775
	Charlotte	2	388	1	775
	Fishburn	2	388	1	775
	Friendship	2	388	1	775
	Golden Grove	2	388	1	775

Ferry class	Vessel name	2008 engine population	Average engine power (hp)	2008 vessel population	Average vessel power (hp)
	Pam Burridge	2	409	1	818
	Scarborough	2	388	1	775
	Sirius	2	388	1	775
	Supply	2	388	1	775
First Fleet / HarbourCat Total		22	391	11	783
Freshwater	Collaroy	2	3,001	1	6,002
	Freshwater	2	3,001	1	6,002
	Narrabeen	2	3,001	1	6,002
	Queenscliff	2	3,001	1	6,002
Freshwater Total		8	3,001	4	6,002
Lady	Lady Herron	1	549	1	549
	Lady Northcott	2	810	1	1,620
Lady Total		3	723	2	1,085
Manly Fast	Eye Spy	1	2,400	1	2,400
	Ocean Dreaming	2	1,400	1	2,800
	Ocean Dreaming 2	2	1,400	1	2,800
Manly Fast Total		5	1,600	3	2,667
Matilda	Executive Rocket	2	409	1	818
	Matilda III	2	225	1	451
Matilda Total		4	317	2	634
Newcastle	MV Hunter	2	409	1	818
Newcastle Total		2	409	1	818
Palm Beach	Fantasea Crystal	2	594	1	1,188
	Fantasea Spirit	2	594	1	1,188
	Golden Spirit	2	409	1	818
	Myra	2	225	1	451
Palm Beach Total		8	456	4	911
RiverCat	Betty Cuthbert	2	500	1	1,000
	Dawn Fraser	2	500	1	1,000
	Evonne Goolagong	2	500	1	1,000
	Marjorie Jackson	2	500	1	1,000
	Marlene Matthews	2	500	1	1,000
	Nicole	2	500	1	1,000

Ferry class	Vessel name	2008 engine population	Average engine power (hp)	2008 vessel population	Average vessel power (hp)
	Livingstone				
	Shane Gould	2	500	1	1,000
RiverCat Total		14	500	7	1,000
SuperCat	Louise Sauvage	2	805	1	1,609
	Mary MacKillop	2	805	1	1,609
	SuperCat 4	2	805	1	1,609
	Susie O'Neill	2	805	1	1,609
SuperCat Total		8	805	4	1,609
Sydney Fast	Eye Spy	1	2,400	1	2,400
	Ocean Dreaming	2	1,400	1	2,800
	Ocean Dreaming 2	2	1,400	1	2,800
Sydney Fast Total		5	1,733	3	2,667
Grand Total		89	809	48	1,499

Activity data has been obtained for commercial fishing boats, including vessel number, engine type, number and power (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (NSW DPI, 2005) for Avoca Lake, Benson's Creek, Botany Bay, Brisbane Water, Broken Bay, Budgewoi, Cockrone Lake, Curl Curl Lagoon, Dee Why Lagoon, Georges River, Hawkesbury River, Hunter River, Karuah River, Kiama, Lake Illawarra, Lake Macquarie, Larpent River, Manly Lagoon, Minnamurra River, Munmorah, Myall Lakes, Myall River, Myall River, Narrabeen Lagoon, Narrabeen Lake, Parramatta River, Patonga, Pittwater, Port Hacking, Port Kembla, Port Stephens, Spring Creek, Sydney Harbour, Tea Gardens, Terrigal Lake, Towradgie Creek, Tuggerah Lakes, Wamberal Lagoon and Wollongong. Table 3-33 presents commercial fishing boat vessel population and power by fuel type in the GMR. Commercial fishing boats are powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines and diesel compression ignition (CI) engines. 2-stroke petrol engines are all outboard, while 4-stroke petrol engines are either inboard or outboard. All diesel engines are inboard.

Table 3-33: Commercial fishing boat vessel population and power by fuel type in the GMR

Fuel type	Average vessel power (hp)	2008 vessel population
Diesel	10	116
	15	125
	21	125
	31	85
	42	85
	56	59
	94	59
	145	88
	223	1,037

Fuel type	Average vessel power (hp)	2008 vessel population
	387	354
	677	142
Diesel Total	219	2,276
Petrol	2	122
	5	185
	9	185
	15	670
	23	394
	31	455
	46	268
	63	269
	87	269
	132	467
	212	97
Petrol Total	51	3,381
Grand Total	118	5,657

Activity data has been obtained for other commercial boats (e.g. assist tugboat, crew boat, dredge and dredging support boat, excursion boat, government boat, towboat/pushboat/tugboat and work boat), including vessel number, engine type, number and power (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b) for Botany Bay, Brisbane Water, Cowan Creek, Fern Bay, Georges River, Hawks Nest, Hawkesbury River, Kiama, Lake Illawarra, Lake Macquarie, Lemon Tree Passage, Patonga, Pittwater, Port Hacking, Port Hunter, Port Jackson, Port Kembla, Shoal Bay to Soldiers Point, Stockton, Tea Gardens, Terrigal, Tuggerah Lakes and Wollongong. Table 3-34 presents other commercial boat engine and vessel population and power by fuel and vessel type in the GMR. Other commercial boats are powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines and diesel compression ignition (CI) engines. 2-stroke petrol engines are all outboard, while 4-stroke petrol engines are either inboard or outboard. All diesel engines are inboard.

Table 3-34: Other commercial boat engine and vessel population and power by fuel and vessel type in the GMR

Fuel type	Vessel type	2008 Engine population	Average engine power (hp)	2008 vessel population	Average vessel power (hp)
Diesel	Cargo vessel	5	473	2	947
	Crane barge	2	113	1	226
	Dive charter	16	274	11	384
	Fishing	106	269	97	295
	Hire and drive	76	55	72	59
	Houseboat	6	59	5	74
	Passenger charter	720	243	500	349
	Passenger ferry	108	711	63	1,227
	Sail charter	80	47	77	49

Fuel type	Vessel type	2008 Engine population	Average engine power (hp)	2008 vessel population	Average vessel power (hp)
	Tug boat	59	1,321	32	2,454
	Vehicular ferry	2	75	2	75
	Water taxi	5	360	5	360
	Workboat	132	335	85	518
Diesel Total		1,317	319	952	441
Petrol	Commercial adventure vessel/ tour vessel	2	183	2	183
	Dive charter	64	140	35	252
	Fishing	1	345	1	345
	Hire and drive	144	23	91	37
	Houseboat	52	32	35	47
	Paraflying	5	136	2	271
	Passenger charter	147	108	95	168
	Rescue vessel	5	101	2	202
	Sail charter	24	16	15	26
	Water taxi	49	157	35	218
	Workboat	191	141	101	266
Petrol Total		683	98	416	161
Grand Total		2,000	243	1,368	356

For commercial fishing boats up to 175 hp, outboard engine sales data for the 2003 and 2004 calendar years (OEDA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and inboard/outboard engines with a given maximum power rating, while the commercial fishing boat survey results (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) have been used to estimate the total number of in-service commercial fishing boat engines. Since sales data for diesel engines is not available, the proportion of 4-stroke petrol engines with a given maximum power rating has been assumed for diesel commercial fishing boat engines up to 175 hp. Table 3-35 presents a summary of outboard engine sales data for NSW.

Table 3-35: Outboard engine sales data for NSW

Maximum rated power (hp)	2003 calendar year		2004 calendar year		2003 and 2004 calendar years			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
≤ 10	1,503	490	1,455	544	2,958	1,034	14.79	15.63
11 to 25	3,246	1,058	3,143	1,176	6,389	2,234	31.95	33.77
26 to 50	2,203	719	2,134	798	4,337	1,517	21.69	22.93
51 to 90	1,681	498	1,633	553	3,314	1,051	16.57	15.89

Maximum rated power (hp)	2003 calendar year		2004 calendar year		2003 and 2004 calendar years			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
91 to 150	1,254	314	1,224	349	2,478	663	12.39	10.02
≥ 151	264	55	258	62	522	117	2.61	1.77
Grand Total	10,151	3,134	9,847	3,482	19,998	6,616	100.00	100.00

The total population of in-service commercial boat engines has been estimated by combining the scheduled ferry service (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010), commercial fishing boat (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and other commercial boat (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) activity data with outboard engines sales data (OEDA, 2005) for commercial fishing boats. In-service scheduled ferry service engine population by engine description and maximum rated power range data for the GMR is presented in Table 3-36 and shown in Figure 3-30.

Table 3-36: Scheduled ferry service engine population in the GMR

Engine description	2008 engine population							
	50 to 75 hp	75 to 100 hp	175 to 300 hp	300 to 600 hp	750 to 1000 hp	1200 to 2000 hp	2000 to 3000 hp	Grand Total
Diesel - Inboard	3	1	8	49	10	8	10	89

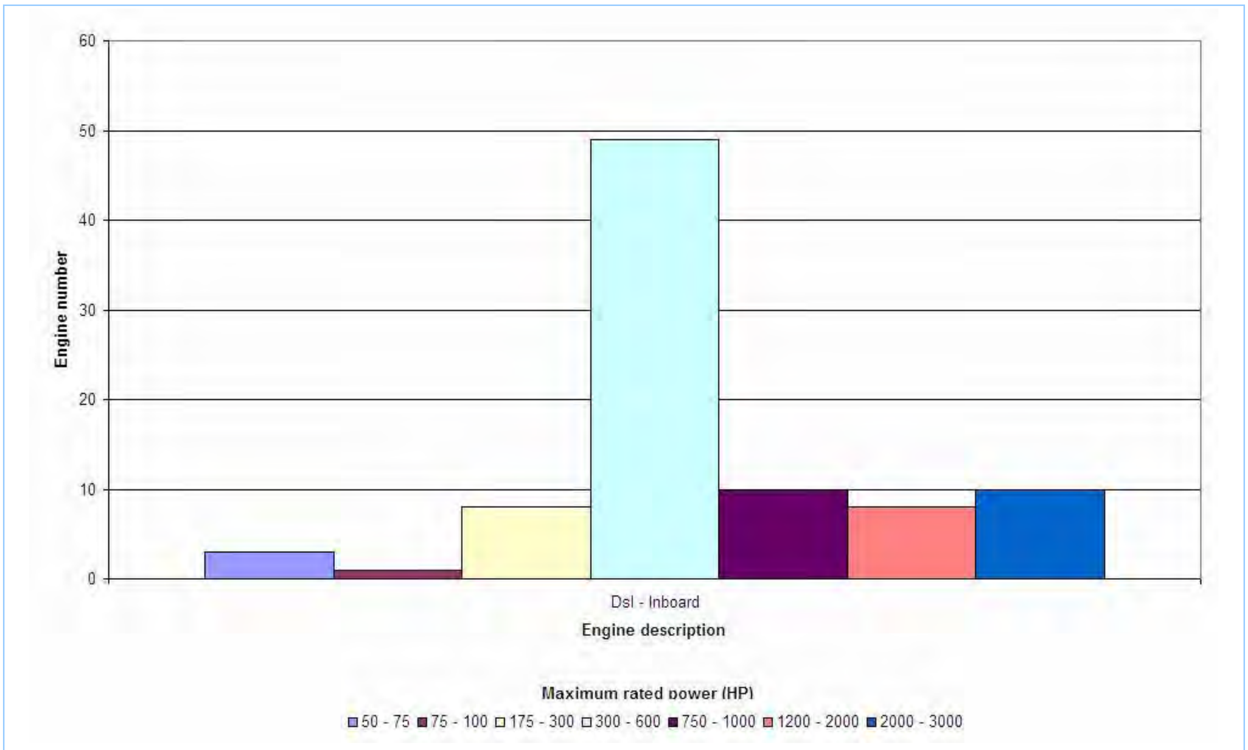

Figure 3-30: Scheduled ferry service engine population in the GMR

The annual operating time of in-service scheduled ferry service engines has been estimated from published timetables (TI, 2010; and NBF, 2010). In-service scheduled ferry service engine annual operating time by engine description for the GMR is presented in Table 3-37 and shown in Figure 3-31.

Table 3-37: Scheduled ferry service engine annual operating time in the GMR

Engine description	Annual operating time (h/year)						
	50 to 75 hp	75 to 100 hp	175 to 300 hp	300 to 600 hp	750 to 1000 hp	1200 to 2000 hp	2000 to 3000 hp
Diesel - Inboard	1,433.4	4,147.0	2,296.8	2,487.9	2,207.7	1,103.6	3,023.5

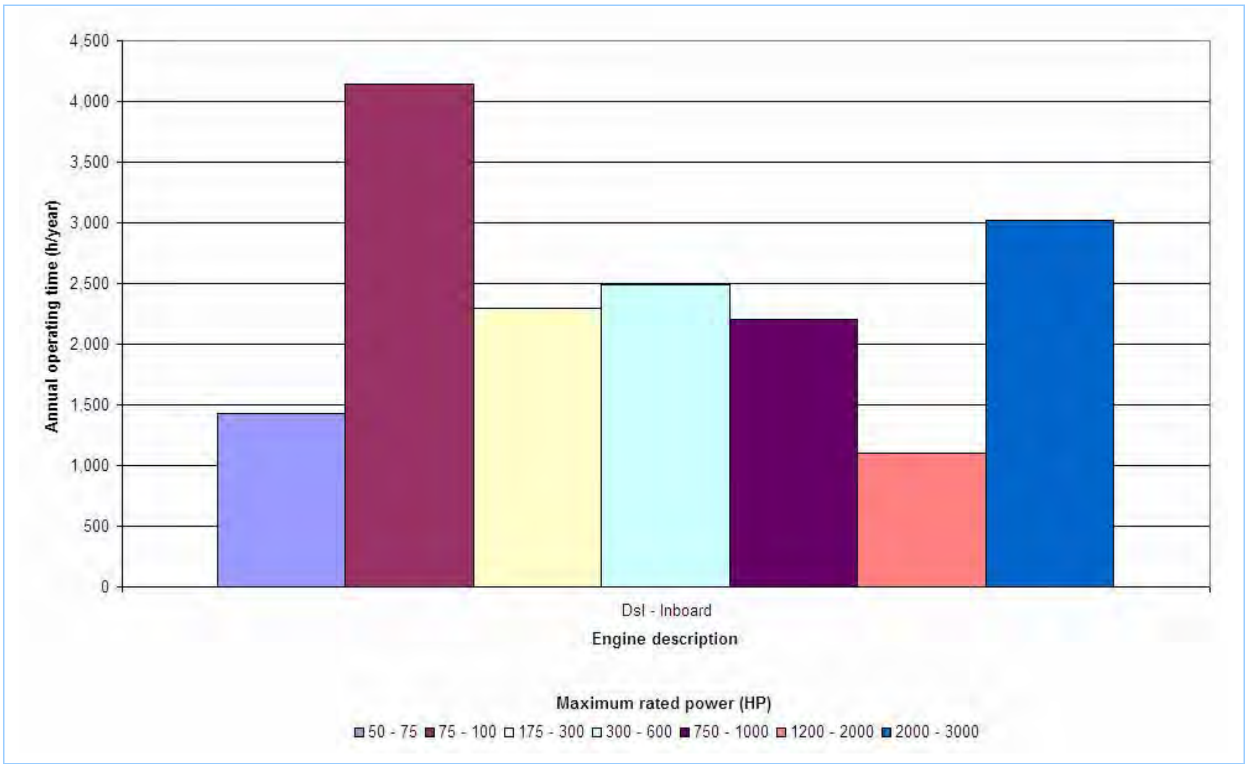

Figure 3-31: Scheduled ferry service engine annual operating time in the GMR

In-service commercial fishing boat engine population by engine description and maximum rated power range data for the GMR is presented in Table 3-38 and shown in Figure 3-32.

Table 3-38: Commercial fishing boat engine population in the GMR

Maximum rated power (hp)	2008 engine population			
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard	Grand Total
1 to 3	122	-	-	122
3 to 6	122	64	-	185
6 to 11	122	64	116	302
11 to 16	394	276	125	795
16 to 25	394	-	125	520

Maximum rated power (hp)	2008 engine population			
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard	Grand Total
25 to 40	268	187	85	540
40 to 50	268	-	85	353
50 to 75	205	65	59	328
75 to 100	205	65	59	328
100 to 175	370	96	88	554
175 to 300	73	24	1,037	1,134
300 to 600	-	-	354	354
600 to 750	-	-	142	142
Grand Total	2,541	841	2,276	5,657

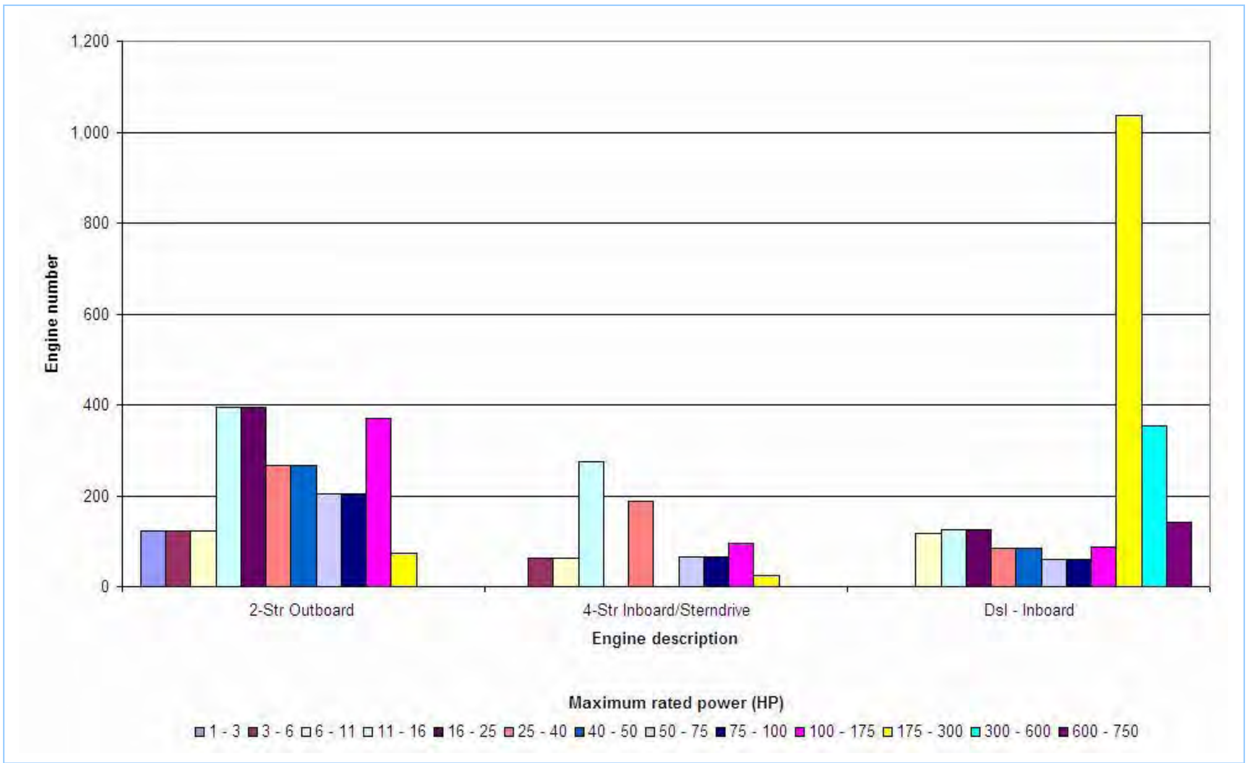

Figure 3-32: Commercial fishing boat engine population in the GMR

The annual operating time of in-service commercial fishing boat engines has been estimated from commercial fishing boat survey data (NSW DPI, 2005). In-service commercial fishing boat engine annual operating time by engine description for the GMR is presented in Table 3-39 and shown in Figure 3-33.

Table 3-39: Commercial fishing boat annual operating time in the GMR

Maximum rated power (hp)	Annual operating time (h/year)		
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard
1 to 3	317.8	-	-
3 to 6	317.8	317.8	-

Maximum rated power (hp)	Annual operating time (h/year)		
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard
6 to 11	317.8	317.8	239.9
11 to 16	317.8	317.8	239.9
16 to 25	317.8	-	239.9
25 to 40	317.8	317.8	239.9
40 to 50	317.8	-	239.9
50 to 75	317.8	317.8	239.9
75 to 100	317.8	317.8	239.9
100 to 175	317.8	317.8	239.9
175 to 300	221.3	221.3	248.8
300 to 600	-	-	214.6
600 to 750	-	-	179.7

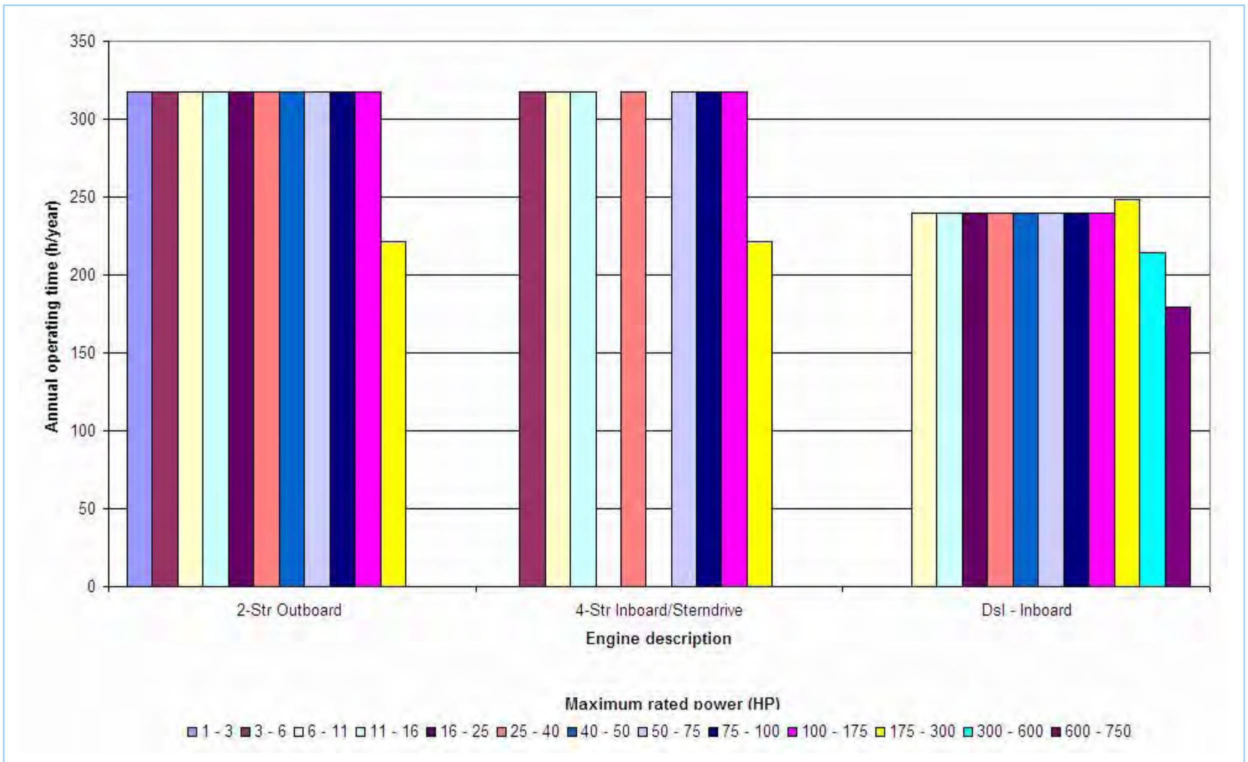

Figure 3-33: Commercial fishing boat annual operating time in the GMR

In-service other commercial boat engine population by engine description and maximum rated power range data for the GMR is presented in Table 3-40 and shown in Figure 3-34.

Table 3-40: Other commercial boat engine population in the GMR

Maximum rated power (hp)	2008 engine population			
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard	Grand Total
3 to 6	1	< 1	-	1
6 to 11	78	26	2	106

Maximum rated power (hp)	2008 engine population			
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard	Grand Total
11 to 16	18	6	8	32
16 to 25	46	-	51	97
25 to 40	27	24	105	155
40 to 50	31	-	39	70
50 to 75	27	19	90	136
75 to 100	53	18	83	154
100 to 175	151	50	220	420
175 to 300	79	26	301	406
300 to 600	-	3	284	287
600 to 750	-	2	40	42
750 to 1000	-	-	36	36
1000 to 1200	-	-	6	6
1200 to 2000	-	-	21	21
2000 to 3000	-	-	32	32
Grand Total	509	174	1,317	2,000

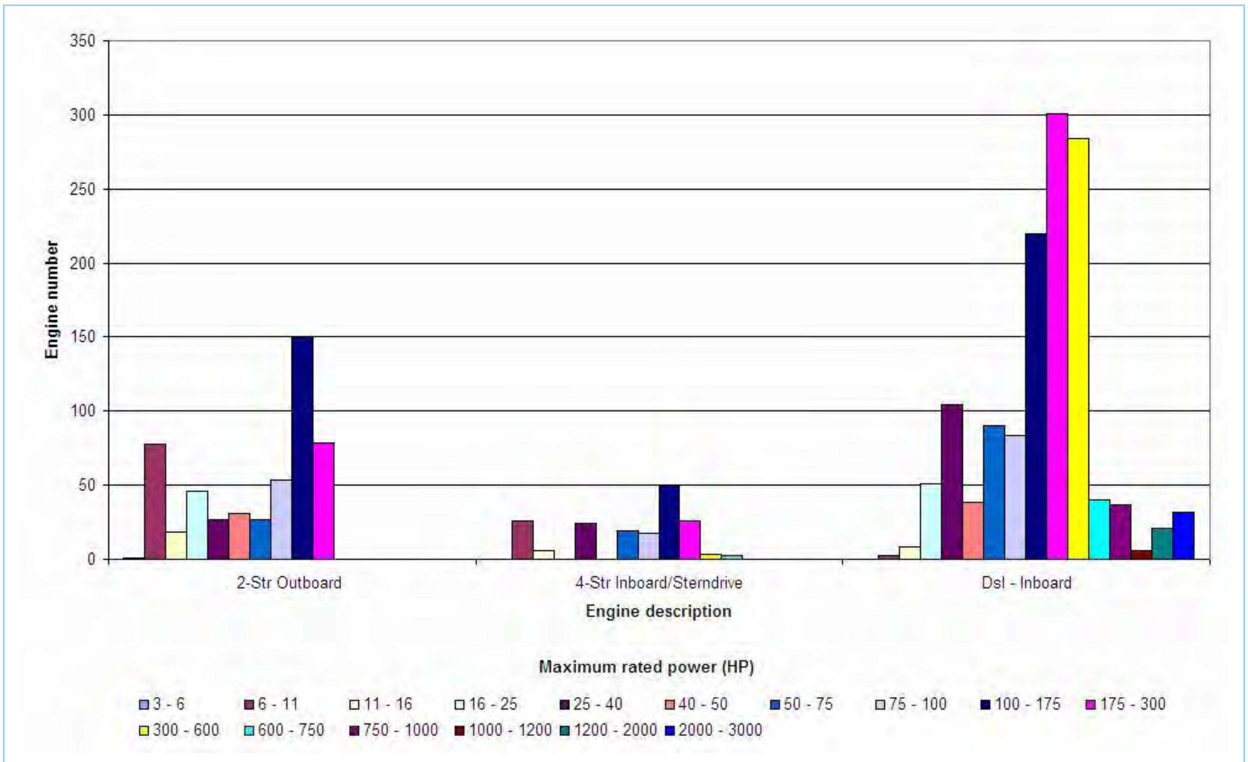

Figure 3-34: Other commercial boat engine population in the GMR

In the absence of GMR specific data, the annual operating time of in-service other commercial boat engines has been estimated from *Puget Sound Maritime Air Forum Maritime Air Emissions Inventory* (SCG, 2007), *The Port of San Diego 2006 Emissions Inventory (SCG, 2008)*, *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) *and Port of Long Beach Air Emissions Inventory - 2009* (SCG, 2010b) in accordance with best practice techniques (ICF, 2009). In-service other commercial boat engine annual operating time by engine description for the GMR is presented in Table 3-41 and shown in Figure 3-35.

Table 3-41: Other commercial boat annual operating time in the GMR

Maximum rated power (hp)	Annual operating time (h/year)		
	2-stroke outboard	4-stroke inboard/sterndrive	Diesel inboard
3 to 6	1,123.2	1,123.2	-
6 to 11	1,408.2	1,408.2	2,358.1
11 to 16	1,299.6	1,299.6	1,476.0
16 to 25	1,283.3	-	1,534.8
25 to 40	1,441.9	1,341.1	1,754.1
40 to 50	1,417.0	-	1,631.7
50 to 75	1,284.1	1,355.5	2,005.6
75 to 100	1,291.1	1,291.1	1,822.6
100 to 175	1,222.0	1,222.0	1,754.0
175 to 300	1,253.9	1,253.9	1,907.9
300 to 600	-	1,666.5	1,835.2
600 to 750	-	2,358.1	1,395.0
750 to 1000	-	-	1,831.2
1000 to 1200	-	-	1,495.2
1200 to 2000	-	-	1,632.5
2000 to 3000	-	-	1,705.0

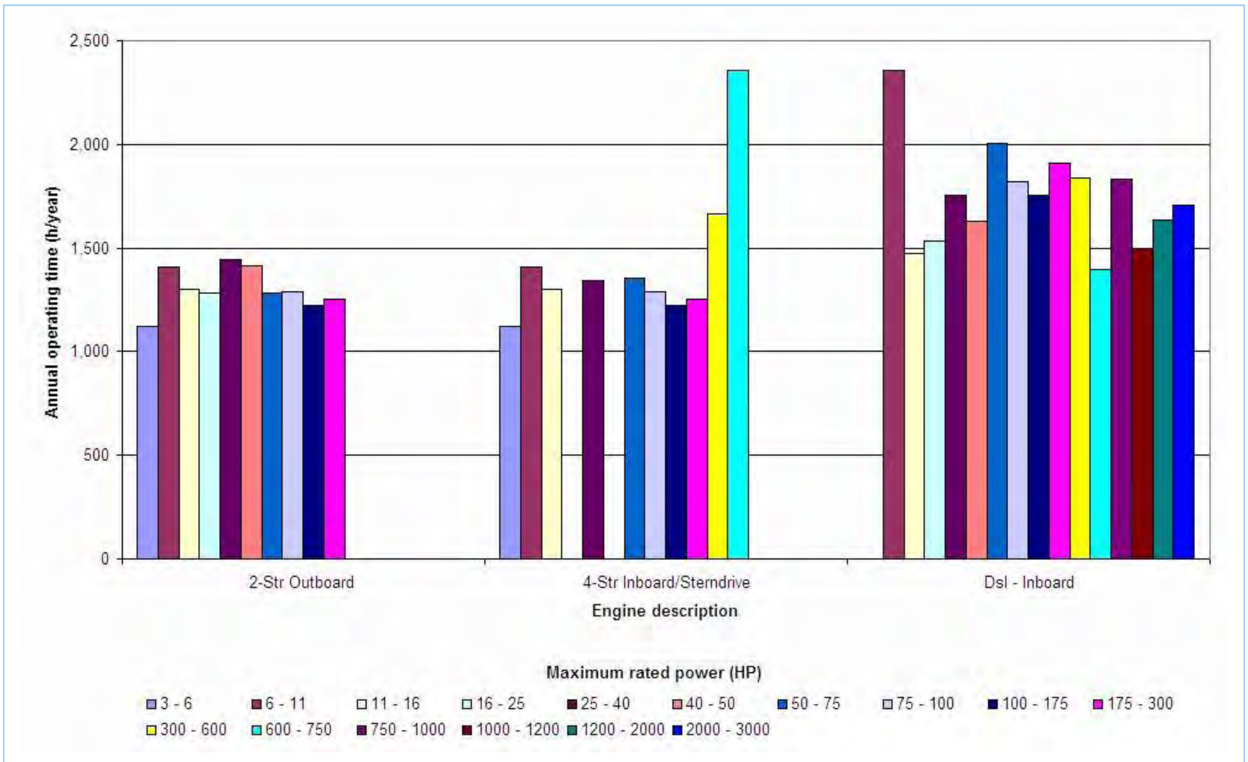

Figure 3-35: Other commercial boat annual operating time in the GMR

Exhaust and evaporative emissions from commercial boat engines have been estimated using: engine population for scheduled ferry services (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010), commercial fishing boats (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009), and other commercial boats (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009); annual operating time for scheduled ferry services (TI, 2010; and NBF, 2010);

commercial fishing boats (NSW DPI, 2005), and other commercial boats (SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b); 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 (TI, 2010; and NBF, 2010) data within the *NONROAD2008a Model* (USEPA, 2009a).

Figure 3-36 shows the NonRoad Model splash screen for the commercial boats emission estimation simulation.

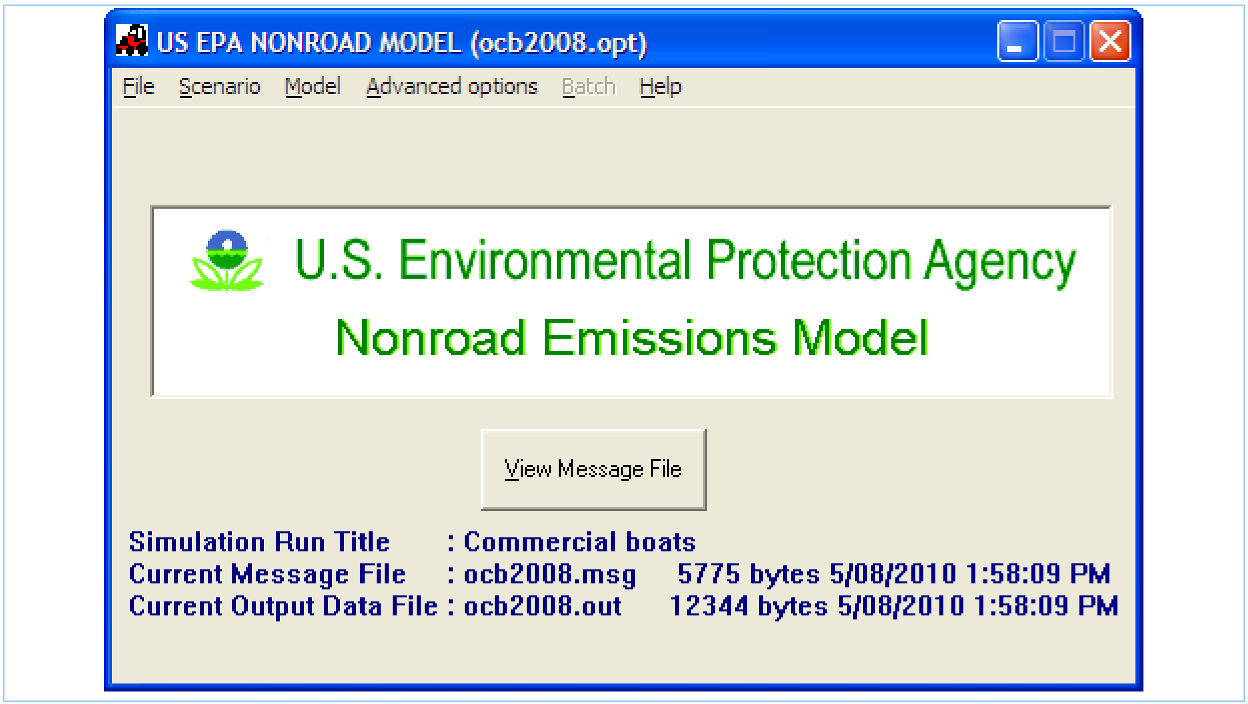

Figure 3-36: Commercial boats NonRoad Model splash screen

Figure 3-37 shows the NonRoad Model options screen for the commercial boats emission estimation simulation.

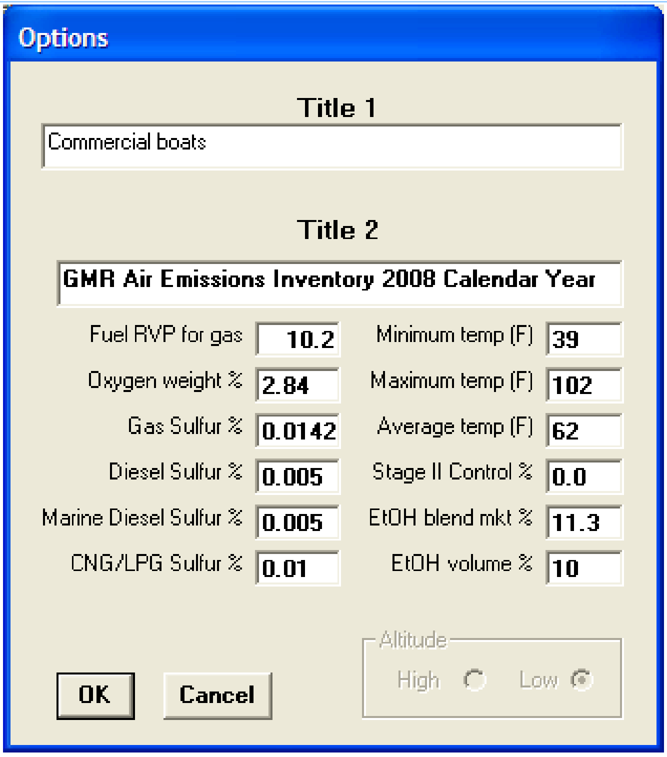

Figure 3-37: Commercial boats NonRoad Model options

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 3-42 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, 2009a).

Table 3-42: Commercial boats 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 3-43 presents the scheduled ferry service engine power rating (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010), useful life (USEPA, 2009a) and population (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-43: Scheduled ferry service NonRoad Model population

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282020005	Dsl - Inboard	50	75	70.0	1400	3.0
2282020005	Dsl - Inboard	75	100	78.0	1400	1.0
2282020005	Dsl - Inboard	175	300	225.3	1400	8.0
2282020005	Dsl - Inboard	300	600	445.1	1400	49.0
2282020005	Dsl - Inboard	750	1000	805.7	1400	10.0
2282020005	Dsl - Inboard	1200	2000	1400.0	1400	8.0
2282020005	Dsl - Inboard	2000	3000	2881.0	1400	10.0

Table 3-44 presents the commercial fishing boat engine power rating (NSW DPI, 2005; and OEDA, 2005), useful life (USEPA, 2009a) and population (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-44: Commercial fishing boat NonRoad Model population

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282005010	2-Str Outboard	1	3	2.08	194	121.7
2282005010	2-Str Outboard	3	6	4.43	194	121.7
2282005010	2-Str Outboard	6	11	9.07	191	121.7
2282005010	2-Str Outboard	11	16	14.83	177	394.3
2282005010	2-Str Outboard	16	25	22.76	162	394.3
2282005010	2-Str Outboard	25	40	32.01	148	267.6
2282005010	2-Str Outboard	40	50	45.58	140	267.6
2282005010	2-Str Outboard	50	75	63.58	126	204.5
2282005010	2-Str Outboard	75	100	85.05	126	204.5
2282005010	2-Str Outboard	100	175	127.8	108	370.3
2282005010	2-Str Outboard	175	300	212.3	97	72.7
2282010005	4-Str Inboard/Sterndrive	3	6	5	197	63.8
2282010005	4-Str Inboard/Sterndrive	6	11	10	197	63.8
2282010005	4-Str Inboard/Sterndrive	11	16	15	197	275.7
2282010005	4-Str Inboard/Sterndrive	25	40	30.47	197	187.2
2282010005	4-Str Inboard/Sterndrive	50	75	59.55	197	64.9
2282010005	4-Str Inboard/Sterndrive	75	100	94.22	197	64.9
2282010005	4-Str Inboard/Sterndrive	100	175	149.7	197	96.3
2282010005	4-Str Inboard/Sterndrive	175	300	211.1	197	24.1
2282020005	Dsl - Inboard	6	11	9.736	1400	116.1
2282020005	Dsl - Inboard	11	16	14.92	1400	125.4
2282020005	Dsl - Inboard	16	25	21.41	1400	125.4
2282020005	Dsl - Inboard	25	40	31.2	1400	85.1

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282020005	Dsl - Inboard	40	50	42.4	1400	85.1
2282020005	Dsl - Inboard	50	75	56.2	1400	59.0
2282020005	Dsl - Inboard	75	100	94.2	1400	59.0
2282020005	Dsl - Inboard	100	175	144.9	1400	87.5
2282020005	Dsl - Inboard	175	300	223.1	1400	1037.0
2282020005	Dsl - Inboard	300	600	387.1	1400	354.1
2282020005	Dsl - Inboard	600	750	677.0	1400	141.9

Table 3-45 presents the other commercial boat engine power rating (NSW Maritime, 2005), useful life (USEPA, 2009a) and population (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-45: Other commercial boat NonRoad Model population

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282005010	2-Str Outboard	3	6	5.8	194	0.9
2282005010	2-Str Outboard	6	11	9.7	191	77.9
2282005010	2-Str Outboard	11	16	14.7	177	18.0
2282005010	2-Str Outboard	16	25	23.5	162	46.2
2282005010	2-Str Outboard	25	40	34.6	148	26.5
2282005010	2-Str Outboard	40	50	48.6	140	30.8
2282005010	2-Str Outboard	50	75	69.5	126	26.5
2282005010	2-Str Outboard	75	100	90.8	126	53.1
2282005010	2-Str Outboard	100	175	137.5	108	150.7
2282005010	2-Str Outboard	175	300	207.4	97	78.7
2282010005	4-Str Inboard/Sterndrive	3	6	5.8	197	0.3
2282010005	4-Str Inboard/Sterndrive	6	11	9.7	197	25.8
2282010005	4-Str Inboard/Sterndrive	11	16	14.7	197	5.9
2282010005	4-Str Inboard/Sterndrive	25	40	27.6	197	24.1
2282010005	4-Str Inboard/Sterndrive	50	75	58.3	197	19.0
2282010005	4-Str Inboard/Sterndrive	75	100	90.8	197	17.6
2282010005	4-Str Inboard/Sterndrive	100	175	137.5	197	49.8
2282010005	4-Str Inboard/Sterndrive	175	300	207.4	197	26.1
2282010005	4-Str Inboard/Sterndrive	300	600	335.5	197	3.4
2282010005	4-Str Inboard/Sterndrive	600	750	625.6	50.4	2.3
2282020005	Dsl - Inboard	6	11	9.9	1400	2.3
2282020005	Dsl - Inboard	11	16	14.0	1400	8.0
2282020005	Dsl - Inboard	16	25	19.3	1400	51.3
2282020005	Dsl - Inboard	25	40	30.9	1400	104.8
2282020005	Dsl - Inboard	40	50	47.9	1400	38.7
2282020005	Dsl - Inboard	50	75	62.0	1400	90.0
2282020005	Dsl - Inboard	75	100	86.9	1400	83.2
2282020005	Dsl - Inboard	100	175	136.0	1400	219.9
2282020005	Dsl - Inboard	175	300	233.1	1400	300.7
2282020005	Dsl - Inboard	300	600	419.5	1400	283.7

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282020005	Dsl - Inboard	600	750	654.0	1400	39.9
2282020005	Dsl - Inboard	750	1000	831.9	1400	36.5
2282020005	Dsl - Inboard	1000	1200	1099.6	1400	5.7
2282020005	Dsl - Inboard	1200	2000	1556.0	1400	20.5
2282020005	Dsl - Inboard	2000	3000	2729.7	1400	31.9

Table 3-46 presents the scheduled ferry service engine load factor (USEPA, 2009a) and annual operating time (TI, 2010; and NBF, 2010) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-46: Scheduled ferry service NonRoad Model load factor and annual operating time

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282020005	Dsl - Inboard	50	75	0.72	1433.4
2282020005	Dsl - Inboard	75	100	0.72	4147.0
2282020005	Dsl - Inboard	175	300	0.72	2296.8
2282020005	Dsl - Inboard	300	600	0.72	2487.9
2282020005	Dsl - Inboard	750	1000	0.72	2207.7
2282020005	Dsl - Inboard	1200	2000	0.72	1103.6
2282020005	Dsl - Inboard	2000	3000	0.72	3023.5

Table 3-47 presents the commercial fishing boat engine load factor (USEPA, 2009a) and annual operating time (NSW DPI, 2005) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-47: Commercial fishing boat NonRoad Model load factor and annual operating time

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282005010	2-Str Outboard	1	3	0.27	317.8
2282005010	2-Str Outboard	3	6	0.27	317.8
2282005010	2-Str Outboard	6	11	0.27	317.8
2282005010	2-Str Outboard	11	16	0.27	317.8
2282005010	2-Str Outboard	16	25	0.27	317.8
2282005010	2-Str Outboard	25	40	0.27	317.8
2282005010	2-Str Outboard	40	50	0.27	317.8
2282005010	2-Str Outboard	50	75	0.27	317.8
2282005010	2-Str Outboard	75	100	0.27	317.8
2282005010	2-Str Outboard	100	175	0.27	317.8
2282005010	2-Str Outboard	175	300	0.27	221.3
2282010005	4-Str Inboard/Sterndrive	3	6	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	6	11	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	11	16	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	25	40	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	50	75	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	75	100	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	100	175	0.27	317.8
2282010005	4-Str Inboard/Sterndrive	175	300	0.27	221.3

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282020005	Dsl – Inboard	6	11	0.27	239.9
2282020005	Dsl – Inboard	11	16	0.27	239.9
2282020005	Dsl – Inboard	16	25	0.27	239.9
2282020005	Dsl – Inboard	25	40	0.27	239.9
2282020005	Dsl – Inboard	40	50	0.27	239.9
2282020005	Dsl – Inboard	50	75	0.27	239.9
2282020005	Dsl – Inboard	75	100	0.27	239.9
2282020005	Dsl – Inboard	100	175	0.27	239.9
2282020005	Dsl – Inboard	175	300	0.27	248.8
2282020005	Dsl – Inboard	300	600	0.27	214.6
2282020005	Dsl – Inboard	600	750	0.27	179.7

Table 3-48 presents the other commercial boat engine load factor (USEPA, 2009a) and annual operating time (NSW Maritime, 2005) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-48: Other commercial boat NonRoad Model load factor and annual operating time

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282005010	2-Str Outboard	3	6	0.54	1123.2
2282005010	2-Str Outboard	6	11	0.58	1408.2
2282005010	2-Str Outboard	11	16	0.56	1299.6
2282005010	2-Str Outboard	16	25	0.56	1283.3
2282005010	2-Str Outboard	25	40	0.59	1441.9
2282005010	2-Str Outboard	40	50	0.58	1417.0
2282005010	2-Str Outboard	50	75	0.55	1284.1
2282005010	2-Str Outboard	75	100	0.53	1291.1
2282005010	2-Str Outboard	100	175	0.52	1222.0
2282005010	2-Str Outboard	175	300	0.52	1253.9
2282010005	4-Str Inboard/Sterndrive	3	6	0.54	1123.2
2282010005	4-Str Inboard/Sterndrive	6	11	0.58	1408.2
2282010005	4-Str Inboard/Sterndrive	11	16	0.56	1299.6
2282010005	4-Str Inboard/Sterndrive	25	40	0.57	1341.1
2282010005	4-Str Inboard/Sterndrive	50	75	0.57	1355.5
2282010005	4-Str Inboard/Sterndrive	75	100	0.53	1291.1
2282010005	4-Str Inboard/Sterndrive	100	175	0.52	1222.0
2282010005	4-Str Inboard/Sterndrive	175	300	0.52	1253.9
2282010005	4-Str Inboard/Sterndrive	300	600	0.57	1666.5
2282010005	4-Str Inboard/Sterndrive	600	750	0.72	2358.1
2282020005	Dsl - Inboard	6	11	0.72	2358.1
2282020005	Dsl - Inboard	11	16	0.59	1476.0
2282020005	Dsl - Inboard	16	25	0.60	1534.8
2282020005	Dsl - Inboard	25	40	0.63	1754.1
2282020005	Dsl - Inboard	40	50	0.61	1631.7
2282020005	Dsl - Inboard	50	75	0.67	2005.6
2282020005	Dsl - Inboard	75	100	0.63	1822.6
2282020005	Dsl - Inboard	100	175	0.61	1754.0

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282020005	Dsl - Inboard	175	300	0.63	1907.9
2282020005	Dsl - Inboard	300	600	0.62	1835.2
2282020005	Dsl - Inboard	600	750	0.55	1395.0
2282020005	Dsl - Inboard	750	1000	0.63	1831.2
2282020005	Dsl - Inboard	1000	1200	0.57	1495.2
2282020005	Dsl - Inboard	1200	2000	0.59	1632.5
2282020005	Dsl - Inboard	2000	3000	0.60	1705.0

The NonRoad Model has been run with the optional weekday/weekend and monthly temporal variation file. Section 3.2.6 provides further details about the temporal variation in exhaust and evaporative emissions from commercial boat engines.

Table 3-49 presents the commercial boat fuel consumption estimates by engine description from the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-49: Commercial boats NonRoad Model fuel consumption by engine description in the GMR

Engine description	2008 fuel consumption (kL/year)			
	2-stroke petrol	4-stroke petrol	Diesel	Grand Total
Inboard/Sterndrive	-	7,070	120,180	127,250
Outboard	25,501	-	-	25,501
Grand Total	25,501	7,070	120,180	152,752

Table 3-50 presents the commercial boat engine fuel consumption estimates by boat type from the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-50: Commercial boats NonRoad Model fuel consumption by boat type in the GMR

Boat type	2008 fuel consumption (kL/year)			
	2-stroke petrol	4-stroke petrol	Diesel	Grand Total
Ferry	-	-	24,849.77	24,849.77
Fishing boat	6,904.56	1,346.13	5,962.43	14,213.12
Other boat	18,596.82	5,724.28	89,367.77	113,688.87
Grand Total	25,501.38	7,070.41	120,179.98	152,751.76

3.2.4 *Emission and Speciation Factors*

Table 3-51 summarises the emission and speciation factors used for commercial boat engines.

Table 3-51: Commercial boats 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, 2009a)
Criteria pollutants: VOC	2-stroke /4-stroke petrol and diesel exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009a)
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)

Substance	Emission source	Emission and speciation factor source
	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)
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*

Substance	Emission source	Emission and speciation factor source
		(Pechan, 2005)
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	2-stroke petrol 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 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, 2009a)
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 3-52 presents average activity weighted 2-stroke/4-stroke petrol and diesel exhaust and evaporative emission factors for commercial boat engines.

Table 3-52: Commercial boats 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	3.45	0.058	0.029	0.149	3.86	3.55	193.89	1.688	331.77	1,749.45	0.0056	3.29×10^{-12}
4-stroke petrol exhaust	20.87	0.058	0.029	0.198	0.18	0.17	16.86	1.807	421.85	2,294.04	0.0191	3.29×10^{-12}
Diesel exhaust	34.69	0.069	0.022	0.083	0.78	0.75	1.33	0.020	5.91	2,709.38	0.0008	4.57×10^{-9}
2-stroke petrol evaporative	-	-	-	-	-	-	2.22	-	-	-	-	-
4-stroke petrol evaporative	-	-	-	-	-	-	2.17	-	-	-	-	-
Diesel evaporative	-	-	-	-	-	-	0.03	-	-	-	-	-

3.2.5 Spatial Distribution of Emissions

Table 3-53 summarises the data used for spatially allocating emissions from commercial boat engines.

Table 3-53: Commercial boats spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from commercial boats	Gridded 1 km x 1 km fuel consumption estimates allocated to water bodies	Scheduled ferry services: diesel - *Central Coast, Church Point, Cronulla, Dangar Island, Manly, Newcastle, Palm Beach and Sydney Harbour water bodies* (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) - *NONROAD2008a Model* (USEPA, 2009a) Commercial fishing boats: 2-stroke petrol, 4-stroke petrol and diesel - *Avoca Lake, Benson's Creek, Botany Bay, Brisbane Water, Broken Bay, Budgewoi, Cockrone Lake, Curl Curl Lagoon, Dee Why Lagoon, Georges River, Hawkesbury River, Hunter River, Karuah River, Kiama, Lake Illawarra, Lake Macquarie, Larpent River, Manly Lagoon, Minnamurra River, Munmorah, Myall Lakes, Myall River, Myall River, Narrabeen Lagoon, Narrabeen Lake, Parramatta River, Patonga, Pittwater, Port Hacking, Port Kembla, Port Stephens, Spring Creek, Sydney Harbour, Tea Gardens, Terrigal Lake, Towradgie Creek, Tuggerah Lakes, Wamberal Lagoon and Wollongong water bodies* (NSW DPI, 2005) - *NONROAD2008a Model* (USEPA, 2009a) Other commercial boats: 2-stroke petrol, 4-stroke petrol and diesel - *Botany Bay, Brisbane Water, Cowan Creek, Fern Bay, Georges River, Hawks Nest, Hawkesbury River, Kiama, Lake Illawarra, Lake Macquarie, Lemon Tree Passage, Patonga, Pittwater, Port Hacking, Port Hunter, Port Jackson, Port Kembla, Shoal Bay to Soldiers Point, Stockton, Tea Gardens, Terrigal, Tuggerah Lakes and Wollongong water bodies* (NSW Maritime, 2005) - *NONROAD2008a Model* (USEPA, 2009a)

Emissions from commercial boats have been spatially distributed according to petrol and diesel consumption, which is proportional to annual operating time within each water body. Commercial boat operating area data has been combined with commercial boat survey data to estimate petrol and diesel consumption for scheduled ferry services, commercial fishing boats and other commercial boats in each 1 km by 1 km grid cell using the following data:

Commercial boat operating area data include:

- *Scheduled ferry services* - Central Coast, Church Point, Cronulla, Dangar Island, Manly, Newcastle, Palm Beach and Sydney Harbour (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010);

- *Commercial fishing boats* - Avoca Lake, Benson's Creek, Botany Bay, Brisbane Water, Broken Bay, Budgewoi, Cockrone Lake, Curl Curl Lagoon, Dee Why Lagoon, Georges River, Hawkesbury River, Hunter River, Karuah River, Kiama, Lake Illawarra, Lake Macquarie, Larpent River, Manly Lagoon, Minnamurra River, Munmorah, Myall Lakes, Myall River, Myall River, Narrabeen

Lagoon, Narrabeen Lake, Parramatta River, Patonga, Pittwater, Port Hacking, Port Kembla, Port Stephens, Spring Creek, Sydney Harbour, Tea Gardens, Terrigal Lake, Towradgie Creek, Tuggerah Lakes, Wamberal Lagoon and Wollongong (NSW DPI, 2005); and

- *Other commercial boats* (e.g. assist tugboat, crew boat, dredge and dredging support boat, excursion boat, government boat, towboat/pushboat/tugboat and work boat) - Botany Bay, Brisbane Water, Cowan Creek, Fern Bay, Georges River, Hawks Nest, Hawkesbury River, Kiama, Lake Illawarra, Lake Macquarie, Lemon Tree Passage, Patonga, Pittwater, Port Hacking, Port Hunter, Port Jackson, Port Kembla, Shoal Bay to Soldiers Point, Stockton, Tea Gardens, Terrigal, Tuggerah Lakes and Wollongong (NSW Maritime, 2005).

Commercial boat survey data include:

- *Scheduled ferry services* – vessel number, engine type, number and power (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010) and operating hours (TI, 2010; and NBF, 2010);

- *Commercial fishing boats* – vessel number, engine type, number and power (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (NSW DPI, 2005); and

- *Other commercial boats* – vessel number, engine type, number and power (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009) and operating hours (SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b).

Commercial boat petrol and diesel consumption by LGA and region is presented in Table 3-54 and shown in Figure 3-38 and Figure 3-39 .

Table 3-54: Commercial boats spatial distribution of petrol and diesel consumption by LGA and region

Region	LGA	2008 fuel consumption (kL/year)		
		Petrol	Diesel	Grand Total
Newcastle	Lake Macquarie	152.47	196.56	349.04
	Maitland	25.41	32.76	58.17
	N/A	3,540.76	4,564.64	8,105.40
	Newcastle	474.36	611.53	1,085.89
	Port Stephens	169.41	218.40	387.82
Newcastle Total		4,362.42	5,623.90	9,986.32
Non Urban	Baulkham Hills	8.88	13.39	22.28
	Gosford	17.77	26.79	44.56
	Great Lakes	76.24	98.28	174.52
	Hawkesbury	15.55	23.44	38.99
	Hornsby	8.88	13.39	22.28
	Lake Macquarie	326.48	492.26	818.73
	Maitland	127.06	163.80	290.86
	N/A	11,996.64	18,081.47	30,078.10
	Port Stephens	1,507.79	1,943.79	3,451.58

Region	LGA	2008 fuel consumption (kL/year)		
		Petrol	Diesel	Grand Total
	Shellharbour	3.74	7.35	11.10
	Wyong	290.94	438.68	729.62
Non Urban Total		14,379.96	21,302.65	35,682.61
Sydney	Ashfield	83.24	715.05	798.28
	Auburn	749.12	6,435.44	7,184.56
	Botany Bay	15.55	23.44	38.99
	Canada Bay	998.83	8,580.58	9,579.41
	Gosford	171.01	257.85	428.86
	Hornsby	124.37	187.53	311.90
	Hunters Hill	249.71	2,145.15	2,394.85
	Leichhardt	416.18	3,575.24	3,991.42
	Manly	332.94	2,860.19	3,193.14
	Mosman	249.71	2,145.15	2,394.85
	N/A	3,217.82	6,987.53	10,205.35
	North Sydney	249.71	2,145.15	2,394.85
	Parramatta	1,331.77	11,440.78	12,772.55
	Pittwater	59.97	90.41	150.38
	Randwick	4.44	6.70	11.14
	Rockdale	7.29	11.27	18.56
	Ryde	416.18	3,575.24	3,991.42
	Sutherland	25.57	50.25	75.82
	Sydney	416.18	3,575.24	3,991.42
	Unincorporated	4,141.37	35,132.37	39,273.74
	Warringah	22.21	33.49	55.70
	Wollongong	0.62	1.23	1.85
	Woollahra	332.94	2,860.19	3,193.14
Sydney Total		13,616.73	92,835.47	106,452.20
Wollongong	N/A	176.51	346.86	523.37
	Shellharbour	8.11	15.93	24.04
	Wollongong	28.07	55.15	83.22
Wollongong Total		212.68	417.95	630.63
Grand Total		32,571.79	120,179.98	152,751.76

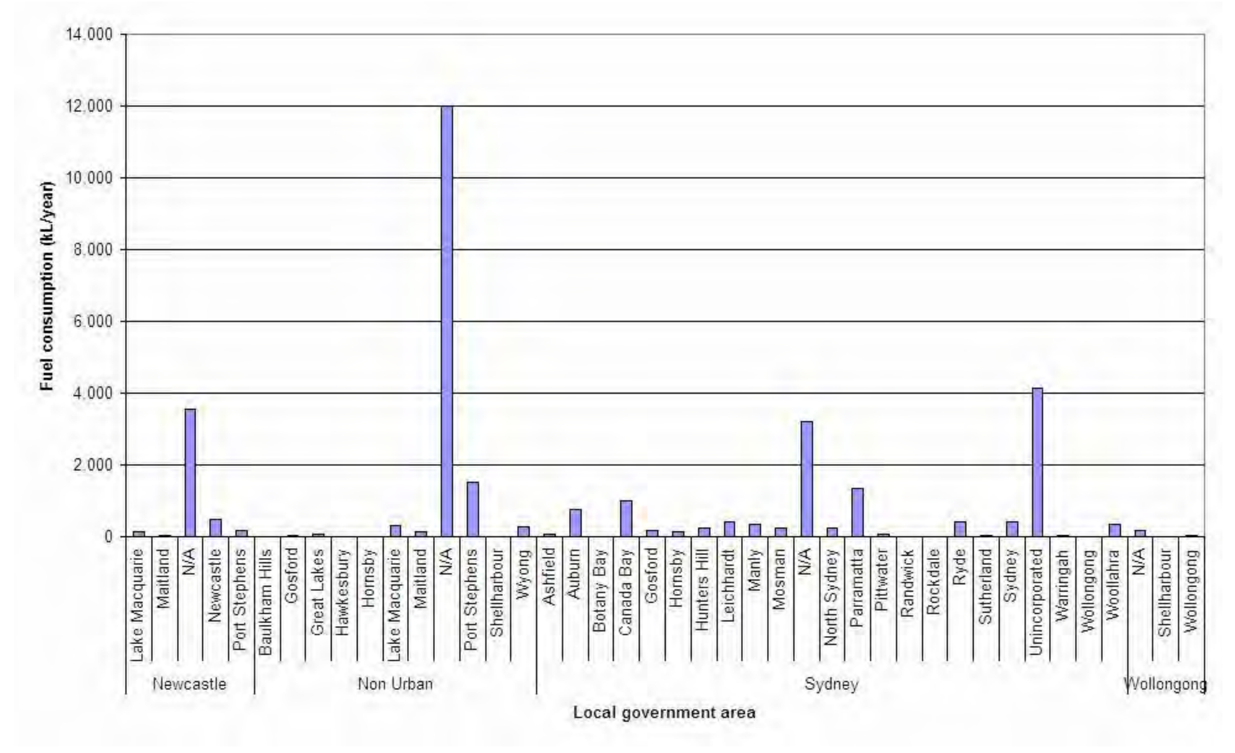

Figure 3-38: Commercial boats spatial distribution of petrol consumption by LGA and region

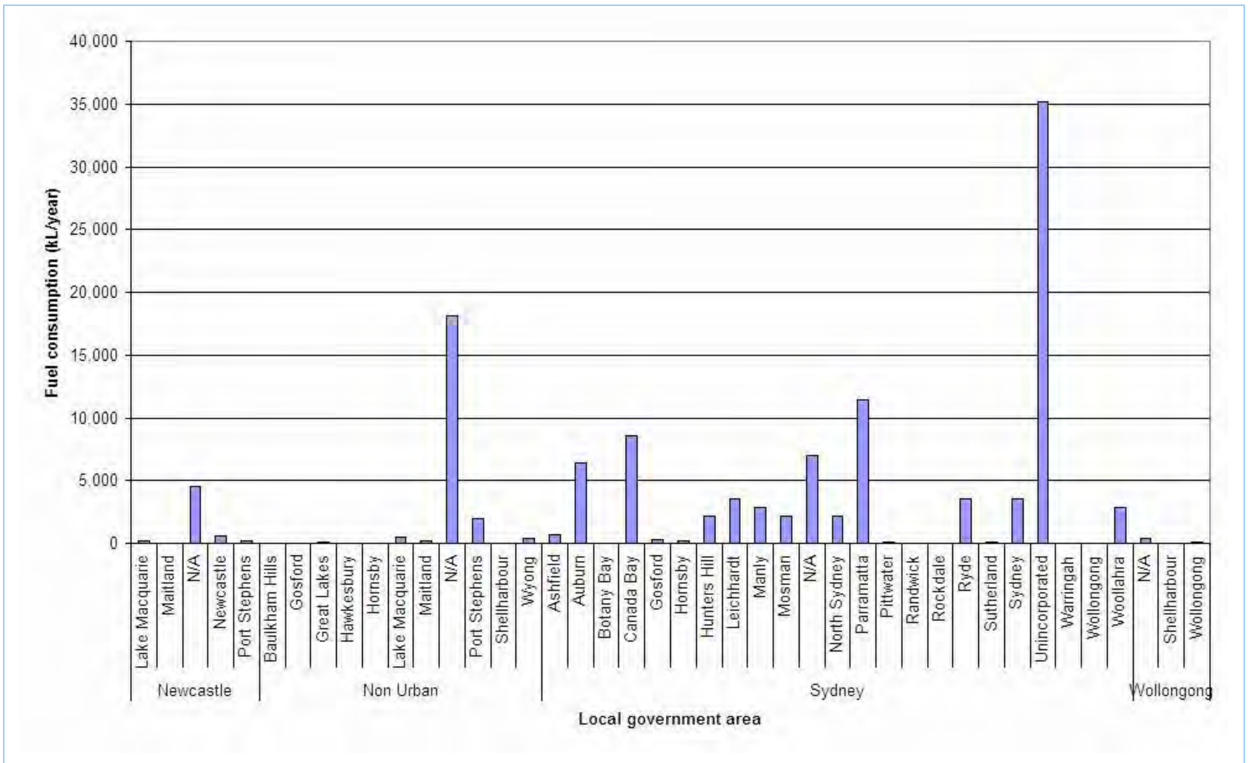

Figure 3-39: Commercial boats spatial distribution of diesel consumption by LGA and region

Figure 3-40 shows the spatial distribution of commercial boats petrol exhaust emissions.

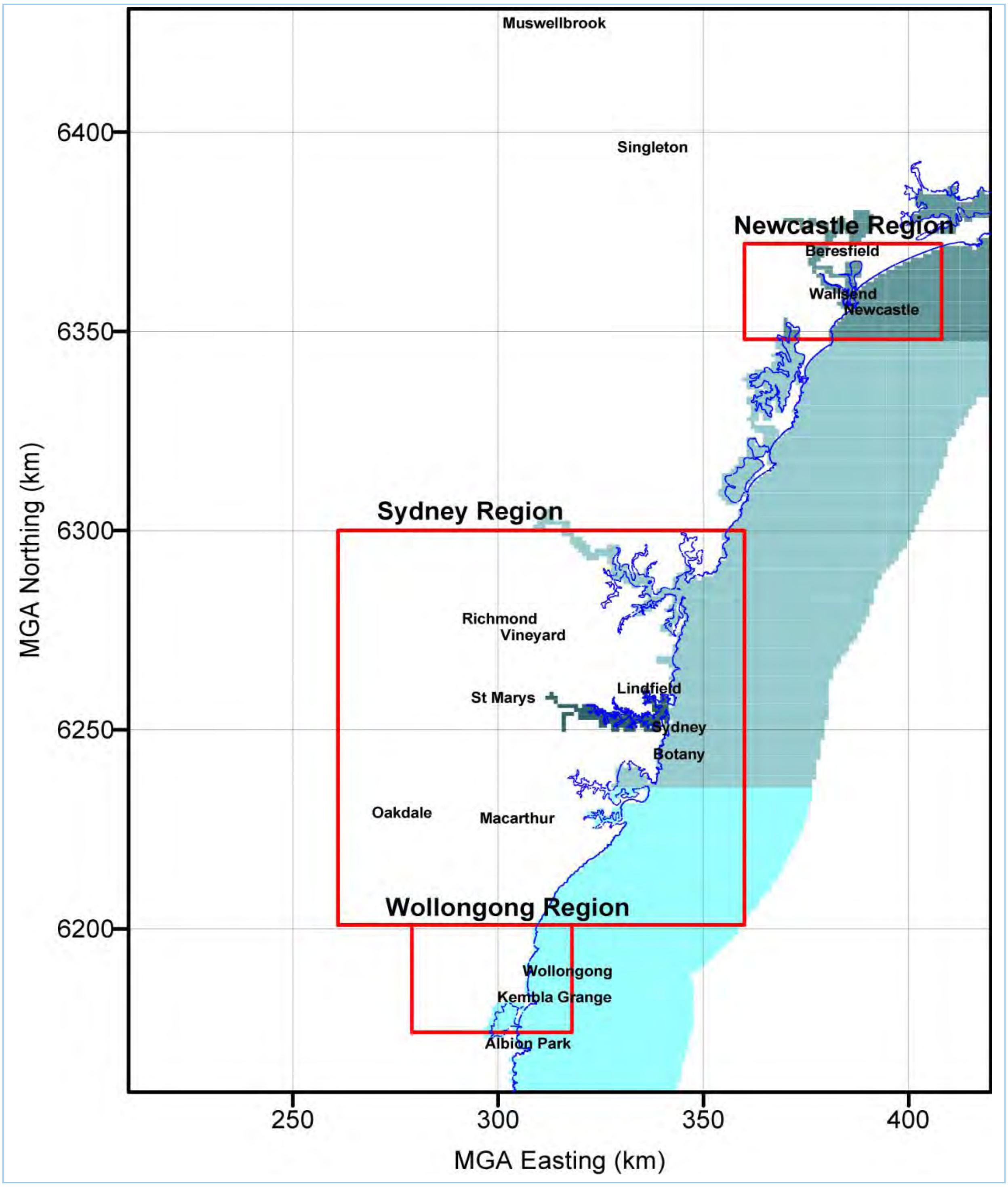

Figure 3-40: Commercial boats spatial distribution of petrol exhaust emissions

Figure 3-41 shows the spatial distribution of commercial boats diesel exhaust emissions.

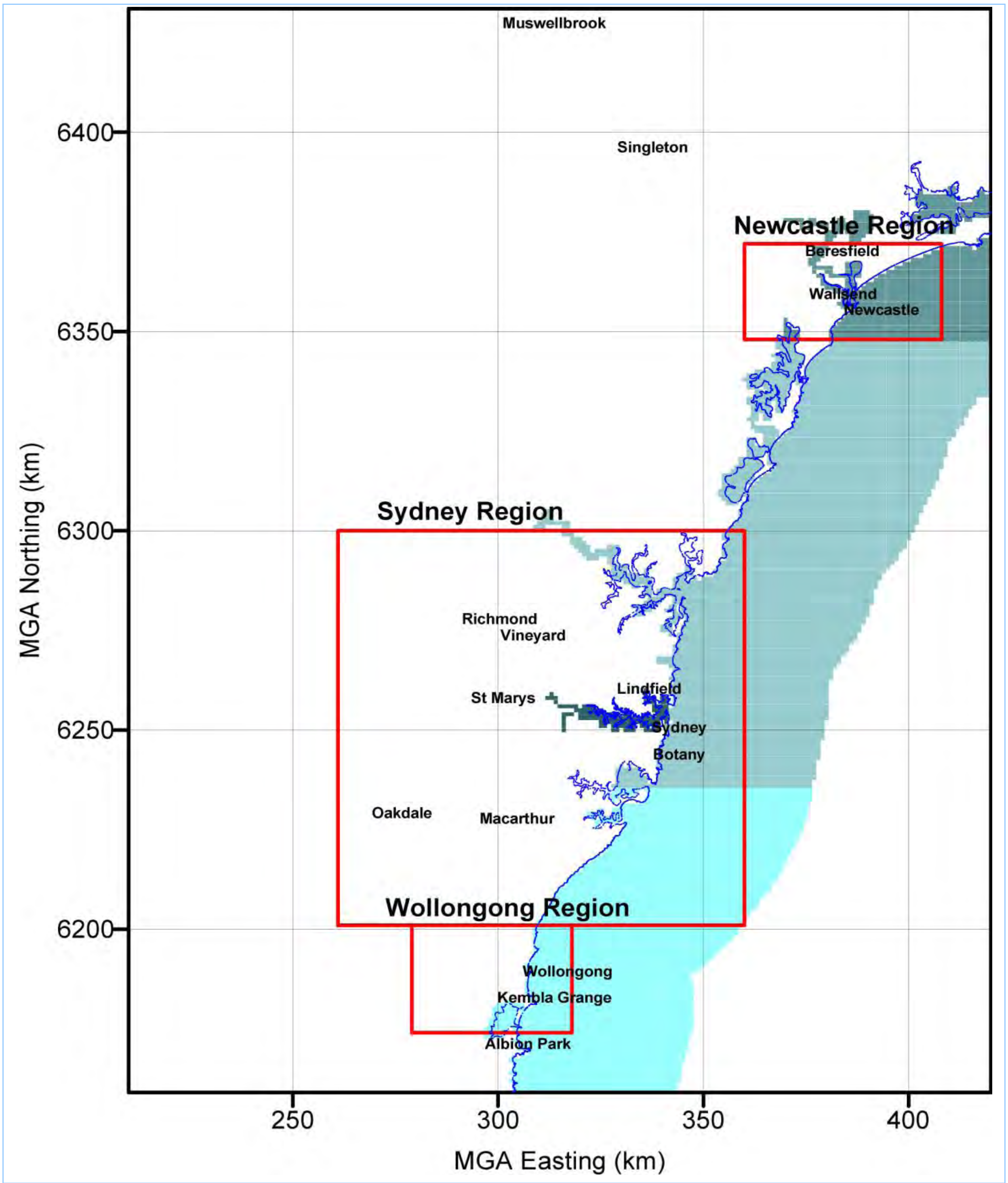

Figure 3-41: Commercial boats spatial distribution of diesel exhaust emissions

Figure 3-42 shows the spatial distribution of commercial boats evaporative emissions.

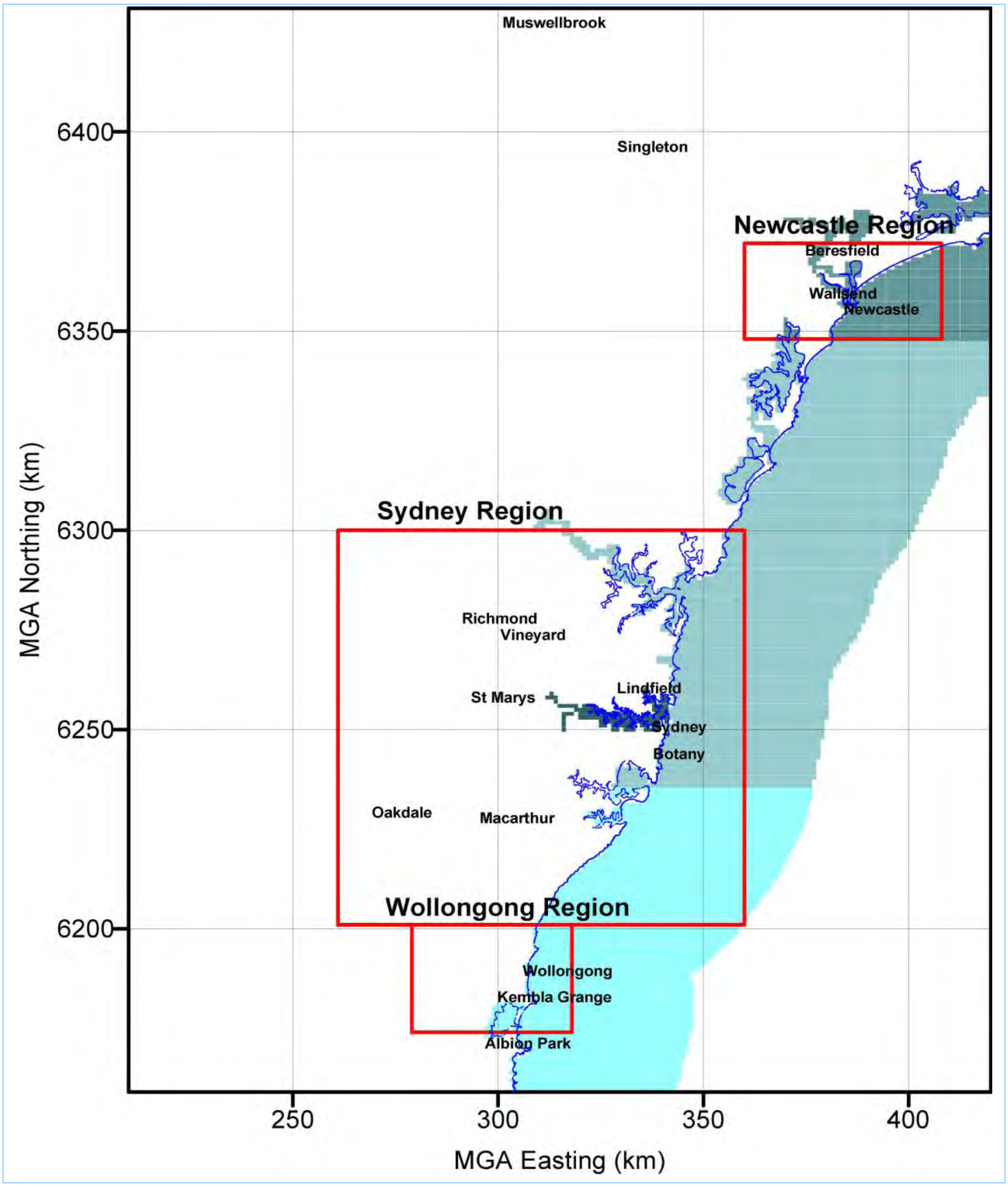

Figure 3-42: Commercial boats spatial distribution of evaporative emissions

3.2.6 *Temporal Variation of Emissions*

Table 3-55 summarises the data used to estimate the temporal variation in emissions from commercial boat engines.

Table 3-55: Commercial boats temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from commercial boats	Monthly, daily and hourly: Derived from Newcastle and Sydney Ferries timetables	- *Ferry Timetables, NSW Transport and Infrastructure* (TI, 2010) - *Timetables and Maps, Newcastle Buses and Ferries* (NBF, 2010)

The temporal variation in exhaust and evaporative emissions from commercial boat engines have been estimated using: engine population for scheduled ferry services (CCF, 2010; CPFS, 2010; CF, 2010; HRTS, 2010; BFC, 2010; MC, 2010; FPB, 2010; and SF, 2010), commercial fishing boats (NSW DPI, 2005; NSW Maritime, 2008; and NSW Maritime, 2009), and other commercial boats (NSW Maritime, 2005; NSW Maritime, 2008; and NSW Maritime, 2009); annual operating time for scheduled ferry services (TI, 2010; and NBF, 2010); commercial fishing boats (NSW DPI, 2005), and other commercial boats (SCG, 2007; SCG, 2008; SCG, 2010a; and SCG, 2010b); 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 (TI, 2010; and NBF, 2010) data within the *NONROAD2008a Model* (USEPA, 2009a). Hourly temporal variation profiles for exhaust emissions are presented in Table 3-56 and shown in Figure 3-43.

Table 3-56: Commercial boats exhaust hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	0.76	0.94	13	5.34	7.86
2	0.00	0.07	14	5.06	7.64
3	0.00	0.00	15	5.25	8.36
4	0.00	0.00	16	5.53	8.22
5	0.00	0.00	17	6.58	8.36
6	0.95	0.22	18	8.68	8.44
7	4.77	1.08	19	8.02	6.99
8	8.11	2.02	20	5.63	4.40
9	9.16	4.33	21	2.86	2.67
10	6.39	6.56	22	2.29	2.52
11	5.53	7.86	23	2.00	2.02
12	5.63	8.07	24	1.43	1.37

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-57 (weighted hourly composite) and shown in Figure 3-44 (weighted hourly composite by source type).

Table 3-57: Commercial boats evaporative hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	1.63	1.91	13	6.14	7.46
2	1.24	1.53	14	5.89	7.27
3	1.23	1.49	15	5.85	7.46
4	1.22	1.48	16	5.76	7.04
5	1.21	1.47	17	6.00	6.63
6	1.69	1.58	18	6.68	6.08
7	3.80	2.11	19	5.82	4.95
8	6.09	2.88	20	4.30	3.57
9	7.40	4.48	21	2.78	2.74
10	6.25	6.11	22	2.45	2.63
11	6.03	7.17	23	2.28	2.39
12	6.28	7.51	24	1.98	2.10

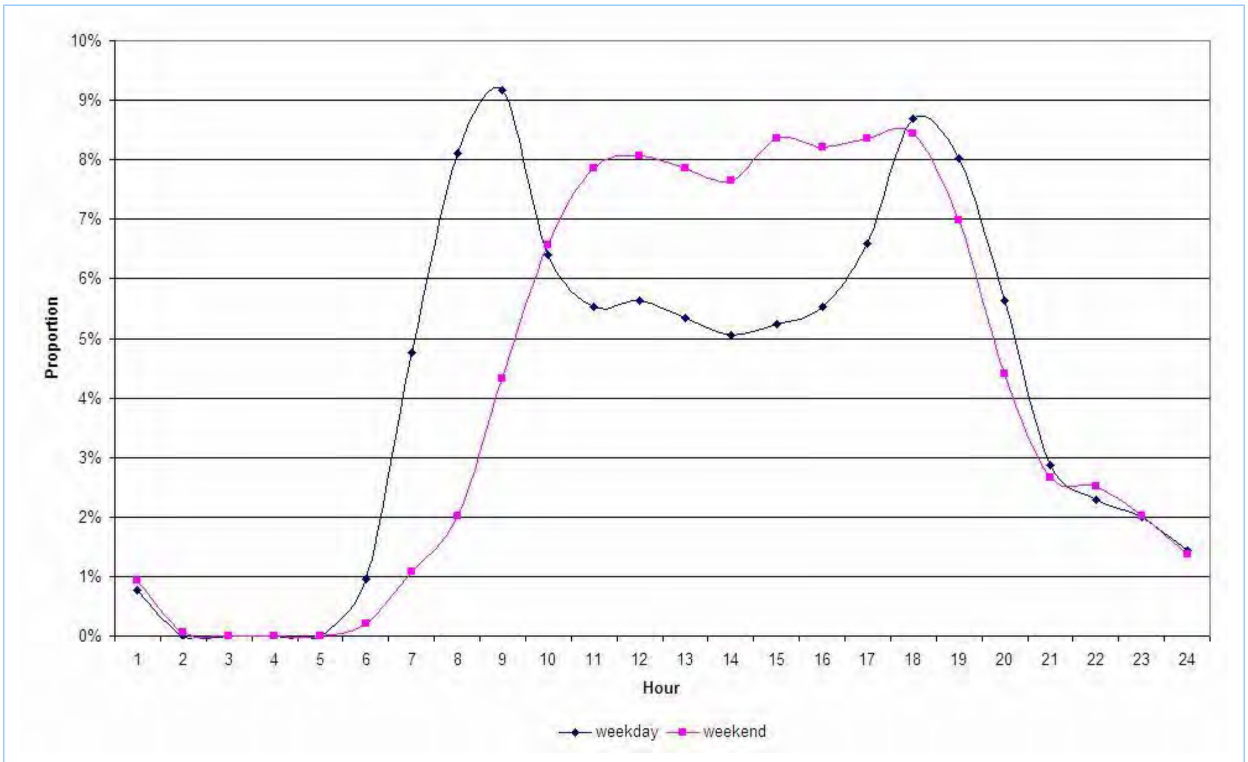

Figure 3-43: Commercial boats exhaust hourly temporal profile

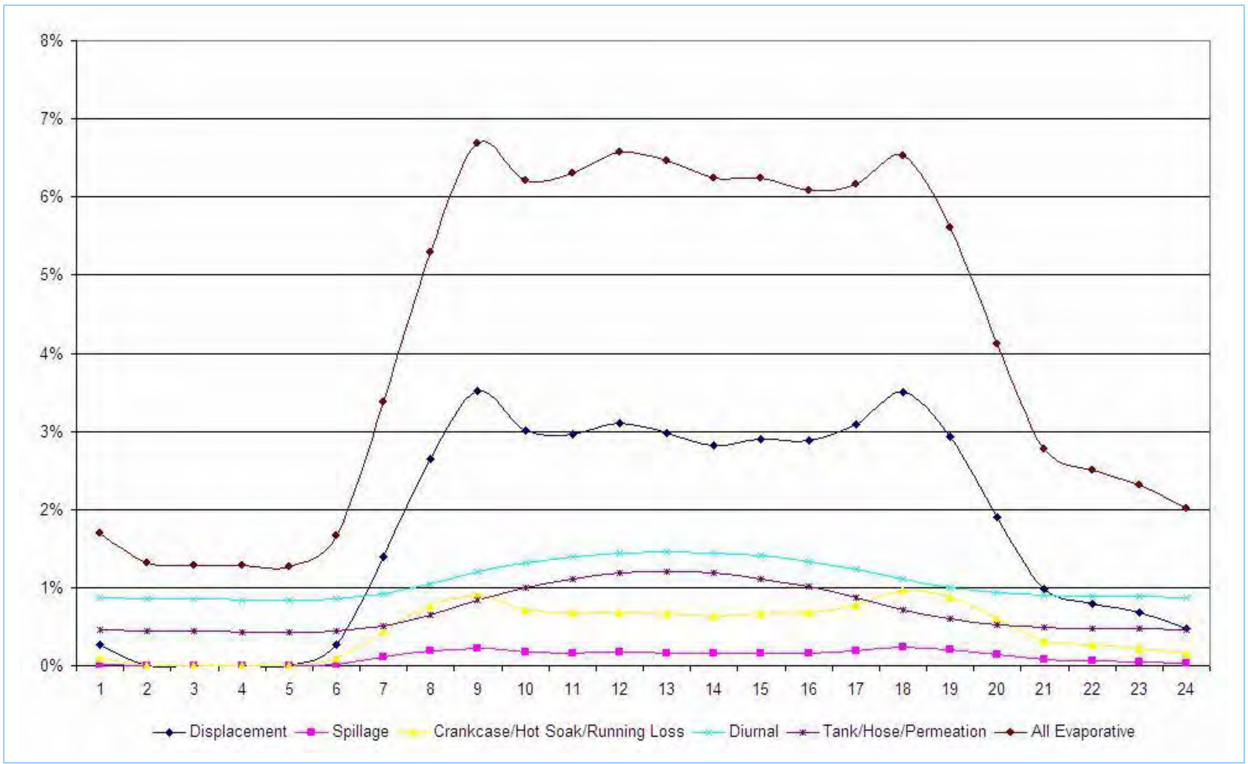

Figure 3-44: Commercial boats evaporative hourly temporal profile

Daily temporal variation profiles for exhaust emissions are presented in Table 3-58 and shown in Figure 3-45.

Table 3-58: Commercial boats exhaust daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	15.61	15.61	15.61	15.61	15.61	11.75	10.18

Daily temporal variation profiles for evaporative emissions are presented in Table 3-59 (weighted daily composite) and shown in Figure 3-46 (weighted daily composite by source type).

Table 3-59: Commercial boats evaporative daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	15.04	15.04	15.04	15.04	15.04	13.28	11.51

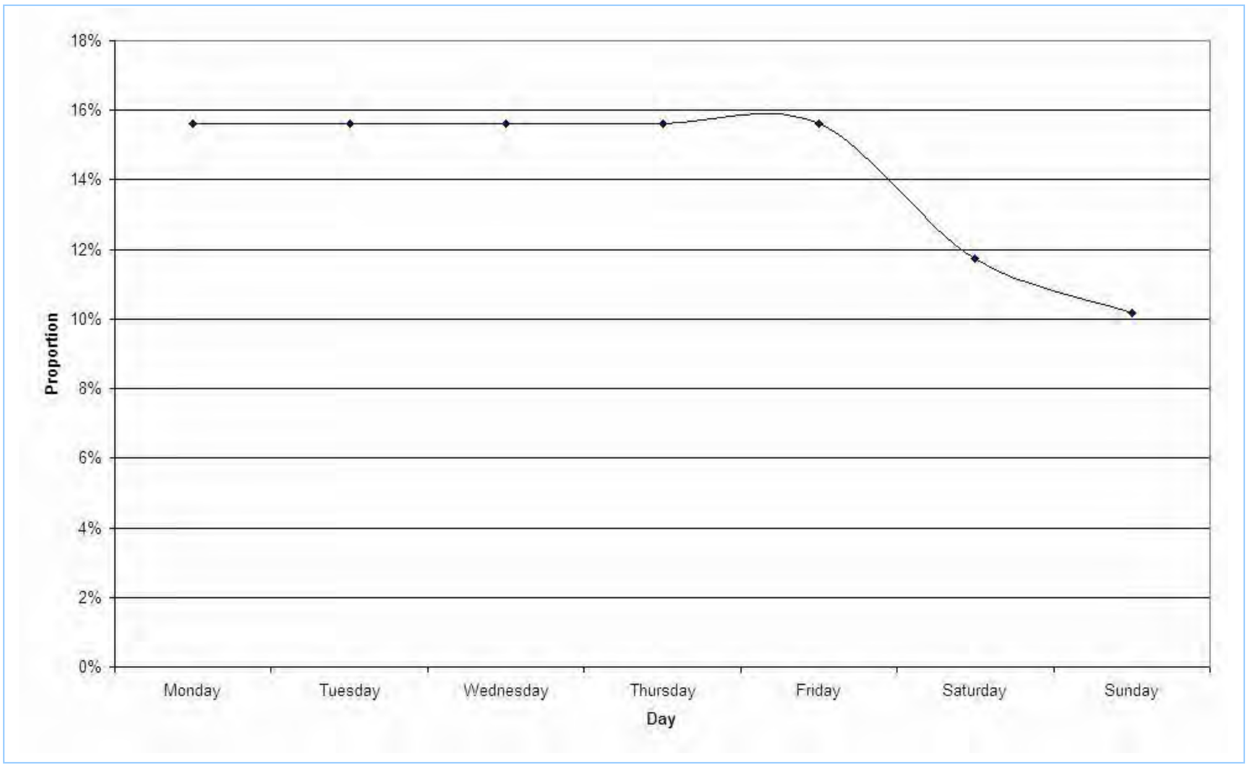

Figure 3-45: Commercial boats exhaust daily temporal profile

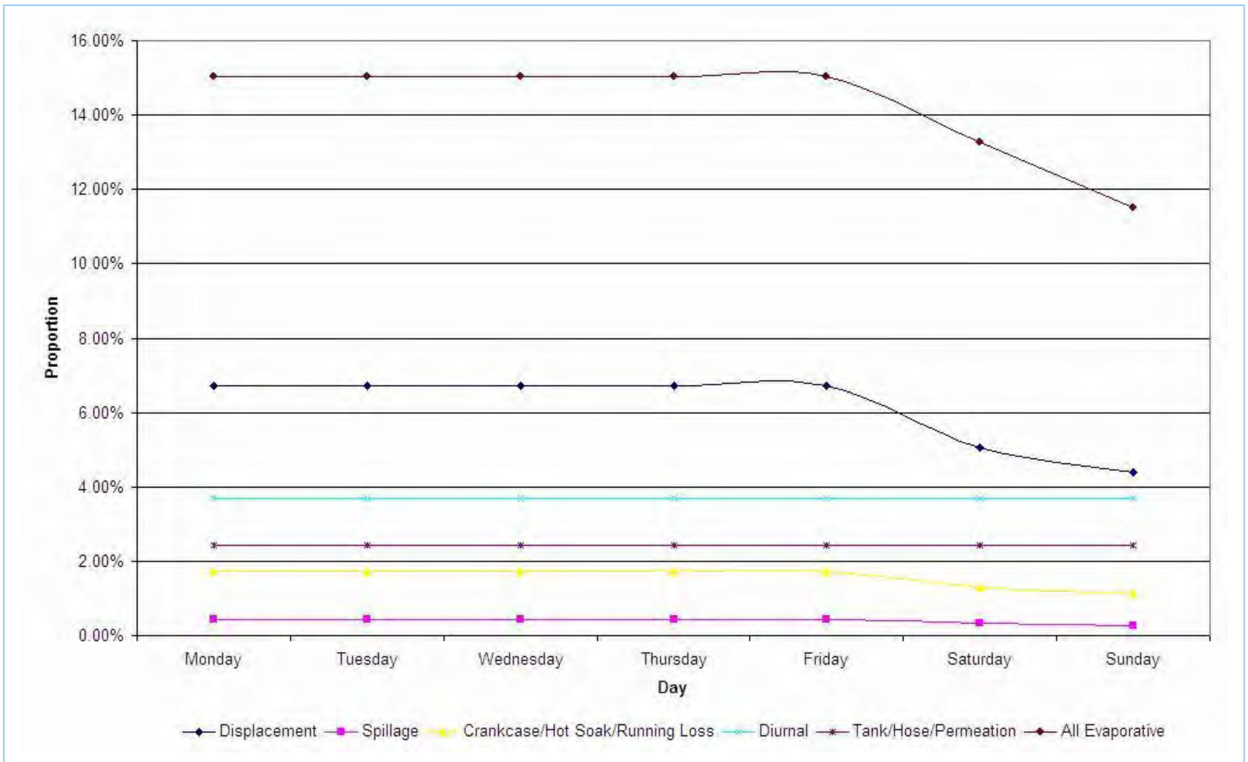

Figure 3-46: Commercial boats evaporative daily temporal profile

Monthly temporal variation profiles for exhaust emissions are presented in Table 3-60 and shown in Figure 3-47.

Table 3-60: Commercial boats exhaust monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.33	July	8.33
February	8.33	August	8.33
March	8.33	September	8.33
April	8.33	October	8.33
May	8.33	November	8.33
June	8.33	December	8.33

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-61 (weighted monthly composite) and shown in Figure 3-48 (weighted monthly composite by source type).

Table 3-61: Commercial boats evaporative monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	9.55	July	7.03
February	9.22	August	7.16
March	8.84	September	7.75
April	8.45	October	8.49
May	7.76	November	8.95
June	7.30	December	9.50

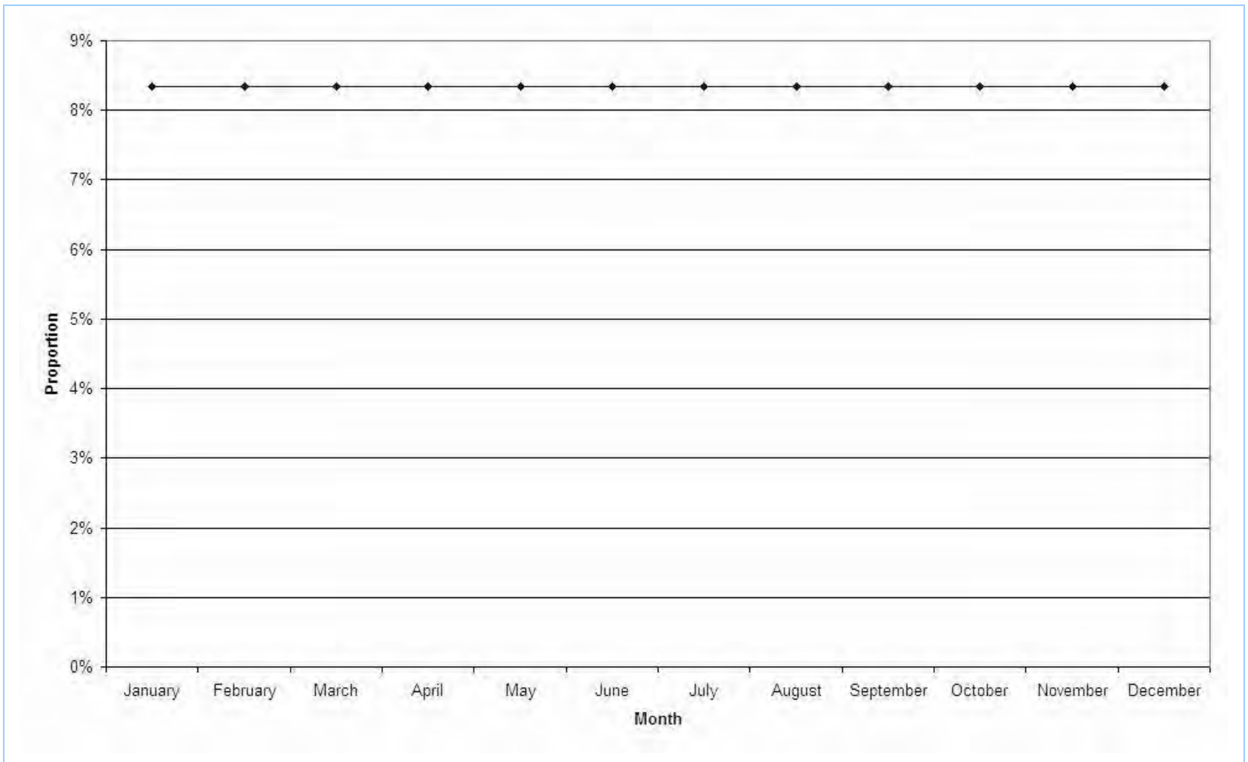

Figure 3-47: Commercial boats exhaust monthly temporal profile

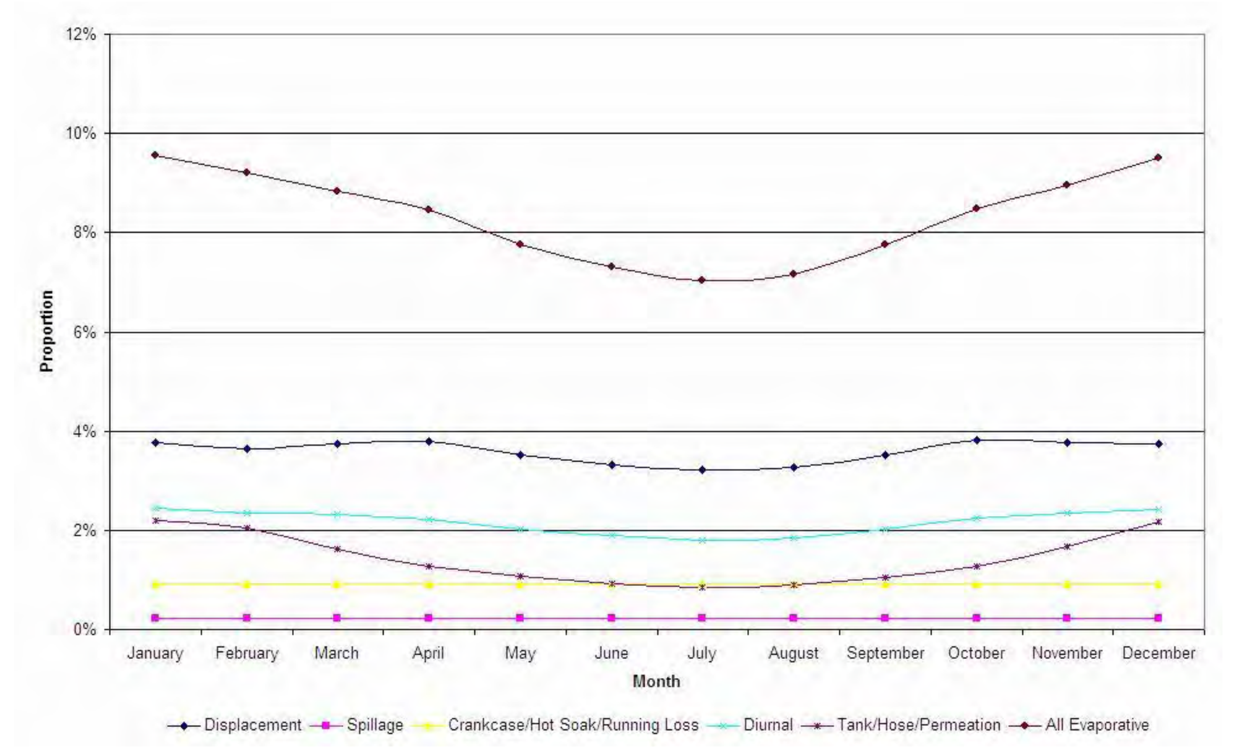

Figure 3-48: Commercial boats evaporative monthly temporal profile

3.2.7 *Emission Estimates*

Table 3-62 presents annual emissions of selected substances from commercial boat engines by activity.

Table 3-62: Commercial boats emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Commercial Boats Exhaust	1,3-BUTADIENE	1,587	5,238	5,139	78	12,042
	ACETALDEHYDE	1,565	5,353	10,200	86	17,203
	BENZENE	17,650	58,255	57,130	864	133,899
	CARBON MONOXIDE	1,565,827	5,177,806	5,332,211	77,188	12,153,031
	FORMALDEHYDE	2,839	9,791	20,693	161	33,483
	ISOMERS OF XYLENE	72,343	238,507	226,871	3,529	541,250
	LEAD & COMPOUNDS	22	72	70	1.07	166
	OXIDES OF NITROGEN	226,636	842,958	3,318,781	16,036	4,404,410
	PARTICULATE MATTER ≤ 10 µm	17,723	60,565	113,726	976	192,990
	PARTICULATE MATTER ≤ 2.5 µm	16,523	56,547	108,229	914	182,213
	POLYCYCLIC AROMATIC HYDROCARBONS	42	140	191	2.15	374
	SULFUR DIOXIDE	1,165	4,069	9,886	69	15,188
	TOLUENE	66,022	217,685	207,578	3,222	494,506

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL SUSPENDED PARTICULATE	18,318	62,616	118,017	1,009	199,960
	TOTAL VOLATILE ORGANIC COMPOUNDS	685,666	2,263,858	2,240,368	33,620	5,223,511
Commercial Boats Evaporative	BENZENE	32	118	434	2.20	586
	ISOMERS OF XYLENE	23	83	306	1.55	414
	TOLUENE	78	287	1,058	5.36	1,429
	TOTAL VOLATILE ORGANIC COMPOUNDS	4,103	15,099	55,705	282	75,189

Table 3-62 presents annual emissions of selected substances from commercial boat engines by source type.

Table 3-63: Commercial boats emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Exhaust - Petrol 2 Stroke	1,3-BUTADIENE	1,421	4,684	4,435	69	10,609
	ACETALDEHYDE	1,102	3,633	3,440	54	8,228
	BENZENE	16,660	54,917	52,002	812	124,391
	CARBON MONOXIDE	1,133,135	3,735,183	3,536,934	55,244	8,460,496
	FORMALDEHYDE	1,681	5,540	5,246	82	12,549
	ISOMERS OF XYLENE	71,182	234,638	222,184	3,470	531,474
	LEAD & COMPOUNDS	17	56	53	0.83	128
	OXIDES OF NITROGEN	11,794	38,877	36,814	575	88,060
	PARTICULATE MATTER ≤ 10 µm	13,185	43,461	41,154	643	98,442
	PARTICULATE MATTER ≤ 2.5 µm	12,130	39,984	37,862	591	90,567
	POLYCYCLIC AROMATIC HYDROCARBONS	19	63	60	0.93	142
	SULFUR DIOXIDE	510	1,683	1,593	25	3,811
	TOLUENE	64,763	213,479	202,149	3,157	483,548
	TOTAL SUSPENDED PARTICULATE	13,592	44,805	42,427	663	101,487
	TOTAL VOLATILE ORGANIC COMPOUNDS	662,217	2,182,882	2,067,023	32,285	4,944,407
Exhaust - Petrol 4 Stroke	1,3-BUTADIENE	152	501	475	7.41	1,135
	ACETALDEHYDE	65	216	204	3.19	489
	BENZENE	838	2,762	2,615	41	6,255
	CARBON MONOXIDE	399,471	1,316,788	1,246,898	19,476	2,982,633
	FORMALDEHYDE	274	903	855	13	2,045

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	ISOMERS OF XYLENE	1,083	3,569	3,379	53	8,083
	LEAD & COMPOUNDS	4.73	16	15	0.23	35
	OXIDES OF NITROGEN	19,759	65,131	61,674	963	147,527
	PARTICULATE MATTER ≤ 10 µm	175	577	546	8.54	1,307
	PARTICULATE MATTER ≤ 2.5 µm	161	531	503	7.85	1,203
	POLYCYCLIC AROMATIC HYDROCARBONS	18	60	57	0.88	135
	SULFUR DIOXIDE	187	618	585	9.14	1,399
	TOLUENE	1,147	3,781	3,581	56	8,565
	TOTAL SUSPENDED PARTICULATE	180	595	563	8.80	1,348
	TOTAL VOLATILE ORGANIC COMPOUNDS	15,968	52,636	49,843	778	119,225
Exhaust - Diesel	1,3-BUTADIENE	14	53	230	1.04	298
	ACETALDEHYDE	397	1,504	6,555	30	8,486
	BENZENE	152	577	2,513	11	3,253
	CARBON MONOXIDE	33,220	125,835	548,378	2,469	709,902
	FORMALDEHYDE	884	3,348	14,592	66	18,890
	ISOMERS OF XYLENE	79	300	1,307	5.88	1,692
	LEAD & COMPOUNDS	0.14	0.52	2.25	1.01×10^{-2}	2.91
	OXIDES OF NITROGEN	195,083	738,950	3,220,293	14,498	4,168,823
	PARTICULATE MATTER ≤ 10 µm	4,363	16,527	72,025	324	93,240
	PARTICULATE MATTER ≤ 2.5 µm	4,232	16,032	69,865	315	90,443
	POLYCYCLIC AROMATIC HYDROCARBONS	4.52	17	75	0.34	96
	SULFUR DIOXIDE	467	1,769	7,707	35	9,978
	TOLUENE	112	424	1,848	8.32	2,393
	TOTAL SUSPENDED PARTICULATE	4,545	17,216	75,026	338	97,125
	TOTAL VOLATILE ORGANIC COMPOUNDS	7,482	28,340	123,502	556	159,879
Evaporative	BENZENE	32	118	434	2.20	586
	ISOMERS OF XYLENE	23	83	306	1.55	414
	TOLUENE	78	287	1,058	5.36	1,429
	TOTAL VOLATILE ORGANIC COMPOUNDS	4,103	15,099	55,705	282	75,189

3.2.8 Emission Projection Methodology

Table 3-64 summarises the data used to estimate the emission projection factors for commercial boat engines, while Figure 3-49 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-64: Commercial boats emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from commercial boats	Final energy consumption for agriculture, commercial & services and domestic water transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

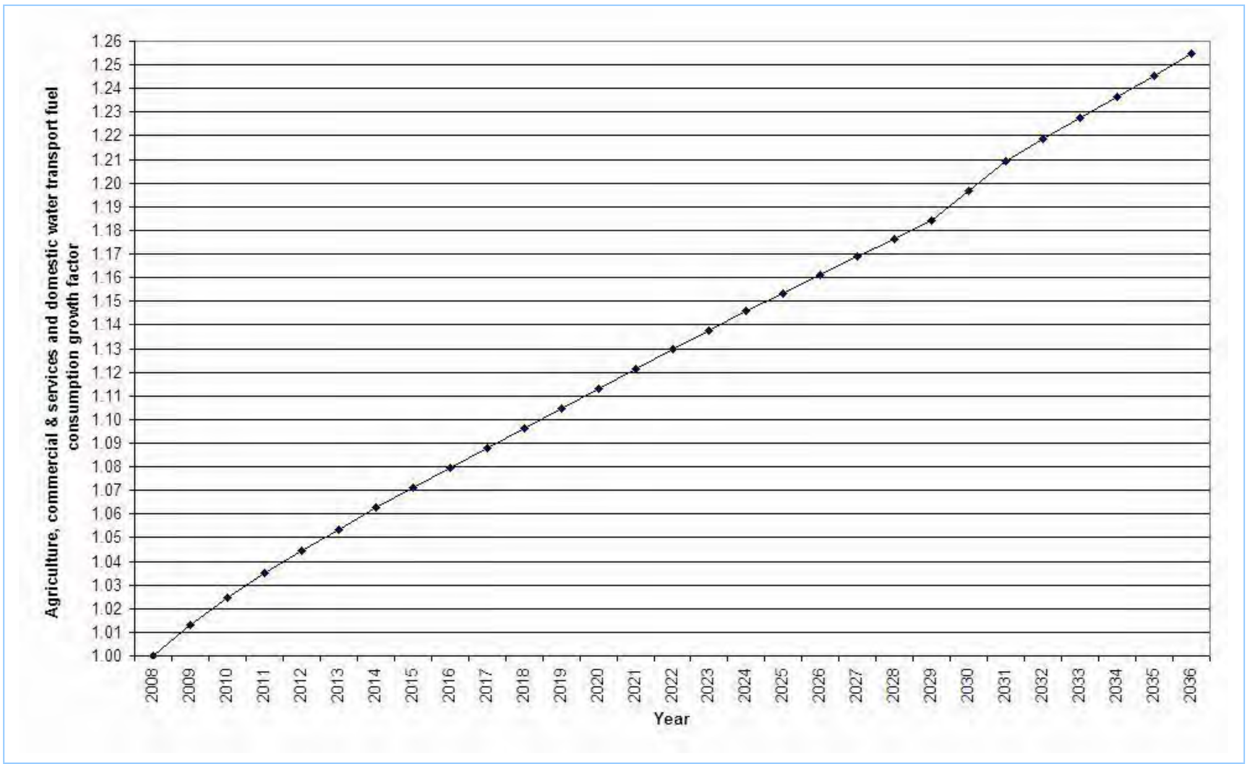

Figure 3-49: Commercial boats emission projection factors

3.3 Commercial Off-Road Vehicles and Equipment

3.3.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from commercial off-road vehicle and 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*

A commercial survey of off-road vehicle and equipment ownership and usage has been conducted, which has provided activity data for 684 commercial businesses (i.e. non-scheduled activity)[11]. 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 month (DECC, 2007a).

Figure 3-50 shows how the commercial survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009a) to develop an inventory of commercial off-road vehicle and equipment emissions.

[11] 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).

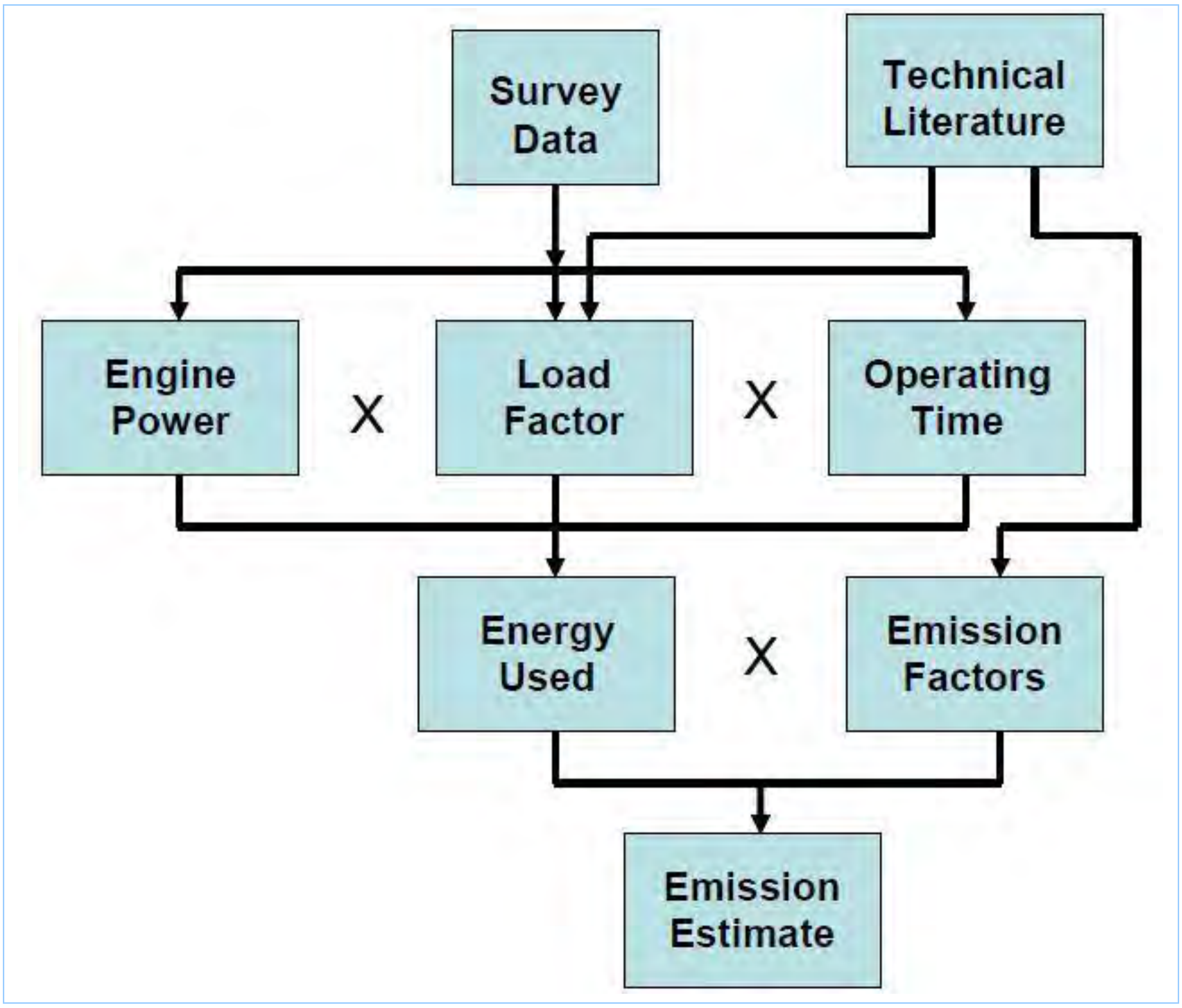

Figure 3-50: Commercial off-road vehicles and equipment – use of survey data

➢ *Commercial business by ANZSIC class*

The inventory includes commercial businesses, which belong to Australian and New Zealand Standard Industrial Classification (ANZSIC) classes (ABS, 1993) as follows:

- *Chemical Product Manufacturing;*
- *Chemical Wholesaling;*
- *Concrete Product Manufacturing;*
- *Concrete Slurry Manufacturing;*
- *Dairy Product Manufacturing;*
- *Electrical Cable and Wire/Equipment Manufacturing;*
- *Fibreglass Product Manufacturing;*
- *Fruit and Vegetable Processing;*

- *Furniture Manufacturing;*
- *Gravel and Sand Quarrying;*
- *Industrial Gas Manufacturing;*
- *Industrial Machinery and Equipment Manufacturing;*
- *Iron and Steel Manufacturing;*
- *Medicinal and Pharmaceutical Product Manufacturing;*
- *Motor Vehicle and Part Manufacturing;*
- *Nonbuilding Construction;*
- *Other Agricultural Crop Processing;*
- *Other Food Manufacturing;*
- *Paint and Ink Manufacturing;*
- *Petroleum Product Wholesaling;*
- *Plastic Injection Moulded Product Manufacturing;*
- *Poultry Farming (Eggs) and (Meat);*
- *Rubber Product Manufacturing;*
- *Soap and Other Detergent Manufacturing;*
- *Structural and Fabricated Metal Product Manufacturing;*
- *Wine Manufacturing; and*
- *Wood Product Manufacturing.*

➢ *Commercial off-road vehicle and equipment type*

The inventory includes commercial off-road vehicles and equipment as follows:

- *Bulldozer/Crawler tractor;*
- *Cement and mortar mixer;*
- *Combine harvester;*
- *Crane;*
- *Excavator;*
- *Forklift;*

- *Front mower;*
- *Generator set;*
- *Grader;*
- *Off-highway truck;*
- *Other construction equipment;*
- *Other general industrial equipment;*
- *Other material handling equipment;*
- *Push mower;*
- *Rear engine riding mower;*
- *Rubber tyre loader;*
- *Scraper;*
- *Skid steer loader;*
- *Sweeper/Scrubber; and*
- *Tractor/Loader/Backhoe.*

➢ *Engine type*

The inventory includes commercial off-road vehicles and equipment powered by 4-stroke spark ignition (SI) petrol, liquid petroleum gas (LPG) and compressed natural gas (CNG) engines and diesel compression ignition (CI) engines.

Since there are no NSW or Australian emission standards, the inventory considers all commercial off-road vehicles and equipment have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009a).

➢ *Fuel type*

The inventory includes commercial off-road vehicles equipment that use automotive gasoline (petrol), liquid petroleum gas (LPG), compressed natural gas (CNG) and automotive diesel oil (ADO).

Table 3-65 presents the commercial off-road vehicles and equipment fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). 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 and LPG/CNG are requirements of the *Fuel Standard (Automotive Diesel) Determination 2001* (Attorney-

General's Department, 2009) and *Fuel Standard (Autogas) Determination 2003* (Attorney-General's Department, 2003) respectively, which are relevant for the 2008 calendar year.

Table 3-65: Commercial off-road vehicles and equipment 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[12]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[13]	2.84 – Weighted average[14]			
Liquid petroleum gas (LPG)	100	-	0.510	25.5	82
Compressed natural gas (CNG)	100	-	0.460	25.0	75
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

➢ *Source type*

The inventory includes emissions of combustion products and evaporation from commercial off-road vehicles and 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, LPG, CNG and diesel engines. 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 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 4-stroke petrol engines;

[12] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[13] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[14] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

- *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 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 4-stroke petrol engines; 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. These occur from 4-stroke petrol engines

Evaporative emissions mainly include VOC (total and speciated).

3.3.2 Emission Estimation Methodology

Table 3-66 summarises the emission estimation methodologies used for commercial off-road vehicles and equipment.

Table 3-66: Commercial off-road vehicles and equipment emission estimation methodologies

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from commercial off-road vehicles and equipment	- *Documentation for the 2008 Mobile Source National Emissions Inventory* (Pechan, 2011) - *NONROAD2008a Model* (USEPA, 2009a)

Exhaust and evaporative emissions from commercial off-road vehicles 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, 2009a).

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

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, 2009a).

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

Deterioration factors (DF) have been applied to 4-stroke petrol, LPG, CNG 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. 4-stroke petrol, LPG and CNG 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, 2009a).

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

Equipment population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and monthly basis. Equipment population and activity rates have been derived from a commercial survey (DECC, 2007a). Emissions have been determined using Equation 8 within the *NONROAD2008a Model* (USEPA, 2009a):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times TAF_{j,k,l} \times DF_{j,k,l} \times EF_{i,j,k,l,m} / 1000}$$ **Equation 8**

where:

$E_{i,j,k,l,m}$	=	Emissions of substance i from commercial off-road vehicles and equipment type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of commercial off-road vehicles and equipment type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of commercial off-road vehicles and equipment type j, engine type k and engine power range l	(h/year)
$HP_{j,k,l}$	=	Maximum rated power of commercial off-road vehicles and equipment type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for commercial off-road vehicles and equipment type j, engine type k and engine power range l	(hp/hp)
$TAF_{j,k,l}$	=	Fractional transient adjustment factor for commercial off-road vehicles and 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 commercial off-road vehicles and 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 commercial off-road vehicles and 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	=	Commercial off-road vehicles and equipment type (either "Bulldozer/Crawler tractor", "Cement and mortar mixer;" "Combine harvester", "Crane", "Excavator", "Forklift", "Front mower", "Generator set", "Grader", "Off-highway truck", "Other construction equipment", "Other general industrial equipment", "Other material handling equipment", "Push mower", "Rear engine riding mower", "Rubber tyre loader", "Scraper", "Skid steer loader", "Sweeper/Scrubber" or "Tractor/Loader/Backhoe")	(-)
k	=	Engine type (either "4-stroke-petrol", "LPG", "CNG" or "diesel")	(-)
l	=	Engine power range	(hp)

where:			
m	=	Source type (either "exhaust", "crankcase", "refuelling", "diurnal", "hot soak", "running loss" or "permeation")	(-)
1000	=	Conversion factor	(g/kg)

3.3.3 *Activity Data*

Table 3-67 summarises the activity data used for commercial off-road vehicles equipment.

Table 3-67: Commercial off-road vehicles and equipment activity data

Activity data	Activity data source
Commercial off-road vehicles and equipment type, number and fleet composition	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)
Commercial off-road vehicles and equipment operating frequency and duration	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)

Activity data has been obtained for commercial off-road vehicles and equipment, including equipment number, engine type, power and operating hours (DECC, 2007a). Table 3-68 presents commercial off-road vehicles and equipment population by engine type, equipment description and ANZSIC class in the GMR.

Table 3-68: Commercial off-road vehicles and equipment population by engine type, equipment description and ANZSIC class in the GMR

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Chemical Product Manufacturing	4-Str Forklifts-40-50	1	-	-	-	1
	Dsl - Forklifts-40-50	-	-	-	4	4
	Dsl - Forklifts-75-100	-	-	-	2	2
	Dsl - Off-highway Trucks-300-600	-	-	-	1	1
	Dsl - Skid Steer Loaders-16-25	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	1	1
	LPG - Forklifts-40-50	-	7	-	-	7

15 Equipment description includes engine type, equipment type, minimum horsepower (hp) and maximum hp details. For example, "4-Str Rear Engine Riding Mowers (com)-11-16" means 4-stroke petrol, commercial rear engine riding mower with maximum power rating range of 11 to 16 hp.

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Chemical Product Manufacturing Total		1	7	-	9	17
Chemical Wholesaling	LPG - Forklifts-40-50	-	5	-	-	5
Chemical Wholesaling Total		-	5	-	-	5
Concrete Product Manufacturing	Dsl - Forklifts-75-100	-	-	-	1	1
	Dsl - Rubber Tire Loaders-100-175	1	-	-	-	1
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	4	4
	Dsl - Tractors/Loaders/Backhoes-175-300	-	-	-	2	2
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	3	3
Concrete Product Manufacturing Total		1	-	-	11	12
Concrete Slurry Manufacturing	4-Str Forklifts-40-50	1	-	-	-	1
	4-Str Forklifts-50-75	1	-	-	-	1
	4-Str Sweepers/Scrubbers-16-25	1	-	-	-	1
	CNG - Forklifts-40-50	-	-	1	-	1
	Dsl - Cement & Mortar Mixers-175-300	-	-	-	1	1
	Dsl - Cement & Mortar Mixers-300-600	-	-	-	1	1
	Dsl - Excavators-300-600	-	-	-	1	1
	Dsl - Forklifts-100-175	-	-	-	1	1
	Dsl - Forklifts-25-40	-	-	-	1	1
	Dsl - Forklifts-40-50	-	-	-	1	1
	Dsl - Forklifts-50-75	-	-	-	1	1
	Dsl - Forklifts-75-100	-	-	-	1	1
	Dsl - Graders-175-300	-	-	-	1	1
	Dsl - Off-highway Trucks-175-300	-	-	-	1	1
	Dsl - Off-highway Trucks-300-600	-	-	-	1	1
	Dsl - Other General Industrial Eqp-100-175	-	-	-	1	1
	Dsl - Other General Industrial Eqp-175-300	-	-	-	1	1
	Dsl - Rubber Tire Loaders-100-175	-	-	-	3	3

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Dsl - Rubber Tire Loaders-175-300	-	-	-	3	3
	Dsl - Rubber Tire Loaders-300-600	-	-	-	1	1
	Dsl - Rubber Tire Loaders-50-75	-	-	-	1	1
	Dsl - Rubber Tire Loaders-75-100	-	-	-	1	1
	Dsl - Skid Steer Loaders-25-40	-	-	-	1	1
	Dsl - Skid Steer Loaders-40-50	-	-	-	1	1
	Dsl - Skid Steer Loaders-50-75	-	-	-	1	1
	Dsl - Sweepers/Scrubbers-100-175	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	1	1
	LPG - Forklifts-25-40	-	1	-	-	1
	LPG - Forklifts-50-75	-	1	-	-	1
	LPG - Forklifts-75-100	-	1	-	-	1
	LPG - Rubber Tire Loaders-25-40	-	1	-	-	1
Concrete Slurry Manufacturing Total		1	2	1	10	12
Dairy Product Manufacturing	LPG - Forklifts-50-75	-	3	-	-	3
Dairy Product Manufacturing Total		-	3	-	-	3
Electrical Cable and Wire/Equipment Manufacturing	4-Str Other General Industrial Eqp-175-300	1	-	-	-	1
	LPG - Forklifts-100-175	-	3	-	-	3
	LPG - Forklifts-40-50	-	2	-	-	2
	LPG - Forklifts-50-75	-	5	-	-	5
Electrical Cable and Wire/Equipment Manufacturing Total		1	10	-	-	11
Fibreglass Product Manufacturing	4-Str Forklifts-40-50	1	-	-	-	1
	4-Str Forklifts-75-100	1	-	-	-	1
	4-Str Other General Industrial Eqp-75-100	1	-	-	-	1
Fibreglass Product Manufacturing Total		3	-	-	-	3
Fruit and Vegetable Processing	LPG - Forklifts-40-50	-	2	-	-	2
Fruit and Vegetable Processing Total		-	2	-	-	2
Furniture Manufacturing	Dsl - Forklifts-25-40	-	-	-	5	5
	LPG - Forklifts-40-50	-	1	-	-	1
	LPG - Forklifts-50-75	-	2	-	-	2
Furniture Manufacturing Total		-	3	-	5	8
Gravel and Sand Quarrying	Dsl - Cranes-175-300	-	-	-	2	2
	Dsl - Crawler Tractor/Dozers-	-	-	-	2	2

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	100-175					
	Dsl - Crawler Tractor/Dozers-300-600	-	-	-	4	4
	Dsl - Crawler Tractor/Dozers-600-750	-	-	-	2	2
	Dsl - Excavators-175-300	-	-	-	10	10
	Dsl - Excavators-300-600	-	-	-	4	4
	Dsl - Forklifts-40-50	-	-	-	2	2
	Dsl - Graders-100-175	-	-	-	2	2
	Dsl - Off-highway Trucks-100-175	-	-	-	6	6
	Dsl - Off-highway Trucks-175-300	-	-	-	4	4
	Dsl - Off-highway Trucks-300-600	-	-	-	14	14
	Dsl - Other Construction Equipment-100-175	-	-	-	4	4
	Dsl - Other Construction Equipment-75-100	-	-	-	4	4
	Dsl - Other Material Handling Eqp-100-175	-	-	-	4	4
	Dsl - Rubber Tire Loaders-175-300	-	-	-	20	20
	Dsl - Rubber Tire Loaders-300-600	-	-	-	8	8
	Dsl - Rubber Tire Loaders-600-750	-	-	-	6	6
	Dsl - Scrapers-300-600	-	-	-	2	2
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	4	4
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	2	2
Gravel and Sand Quarrying Total		-	-	-	106	106
Industrial Gas Manufacturing	LPG - Forklifts-40-50	-	2	-	-	2
Industrial Gas Manufacturing Total		-	2	-	-	2
Industrial Machinery and Equipment Manufacturing	Dsl - Forklifts-100-175	-	-	-	1	1
	LPG - Forklifts-50-75	-	2	-	-	2
Industrial Machinery and Equipment Manufacturing Total		-	2	-	1	3
Iron and Steel Manufacturing	Dsl - Forklifts-100-175	-	-	-	1	1
	Dsl - Off-highway Trucks-300-600	-	-	-	1	1
	Dsl - Rubber Tire Loaders-50-	-	-	-	1	1

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	75					
	LPG - Forklifts-100-175	-	2	-	-	2
	LPG - Forklifts-25-40	-	2	-	-	2
Iron and Steel Manufacturing Total		-	4	-	3	7
Medicinal and Pharmaceutical Product Manufacturing	Dsl - Forklifts-40-50	-	-	-	1	1
Medicinal and Pharmaceutical Product Manufacturing Total		-	-	-	1	1
Motor Vehicle and Part Manufacturing	LPG - Forklifts-40-50	-	2	-	-	2
Motor Vehicle and Part Manufacturing Total		-	2	-	-	2
Nonbuilding Construction	Dsl - Off-highway Trucks-100-175	-	-	-	1	1
	Dsl - Skid Steer Loaders-75-100	-	-	-	1	1
	LPG - Forklifts-40-50	-	4	-	-	4
Nonbuilding Construction Total		-	4	-	2	6
Other Agricultural Crop Processing	LPG - Forklifts-40-50	-	1	-	-	1
Other Agricultural Crop Processing Total		-	1	-	-	1
Other Food Manufacturing	4-Str Other General Industrial Eqp-100-175	1	-	-	-	1
	LPG - Forklifts-40-50	-	14	-	-	14
	LPG - Forklifts-50-75	-	1	-	-	1
Other Food Manufacturing Total		1	15	-	-	16
Paint and Ink Manufacturing	Dsl - Forklifts-40-50	-	-	-	6	6
	Dsl - Forklifts-50-75	-	-	-	8	8
	Dsl - Forklifts-75-100	-	-	-	1	1
Paint and Ink Manufacturing Total		-	-	-	15	15
Petroleum Product Wholesaling	4-Str Other General Industrial Eqp-75-100	1	-	-	-	1
	Dsl - Forklifts-40-50	-	-	-	3	3
	Dsl - Off-highway Trucks-175-300	-	-	-	1	1
	LPG - Forklifts-40-50	-	1	-	-	1
	LPG - Forklifts-50-75	-	3	-	-	3
Petroleum Product Wholesaling Total		1	4	-	4	9
Plastic Injection Moulded Product Manufacturing	4-Str Forklifts-175-300	1	-	-	-	1
	LPG - Forklifts-100-175	-	1	-	-	1
	LPG - Forklifts-40-50	-	8	-	-	8
	LPG - Forklifts-50-75	-	1	-	-	1
Plastic Injection Moulded Product Manufacturing Total		1	10	-	-	11
Poultry Farming (Eggs) and (Meat)	4-Str Rear Engine Riding Mowers (com)-11-16	1	-	-	-	1
	Dsl - Commercial Mowers	-	-	-	1	1

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	(com)-25-40					
	Dsl - Other General Industrial Eqp-175-300	-	-	-	2	2
	Dsl - Other General Industrial Eqp-75-100	-	-	-	2	2
	Dsl - Rubber Tire Loaders-100-175	-	-	-	1	1
	Dsl - Rubber Tire Loaders-50-75	-	-	-	1	1
	Dsl - Rubber Tire Loaders-75-100	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-25-40	-	-	-	1	1
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	11	11
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	7	7
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	3	3
Poultry Farming (Eggs) and (Meat) Total		1	-	-	28	28
Rubber Product Manufacturing	LPG - Forklifts-40-50	-	1	-	-	1
Rubber Product Manufacturing Total		-	1	-	-	1
Soap and Other Detergent Manufacturing	Dsl - Forklifts-40-50	-	-	-	1	1
	LPG - Forklifts-40-50	-	1	-	-	1
Soap and Other Detergent Manufacturing Total		-	1	-	1	2
Structural and Fabricated Metal Product Manufacturing	4-Str Forklifts-40-50	2	-	-	-	2
	Dsl - Cranes-175-300	-	-	-	2	2
	Dsl - Forklifts-40-50	-	-	-	2	2
	Dsl - Forklifts-50-75	-	-	-	2	2
	Dsl - Forklifts-75-100	-	-	-	7	7
	Dsl - Off-highway Trucks-175-300	-	-	-	1	1
	LPG - Forklifts-100-175	-	1	-	-	1
	LPG - Forklifts-25-40	-	2	-	-	2
	LPG - Forklifts-40-50	-	25	-	-	25
	LPG - Forklifts-50-75	-	3	-	-	3
	LPG - Forklifts-75-100	-	1	-	-	1

ANZSIC class	Equipment description[15]	2008 equipment population				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Structural and Fabricated Metal Product Manufacturing Total		2	32	-	14	48
Wine Manufacturing	4-Str Forklifts-40-50	32	-	-	-	32
	4-Str Lawn mowers (Com)-3-6	11	-	-	-	11
	4-Str Other General Industrial Eqp-25-40	11	-	-	-	11
	4-Str Other General Industrial Eqp-50-75	11	-	-	-	11
	4-Str Rear Engine Riding Mowers (com)-16-25	21	-	-	-	21
	Dsl - Combines-100-175	-	-	-	11	11
	Dsl - Commercial Mowers (com)-16-25	-	-	-	11	11
	Dsl - Forklifts-40-50	-	-	-	11	11
	Dsl - Generator Sets-75-100	-	-	-	11	11
	Dsl - Off-highway Trucks-100-175	-	-	-	32	32
	Dsl - Tractors/Loaders/Backhoes-16-25	-	-	-	21	21
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	83	83
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	114	114
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	11	11
	LPG - Forklifts-25-40	-	11	-	-	11
	LPG - Forklifts-40-50	-	32	-	-	32
	LPG - Forklifts-50-75	-	11	-	-	11
Wine Manufacturing Total		83	52	-	301	436
Wood Product Manufacturing	LPG - Forklifts-40-50	-	2	-	-	2
	LPG - Forklifts-50-75	-	1	-	-	1
Wood Product Manufacturing Total		-	3	-	-	3
Grand Total		95	165	1	509	768

Table 3-69 presents commercial off-road vehicles and equipment power by engine type, equipment description and ANZSIC class in the GMR.

Table 3-69: Commercial off-road vehicles and equipment power by engine type, equipment description and ANZSIC class in the GMR

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Chemical Product Manufacturing	4-Str Forklifts-40-50	45	-	-	-	45
	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Forklifts-75-100	-	-	-	94	94
	Dsl - Off-highway Trucks-300-600	-	-	-	430	430
	Dsl - Skid Steer Loaders-16-25	-	-	-	20	20
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	85	85
	LPG - Forklifts-40-50	-	43	-	-	43
Chemical Product Manufacturing Total		45	43	-	100	73
Chemical Wholesaling	LPG - Forklifts-40-50	-	45	-	-	45
Chemical Wholesaling Total		-	45	-	-	45
Concrete Product Manufacturing	Dsl - Forklifts-75-100	-	-	-	80	80
	Dsl - Rubber Tire Loaders-100-175	160	-	-	-	160
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	119	119
	Dsl - Tractors/Loaders/Backhoes-175-300	-	-	-	234	234
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	73	73
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	83	83
Concrete Product Manufacturing Total		160	-	-	122	125
Concrete Slurry Manufacturing	4-Str Forklifts-40-50	40	-	-	-	40
	4-Str Forklifts-50-75	60	-	-	-	60
	4-Str Sweepers/Scrubbers-16-25	20	-	-	-	20
	CNG - Forklifts-40-50	-	-	40	-	40
	Dsl - Cement & Mortar Mixers-175-300	-	-	-	240	240
	Dsl - Cement & Mortar Mixers-300-600	-	-	-	335	335
	Dsl - Excavators-300-600	-	-	-	365	365
	Dsl - Forklifts-100-175	-	-	-	145	145
	Dsl - Forklifts-25-40	-	-	-	28	28
	Dsl - Forklifts-40-50	-	-	-	40	40
	Dsl - Forklifts-50-75	-	-	-	56	56

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Dsl - Forklifts-75-100	-	-	-	85	85
	Dsl - Graders-175-300	-	-	-	235	235
	Dsl - Off-highway Trucks-175-300	-	-	-	245	245
	Dsl - Off-highway Trucks-300-600	-	-	-	371	371
	Dsl - Other General Industrial Eqp-100-175	-	-	-	133	133
	Dsl - Other General Industrial Eqp-175-300	-	-	-	201	201
	Dsl - Rubber Tire Loaders-100-175	-	-	-	125	125
	Dsl - Rubber Tire Loaders-175-300	-	-	-	212	212
	Dsl - Rubber Tire Loaders-300-600	-	-	-	341	341
	Dsl - Rubber Tire Loaders-50-75	-	-	-	66	66
	Dsl - Rubber Tire Loaders-75-100	-	-	-	88	88
	Dsl - Skid Steer Loaders-25-40	-	-	-	38	38
	Dsl - Skid Steer Loaders-40-50	-	-	-	40	40
	Dsl - Skid Steer Loaders-50-75	-	-	-	74	74
	Dsl - Sweepers/Scrubbers-100-175	-	-	-	139	139
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	110	110
	LPG - Forklifts-25-40	-	27	-	-	27
	LPG - Forklifts-50-75	-	68	-	-	68
	LPG - Forklifts-75-100	-	93	-	-	93
	LPG - Rubber Tire Loaders-25-40	-	27	-	-	27
Concrete Slurry Manufacturing Total		36	62	40	151	132
Dairy Product Manufacturing	LPG - Forklifts-50-75	-	54	-	-	54
Dairy Product Manufacturing Total		-	54	-	-	54
Electrical Cable and Wire/Equipment Manufacturing	4-Str Other General Industrial Eqp-175-300	177	-	-	-	177
	LPG - Forklifts-100-175	-	107	-	-	107
	LPG - Forklifts-40-50	-	45	-	-	45
	LPG - Forklifts-50-75	-	54	-	-	54
Electrical Cable and Wire/Equipment Manufacturing Total		177	68	-	-	78

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Fibreglass Product Manufacturing	4-Str Forklifts-40-50	45	-	-	-	45
	4-Str Forklifts-75-100	80	-	-	-	80
	4-Str Other General Industrial Eqp-75-100	97	-	-	-	97
Fibreglass Product Manufacturing Total		74	-	-	-	74
Fruit and Vegetable Processing	LPG - Forklifts-40-50	-	45	-	-	45
Fruit and Vegetable Processing Total		-	45	-	-	45
Furniture Manufacturing	Dsl - Forklifts-25-40	-	-	-	28	28
	LPG - Forklifts-40-50	-	45	-	-	45
	LPG - Forklifts-50-75	-	53	-	-	53
Furniture Manufacturing Total		-	51	-	28	36
Gravel and Sand Quarrying	Dsl - Cranes-175-300	-	-	-	177	177
	Dsl - Crawler Tractor/Dozers-100-175	-	-	-	140	140
	Dsl - Crawler Tractor/Dozers-300-600	-	-	-	490	490
	Dsl - Crawler Tractor/Dozers-600-750	-	-	-	600	600
	Dsl - Excavators-175-300	-	-	-	242	242
	Dsl - Excavators-300-600	-	-	-	300	300
	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Graders-100-175	-	-	-	115	115
	Dsl - Off-highway Trucks-100-175	-	-	-	145	145
	Dsl - Off-highway Trucks-175-300	-	-	-	225	225
	Dsl - Off-highway Trucks-300-600	-	-	-	344	344
	Dsl - Other Construction Equipment-100-175	-	-	-	121	121
	Dsl - Other Construction Equipment-75-100	-	-	-	83	83
	Dsl - Other Material Handling Eqp-100-175	-	-	-	101	101
	Dsl - Rubber Tire Loaders-175-300	-	-	-	229	229
	Dsl - Rubber Tire Loaders-300-600	-	-	-	316	316
	Dsl - Rubber Tire Loaders-600-750	-	-	-	625	625
	Dsl - Scrapers-300-600	-	-	-	450	450
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	170	170
	Dsl -	-	-	-	70	70

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Tractors/Loaders/Backhoes-50-75					
Gravel and Sand Quarrying Total		-	-	-	265	265
Industrial Gas Manufacturing	LPG - Forklifts-40-50	-	43	-	-	43
Industrial Gas Manufacturing Total		-	43	-	-	43
Industrial Machinery and Equipment Manufacturing	Dsl - Forklifts-100-175	-	-	-	107	107
	LPG - Forklifts-50-75	-	64	-	-	64
Industrial Machinery and Equipment Manufacturing Total		-	64	-	107	78
Iron and Steel Manufacturing	Dsl - Forklifts-100-175	-	-	-	161	161
	Dsl - Off-highway Trucks-300-600	-	-	-	320	320
	Dsl - Rubber Tire Loaders-50-75	-	-	-	67	67
	LPG - Forklifts-100-175	-	148	-	-	148
	LPG - Forklifts-25-40	-	27	-	-	27
Iron and Steel Manufacturing Total		-	87	-	183	128
Medicinal and Pharmaceutical Product Manufacturing	Dsl - Forklifts-40-50	-	-	-	44	44
Medicinal and Pharmaceutical Product Manufacturing Total		-	-	-	44	44
Motor Vehicle and Part Manufacturing	LPG - Forklifts-40-50	-	45	-	-	45
Motor Vehicle and Part Manufacturing Total		-	45	-	-	45
Nonbuilding Construction	Dsl - Off-highway Trucks-100-175	-	-	-	161	161
	Dsl - Skid Steer Loaders-75-100	-	-	-	75	75
	LPG - Forklifts-40-50	-	45	-	-	45
Nonbuilding Construction Total		-	45	-	118	70
Other Agricultural Crop Processing	LPG - Forklifts-40-50	-	41	-	-	41
Other Agricultural Crop Processing Total		-	41	-	-	41
Other Food Manufacturing	4-Str Other General Industrial Eqp-100-175	126	-	-	-	126
	LPG - Forklifts-40-50	-	43	-	-	43
	LPG - Forklifts-50-75	-	59	-	-	59
Other Food Manufacturing Total		126	44	-	-	49
Paint and Ink Manufacturing	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Forklifts-50-75	-	-	-	57	57
	Dsl - Forklifts-75-100	-	-	-	80	80
Paint and Ink Manufacturing Total		-	-	-	53	53
Petroleum Product	4-Str Other General	97	-	-	-	97

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Wholesaling	Industrial Eqp-75-100					
	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Off-highway Trucks-175-300	-	-	-	230	230
	LPG - Forklifts-40-50	-	45	-	-	45
	LPG - Forklifts-50-75	-	62	-	-	62
Petroleum Product Wholesaling Total		97	58	-	90	77
Plastic Injection Moulded Product Manufacturing	4-Str Forklifts-175-300	188	-	-	-	188
	LPG - Forklifts-100-175	-	120	-	-	120
	LPG - Forklifts-40-50	-	43	-	-	43
	LPG - Forklifts-50-75	-	54	-	-	54
Plastic Injection Moulded Product Manufacturing Total		188	52	-	-	64
Poultry Farming (Eggs) and (Meat)	4-Str Rear Engine Riding Mowers (com)-11-16	13	-	-	-	13
	Dsl - Commercial Mowers (com)-25-40	-	-	-	27	27
	Dsl - Other General Industrial Eqp-175-300	-	-	-	211	211
	Dsl - Other General Industrial Eqp-75-100	-	-	-	80	80
	Dsl - Rubber Tire Loaders-100-175	-	-	-	105	105
	Dsl - Rubber Tire Loaders-50-75	-	-	-	60	60
	Dsl - Rubber Tire Loaders-75-100	-	-	-	85	85
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	100	100
	Dsl - Tractors/Loaders/Backhoes-25-40	-	-	-	30	30
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	40	40
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	58	58
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	81	81
Poultry Farming (Eggs) and (Meat) Total		13	-	-	67	66
Rubber Product Manufacturing	LPG - Forklifts-40-50	-	45	-	-	45
Rubber Product Manufacturing Total		-	45	-	-	45
Soap and Other	Dsl - Forklifts-40-50	-	-	-	44	44

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Detergent Manufacturing	LPG - Forklifts-40-50	-	45	-	-	45
Soap and Other Detergent Manufacturing Total		-	45	-	44	45
Structural and Fabricated Metal Product Manufacturing	4-Str Forklifts-40-50	45	-	-	-	45
	Dsl - Cranes-175-300	-	-	-	177	177
	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Forklifts-50-75	-	-	-	59	59
	Dsl - Forklifts-75-100	-	-	-	83	83
	Dsl - Off-highway Trucks-175-300	-	-	-	280	280
	LPG - Forklifts-100-175	-	114	-	-	114
	LPG - Forklifts-25-40	-	32	-	-	32
	LPG - Forklifts-40-50	-	43	-	-	43
	LPG - Forklifts-50-75	-	53	-	-	53
	LPG - Forklifts-75-100	-	86	-	-	86
Structural and Fabricated Metal Product Manufacturing Total		45	47	-	101	63
Wine Manufacturing	4-Str Forklifts-40-50	44	-	-	-	44
	4-Str Lawn mowers (Com)-3-6	5	-	-	-	5
	4-Str Other General Industrial Eqp-25-40	35	-	-	-	35
	4-Str Other General Industrial Eqp-50-75	50	-	-	-	50
	4-Str Rear Engine Riding Mowers (com)-16-25	16	-	-	-	16
	Dsl - Combines-100-175	-	-	-	120	120
	Dsl - Commercial Mowers (com)-16-25	-	-	-	20	20
	Dsl - Forklifts-40-50	-	-	-	44	44
	Dsl - Generator Sets-75-100	-	-	-	80	80
	Dsl - Off-highway Trucks-100-175	-	-	-	141	141
	Dsl - Tractors/Loaders/Backhoes-16-25	-	-	-	19	19
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	45	45
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	59	59
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	75	75
	LPG - Forklifts-25-40	-	25	-	-	25

ANZSIC class	Equipment description	Average power (hp)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	LPG - Forklifts-40-50	-	43	-	-	43
	LPG - Forklifts-50-75	-	60	-	-	60
Wine Manufacturing Total		32	43	-	62	54
Wood Product Manufacturing	LPG - Forklifts-40-50	-	41	-	-	41
	LPG - Forklifts-50-75	-	67	-	-	67
Wood Product Manufacturing Total		-	50	-	-	50
Grand Total		62	53	40	141	113

Table 3-70 presents commercial off-road vehicles and equipment annual operating time by engine type, equipment description and ANZSIC class in the GMR.

Table 3-70: Commercial off-road vehicles and equipment annual operating time by engine type, equipment description and ANZSIC class in the GMR

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Chemical Product Manufacturing	4-Str Forklifts-40-50	32.1	-	-	-	32.1
	Dsl - Forklifts-40-50	-	-	-	326.3	326.3
	Dsl - Forklifts-75-100	-	-	-	411.3	411.3
	Dsl - Off-highway Trucks-300-600	-	-	-	137.1	137.1
	Dsl - Skid Steer Loaders-16-25	-	-	-	411.3	411.3
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	411.3	411.3
	LPG - Forklifts-40-50	-	1,521.3	-	-	1,521.3
Chemical Product Manufacturing Total		32.1	1,521.3	-	343.1	809.9
Chemical Wholesaling	LPG - Forklifts-40-50	-	3,403.0	-	-	3,403.0
Chemical Wholesaling Total		-	3,403.0	-	-	3,403.0
Concrete Product Manufacturing	Dsl - Forklifts-75-100	-	-	-	63.6	63.6
	Dsl - Rubber Tire Loaders-100-175	23.4	-	-	-	23.4
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	575.2	575.2
	Dsl - Tractors/Loaders/Backhoes-175-300	-	-	-	686.0	686.0
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	923.3	923.3
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	298.1	298.1

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
Concrete Product Manufacturing Total		23.4	-	-	504.9	464.8
Concrete Slurry Manufacturing	4-Str Forklifts-40-50	50.1	-	-	-	50.1
	4-Str Forklifts-50-75	2.6	-	-	-	2.6
	4-Str Sweepers/Scrubbers-16-25	111.9	-	-	-	111.9
	CNG - Forklifts-40-50	-	-	4,864.9	-	4,864.9
	Dsl - Cement & Mortar Mixers-175-300	-	-	-	39.3	39.3
	Dsl - Cement & Mortar Mixers-300-600	-	-	-	2.3	2.3
	Dsl - Excavators-300-600	-	-	-	37.6	37.6
	Dsl - Forklifts-100-175	-	-	-	185.5	185.5
	Dsl - Forklifts-25-40	-	-	-	4.7	4.7
	Dsl - Forklifts-40-50	-	-	-	47.2	47.2
	Dsl - Forklifts-50-75	-	-	-	366.7	366.7
	Dsl - Forklifts-75-100	-	-	-	250.6	250.6
	Dsl - Graders-175-300	-	-	-	7.5	7.5
	Dsl - Off-highway Trucks-175-300	-	-	-	37.8	37.8
	Dsl - Off-highway Trucks-300-600	-	-	-	76.6	76.6
	Dsl - Other General Industrial Eqp-100-175	-	-	-	10.4	10.4
	Dsl - Other General Industrial Eqp-175-300	-	-	-	4.6	4.6
	Dsl - Rubber Tire Loaders-100-175	-	-	-	1,339.3	1,339.3
	Dsl - Rubber Tire Loaders-175-300	-	-	-	373.1	373.1
	Dsl - Rubber Tire Loaders-300-600	-	-	-	74.2	74.2
	Dsl - Rubber Tire Loaders-50-75	-	-	-	21.5	21.5
	Dsl - Rubber Tire Loaders-75-100	-	-	-	1,136.8	1,136.8
	Dsl - Skid Steer Loaders-25-40	-	-	-	0.2	0.2
	Dsl - Skid Steer Loaders-40-50	-	-	-	7.9	7.9
	Dsl - Skid Steer Loaders-50-75	-	-	-	4.5	4.5
	Dsl - Sweepers/Scrubbers-100-175	-	-	-	5.8	5.8
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	11.8	11.8
	LPG - Forklifts-25-40	-	348.7	-	-	348.7
	LPG - Forklifts-50-75	-	609.2	-	-	609.2
	LPG - Forklifts-75-100	-	365.0	-	-	365.0

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	LPG - Rubber Tire Loaders-25-40	-	2.5	-	-	2.5
Concrete Slurry Manufacturing Total		164.5	770.8	4,864.9	744.5	1,152.2
Dairy Product Manufacturing	LPG - Forklifts-50-75	-	1,256.3	-	-	1,256.3
Dairy Product Manufacturing Total		-	1,256.3	-	-	1,256.3
Electrical Cable and Wire/Equipment Manufacturing	4-Str Other General Industrial Eqp-175-300	220.0	-	-	-	220.0
	LPG - Forklifts-100-175	-	1,440.0	-	-	1,440.0
	LPG - Forklifts-40-50	-	2,191.3	-	-	2,191.3
	LPG - Forklifts-50-75	-	1,317.3	-	-	1,317.3
Electrical Cable and Wire/Equipment Manufacturing Total		220.0	1,528.9	-	-	1,409.9
Fibreglass Product Manufacturing	4-Str Forklifts-40-50	200.0	-	-	-	200.0
	4-Str Forklifts-75-100	27.1	-	-	-	27.1
	4-Str Other General Industrial Eqp-75-100	365.0	-	-	-	365.0
Fibreglass Product Manufacturing Total		197.4	-	-	-	197.4
Fruit and Vegetable Processing	LPG - Forklifts-40-50	-	960.8	-	-	960.8
Fruit and Vegetable Processing Total		-	960.8	-	-	960.8
Furniture Manufacturing	Dsl - Forklifts-25-40	-	-	-	2.4	2.4
	LPG - Forklifts-40-50	-	185.8	-	-	185.8
	LPG - Forklifts-50-75	-	538.2	-	-	538.2
Furniture Manufacturing Total		-	420.7	-	2.4	159.2
Gravel and Sand Quarrying	Dsl - Cranes-175-300	-	-	-	58.6	58.6
	Dsl - Crawler Tractor/Dozers-100-175	-	-	-	456.9	456.9
	Dsl - Crawler Tractor/Dozers-300-600	-	-	-	1,142.4	1,142.4
	Dsl - Crawler Tractor/Dozers-600-750	-	-	-	365.6	365.6
	Dsl - Excavators-175-300	-	-	-	540.3	540.3
	Dsl - Excavators-300-600	-	-	-	791.9	791.9
	Dsl - Forklifts-40-50	-	-	-	29.3	29.3
	Dsl - Graders-100-175	-	-	-	14.3	14.3
	Dsl - Off-highway Trucks-100-175	-	-	-	124.3	124.3
	Dsl - Off-highway Trucks-175-300	-	-	-	307.0	307.0
	Dsl - Off-highway Trucks-300-600	-	-	-	864.6	864.6
	Dsl - Other Construction Equipment-100-175	-	-	-	214.2	214.2
	Dsl - Other Construction	-	-	-	58.6	58.6

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Equipment-75-100					
	Dsl - Other Material Handling Eqp-100-175	-	-	-	427.8	427.8
	Dsl - Rubber Tire Loaders-175-300	-	-	-	1,104.8	1,104.8
	Dsl - Rubber Tire Loaders-300-600	-	-	-	591.2	591.2
	Dsl - Rubber Tire Loaders-600-750	-	-	-	498.1	498.1
	Dsl - Scrapers-300-600	-	-	-	1,142.4	1,142.4
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	293.0	293.0
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	285.6	285.6
Gravel and Sand Quarrying Total		-	-	-	619.9	619.9
Industrial Gas Manufacturing	LPG - Forklifts-40-50	-	421.2	-	-	421.2
Industrial Gas Manufacturing Total		-	421.2	-	-	421.2
Industrial Machinery and Equipment Manufacturing	Dsl - Forklifts-100-175	-	-	-	720.0	720.0
	LPG - Forklifts-50-75	-	165.8	-	-	165.8
Industrial Machinery and Equipment Manufacturing Total		-	165.8	-	720.0	350.6
Iron and Steel Manufacturing	Dsl - Forklifts-100-175	-	-	-	81.1	81.1
	Dsl - Off-highway Trucks-300-600	-	-	-	22.6	22.6
	Dsl - Rubber Tire Loaders-50-75	-	-	-	660.0	660.0
	LPG - Forklifts-100-175	-	165.0	-	-	165.0
	LPG - Forklifts-25-40	-	880.0	-	-	880.0
Iron and Steel Manufacturing Total		-	522.5	-	254.6	407.7
Medicinal and Pharmaceutical Product Manufacturing	Dsl - Forklifts-40-50	-	-	-	148.2	148.2
Medicinal and Pharmaceutical Product Manufacturing Total		-	-	-	148.2	148.2
Motor Vehicle and Part Manufacturing	LPG - Forklifts-40-50	-	1,280.2	-	-	1,280.2
Motor Vehicle and Part Manufacturing Total		-	1,280.2	-	-	1,280.2
Nonbuilding Construction	Dsl - Off-highway Trucks-100-175	-	-	-	448.0	448.0
	Dsl - Skid Steer Loaders-75-	-	-	-	3,120.0	3,120.0

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	100					
	LPG - Forklifts-40-50	-	2,255.0	-	-	2,255.0
Nonbuilding Construction Total		-	2,255.0	-	1,784.0	2,098.0
Other Agricultural Crop Processing	LPG - Forklifts-40-50	-	1,939.7	-	-	1,939.7
Other Agricultural Crop Processing Total		-	1,939.7	-	-	1,939.7
Other Food Manufacturing	4-Str Other General Industrial Eqp-100-175	5.1	-	-	-	5.1
	LPG - Forklifts-40-50	-	4,045.9	-	-	4,045.9
	LPG - Forklifts-50-75	-	6,912.0	-	-	6,912.0
Other Food Manufacturing Total		5.1	4,237.0	-	-	3,972.5
Paint and Ink Manufacturing	Dsl - Forklifts-40-50	-	-	-	245.6	245.6
	Dsl - Forklifts-50-75	-	-	-	675.2	675.2
	Dsl - Forklifts-75-100	-	-	-	220.8	220.8
Paint and Ink Manufacturing Total		-	-	-	473.1	473.1
Petroleum Product Wholesaling	4-Str Other General Industrial Eqp-75-100	16.7	-	-	-	16.7
	Dsl - Forklifts-40-50	-	-	-	85.9	85.9
	Dsl - Off-highway Trucks-175-300	-	-	-	220.5	220.5
	LPG - Forklifts-40-50	-	165.2	-	-	165.2
	LPG - Forklifts-50-75	-	2,162.7	-	-	2,162.7
Petroleum Product Wholesaling Total		16.7	1,663.3	-	119.6	794.3
Plastic Injection Moulded Product Manufacturing	4-Str Forklifts-175-300	9.7	-	-	-	9.7
	LPG - Forklifts-100-175	-	2,233.8	-	-	2,233.8
	LPG - Forklifts-40-50	-	1,331.1	-	-	1,331.1
	LPG - Forklifts-50-75	-	1,673.6	-	-	1,673.6
Plastic Injection Moulded Product Manufacturing Total		9.7	1,455.6	-	-	1,324.1
Poultry Farming (Eggs) and (Meat)	4-Str Rear Engine Riding Mowers (com)-11-16	221.0	-	-	-	221.0
	Dsl - Commercial Mowers (com)-25-40	-	-	-	162.0	162.0
	Dsl - Other General Industrial Eqp-175-300	-	-	-	129.8	129.8
	Dsl - Other General Industrial Eqp-75-100	-	-	-	130.6	130.6
	Dsl - Rubber Tire Loaders-100-175	-	-	-	27.3	27.3
	Dsl - Rubber Tire Loaders-50-75	-	-	-	98.9	98.9
	Dsl - Rubber Tire Loaders-75-100	-	-	-	54.6	54.6
	Dsl - Tractors/Loaders/Backhoes-100-175	-	-	-	27.3	27.3

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Dsl - Tractors/Loaders/Backhoes-25-40	-	-	-	299.3	299.3
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	1,231.7	1,231.7
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	5,784.0	5,784.0
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	94.6	94.6
Poultry Farming (Eggs) and (Meat) Total		221.0	-	-	1,989.5	1,952.3
Rubber Product Manufacturing	LPG - Forklifts-40-50	-	260.0	-	-	260.0
Rubber Product Manufacturing Total		-	260.0	-	-	260.0
Soap and Other Detergent Manufacturing	Dsl - Forklifts-40-50	-	-	-	148.2	148.2
	LPG - Forklifts-40-50	-	743.4	-	-	743.4
Soap and Other Detergent Manufacturing Total		-	743.4	-	148.2	445.8
Structural and Fabricated Metal Product Manufacturing	4-Str Forklifts-40-50	1,932.8	-	-	-	1,932.8
	Dsl - Cranes-175-300	-	-	-	23.3	23.3
	Dsl - Forklifts-40-50	-	-	-	444.6	444.6
	Dsl - Forklifts-50-75	-	-	-	1,422.6	1,422.6
	Dsl - Forklifts-75-100	-	-	-	1,231.0	1,231.0
	Dsl - Off-highway Trucks-175-300	-	-	-	289.8	289.8
	LPG - Forklifts-100-175	-	656.9	-	-	656.9
	LPG - Forklifts-25-40	-	910.4	-	-	910.4
	LPG - Forklifts-40-50	-	1,311.8	-	-	1,311.8
	LPG - Forklifts-50-75	-	1,405.9	-	-	1,405.9
	LPG - Forklifts-75-100	-	1,462.4	-	-	1,462.4
Structural and Fabricated Metal Product Manufacturing Total		1,932.8	1,279.8	-	906.3	1,198.1
Wine Manufacturing	4-Str Forklifts-40-50	12.6	-	-	-	12.6
	4-Str Lawn mowers (Com)-3-6	117.3	-	-	-	117.3
	4-Str Other General Industrial Eqp-25-40	14.3	-	-	-	14.3
	4-Str Other General Industrial Eqp-50-75	132.5	-	-	-	132.5
	4-Str Rear Engine Riding Mowers (com)-16-25	17.8	-	-	-	17.8
	Dsl - Combines-100-175	-	-	-	66.8	66.8
	Dsl - Commercial Mowers (com)-16-25	-	-	-	76.7	76.7

ANZSIC class	Equipment description	Annual operating time (h/year)				
		4-stroke petrol	LPG	CNG	Diesel	Grand Total
	Dsl - Forklifts-40-50	-	-	-	131.5	131.5
	Dsl - Generator Sets-75-100	-	-	-	470.9	470.9
	Dsl - Off-highway Trucks-100-175	-	-	-	69.4	69.4
	Dsl - Tractors/Loaders/Backhoes-16-25	-	-	-	299.1	299.1
	Dsl - Tractors/Loaders/Backhoes-40-50	-	-	-	226.3	226.3
	Dsl - Tractors/Loaders/Backhoes-50-75	-	-	-	315.3	315.3
	Dsl - Tractors/Loaders/Backhoes-75-100	-	-	-	667.6	667.6
	LPG - Forklifts-25-40	-	38.2	-	-	38.2
	LPG - Forklifts-40-50	-	154.2	-	-	154.2
	LPG - Forklifts-50-75	-	300.0	-	-	300.0
Wine Manufacturing Total		42.2	160.2	-	258.6	205.6
Wood Product Manufacturing	LPG - Forklifts-40-50	-	1,157.3	-	-	1,157.3
	LPG - Forklifts-50-75	-	284.9	-	-	284.9
Wood Product Manufacturing Total		-	866.5	-	-	866.5
Grand Total		91.3	1,249.9	4,864.9	468.6	595.5

The total population of in-service commercial off-road vehicles and equipment has been estimated from the commercial survey (DECC, 2007a). In-service commercial off-road vehicles and equipment population by equipment description and maximum rated power range data for the GMR is presented in Table 3-71 and shown in Figure 3-51 .

Table 3-71: Commercial off-road vehicles and equipment population in the GMR

Equipment description	2008 equipment population											
	3 to 6 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	Grand Total
4-Str Forklifts	-	-	-	-	35	1	1	-	1	-	-	38
4-Str Lawn mowers (Com)	10	-	-	-	-	-	-	-	-	-	-	10
4-Str Other General Industrial Eqp	-	-	-	10	-	10	2	1	1	-	-	25
4-Str Rear Engine Riding Mowers (com)	-	1	21	-	-	-	-	-	-	-	-	22
4-Str Sweepers/Scrubbers	-	-	1	-	-	-	-	-	-	-	-	1
CNG - Forklifts	-	-	-	-	1	-	-	-	-	-	-	1

Equipment description	2008 equipment population											
	3 to 6 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	Grand Total
Dsl - Cement & Mortar Mixers	-	-	-	-	-	-	-	-	1	1	-	2
Dsl - Combines	-	-	-	-	-	-	-	10	-	-	-	10
Dsl - Commercial Mowers (com)	-	-	10	1	-	-	-	-	-	-	-	11
Dsl - Cranes	-	-	-	-	-	-	-	-	4	-	-	4
Dsl - Crawler Tractor/Dozers	-	-	-	-	-	-	-	2	-	4	2	8
Dsl - Excavators	-	-	-	-	-	-	-	-	10	4	-	14
Dsl - Forklifts	-	-	-	5	30	11	11	2	-	-	-	59
Dsl - Generator Sets	-	-	-	-	-	-	10	-	-	-	-	10
Dsl - Graders	-	-	-	-	-	-	-	2	1	-	-	3
Dsl - Off-highway Trucks	-	-	-	-	-	-	-	38	6	16	-	60
Dsl - Other Construction Equipment	-	-	-	-	-	-	4	4	-	-	-	8
Dsl - Other General Industrial Eqp	-	-	-	-	-	-	2	1	2	-	-	5
Dsl - Other Material Handling Eqp	-	-	-	-	-	-	-	4	-	-	-	4
Dsl - Rubber Tire Loaders	-	-	-	-	-	2	1	4	23	8	6	44
Dsl - Scrapers	-	-	-	-	-	-	-	-	-	2	-	2
Dsl - Skid Steer Loaders	-	-	1	1	1	1	1	-	-	-	-	5
Dsl - Sweepers/Scrubbers	-	-	-	-	-	-	-	1	-	-	-	1
Dsl - Tractors/Loaders/Backhoes	-	-	21	1	93	124	17	9	2	-	-	266
LPG - Forklifts	-	-	-	15	109	32	1	7	-	-	-	164
LPG - Rubber Tire Loaders	-	-	-	1	-	-	-	-	-	-	-	1
Grand Total	10	1	54	34	269	181	51	86	51	35	8	780

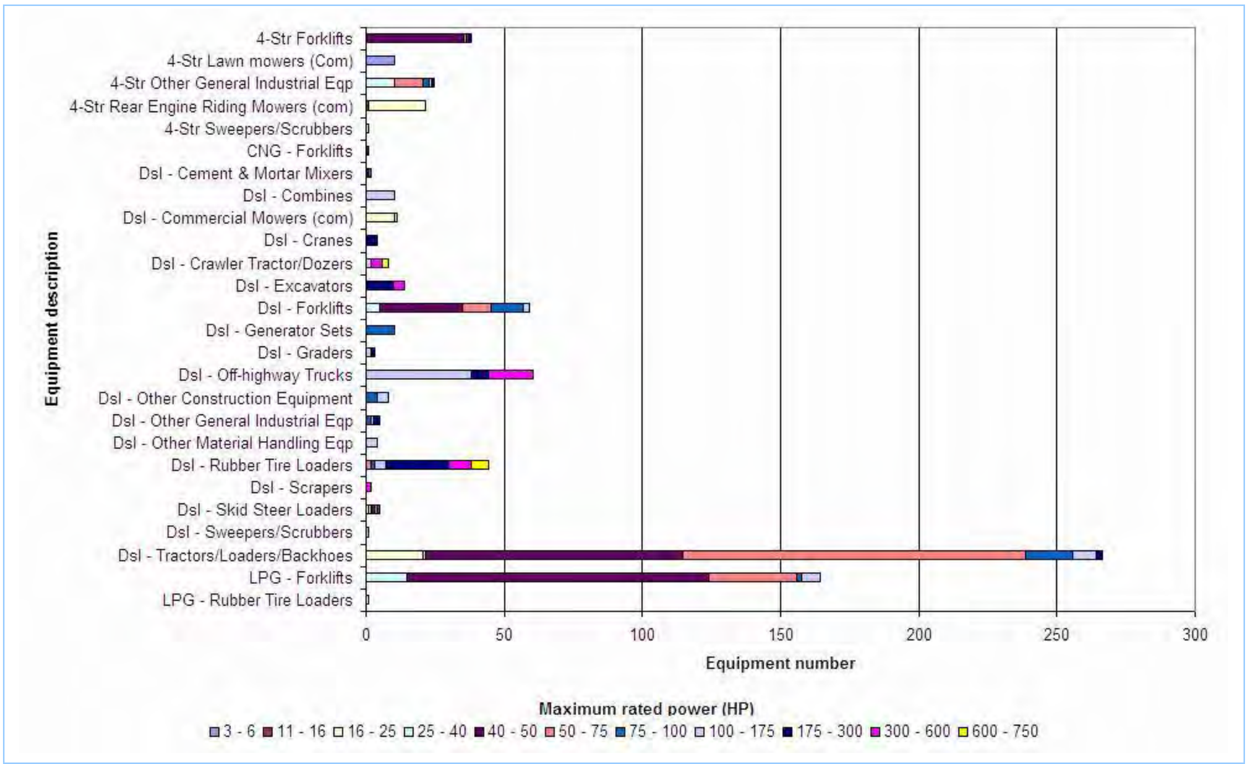

Figure 3-51: Commercial off-road vehicles and equipment population in the GMR

The annual operating time of commercial off-road vehicles and equipment has been estimated from the commercial survey (DECC, 2007a). In-service commercial vehicles and equipment annual operating time by engine description for the GMR is presented in Table 3-72 and shown in Figure 3-52.

Table 3-72: Commercial off-road vehicles and equipment annual operating time in the GMR

Equipment description	Annual operating time (h/year)										
	3 to 6 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp
4-Stroke Forklifts	-	-	-	-	129.1	2.6	27.1	-	9.7	-	-
4-Stroke Lawn mowers (Commercial)	117.3	-	-	-	-	-	-	-	-	-	-
4-Stroke Other General Industrial Equipment	-	-	-	14.3	-	132.5	190.9	5.1	220.0	-	-
4-Stroke Rear Engine Riding Mowers (Commercial)	-	221.0	17.8	-	-	-	-	-	-	-	-
4-Stroke Sweepers/Scrubbers	-	-	111.9	-	-	-	-	-	-	-	-
CNG Forklifts	-	-	-	-	4,864.9	-	-	-	-	-	-
Diesel Cement & Mortar Mixers	-	-	-	-	-	-	-	-	39.3	2.3	-
Diesel Combines	-	-	-	-	-	-	-	66.8	-	-	-
Diesel Cranes	-	-	-	-	-	-	-	-	40.9	-	-
Diesel Crawler Tractors	-	-	-	-	-	-	-	456.9	-	1,142.4	365.6
Diesel Excavators	-	-	-	-	-	-	-	-	540.3	792.8	-
Diesel Forklifts	-	-	-	3.2	191.9	809.2	879.3	436.9	-	-	-
Diesel Front Mowers (Commercial)	-	-	76.7	162.0	-	-	-			-	-
Diesel Graders	-	-	-	-	-	-	-	14.3	7.5	-	-
Diesel Light Commercial Generator Sets	-	-	-	-	-	-	470.9			-	-
Diesel Off-highway Trucks	-	-	-	-	-	-	-	88.0	287.8	670.4	-
Diesel Other Construction Equipment	-	-	-	-	-	-	58.6	214.2		-	-
Diesel Other General Industrial Equipment	-	-	-	-	-	-	130.6	10.4	129.2	-	-
Diesel Other Material Handling Equipment	-	-	-	-	-	-	-	427.8		-	-
Diesel Rubber Tire Loaders	-	-	-	-	-	454.5	848.1	816.5	1,010.1	594.1	498.1
Diesel Scrapers	-	-	-	-	-	-	-	-	-	1,142.4	-

Equipment description	Annual operating time (h/year)										
	3 to 6 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp
Diesel Skid Steer Loaders	-	-	411.3	0.2	7.9	4.5	3,120.0	-	-	-	-
Diesel Sweepers/Scrubbers	-	-	-	-	-	-	-	5.8	-	-	-
Diesel Tractors/Loaders/Backhoes	-	-	299.1	299.3	335.4	626.1	476.5	531.3	686.0	-	-
LPG Forklifts	-	-	-	292.5	1,438.3	1,091.0	1,278.0	1,077.2	-	-	-
LPG Rubber Tire Loaders	-	-	-	2.5	-	-	-	-	-	-	-

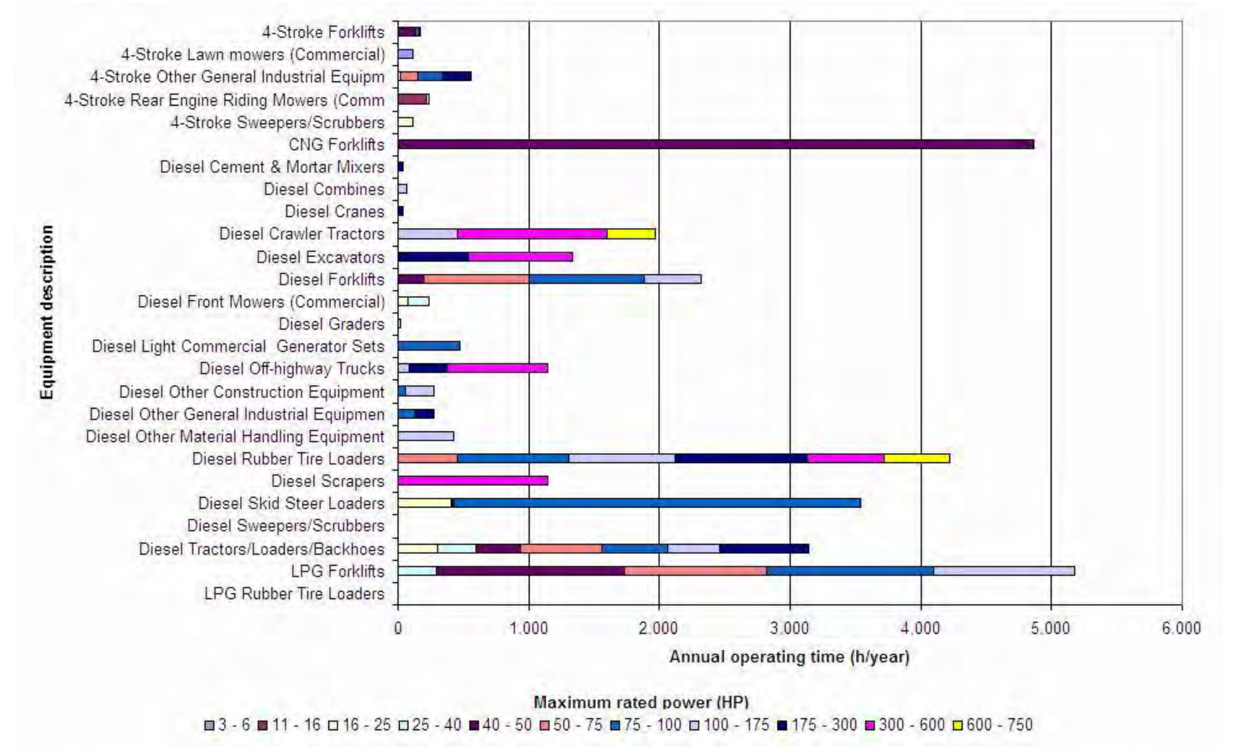

Figure 3-52: Commercial off-road vehicles and equipment annual operating time in the GMR

Exhaust and evaporative emissions from commercial off-road vehicles and equipment have been estimated using equipment population (DECC, 2007a), annual operating time (DECC, 2007a), fuel properties (Attorney-General's Department, 2003; Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECC, 2007a) data within the *NONROAD2008a Model* (USEPA, 2009a).

Figure 3-53 shows the NonRoad Model splash screen for the commercial off-road vehicles and equipment emission estimation simulation.

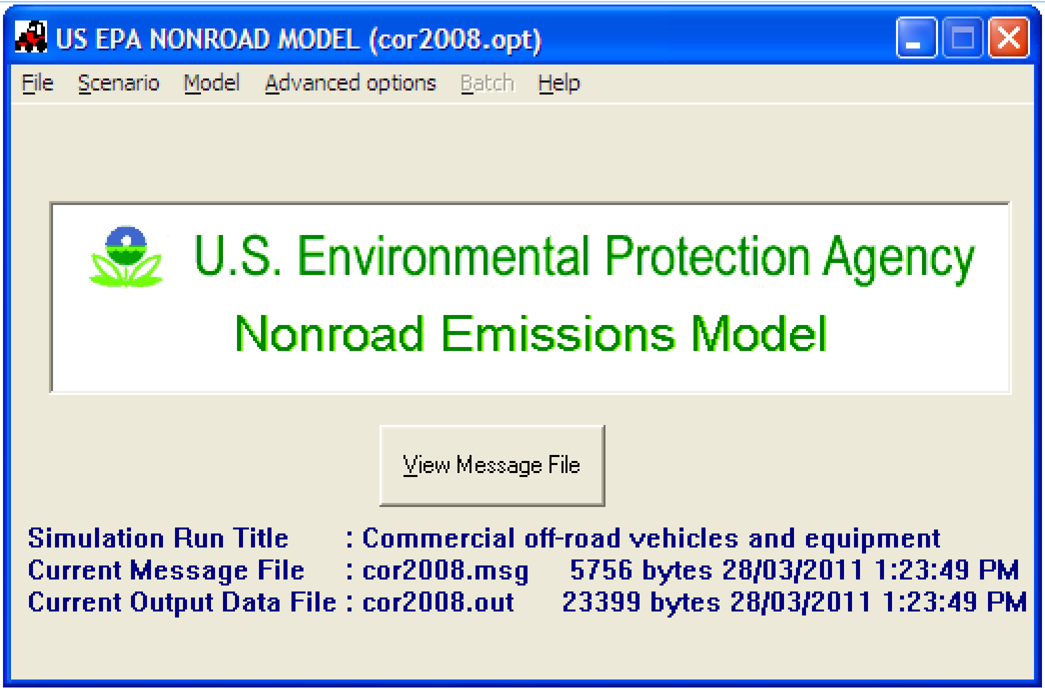

Figure 3-53: Commercial off-road vehicles and equipment NonRoad Model splash screen

Figure 3-54 shows the NonRoad Model options screen for the commercial off-road vehicles and equipment emission estimation simulation.

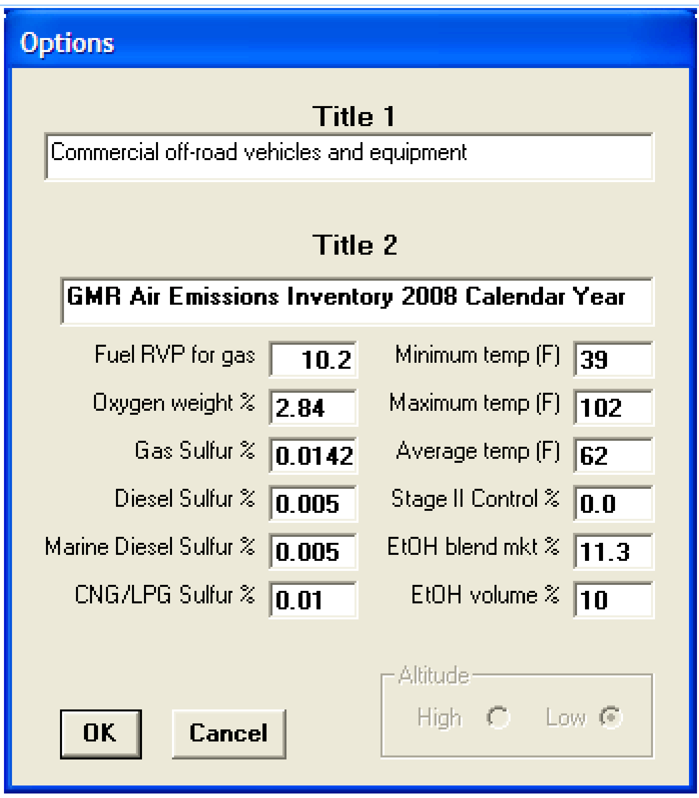

Figure 3-54: Commercial off-road vehicles and equipment NonRoad Model options

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).

Since there is little monthly temporal variation in commercial off-road vehicles and equipment use, the NonRoad Model has been run with average daily minimum, maximum and average ambient temperature (Hurley, 2005) and petrol RVP (PCO, 2011), which are shown in the NonRoad Model options screen in Figure 3-54.

Table 3-73 presents commercial off-road vehicles and equipment power rating (DECC, 2007a), useful life (USEPA, 2009a) and population (DECC, 2007a) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-73: Commercial off-road vehicles and equipment NonRoad Model population

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2265003020	4-Str Forklifts	175	300	187.7	4500	1
2265003020	4-Str Forklifts	40	50	43.6	4500	35.2
2265003020	4-Str Forklifts	50	75	60	4500	1
2265003020	4-Str Forklifts	75	100	80.5	4500	1
2265004011	4-Str Lawn mowers (Com)	3	6	5	268	10.4
2265003040	4-Str Other General Industrial Eqp	100	175	126.1	3000	1
2265003040	4-Str Other General Industrial Eqp	175	300	177	3000	1
2265003040	4-Str Other General Industrial Eqp	25	40	34.9	1500	10.4
2265003040	4-Str Other General Industrial Eqp	50	75	50	3000	10.4
2265003040	4-Str Other General Industrial Eqp	75	100	96.6	3000	2
2265004041	4-Str Rear Engine Riding Mowers (com)	11	16	13	627	1
2265004041	4-Str Rear Engine Riding Mowers (com)	16	25	16	750	20.7
2265003030	4-Str Sweepers/Scrubbers	16	25	20	750	1
2268003020	CNG - Forklifts	40	50	40	4500	1
2270002042	Dsl - Cement & Mortar Mixers	175	300	240	4667	1
2270002042	Dsl - Cement & Mortar Mixers	300	600	335.3	7000	1
2270005020	Dsl - Combines	100	175	120	4667	10.4
2270004046	Dsl - Commercial Mowers (com)	16	25	20	2500	10.4
2270004046	Dsl - Commercial Mowers (com)	25	40	27	2500	1
2270002045	Dsl - Cranes	175	300	177	4667	4
2270002069	Dsl - Crawler Tractor/Dozers	100	175	140	4667	2
2270002069	Dsl - Crawler Tractor/Dozers	300	600	490	7000	4
2270002069	Dsl - Crawler Tractor/Dozers	600	750	600	7000	2
2270002036	Dsl - Excavators	175	300	242	4667	10
2270002036	Dsl - Excavators	300	600	321.7	7000	4
2270003020	Dsl - Forklifts	100	175	142.5	4667	2.3
2270003020	Dsl - Forklifts	25	40	27.6	2500	5.1
2270003020	Dsl - Forklifts	40	50	42.9	2500	29.7
2270003020	Dsl - Forklifts	50	75	56.3	4667	10.6
2270003020	Dsl - Forklifts	75	100	84.6	4667	11.3

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270006005	Dsl - Generator Sets	75	100	80.5	4667	10.4
2270002048	Dsl - Graders	100	175	115	4667	2
2270002048	Dsl - Graders	175	300	235	4667	1
2270002051	Dsl - Off-highway Trucks	100	175	145.5	4667	38.1
2270002051	Dsl - Off-highway Trucks	175	300	242.3	4667	6.2
2270002051	Dsl - Off-highway Trucks	300	600	355.8	7000	16.1
2270002081	Dsl - Other Construction Equipment	100	175	121.4	4667	4
2270002081	Dsl - Other Construction Equipment	75	100	83	4667	4
2270003040	Dsl - Other General Industrial Eqp	100	175	132.8	4667	1
2270003040	Dsl - Other General Industrial Eqp	175	300	208.2	4667	1.9
2270003040	Dsl - Other General Industrial Eqp	75	100	80	4667	1.9
2270003050	Dsl - Other Material Handling Eqp	100	175	100.6	4667	4
2270002060	Dsl - Rubber Tire Loaders	100	175	125.4	4667	4.1
2270002060	Dsl - Rubber Tire Loaders	175	300	214.2	4667	22.9
2270002060	Dsl - Rubber Tire Loaders	300	600	324.1	7000	8.1
2270002060	Dsl - Rubber Tire Loaders	50	75	64.9	4667	1.7
2270002060	Dsl - Rubber Tire Loaders	600	750	625	7000	6
2270002060	Dsl - Rubber Tire Loaders	75	100	88	4667	1.4
2270002018	Dsl - Scrapers	300	600	450	7000	2
2270002072	Dsl - Skid Steer Loaders	16	25	20	2500	1
2270002072	Dsl - Skid Steer Loaders	25	40	37.5	2500	1
2270002072	Dsl - Skid Steer Loaders	40	50	40	2500	1
2270002072	Dsl - Skid Steer Loaders	50	75	73.8	4667	1
2270002072	Dsl - Skid Steer Loaders	75	100	75	4667	1
2270003030	Dsl - Sweepers/Scrubbers	100	175	139.5	4667	1
2270002066	Dsl - Tractors/Loaders/Backhoes	100	175	122.1	4667	8.8
2270002066	Dsl - Tractors/Loaders/Backhoes	16	25	19	2500	20.7
2270002066	Dsl - Tractors/Loaders/Backhoes	175	300	234.1	4667	2
2270002066	Dsl - Tractors/Loaders/Backhoes	25	40	30	2500	1
2270002066	Dsl - Tractors/Loaders/Backhoes	40	50	41.7	2500	93
2270002066	Dsl - Tractors/Loaders/Backhoes	50	75	59.7	4667	123.9
2270002066	Dsl - Tractors/Loaders/Backhoes	75	100	81.6	4667	16.9
2267003020	LPG - Forklifts	100	175	121.6	4500	7
2267003020	LPG - Forklifts	25	40	27.4	4500	14.8
2267003020	LPG - Forklifts	40	50	43.6	4500	109.1
2267003020	LPG - Forklifts	50	75	61.8	4500	32.1
2267003020	LPG - Forklifts	75	100	92.2	4500	1.4
2267002060	LPG - Rubber Tire Loaders	25	40	26.8	1500	1

Table 3-74 presents the commercial off-road vehicles and equipment load factor (USEPA, 2009a) and annual operating time (DECC, 2007a) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-74: Commercial off-road vehicles and equipment NonRoad Model load factor and annual operating time

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2265003020	4-Stroke Forklifts	175	300	0.30	9.7
2265003020	4-Stroke Forklifts	40	50	0.30	129.1
2265003020	4-Stroke Forklifts	50	75	0.30	2.6
2265003020	4-Stroke Forklifts	75	100	0.30	27.1
2265004011	4-Stroke Lawn mowers (Commercial)	3	6	0.33	117.3
2265003040	4-Stroke Other General Industrial Equipm	100	175	0.54	5.1
2265003040	4-Stroke Other General Industrial Equipm	175	300	0.54	220.0
2265003040	4-Stroke Other General Industrial Equipm	25	40	0.54	14.3
2265003040	4-Stroke Other General Industrial Equipm	50	75	0.54	132.5
2265003040	4-Stroke Other General Industrial Equipm	75	100	0.54	190.9
2265004041	4-Stroke Rear Engine Riding Mowers (Comm.)	11	16	0.38	221.0
2265004041	4-Stroke Rear Engine Riding Mowers (Comm.)	16	25	0.38	17.8
2265003030	4-Stroke Sweepers/Scrubbers	16	25	0.71	111.9
2268003020	CNG Forklifts	40	50	0.30	4864.9
2270002042	Diesel Cement & Mortar Mixers	175	300	0.43	39.3
2270002042	Diesel Cement & Mortar Mixers	300	600	0.43	2.3
2270005020	Diesel Combines	100	175	0.59	66.8
2270004046	Diesel Front Mowers (Commercial)	16	25	0.43	76.7
2270004046	Diesel Front Mowers (Commercial)	25	40	0.43	162.0
2270002045	Diesel Cranes	175	300	0.43	40.9
2270002069	Diesel Crawler Tractors	100	175	0.59	456.9
2270002069	Diesel Crawler Tractors	300	600	0.59	1142.4
2270002069	Diesel Crawler Tractors	600	750	0.59	365.6
2270002036	Diesel Excavators	175	300	0.59	540.3
2270002036	Diesel Excavators	300	600	0.59	792.8
2270003020	Diesel Forklifts	100	175	0.59	436.9
2270003020	Diesel Forklifts	25	40	0.59	3.2
2270003020	Diesel Forklifts	40	50	0.59	191.9
2270003020	Diesel Forklifts	50	75	0.59	809.2
2270003020	Diesel Forklifts	75	100	0.59	879.3
2270006005	Diesel Light Commercial Generator Sets	75	100	0.43	470.9
2270002048	Diesel Graders	100	175	0.59	14.3
2270002048	Diesel Graders	175	300	0.59	7.5
2270002051	Diesel Off-highway Trucks	100	175	0.59	88.0
2270002051	Diesel Off-highway Trucks	175	300	0.59	287.8
2270002051	Diesel Off-highway Trucks	300	600	0.59	764.9
2270002081	Diesel Other Construction Equipment	100	175	0.59	214.2
2270002081	Diesel Other Construction Equipment	75	100	0.59	58.6
2270003040	Diesel Other General Industrial Equipment	100	175	0.43	10.4
2270003040	Diesel Other General Industrial Equipment	175	300	0.43	129.2
2270003040	Diesel Other General Industrial Equipment	75	100	0.43	130.6
2270003050	Diesel Other Material Handling Equipment	100	175	0.21	427.8
2270002060	Diesel Rubber Tire Loaders	100	175	0.59	816.5

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2270002060	Diesel Rubber Tire Loaders	175	300	0.59	1010.1
2270002060	Diesel Rubber Tire Loaders	300	600	0.59	594.1
2270002060	Diesel Rubber Tire Loaders	50	75	0.59	454.5
2270002060	Diesel Rubber Tire Loaders	600	750	0.59	498.1
2270002060	Diesel Rubber Tire Loaders	75	100	0.59	848.1
2270002018	Diesel Scrapers	300	600	0.59	1142.4
2270002072	Diesel Skid Steer Loaders	16	25	0.21	411.3
2270002072	Diesel Skid Steer Loaders	25	40	0.21	0.2
2270002072	Diesel Skid Steer Loaders	40	50	0.21	7.9
2270002072	Diesel Skid Steer Loaders	50	75	0.21	4.5
2270002072	Diesel Skid Steer Loaders	75	100	0.21	3120.0
2270003030	Diesel Sweepers/Scrubbers	100	175	0.43	5.8
2270002066	Diesel Tractors/Loaders/Backhoes	100	175	0.21	397.2
2270002066	Diesel Tractors/Loaders/Backhoes	16	25	0.21	299.1
2270002066	Diesel Tractors/Loaders/Backhoes	175	300	0.21	686.0
2270002066	Diesel Tractors/Loaders/Backhoes	25	40	0.21	299.3
2270002066	Diesel Tractors/Loaders/Backhoes	40	50	0.21	335.4
2270002066	Diesel Tractors/Loaders/Backhoes	50	75	0.21	626.1
2270002066	Diesel Tractors/Loaders/Backhoes	75	100	0.21	501.1
2267003020	LPG Forklifts	100	175	0.30	1077.2
2267003020	LPG Forklifts	25	40	0.30	292.5
2267003020	LPG Forklifts	40	50	0.30	1438.3
2267003020	LPG Forklifts	50	75	0.30	1091.0
2267003020	LPG Forklifts	75	100	0.30	1278.0
2267002060	LPG Rubber Tire Loaders	25	40	0.71	2.5

Table 3-75 presents the commercial off-road vehicles and equipment fuel consumption estimates by equipment description from the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-75: Commercial off-road vehicles and equipment NonRoad Model fuel consumption by equipment description in the GMR

Equipment description	2008 fuel consumption (kL/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Cement & Mortar Mixers	-	-	-	1	1
Combines	-	-	-	10	10
Cranes	-	-	-	2	2
Crawler Tractor/Dozers	-	-	-	328	328
Excavators	-	-	-	272	272
Forklifts	23	1,304	28	220	1,575
Front Mowers	-	-	-	2	2
Generator Sets	-	-	-	37	37
Graders	-	-	-	1	1
Lawn mowers	2	-	-	-	2

Equipment description	2008 fuel consumption (kL/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Off-highway Trucks	-	-	-	636	636
Other Construction Equipment	-	-	-	15	15
Other General Industrial Eqp	30	-	-	6	37
Other Material Handling Eqp	-	-	-	8	8
Rear Engine Riding Mowers	2	-	-	-	2
Rubber Tire Loaders	-	1	-	1,047	1,048
Scrapers	-	-	-	120	120
Skid Steer Loaders	-	-	-	13	13
Sweepers/Scrubbers	1	-	-	0	1
Tractors/Loaders/Backhoes	-	-	-	410	410
Grand Total	57	1,304	28	3,128	4,518

Commercial off-road vehicles and equipment fuel consumption estimates by ANZSIC class from the *NONROAD2008a Model* (USEPA, 2009a) are presented in Table 3-76 and shown in Figure 3-55 for all ANZSIC classes.

Table 3-76: Commercial off-road vehicles and equipment NonRoad Model fuel consumption by ANZSIC class in the GMR

ANZSIC class	2008 fuel consumption (kL/year)			
	4-stroke petrol	LPG and CNG[16]	Diesel	Grand Total
Chemical Product Manufacturing	0.16	62.30	27.25	89.71
Chemical Wholesaling	-	101.28	-	101.28
Concrete Product Manufacturing	0.50	-	39.36	39.86
Concrete Slurry Manufacturing	0.19	29.14	95.43	124.76
Dairy Product Manufacturing	-	26.55	-	26.55
Electrical Cable and Wire/Equipment Manufacturing	7.84	133.66	-	141.50
Fibreglass Product Manufacturing	8.36	-	-	8.36
Fruit and Vegetable Processing	-	11.44	-	11.44
Furniture Manufacturing	-	8.63	4.32E-2	8.67
Gravel and Sand Quarrying	-	-	2,284.76	2,284.76
Industrial Gas Manufacturing	-	4.65	-	4.65
Industrial Machinery and Equipment Manufacturing	-	2.65	9.21	11.86

[16] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

ANZSIC class	2008 fuel consumption (kL/year)			
	4-stroke petrol	LPG and CNG[16]	Diesel	Grand Total
Iron and Steel Manufacturing	-	12.59	8.28	20.87
Medicinal and Pharmaceutical Product Manufacturing	-	-	0.86	0.86
Motor Vehicle and Part Manufacturing	-	15.24	-	15.24
Nonbuilding Construction	-	53.69	21.49	75.18
Other Agricultural Crop Processing	-	10.52	-	10.52
Other Food Manufacturing	0.13	370.88	-	371.01
Paint and Ink Manufacturing	-	-	48.57	48.57
Petroleum Product Wholesaling	0.33	53.02	7.55	60.90
Plastic Injection Moulded Product Manufacturing	0.20	106.97	-	107.17
Poultry Farming (Eggs)	2.83E-2	-	42.11	42.14
Poultry Farming (Meat)	7.44E-2	-	110.62	110.70
Rubber Product Manufacturing	-	1.55	-	1.55
Soap and Other Detergent Manufacturing	-	4.42	0.86	5.29
Structural and Fabricated Metal Product Manufacturing	19.60	254.90	132.75	407.25
Wine Manufacturing	19.82	52.61	299.09	371.52
Wood Product Manufacturing	-	15.06	-	15.06
Grand Total	57.24	1,331.75	3,128.26	4,517.25

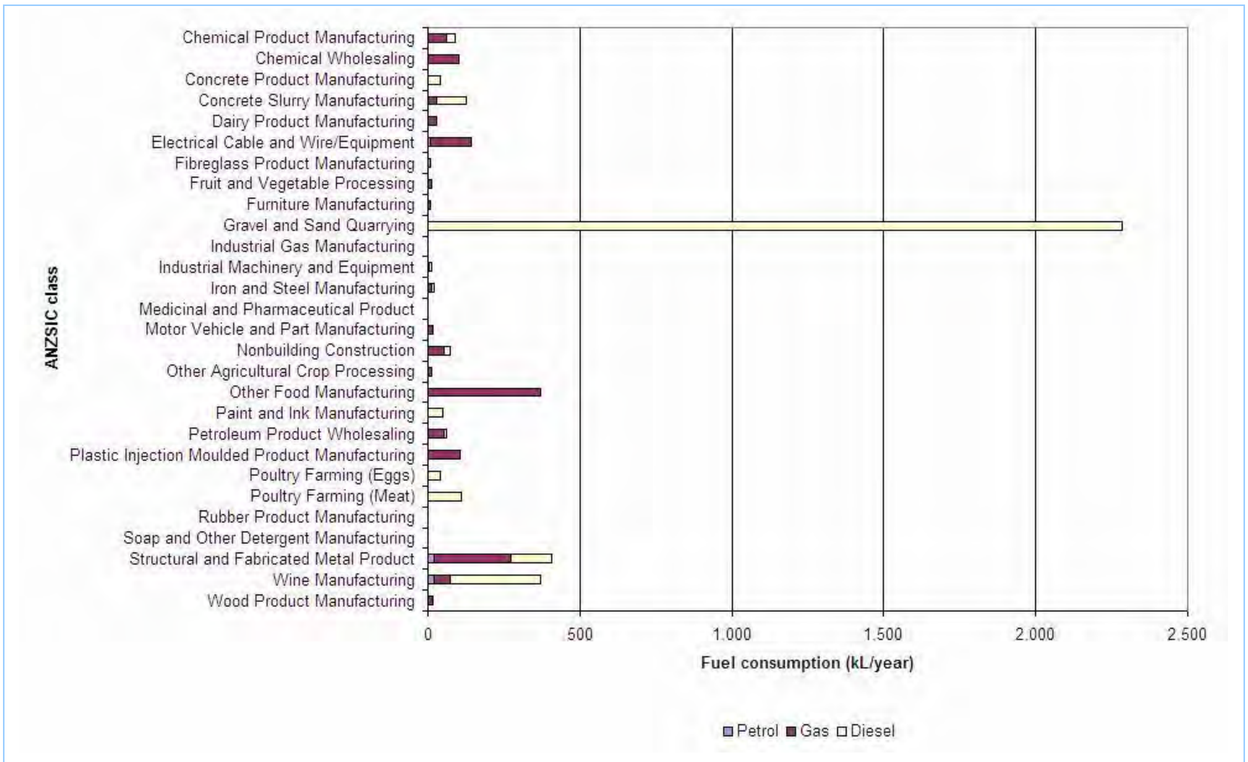

Figure 3-55: Commercial off-road vehicles and equipment NonRoad Model fuel consumption by ANZSIC class in the GMR

Figure 3-56 shows commercial off-road vehicles and equipment fuel consumption estimates by ANZSIC class from the *NONROAD2008a Model* (USEPA, 2009a) for all ANZSIC class except Gravel and Sand Quarrying.

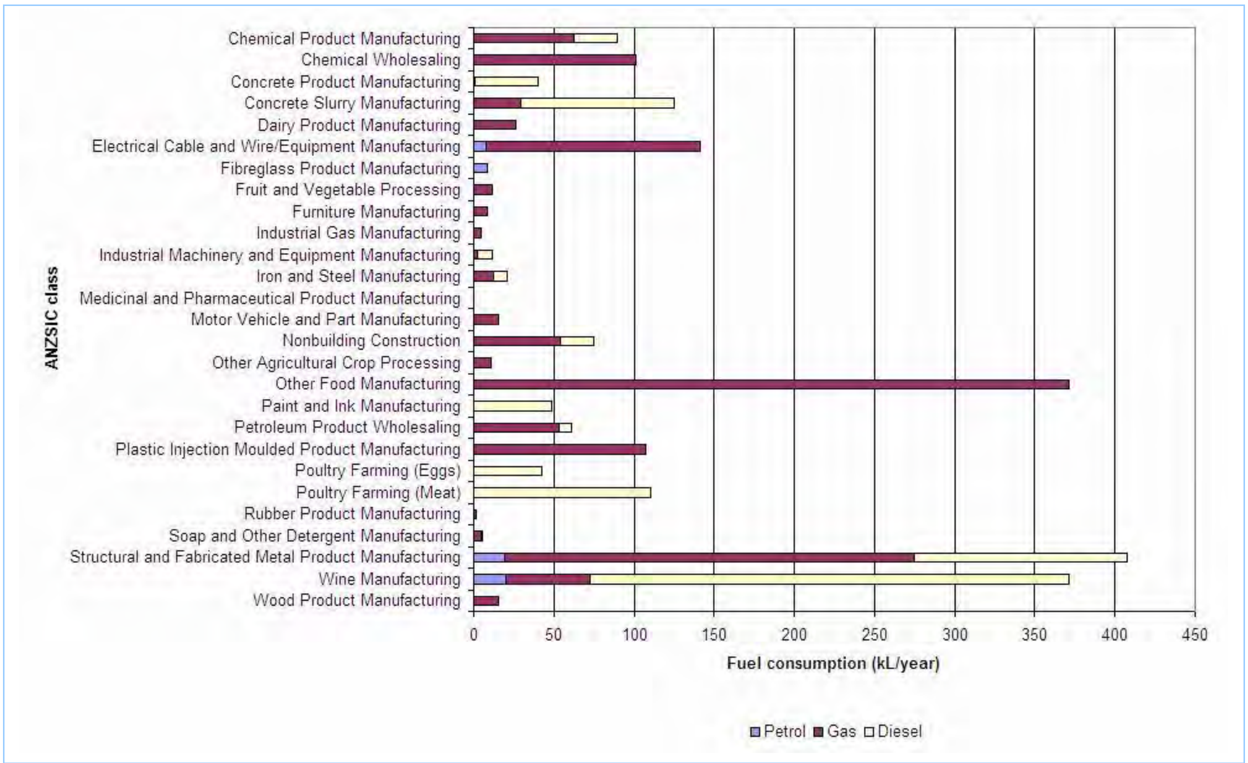

Figure 3-56: Commercial off-road vehicles and equipment NonRoad Model fuel consumption for selected ANZSIC class in the GMR

3.3.4 Emission and Speciation Factors

Table 3-77 summarises the emission and speciation factors used for commercial off-road vehicles and equipment.

Table 3-77: Commercial off-road vehicles and equipment 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	4-stroke petrol, LPG, CNG and diesel exhaust	- *NONROAD2008a Model* (USEPA, 2009a)
Criteria pollutants: VOC	4-stroke petrol, LPG, CNG and diesel exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009a)
Criteria pollutants: TSP	4-stroke petrol exhaust	- *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	LPG and CNG exhaust	- *PMPROF 120 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	diesel exhaust	- *PMPROF 116 - California Emission Inventory and Reporting*

Substance	Emission source	Emission and speciation factor source
		System (CEIDARS), Particulate Matter (PM) Speciation Profiles (CARB, 2008b)
Speciated NO_x	4-stroke petrol, LPG, CNG and diesel exhaust	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	4-stroke petrol exhaust and evaporative	- *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)
	LPG and CNG exhaust and evaporative	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a) - *ORGPROF 719 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust and evaporative	- *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)
Organic air toxics	4-stroke petrol exhaust and evaporative	- *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)
	LPG and CNG exhaust and evaporative	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a) - *ORGPROF 719 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust and evaporative	- *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)
Metal air toxics	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*

Substance	Emission source	Emission and speciation factor source
		(CARB, 2007)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a) - *PMPROF 123 - 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	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)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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 and Polychlorinated dibenzofurans: PCDD and PCDF	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)
	LPG and CNG exhaust	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	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	4-stroke petrol and diesel exhaust	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	LPG and CNG exhaust	- *Table III-1 - 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, 2009a)
Greenhouse gases: N_2O	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)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998)

Table 3-78 presents average activity weighted 4-stroke petrol, LPG, CNG and diesel exhaust and evaporative emission factors for commercial off-road vehicles and equipment.

Table 3-78: Commercial off-road vehicles and equipment 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
4-stroke petrol exhaust and evaporative	32.01	0.058	0.029	0.198	0.23	0.21	110.23	2.158	425.07	2,299.00	0.0233	3.29×10^{-12}
LPG and CNG[17] exhaust and evaporative	28.56	0.023	0.006	0.103	0.13	0.13	7.82	2.200	114.51	1,588.95	0.0038	1.28×10^{-11}
Diesel exhaust and evaporative	39.08	0.069	0.022	0.083	3.36	3.26	4.95	0.298	25.32	2,698.42	0.0035	4.57×10^{-9}

[17] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

3.3.5 Spatial Distribution of Emissions

Table 3-79 summarises the data used for spatially allocating emissions from commercial off-road vehicles and equipment.

Table 3-79: Commercial off-road vehicles and equipment spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from commercial off-road vehicles and equipment	Gridded 1 km x 1 km site-specific petrol, diesel and gas consumption estimates	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a) - *NONROAD2008a Model* (USEPA, 2009a)

Emissions from commercial off-road vehicles and equipment have been spatially distributed according to petrol, LPG, CNG and diesel consumption, which is based on site-specific fuel consumption estimated using commercial survey data (DECC, 2007a) within the *NONROAD2008a Model* (USEPA, 2009a).

Commercial business addresses have been geocoded to obtain the latitude and longitude (i.e. geographical coordinates). The geocoding process uses calibrated map layers to search for postcode, suburb, street name and street number in order to return the most accurate spatial coordinates for each commercial business. Where the street number coordinate could not be found, the street centroid coordinate was used. Similarly, where the street name coordinate could not be found, the suburb centroid coordinate was used. Geographical coordinates have been converted to MGA easting and northing in km (i.e. gridded coordinates) using Redfearn's formula (ICSM, 2006).

Commercial off-road vehicles and equipment petrol, gas (i.e. LPG and CNG) and diesel consumption by LGA and region is presented in Table 3-80 and shown in Figure 3-57 for all LGA.

Table 3-80: Commercial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption by LGA and region

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[18]	Diesel	Grand Total
Newcastle	Lake Macquarie	1.80×10^{-2}	13.27	11.27	24.56
	Newcastle	3.04×10^{-2}	90.99	218.05	309.07
	Port Stephens	1.29×10^{-3}	-	1.92	1.92

[18] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[18]	Diesel	Grand Total
Newcastle Total		4.96×10^{-2}	104.26	231.24	335.55
Non Urban	Baulkham Hills	1.95×10^{-4}	-	0.29	0.29
	Blue Mountains	-	-	0.21	0.21
	Cessnock	4.89	13.27	78.47	96.63
	Dungog	0.11	0.59	10.89	11.59
	Gosford	26.59	30.54	83.78	140.91
	Great Lakes	8.64×10^{-3}	0.31	15.74	16.05
	Hawkesbury	1.22×10^{-3}	7.53	1.85	9.38
	Kiama	1.02	0.31	20.38	21.70
	Lake Macquarie	8.99×10^{-3}	239.22	7.52	246.75
	Lithgow	0.33	-	150.76	151.09
	Maitland	4.90	15.89	265.03	285.81
	Muswellbrook	4.94	13.12	341.81	359.87
	Port Stephens	1.47×10^{-2}	3.24	84.35	87.61
	Shellharbour	2.03×10^{-3}	0.31	1.06	1.37
	Singleton	2.79	7.40	42.89	53.07
	Wingecarribee	0.27	82.12	132.17	214.56
	Wyong	0.17	6.22	58.95	65.34
Non Urban Total		46.04	420.04	1,296.15	1,762.22
Sydney	Auburn	0.13	-	17.65	17.78
	Bankstown	0.13	87.21	26.30	113.64
	Baulkham Hills	0.25	0.63	20.49	21.36
	Blacktown	7.87	209.14	88.52	305.53
	Blue Mountains	2.01×10^{-3}	0.31	20.41	20.72
	Botany Bay	-	3.76	-	3.76
	Burwood	1.99×10^{-3}	0.31	1.01	1.31
	Camden	2.53×10^{-2}	0.35	26.93	27.31
	Campbelltown	6.97×10^{-3}	28.36	22.16	50.52
	Canterbury	1.99×10^{-3}	5.53	1.01	6.53
	Fairfield	6.68×10^{-2}	45.58	56.34	101.99
	Gosford	1.20×10^{-4}	-	351.11	351.11
	Hawkesbury	1.28×10^{-2}	0.93	26.56	27.50
	Holroyd	-	104.09	-	104.09
	Hornsby	2.10×10^{-5}	32.40	3.12×10^{-2}	32.44
	Hunters Hill	5.35×10^{-3}	1.42×10^{-2}	8.07×10^{-2}	0.10
	Hurstville	-	31.55	-	31.55
	Ku-ring-gai	-	-	37.31	37.31
	Liverpool	1.25×10^{-2}	23.05	36.27	59.33
	Marrickville	-	3.61	-	3.61
	N/A	5.78×10^{-4}	-	0.86	0.86
	Parramatta	8.29×10^{-3}	1.23	39.81	41.05
	Penrith	5.44×10^{-2}	105.43	592.94	698.43
	Pittwater	-	6.64	-	6.64
	Rockdale	-	4.57	-	4.57

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[18]	Diesel	Grand Total
	Ryde	1.79	33.32	26.98	62.08
	Strathfield	-	15.24	-	15.24
	Sutherland	0.21	48.22	22.17	70.60
	Sydney	0.56	1.48	26.04	28.07
	Unincorporated	-	11.44	8.60	20.03
	Warringah	5.97×10^{-3}	0.92	55.96	56.89
	Wingecarribee	1.88×10^{-4}	-	0.28	0.28
	Wollondilly	1.31×10^{-2}	-	48.11	48.13
	Wollongong	1.99×10^{-3}	0.31	1.01	1.31
Sydney Total		11.15	805.60	1,554.94	2,371.69
Wollongong	Wollongong	2.32×10^{-3}	1.85	45.93	47.79
Wollongong Total		2.32×10^{-3}	1.85	45.93	47.79
Grand Total		57.24	1,331.75	3,128.26	4,517.25

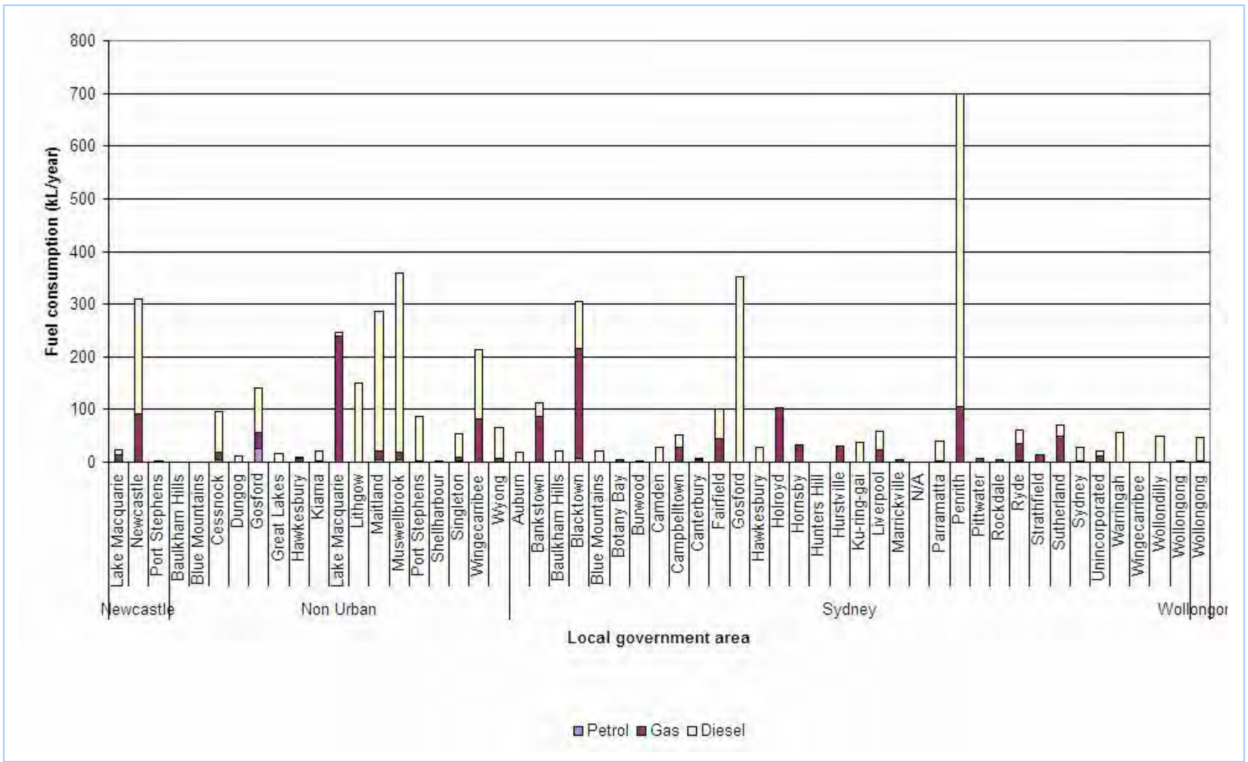

Figure 3-57: Commercial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption by LGA and region

Figure 3-58 shows commercial off-road vehicles and equipment petrol, gas (i.e. LPG and CNG) and diesel consumption by LGA and region for all LGA except Penrith.

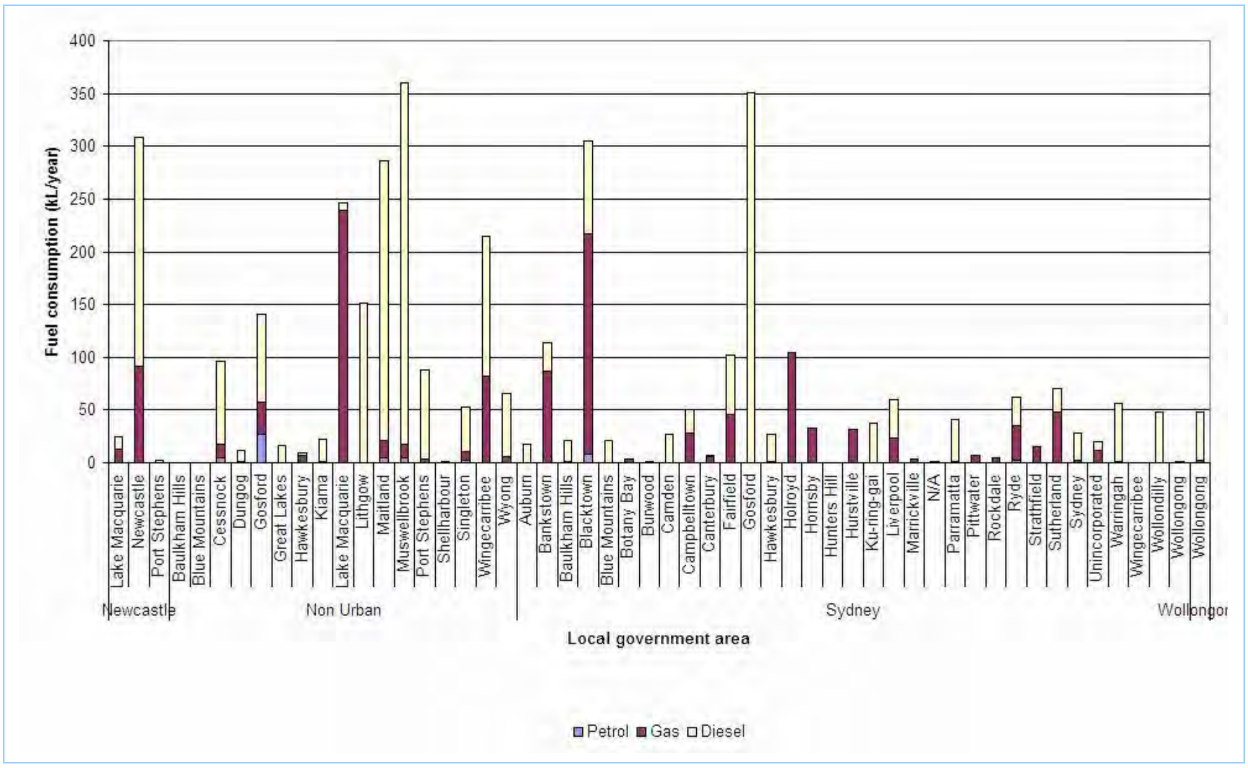

Figure 3-58: Commercial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption for selected LGA and region

Figure 3-59 shows the spatial distribution of commercial off-road vehicles and equipment petrol exhaust and evaporative emissions.

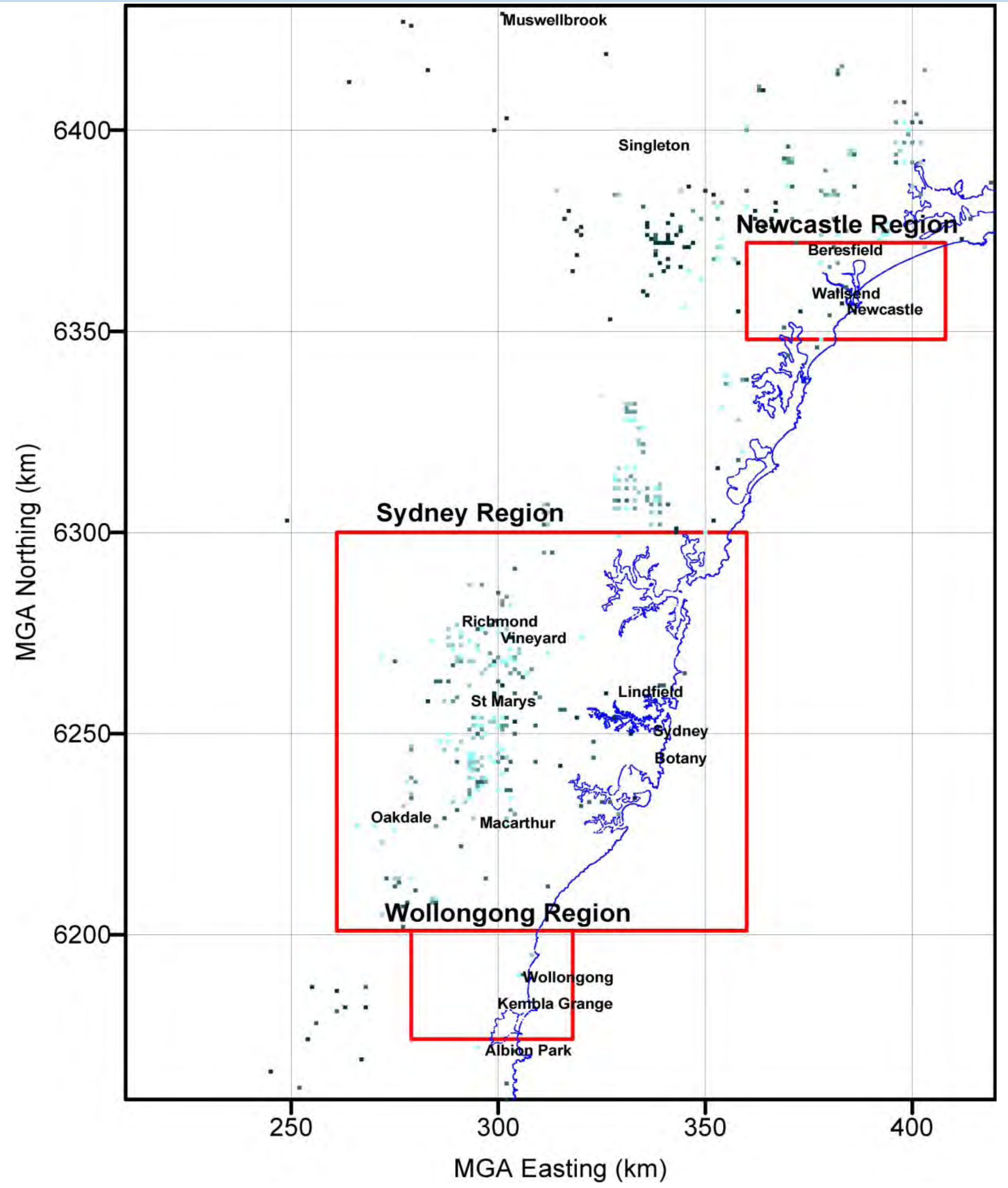

Figure 3-59: Commercial off-road vehicles and equipment petrol exhaust and evaporative emissions

Figure 3-60 shows the spatial distribution of commercial off-road vehicles and equipment gas (i.e. LPG and CNG) exhaust and evaporative emissions.

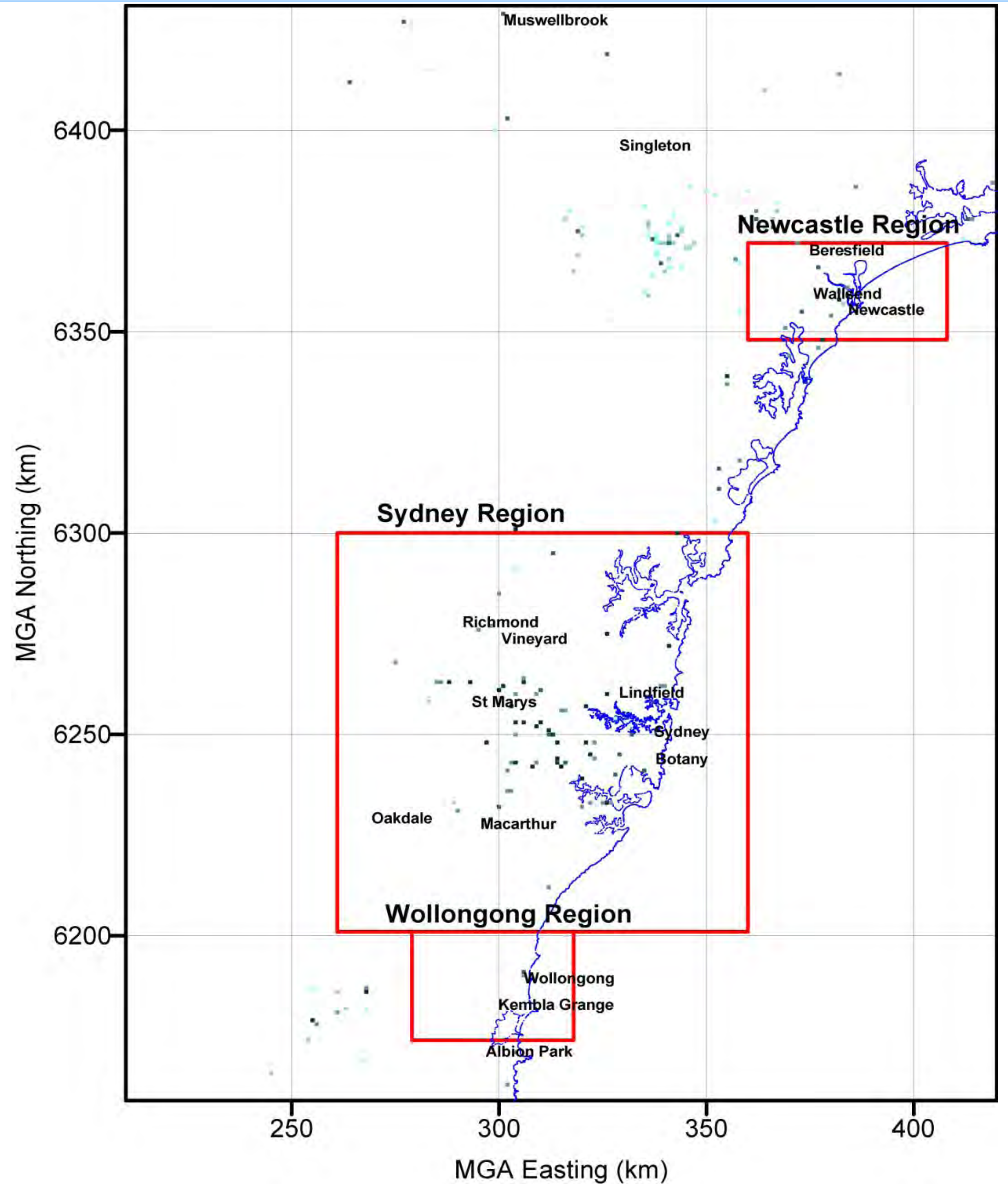

Figure 3-60: Commercial off-road vehicles and equipment gas exhaust and evaporative emissions

Figure 3-61 shows the spatial distribution of commercial off-road vehicles and equipment diesel exhaust and evaporative emissions.

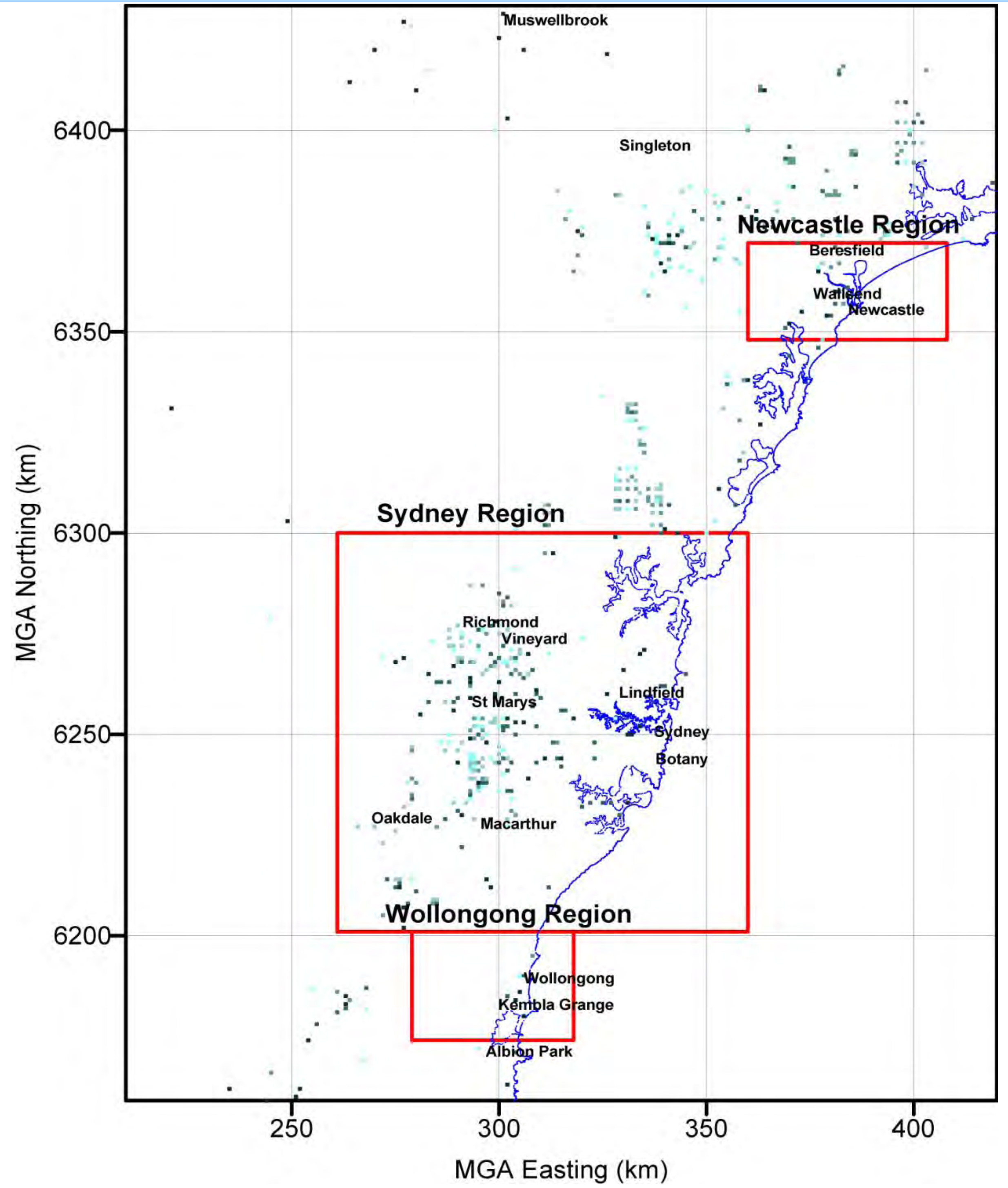

Figure 3-61: Commercial off-road vehicles and equipment diesel exhaust and evaporative emissions

3.3.6 Temporal Variation of Emissions

Table 3-81 summarises the data used to estimate the temporal variation in emissions from commercial off-road vehicles and equipment.

Table 3-81: Commercial off-road vehicles and equipment temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from commercial off-road vehicles and equipment	Monthly, daily and hourly: Derived from commercial off-road vehicles and equipment pollution survey	- *Commercial Off-Road Vehicles and Equipment Pollution Survey* (DECC, 2007a)

The temporal variation in exhaust and evaporative emissions from commercial off-road vehicles and equipment have been estimated using equipment population (DECC, 2007a), annual operating time (DECC, 2007a), fuel properties (Attorney-General's Department, 2003; Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECC, 2007a) data within the *NONROAD2008a Model* (USEPA, 2009a). While the temporal variation in emissions is different for each of the 684 commercial businesses, Figure 3-62, Figure 3-63 and Figure 3-64 show the hourly, daily and monthly variation in petrol, gas (i.e. LPG and CNG) and diesel consumption, respectively in the GMR for all 684 commercial businesses.

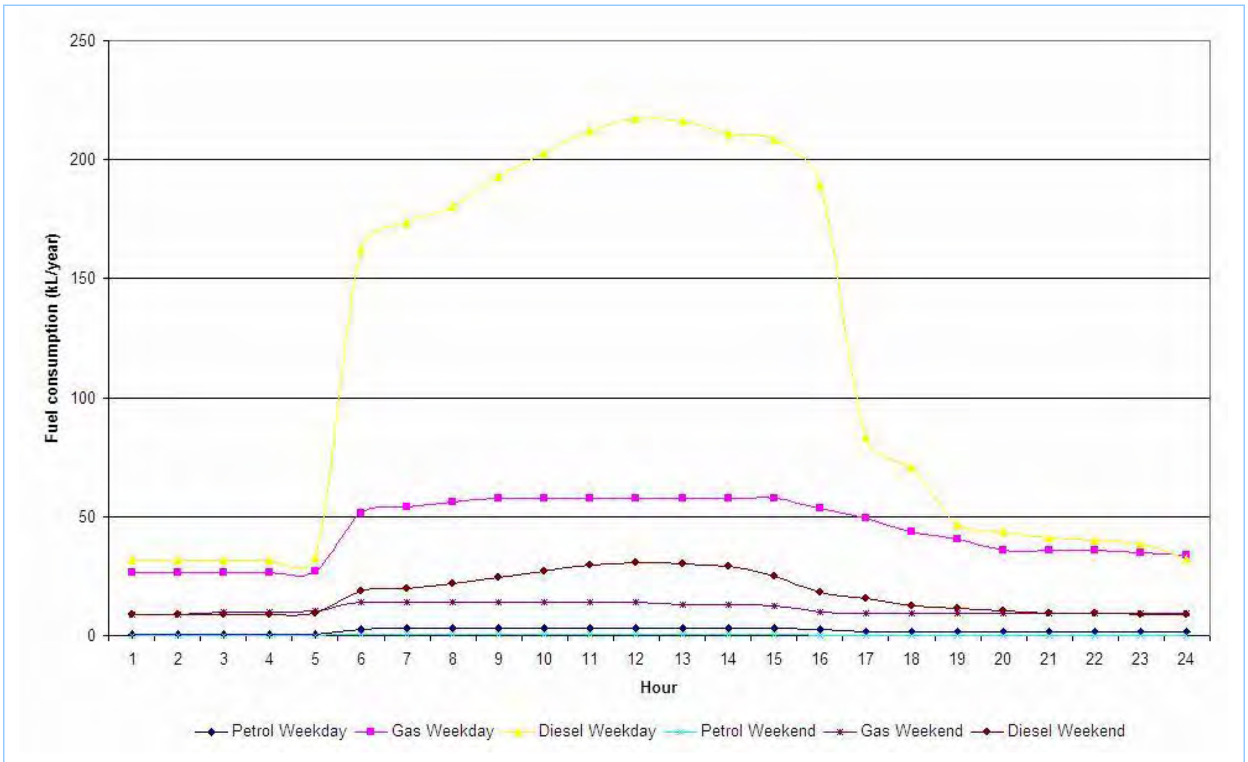

Figure 3-62: Commercial off-road vehicles and equipment hourly variation in petrol, gas and diesel consumption

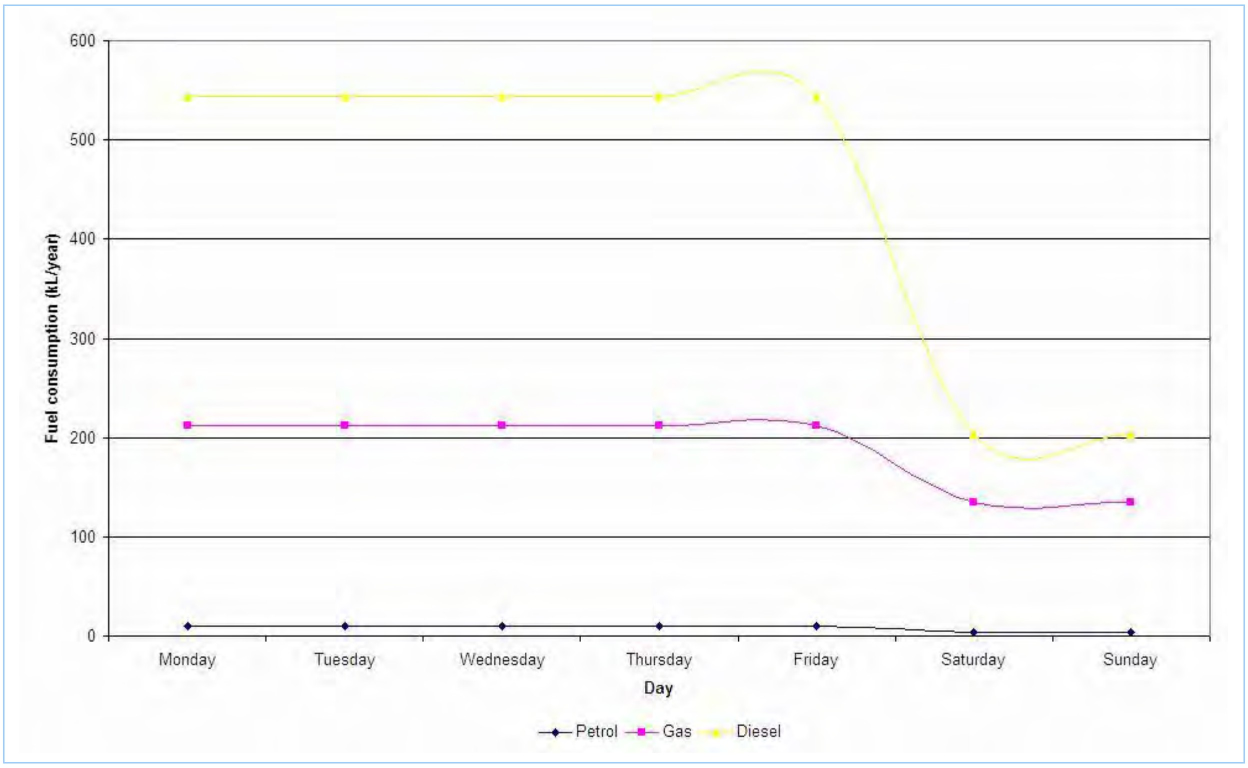

Figure 3-63: Commercial off-road vehicles and equipment daily variation in petrol, gas and diesel consumption

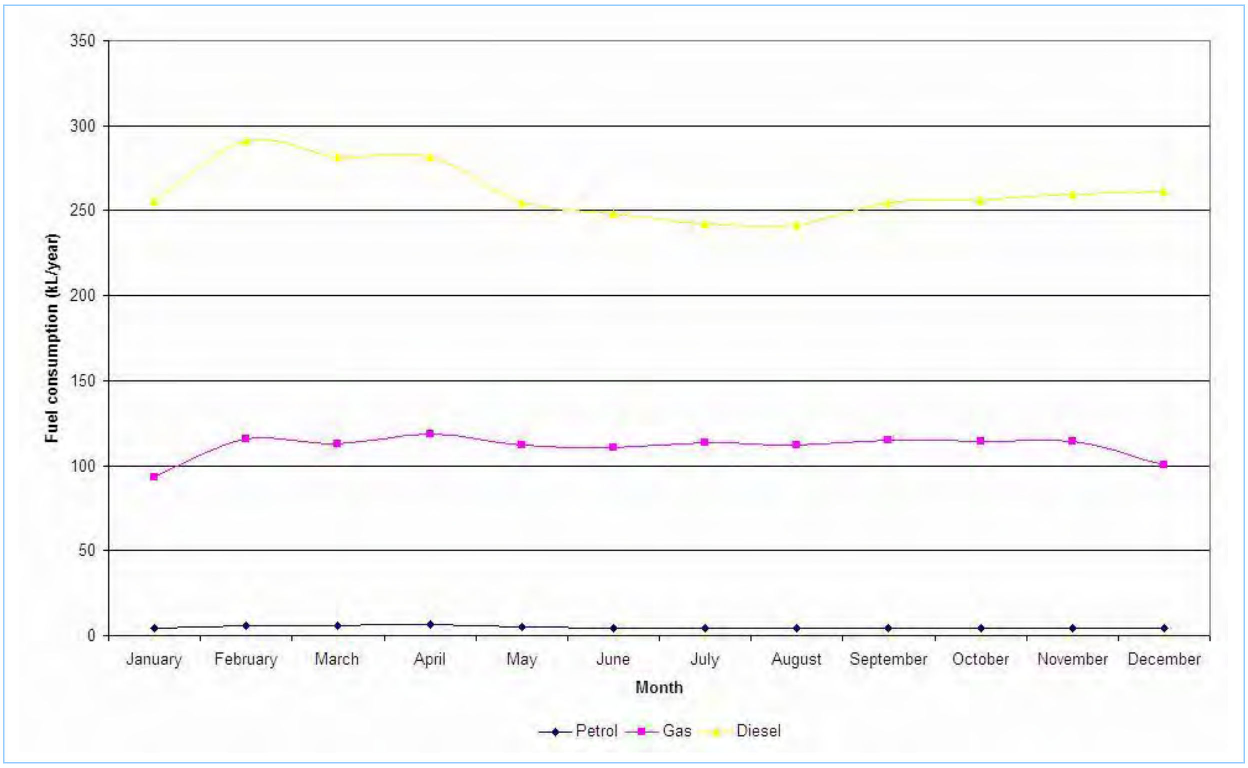

Figure 3-64: Commercial off-road vehicles and equipment monthly variation in petrol, gas and diesel consumption

3.3.7 Emission Estimates

Table 3-82 presents annual emissions of selected substances from commercial off-road vehicles and equipment by activity.

Table 3-82: Commercial off-road vehicles and equipment emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Commercial Vehicles and Equipment	1,3-BUTADIENE	2.60	62	29	0.43	94
	ACETALDEHYDE	74	414	514	12	1,014
	BENZENE	24	399	226	4.65	655
	CARBON MONOXIDE	17,814	100,483	136,354	1,376	256,027
	FORMALDEHYDE	218	1,178	1,569	28	2,993
	ISOMERS OF XYLENE	13	413	167	2.43	595
	LEAD & COMPOUNDS	2.45×10^{-2}	0.37	0.22	4.84×10^{-3}	0.61
	OXIDES OF NITROGEN	12,016	64,126	84,135	1,848	162,126
	PARTICULATE MATTER ≤ 10 µm	791	4,423	5,337	155	10,706
	PARTICULATE MATTER ≤ 2.5 µm	768	4,292	5,180	150	10,389
	PERCHLOROETHYLENE	3.88×10^{-3}	1.56×10^{-2}	3.0×10^{-2}	6.91×10^{-5}	4.96×10^{-2}
	POLYCYCLIC AROMATIC HYDROCARBONS	1.21	7.19	8.76	0.17	17
	SULFUR DIOXIDE	30	160	214	3.99	407
	TOLUENE	18	463	208	3.43	693
	TOTAL SUSPENDED PARTICULATE	824	4,605	5,555	161	11,144
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,965	14,772	15,224	242	32,203

Table 3-83 presents annual emissions of selected substances from commercial off-road vehicles and equipment by source type.

Table 3-83: Commercial off-road vehicles and equipment emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Petrol	1,3-BUTADIENE	5.21×10^{-2}	48	12	2.44×10^{-3}	60
	ACETALDEHYDE	2.24×10^{-2}	21	5.04	1.05×10^{-3}	26
	BENZENE	0.29	266	64	1.34×10^{-2}	331
	CARBON MONOXIDE	21	19,569	4,740	0.99	24,331
	FORMALDEHYDE	9.38×10^{-2}	87	21	4.39×10^{-3}	108
	ISOMERS OF XYLENE	0.37	344	83	1.73×10^{-2}	428
	LEAD & COMPOUNDS	2.48×10^{-4}	0.23	5.58×10^{-2}	1.16×10^{-5}	0.29
	OXIDES OF NITROGEN	1.59	1,474	357	7.43×10^{-2}	1,832
	PARTICULATE MATTER ≤ 10 µm	1.12×10^{-2}	10	2.51	5.22×10^{-4}	13

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	PARTICULATE MATTER ≤ 2.5 µm	1.03×10^{-2}	9.53	2.31	4.81×10^{-4}	12
	POLYCYCLIC AROMATIC HYDROCARBONS	1.16×10^{-3}	1.07	0.26	5.41×10^{-5}	1.33
	SULFUR DIOXIDE	9.85×10^{-3}	9.13	2.21	4.60×10^{-4}	11
	TOLUENE	0.39	365	88	1.84×10^{-2}	453
	TOTAL SUSPENDED PARTICULATE	1.15×10^{-2}	11	2.59	5.39×10^{-4}	13
	TOTAL VOLATILE ORGANIC COMPOUNDS	5.47	5,075	1,229	0.26	6,310
Diesel	1,3-BUTADIENE	2.13	12	14	0.42	29
	ACETALDEHYDE	61	340	408	12	821
	BENZENE	23	130	156	4.62	315
	CARBON MONOXIDE	5,855	32,817	39,369	1,163	79,203
	FORMALDEHYDE	135	757	909	27	1,828
	ISOMERS OF XYLENE	12	68	81	2.40	164
	LEAD & COMPOUNDS	2.43×10^{-2}	0.14	0.16	4.82×10^{-3}	0.33
	OXIDES OF NITROGEN	9,037	50,656	60,770	1,795	122,258
	PARTICULATE MATTER ≤ 10 µm	777	4,356	5,226	154	10,514
	PARTICULATE MATTER ≤ 2.5 µm	754	4,226	5,070	150	10,199
	POLYCYCLIC AROMATIC HYDROCARBONS	0.80	4.51	5.41	0.16	11
	SULFUR DIOXIDE	19	107	129	3.80	259
	TOLUENE	17	96	115	3.40	232
	TOTAL SUSPENDED PARTICULATE	810	4,538	5,444	161	10,953
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,144	6,411	7,691	227	15,473
Gas	1,3-BUTADIENE	0.42	1.68	3.23	7.44×10^{-3}	5.34
	ACETALDEHYDE	13	53	101	0.23	167
	BENZENE	0.69	2.78	5.32	1.23×10^{-2}	8.80
	CARBON MONOXIDE	11,938	48,097	92,245	212	152,493
	FORMALDEHYDE	83	333	639	1.47	1,056
	ISOMERS OF XYLENE	0.29	1.16	2.23	5.13×10^{-3}	3.68
	OXIDES OF NITROGEN	2,978	11,996	23,008	53	38,035
	PARTICULATE MATTER ≤ 10 µm	14	56	108	0.25	179
	PARTICULATE MATTER ≤ 2.5 µm	14	56	108	0.25	179
	PERCHLOROETHYLENE	3.88×10^{-3}	1.56×10^{-2}	3.0×10^{-2}	6.91×10^{-5}	4.96×10^{-2}
	POLYCYCLIC AROMATIC HYDROCARBONS	0.40	1.61	3.09	7.11×10^{-3}	5.10
	SULFUR DIOXIDE	11	43	83	0.19	137
	TOLUENE	0.64	2.57	4.94	1.14×10^{-2}	8.16

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL SUSPENDED PARTICULATE	14	56	108	0.25	179
	TOTAL VOLATILE ORGANIC COMPOUNDS	816	3,287	6,304	15	10,421

Table 3-84 presents annual emissions of selected substances from commercial off-road vehicles and equipment by ANZSIC class.

Table 3-84: Commercial off-road vehicles and equipment emissions by ANZSIC class

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
Newcastle	Commercial Vehicles and Equipment - Petrol	Concrete Slurry Manufacturing	10	0.76	5.35×10^{-3}	4.93×10^{-3}	4.72×10^{-3}	2.62
		Poultry Farming (Meat)	0.61	4.62×10^{-2}	3.25×10^{-4}	2.99×10^{-4}	2.86×10^{-4}	0.16
		Wine Manufacturing	10	0.78	5.50×10^{-3}	5.06×10^{-3}	4.84×10^{-3}	2.69
	Commercial Vehicles and Equipment - Petrol Total		21	1.59	1.12×10^{-2}	1.03×10^{-2}	9.85×10^{-3}	5.47
	Commercial Vehicles and Equipment – Diesel	Chemical Product Manufacturing	680	1,049	90	88	2.22	133
		Concrete Slurry Manufacturing	304	470	40	39	0.99	59
		Gravel and Sand Quarrying	1,839	2,838	244	237	6.00	359
		Poultry Farming (Meat)	54	84	7.21	6.99	0.18	11
		Structural and Fabricated Metal Product Manufacturing	2,968	4,582	394	382	9.69	580
		Wine Manufacturing	9.33	14	1.24	1.20	3.05×10^{-2}	1.82
	Commercial Vehicles and Equipment - Diesel Total		5,855	9,037	777	754	19	1,144
	Commercial Vehicles and Equipment – Gas	Chemical Wholesaling	1,689	421	1.98	1.98	1.52	115
		Concrete Slurry Manufacturing	420	105	0.49	0.49	0.38	29
		Other Agricultural Crop Processing	1,205	300	1.41	1.41	1.08	82
		Structural and Fabricated Metal Product	8,617	2,149	10	10	7.76	589

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Manufacturing						
		Wine Manufacturing	7.42	1.85	8.68×10^{-3}	8.68×10^{-3}	6.68×10^{-3}	0.51
	Commercial Vehicles and Equipment - Gas Total		11,938	2,978	14	14	11	816
Newcastle Total			17,814	12,016	791	768	30	1,965
Non Urban	Commercial Vehicles and Equipment – Petrol	Chemical Product Manufacturing	69	5.21	3.66×10^{-2}	3.37×10^{-2}	3.23×10^{-2}	18
		Concrete Product Manufacturing	215	16	0.11	0.10	0.10	56
		Concrete Slurry Manufacturing	14	1.08	7.61×10^{-3}	7.0×10^{-3}	6.71×10^{-3}	3.73
		Fibreglass Product Manufacturing	3,448	260	1.83	1.68	1.61	894
		Petroleum Product Wholesaling	138	10	7.33×10^{-2}	6.74×10^{-2}	6.46×10^{-2}	36
		Poultry Farming (Eggs)	1.22	9.19×10^{-2}	6.46×10^{-4}	5.95×10^{-4}	5.70×10^{-4}	0.32
		Poultry Farming (Meat)	15	1.16	8.16×10^{-3}	7.50×10^{-3}	7.19×10^{-3}	3.99
		Structural and Fabricated Metal Product Manufacturing	8,277	623	4.38	4.03	3.86	2,146
		Wine Manufacturing	7,391	557	3.91	3.60	3.45	1,917
	Commercial Vehicles and Equipment - Petrol Total		19,569	1,474	10	9.53	9.13	5,075
	Commercial Vehicles and Equipment – Diesel	Concrete Product Manufacturing	675	1,041	90	87	2.20	132
		Concrete Slurry Manufacturing	433	668	57	56	1.41	85

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Furniture Manufacturing	1.09	1.69	0.15	0.14	3.57×10^{-3}	0.21
		Gravel and Sand Quarrying	22,924	35,386	3,043	2,952	75	4,478
		Industrial Machinery and Equipment Manufacturing	233	360	31	30	0.76	46
		Medicinal and Pharmaceutical Product Manufacturing	22	34	2.90	2.82	7.14×10^{-2}	4.27
		Petroleum Product Wholesaling	169	261	22	22	0.55	33
		Poultry Farming (Eggs)	108	167	14	14	0.35	21
		Poultry Farming (Meat)	1,364	2,106	181	176	4.45	266
		Structural and Fabricated Metal Product Manufacturing	245	378	33	32	0.80	48
		Wine Manufacturing	6,642	10,253	882	855	22	1,298
	Commercial Vehicles and Equipment - Diesel Total		32,817	50,656	4,356	4,226	107	6,411
	Commercial Vehicles and Equipment – Gas	Chemical Product Manufacturing	355	88	0.42	0.42	0.32	24
		Concrete Slurry Manufacturing	597	149	0.70	0.70	0.54	41
		Electrical Cable and Wire/Equipment Manufacturing	6,969	1,738	8.16	8.16	6.27	476
		Furniture Manufacturing	862	215	1.01	1.01	0.78	59
		Industrial Machinery and	304	76	0.36	0.36	0.27	21

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Equipment Manufacturing						
		Other Food Manufacturing	27,287	6,806	32	32	25	1,865
		Petroleum Product Wholesaling	2,361	589	2.76	2.76	2.12	161
		Plastic Injection Moulded Product Manufacturing	299	75	0.35	0.35	0.27	20
		Structural and Fabricated Metal Product Manufacturing	3,493	871	4.09	4.09	3.14	239
		Wine Manufacturing	5,284	1,318	6.18	6.18	4.76	361
		Wood Product Manufacturing	287	72	0.34	0.34	0.26	20
	Commercial Vehicles and Equipment - Gas Total		48,097	11,996	56	56	43	3,287
Non Urban Total			100,483	64,126	4,423	4,292	160	14,772
Sydney	Commercial Vehicles and Equipment – Petrol	Concrete Slurry Manufacturing	55	4.14	2.91×10^{-2}	2.68×10^{-2}	2.56×10^{-2}	14
		Electrical Cable and Wire/Equipment Manufacturing	3,333	251	1.77	1.62	1.56	864
		Fibreglass Product Manufacturing	104	7.82	5.50×10^{-2}	5.06×10^{-2}	4.84×10^{-2}	27
		Other Food Manufacturing	55	4.17	2.93×10^{-2}	2.70×10^{-2}	2.58×10^{-2}	14
		Plastic Injection Moulded Product Manufacturing	87	6.51	4.58×10^{-2}	4.21×10^{-2}	4.04×10^{-2}	22

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Poultry Farming (Eggs)	11	0.81	5.73×10^{-3}	5.27×10^{-3}	5.05×10^{-3}	2.80
		Poultry Farming (Meat)	15	1.16	8.19×10^{-3}	7.53×10^{-3}	7.22×10^{-3}	4.01
		Structural and Fabricated Metal Product Manufacturing	55	4.17	2.93×10^{-2}	2.70×10^{-2}	2.58×10^{-2}	14
		Wine Manufacturing	1,025	77	0.54	0.50	0.48	266
	Commercial Vehicles and Equipment - Petrol Total		4,740	357	2.51	2.31	2.21	1,229
	Commercial Vehicles and Equipment – Diesel	Chemical Product Manufacturing	10	16	1.39	1.35	3.43×10^{-2}	2.05
		Concrete Product Manufacturing	87	135	12	11	0.29	17
		Concrete Slurry Manufacturing	1,654	2,553	220	213	5.40	323
		Gravel and Sand Quarrying	32,194	49,694	4,274	4,146	105	6,289
		Iron and Steel Manufacturing	210	324	28	27	0.68	41
		Nonbuilding Construction	544	840	72	70	1.78	106
		Paint and Ink Manufacturing	1,230	1,898	163	158	4.02	240
		Petroleum Product Wholesaling	22	34	2.90	2.82	7.14×10^{-2}	4.27
		Poultry Farming (Eggs)	958	1,479	127	123	3.13	187
		Poultry Farming (Meat)	1,370	2,115	182	176	4.47	268
		Soap and Other Detergent Manufacturing	22	34	2.90	2.82	7.14×10^{-2}	4.27

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Structural and Fabricated Metal Product Manufacturing	148	228	20	19	0.48	29
		Wine Manufacturing	921	1,421	122	119	3.01	180
	Commercial Vehicles and Equipment - Diesel Total		39,369	60,770	5,226	5,070	129	7,691
	Commercial Vehicles and Equipment – Gas	Chemical Product Manufacturing	6,779	1,691	7.93	7.93	6.10	463
		Chemical Wholesaling	9,908	2,471	12	12	8.92	677
		Concrete Slurry Manufacturing	2,283	569	2.67	2.67	2.05	156
		Dairy Product Manufacturing	3,040	758	3.56	3.56	2.74	208
		Electrical Cable and Wire/Equipment Manufacturing	8,335	2,079	9.76	9.76	7.50	570
		Fruit and Vegetable Processing	1,310	327	1.53	1.53	1.18	90
		Furniture Manufacturing	127	32	0.15	0.15	0.11	8.66
		Industrial Gas Manufacturing	532	133	0.62	0.62	0.48	36
		Iron and Steel Manufacturing	1,442	360	1.69	1.69	1.30	99
		Motor Vehicle and Part Manufacturing	1,745	435	2.04	2.04	1.57	119
		Nonbuilding Construction	6,148	1,533	7.20	7.20	5.53	420
		Other Food	15,181	3,786	18	18	14	1,037

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Manufacturing						
		Petroleum Product Wholesaling	3,710	925	4.34	4.34	3.34	254
		Plastic Injection Moulded Product Manufacturing	11,950	2,981	14	14	11	817
		Soap and Other Detergent Manufacturing	507	126	0.59	0.59	0.46	35
		Structural and Fabricated Metal Product Manufacturing	17,078	4,260	20	20	15	1,167
		Wine Manufacturing	732	183	0.86	0.86	0.66	50
		Wood Product Manufacturing	1,438	359	1.68	1.68	1.29	98
	Commercial Vehicles and Equipment – Gas Total		92,245	23,008	108	108	83	6,304
Sydney Total			136,354	84,135	5,337	5,180	214	15,224
Wollongong	Commercial Vehicles and Equipment – Petrol	Concrete Slurry Manufacturing	0.85	6.37×10^{-2}	4.48×10^{-4}	4.12×10^{-4}	3.94×10^{-4}	0.22
		Poultry Farming (Meat)	0.14	1.06×10^{-2}	7.48×10^{-5}	6.88×10^{-5}	6.59×10^{-5}	3.66×10^{-2}
	Commercial Vehicles and Equipment - Petrol Total		0.99	7.43×10^{-2}	5.22×10^{-4}	4.81×10^{-4}	4.60×10^{-4}	0.26
	Commercial Vehicles and Equipment – Diesel	Concrete Product Manufacturing	234	362	31	30	0.77	46
		Concrete Slurry Manufacturing	25	39	3.38	3.28	8.31×10^{-2}	4.97
		Gravel and Sand Quarrying	891	1,375	118	115	2.91	174
		Poultry Farming (Meat)	13	19	1.66	1.61	4.09×10^{-2}	2.44

Region	Source type	ANZSIC class	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
	Commercial Vehicles and Equipment - Diesel Total		1,163	1,795	154	150	3.80	227
	Commercial Vehicles and Equipment – Gas	Concrete Slurry Manufacturing	35	8.77	4.11×10^{-2}	4.11×10^{-2}	3.16×10^{-2}	2.40
		Rubber Product Manufacturing	177	44	0.21	0.21	0.16	12
	Commercial Vehicles and Equipment – Gas Total		212	53	0.25	0.25	0.19	15
Wollongong Total			1,376	1,848	155	150	3.99	242
Grand Total			256,027	162,126	10,706	10,389	407	32,203

3.3.8 Emission Projection Methodology

Table 3-85 summarises the data used to estimate the emission projection factors for commercial off-road vehicles and equipment, while Figure 3-65 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-85: Commercial off-road vehicles and equipment emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from commercial off-road vehicles and equipment	Final energy consumption for agriculture, manufacturing & construction and mining using liquid petroleum gas, petroleum and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

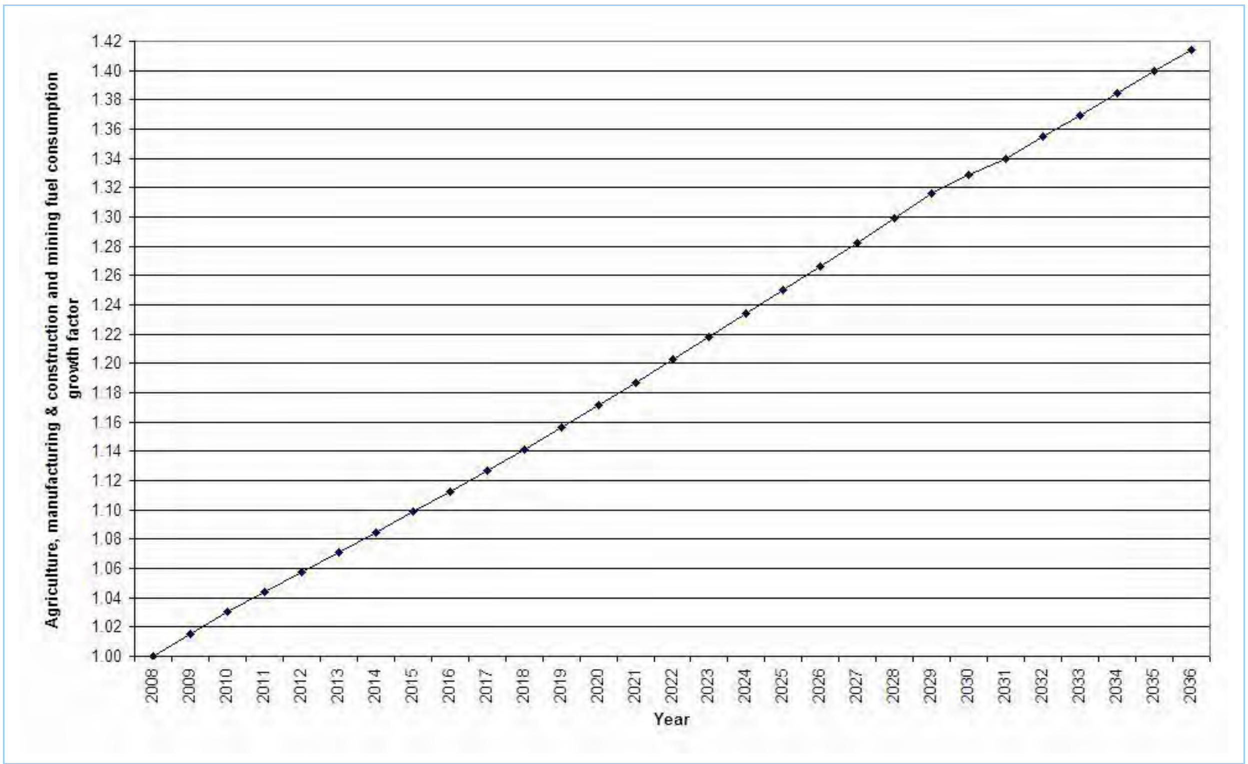

Figure 3-65: Commercial off-road vehicles and equipment emission projection factors

3.4 Industrial Off-Road Vehicles and Equipment

3.4.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from industrial off-road vehicle and 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:

- *Industrial survey*

An industrial survey of off-road vehicle and equipment ownership and usage has been conducted, which has provided activity data for 842 EPA-licensed premises (i.e. scheduled activity)[19]. 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 month (DECCW, 2009).

Figure 3-66 shows how the industrial survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009a) to develop an inventory of industrial off-road vehicle and equipment emissions.

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

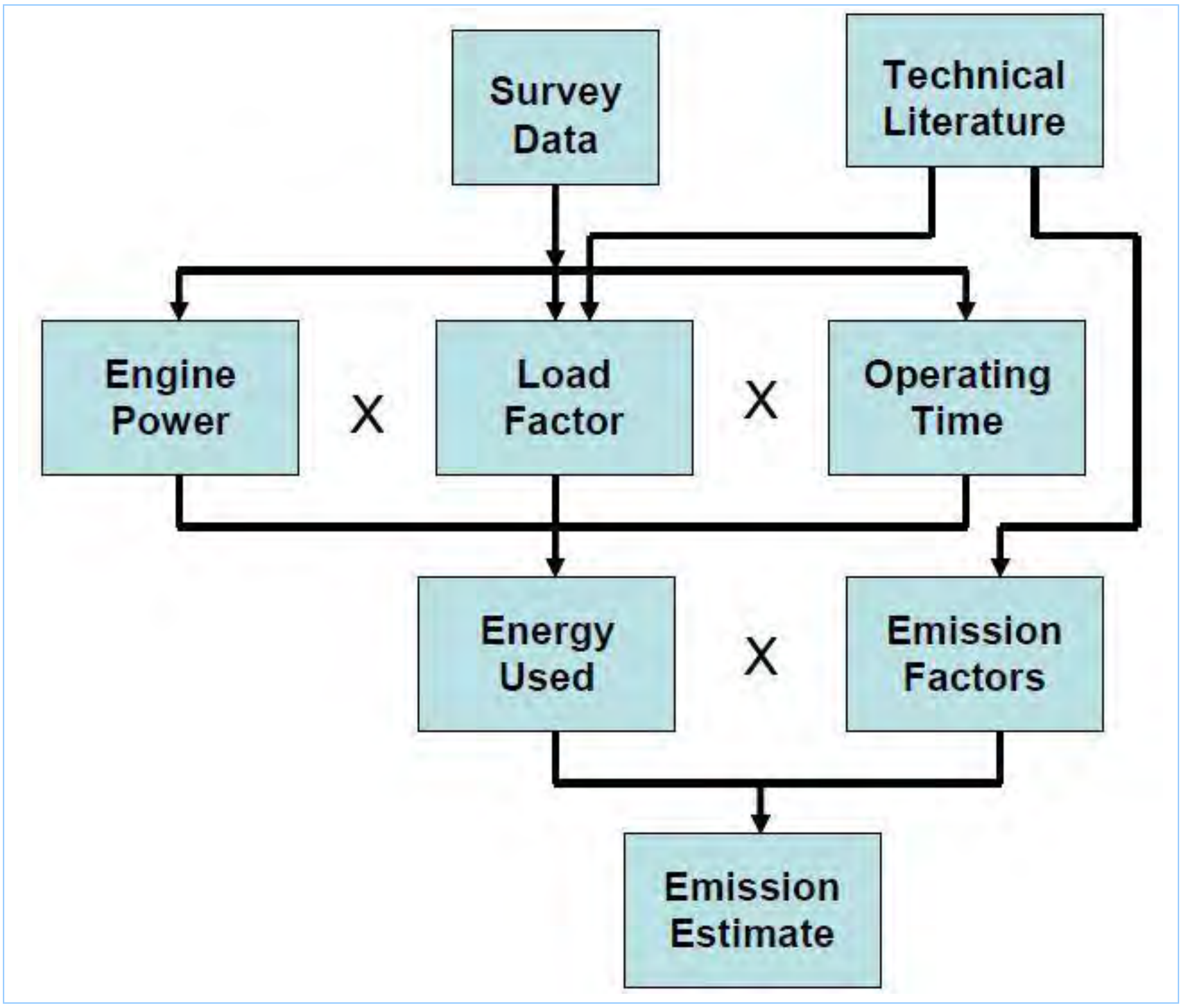

Figure 3-66: Industrial off-road vehicles and equipment - use of survey data

➢ *EPA-licensed premises by POEO Scheduled Activity*

The inventory includes EPA-licensed premises, which belong to *Protection of the Environment (Operations) Act 1997* (POEO) scheduled activities (PCO, 2010a) as follows:

- *Agricultural fertiliser (phosphate) production;*
- *Aluminium production (alumina);*
- *Aluminium production (scrap metal);*
- *Ammonium nitrate production;*
- *Animal accommodation;*
- *Battery production;*
- *Bird accommodation;*
- *Bitumen mixing;*

- *Boat construction/maintenance (dry/float);*
- *Boat construction/maintenance (general);*
- *Boat mooring and storage;*
- *Brewing and distilling;*
- *Cement or lime handling;*
- *Cement or lime production;*
- *Ceramics production;*
- *Chemical production;*
- *Chemical storage;*
- *Coal washery reject or slag landfilling;*
- *Coal works;*
- *Coke production;*
- *Composting;*
- *Concrete works;*
- *Container reconditioning;*
- *Contaminated soil treatment;*
- *Crushing, grinding or separating;*
- *Dairy animal accommodation;*
- *Dairy processing;*
- *Explosives production;*
- *General agricultural processing;*
- *General animal products production;*
- *General chemicals storage;*
- *Generation of electrical power from coal;*
- *Generation of electrical power from gas;*
- *Generation of electricity not coal or gas;*
- *Glass production (container);*

- *Glass production (float);*
- *Hazardous, industrial or group A waste D;*
- *Hazardous, industrial or group A waste G;*
- *Helicopter-related activity;*
- *Inert waste landfilling;*
- *Iron or steel production (iron ore);*
- *Iron or steel production (scrap metal);*
- *Land-based extractive activity;*
- *Metal plating or coating;*
- *Metal processing;*
- *Mining for coal;*
- *Mining for minerals;*
- *Miscellaneous licensed discharges to waters (at any time);*
- *Non-ferrous metal production (scrap);*
- *Non-thermal treatment of waste;*
- *Other land-based extraction;*
- *Paints/polishes/adhesives production;*
- *Paper or pulp production;*
- *Paper production using recycle materials;*
- *Pesticides and related products production;*
- *Petrochemical production;*
- *Petroleum products and fuel production;*
- *Petroleum products storage;*
- *Pharmaceutical and veterinary products production;*
- *Pig accommodation;*
- *Plastics resins production;*
- *Printing, packaging and visual media production;*

- *Railway systems activities;*
- *Recovery of waste;*
- *Recovery of waste oil;*
- *Recovery of waste tyres;*
- *Rendering or fat extraction;*
- *Road construction;*
- *Rubber products/tyre production;*
- *Scrap metal processing;*
- *Sewage treatment - large plants;*
- *Sewage treatment - small plants;*
- *Shipping in bulk;*
- *Slaughtering or processing of animals;*
- *Soap and detergent production;*
- *Solid waste landfilling;*
- *Sterilisation activities;*
- *Waste disposal (application to land);*
- *Waste storage;*
- *Water-based extractive activity; and*
- *Wood or timber milling or processing.*

➢ *Industrial off-road vehicle and equipment type*

The inventory includes industrial off-road vehicles and equipment as follows:

- *Aerial lift;*
- *All terrain vehicle;*
- *Bore/Drill rig;*
- *Bulldozer/Crawler tractor;*
- *Cement and mortar mixer;*
- *Concrete/Industrial saw;*

- *Crane;*
- *Crushing/Processing equipment;*
- *Dumper/Tender;*
- *Excavator;*
- *Forklift;*
- *Front mower;*
- *Golf cart;*
- *Grader;*
- *Inboard/Sterndrive boat;*
- *Off-highway truck;*
- *Other construction equipment;*
- *Other general industrial equipment;*
- *Other underground mining equipment;*
- *Paver;*
- *Pressure washer;*
- *Pump;*
- *Push mower;*
- *Railway maintenance;*
- *Rear engine riding mower;*
- *Roller;*
- *Rubber tyre loader;*
- *Scraper;*
- *Shredder;*
- *Skid steer loader;*
- *Specialty vehicle cart;*
- *Sweeper/Scrubber; and*
- *Tractor/Loader/Backhoe.*

- *Engine type*

The inventory includes industrial off-road vehicles and equipment powered by 4-stroke spark ignition (SI) petrol, liquid petroleum gas (LPG) and compressed natural gas (CNG) engines and diesel compression ignition (CI) engines.

Since there are no NSW or Australian emission standards, the inventory considers all industrial off-road vehicles and equipment have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009a).

- *Fuel type*

The inventory includes industrial off-road vehicles equipment that use automotive gasoline (petrol), liquid petroleum gas (LPG), compressed natural gas (CNG) and automotive diesel oil (ADO).

Table 3-86 presents the industrial off-road vehicles and equipment fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). 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 and LPG/CNG are requirements of the *Fuel Standard (Automotive Diesel) Determination 2001* (Attorney-General's Department, 2009) and *Fuel Standard (Autogas) Determination 2003* (Attorney-General's Department, 2003) respectively, which are relevant for the 2008 calendar year.

Table 3-86: Industrial off-road vehicles and equipment 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[20]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[21]	2.84 – Weighted average[22]			
Liquid petroleum gas (LPG)	100	-	0.510	25.5	82
Compressed natural	100	-	0.460	25.0	75

[20] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[21] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[22] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

Fuel type	Sulfur content (ppm)	Oxygen content (%)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
gas (CNG)					
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

➢ *Source type*

The inventory includes emissions of combustion products and evaporation from industrial off-road vehicles and 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, LPG, CNG and diesel engines. 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 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 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 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 4-stroke petrol engines; 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. These occur from 4-stroke petrol engines

Evaporative emissions mainly include VOC (total and speciated).

3.4.2 *Emission Estimation Methodology*

Table 3-87 summarises the emission estimation methodologies used for industrial off-road vehicles and equipment.

Table 3-87: Industrial off-road vehicles and equipment emission estimation methodologies

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from industrial off-road vehicles and equipment	- *Documentation for the 2008 Mobile Source National Emissions Inventory* (Pechan, 2011) - *NONROAD2008a Model* (USEPA, 2009a)

Exhaust and evaporative emissions from industrial off-road vehicles 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, 2009a).

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

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, 2009a).

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

Deterioration factors (DF) have been applied to 4-stroke petrol, LPG, CNG 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. 4-stroke petrol, LPG and CNG 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, 2009a).

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

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

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

where:			
$E_{i,j,k,l,m}$	=	Emissions of substance i from industrial off-road vehicles and equipment type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of industrial off-road vehicles and equipment type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of industrial off-road vehicles and equipment type j, engine type k and engine power range l	(h/year)

where:			
$HP_{j,k,l}$	=	Maximum rated power of industrial off-road vehicles and equipment type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for industrial off-road vehicles and equipment type j, engine type k and engine power range l	(hp/hp)
$TAF_{j,k,l}$	=	Fractional transient adjustment factor for industrial off-road vehicles and 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 industrial off-road vehicles and 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 industrial off-road vehicles and 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	=	Industrial off-road vehicles and equipment type (either "Aerial lift", "All terrain vehicle", "Bore/Drill rig", "Bulldozer/Crawler tractor", "Cement and mortar mixer", "Concrete/Industrial saw", "Crane", "Crushing/Processing equipment", "Dumper/Tender", "Excavator", "Forklift", "Front mower", "Golf cart", "Grader", " Inboard/Sterndrive boat", "Off-highway truck", "Other construction equipment", "Other general industrial equipment", "Other underground mining equipment", "Paver", "Pressure washer", "Pump", "Push mower", "Railway maintenance", "Rear engine riding mower", "Roller", "Rubber tyre loader", "Scraper", "Shredder", "Skid steer loader", "Specialty vehicle cart", "Sweeper/Scrubber" or "Tractor/Loader/Backhoe")	(-)
k	=	Engine type (either "4-stroke-petrol", "LPG", "CNG" 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)

3.4.3 *Activity Data*

Table 3-88 summarises the activity data used for industrial off-road vehicles equipment.

Table 3-88: Industrial off-road vehicles and equipment activity data

Activity data	Activity data source
Industrial off-road vehicles and equipment type, number and fleet composition	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)
Industrial off-road vehicles and equipment operating frequency and duration	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)

The industrial survey questionnaire form is included at Appendix B. Industrial Survey Questionnaire Form (DECCW, 2009).

Activity data has been obtained for industrial off-road vehicles and equipment, including equipment number, engine type, power and operating hours (DECCW, 2009). Table 3-89 presents industrial off-road vehicles and equipment population by engine type and equipment description in the GMR.

Table 3-89: Industrial off-road vehicles and equipment population by engine type and equipment description and in the GMR

Equipment description	2008 equipment population				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
4-Str Aerial Lifts	1	-	-	-	1
4-Str All Terrain Vehicles	82	-	-	-	82
4-Str Forklifts	14	-	-	-	14
4-Str Golf Carts	1	-	-	-	1
4-Str Inboard/Sterndrive	3	-	-	-	3
4-Str Other General Industrial Eqp	208	-	-	-	208
4-Str Rear Engine Riding Mowers (com)	11	-	-	-	11
4-Str Specialty Vehicle Carts	10	-	-	-	10
4-Str Sweepers/Scrubbers	4	-	-	-	4
4-Str Tractors/Loaders/Backhoes	2	-	-	-	2
CNG - Forklifts	-	-	72	-	72
CNG - Other General Industrial Eqp	-	-	2	-	2
Dsl - Aerial Lifts	-	-	-	49	49
Dsl - Bore/Drill Rigs	-	-	-	57	57
Dsl - Cement & Mortar Mixers	-	-	-	4	4
Dsl - Commercial Mowers (com)	-	-	-	29	29
Dsl - Concrete/Industrial Saws	-	-	-	1	1
Dsl - Cranes	-	-	-	78	78
Dsl - Crawler Tractor/Dozers	-	-	-	426	426
Dsl - Crushing/Proc. Equipment	-	-	-	85	85
Dsl - Dumpers/Tenders	-	-	-	3	3
Dsl - Excavators	-	-	-	490	490
Dsl - Forklifts	-	-	-	890	890
Dsl - Graders	-	-	-	128	128
Dsl - Inboard	-	-	-	5	5
Dsl - Off-highway Trucks	-	-	-	1,295	1,295
Dsl - Other Construction Equipment	-	-	-	5	5
Dsl - Other General Industrial Eqp	-	-	-	711	711
Dsl - Other Underground Mining Equip	-	-	-	67	67
Dsl - Pavers	-	-	-	1	1
Dsl - Pressure Washers	-	-	-	2	2
Dsl - Pumps	-	-	-	14	14
Dsl - Railway Maintenance	-	-	-	17	17
Dsl - Rollers	-	-	-	83	83
Dsl - Rubber Tire Loaders	-	-	-	1,050	1,050
Dsl - Scrapers	-	-	-	23	23
Dsl - Shredders > 6 HP	-	-	-	3	3

Equipment description	2008 equipment population				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Dsl - Skid Steer Loaders	-	-	-	129	129
Dsl - Sweepers/Scrubbers	-	-	-	48	48
Dsl - Tractors/Loaders/Backhoes	-	-	-	156	156
LPG - Forklifts	-	995	-	-	995
LPG - Other General Industrial Eqp	-	11	-	-	11
LPG - Rubber Tire Loaders	-	2	-	-	2
LPG - Skid Steer Loaders	-	1	-	-	1
LPG - Sweepers/Scrubbers	-	10	-	-	10
LPG - Tractors/Loaders/Backhoes	-	1	-	-	1
Grand Total	336	1,020	74	5,849	7,279

Table 3-90 presents industrial off-road vehicles and equipment power by engine type and equipment description in the GMR.

Table 3-90: Industrial off-road vehicles and equipment power by engine type and equipment description in the GMR

Equipment description	Average power (hp)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
4-Str Aerial Lifts	54	-	-	-	54
4-Str All Terrain Vehicles	1	-	-	-	1
4-Str Forklifts	56	-	-	-	56
4-Str Golf Carts	11	-	-	-	11
4-Str Inboard/Sterndrive	25	-	-	-	25
4-Str Other General Industrial Eqp	164	-	-	-	164
4-Str Rear Engine Riding Mowers (com)	14	-	-	-	14
4-Str Specialty Vehicle Carts	23	-	-	-	23
4-Str Sweepers/Scrubbers	29	-	-	-	29
4-Str Tractors/Loaders/Backhoes	28	-	-	-	28
CNG - Forklifts	-	-	40	-	40
CNG - Other General Industrial Eqp	-	-	100	-	100
Dsl - Aerial Lifts	-	-	-	78	78
Dsl - Bore/Drill Rigs	-	-	-	604	604
Dsl - Cement & Mortar Mixers	-	-	-	264	264
Dsl - Commercial Mowers (com)	-	-	-	18	18
Dsl - Concrete/Industrial Saws	-	-	-	58	58
Dsl - Cranes	-	-	-	250	250
Dsl - Crawler Tractor/Dozers	-	-	-	618	618
Dsl - Crushing/Proc. Equipment	-	-	-	221	221
Dsl - Dumpers/Tenders	-	-	-	27	27
Dsl - Excavators	-	-	-	456	456
Dsl - Forklifts	-	-	-	83	83
Dsl - Graders	-	-	-	274	274

Equipment description	Average power (hp)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Dsl - Inboard	-	-	-	30	30
Dsl - Off-highway Trucks	-	-	-	1,067	1,067
Dsl - Other Construction Equipment	-	-	-	713	713
Dsl - Other General Industrial Eqp	-	-	-	154	154
Dsl - Other Underground Mining Equip	-	-	-	85	85
Dsl - Pavers	-	-	-	150	150
Dsl - Pressure Washers	-	-	-	180	180
Dsl - Pumps	-	-	-	1,749	1,749
Dsl - Railway Maintenance	-	-	-	355	355
Dsl - Rollers	-	-	-	288	288
Dsl - Rubber Tire Loaders	-	-	-	287	287
Dsl - Scrapers	-	-	-	487	487
Dsl - Shredders > 6 HP	-	-	-	40	40
Dsl - Skid Steer Loaders	-	-	-	48	48
Dsl - Sweepers/Scrubbers	-	-	-	108	108
Dsl - Tractors/Loaders/Backhoes	-	-	-	78	78
LPG - Forklifts	-	66	-	-	66
LPG - Other General Industrial Eqp	-	160	-	-	160
LPG - Rubber Tire Loaders	-	27	-	-	27
LPG - Skid Steer Loaders	-	54	-	-	54
LPG - Sweepers/Scrubbers	-	50	-	-	50
LPG - Tractors/Loaders/Backhoes	-	94	-	-	94
Grand Total	106	67	42	439	367

Table 3-91 presents industrial off-road vehicles and equipment annual operating time by engine type, and equipment description in the GMR.

Table 3-91: Industrial off-road vehicles and equipment annual operating time by engine type and equipment description in the GMR

Equipment description	Annual operating time (h/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
4-Str Aerial Lifts	59.7	-	-	-	59.7
4-Str All Terrain Vehicles	1,042.3	-	-	-	1,042.3
4-Str Forklifts	2,427.2	-	-	-	2,427.2
4-Str Golf Carts	520.0	-	-	-	520.0
4-Str Inboard/Sterndrive	7,375.9	-	-	-	7,375.9
4-Str Other General Industrial Eqp	280.0	-	-	-	280.0
4-Str Rear Engine Riding Mowers (com)	351.7	-	-	-	351.7
4-Str Specialty Vehicle Carts	203.2	-	-	-	203.2
4-Str Sweepers/Scrubbers	743.9	-	-	-	743.9
4-Str Tractors/Loaders/Backhoes	340.5	-	-	-	340.5
CNG – Forklifts	-	-	3,720.6	-	3,720.6

Equipment description	Annual operating time (h/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
CNG - Other General Industrial Eqp	-	-	3,500.0	-	3,500.0
Dsl - Aerial Lifts	-	-	-	1,888.0	1,888.0
Dsl - Bore/Drill Rigs	-	-	-	2,462.0	2,462.0
Dsl - Cement & Mortar Mixers	-	-	-	241.5	241.5
Dsl - Commercial Mowers (com)	-	-	-	797.1	797.1
Dsl - Concrete/Industrial Saws	-	-	-	169.2	169.2
Dsl – Cranes	-	-	-	1,221.4	1,221.4
Dsl - Crawler Tractor/Dozers	-	-	-	2,279.7	2,279.7
Dsl - Crushing/Proc. Equipment	-	-	-	760.2	760.2
Dsl - Dumpers/Tenders	-	-	-	264.4	264.4
Dsl – Excavators	-	-	-	1,249.3	1,249.3
Dsl – Forklifts	-	-	-	830.7	830.7
Dsl – Graders	-	-	-	2,127.8	2,127.8
Dsl – Inboard	-	-	-	713.3	713.3
Dsl - Off-highway Trucks	-	-	-	2,254.9	2,254.9
Dsl - Other Construction Equipment	-	-	-	382.4	382.4
Dsl - Other General Industrial Eqp	-	-	-	965.0	965.0
Dsl - Other Underground Mining Equip	-	-	-	1,289.8	1,289.8
Dsl – Pavers	-	-	-	429.3	429.3
Dsl - Pressure Washers	-	-	-	282.5	282.5
Dsl – Pumps	-	-	-	1,786.8	1,786.8
Dsl - Railway Maintenance	-	-	-	552.0	552.0
Dsl – Rollers	-	-	-	1,006.2	1,006.2
Dsl - Rubber Tire Loaders	-	-	-	1,349.3	1,349.3
Dsl – Scrapers	-	-	-	641.5	641.5
Dsl - Shredders > 6 HP	-	-	-	2,007.2	2,007.2
Dsl - Skid Steer Loaders	-	-	-	734.9	734.9
Dsl - Sweepers/Scrubbers	-	-	-	637.3	637.3
Dsl - Tractors/Loaders/Backhoes	-	-	-	1,047.2	1,047.2
LPG – Forklifts	-	2,155.9	-	-	2,155.9
LPG - Other General Industrial Eqp	-	127.6	-	-	127.6
LPG - Rubber Tire Loaders	-	29.1	-	-	29.1
LPG - Skid Steer Loaders	-	53.3	-	-	53.3
LPG - Sweepers/Scrubbers	-	250.7	-	-	250.7
LPG - Tractors/Loaders/Backhoes	-	858.0	-	-	858.0
Grand Total	624.9	2,107.8	3,714.6	1,462.8	1,537.4

The total population of in-service industrial off-road vehicles and equipment has been estimated from the industrial survey (DECCW, 2009). In-service industrial off-road vehicles and equipment population by equipment description and maximum rated power range data for the GMR is presented in Table 3-92 and shown in Figure 3-67.

Table 3-92: Industrial off-road vehicles and equipment population in the GMR

Equipment description	2008 equipment population																
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp	Grand Total
4-Str Aerial Lifts	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
4-Str All Terrain Vehicles	82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82
4-Str Forklifts	-	-	-	-	-	3	11	-	-	-	-	-	-	-	-	-	14
4-Str Golf Carts	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
4-Str Inboard/Sterndrive	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3
4-Str Other General Industrial Eqp	-	-	-	-	2	-	5	4	164	33	-	-	-	-	-	-	208
4-Str Rear Engine Riding Mowers (com)	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	11
4-Str Specialty Vehicle Carts	-	-	3	-	7	-	-	-	-	-	-	-	-	-	-	-	10
4-Str Sweepers/Scrubbers	-	1	-	2	-	-	1	-	-	-	-	-	-	-	-	-	4
4-Str Tractors/Loaders/Backhoes	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
CNG – Forklifts	-	-	-	-	-	72	-	-	-	-	-	-	-	-	-	-	72
CNG - Other General Industrial Eqp	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2
Dsl - Aerial Lifts	-	1	-	-	3	3	4	26	12	-	-	-	-	-	-	-	49
Dsl - Bore/Drill Rigs	-	-	-	-	-	-	1	1	3	2	21	12	17	-	-	-	57
Dsl - Cement & Mortar Mixers	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	4
Dsl - Commercial Mowers (com)	-	-	21	-	8	-	-	-	-	-	-	-	-	-	-	-	29
Dsl - Concrete/Industrial Saws	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Dsl – Cranes	-	-	-	-	1	2	1	3	23	28	19	1	-	-	-	-	78
Dsl - Crawler Tractor/Dozers	-	-	-	-	-	-	-	2	23	23	176	36	143	23	-	-	426
Dsl - Crushing/Proc. Equipment	-	-	-	-	2	1	11	23	8	8	32	-	-	-	-	-	85
Dsl - Dumpers/Tenders	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3

Equipment description	2008 equipment population																
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp	Grand Total
Dsl – Excavators	-	-	-	5	21	5	27	20	90	112	142	11	3	7	15	32	490
Dsl – Forklifts	-	-	4	-	25	135	421	79	158	59	9	-	-	-	-	-	890
Dsl – Graders	-	-	-	-	-	-	4	5	24	61	34	-	-	-	-	-	128
Dsl – Inboard	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	5
Dsl - Off-highway Trucks	-	-	-	-	-	-	-	-	64	193	331	107	100	23	201	276	1,295
Dsl - Other Construction Equipment	-	-	-	-	-	-	-	-	-	1	-	-	4	-	-	-	5
Dsl - Other General Industrial Eqp	-	-	10	1	6	1	36	158	295	144	58	2	-	-	-	-	711
Dsl - Other Underground Mining Equip	-	-	-	-	-	-	14	42	11	-	-	-	-	-	-	-	67
Dsl – Pavers	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Dsl - Pressure Washers	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	2
Dsl – Pumps	-	-	-	-	-	1	-	-	-	-	4	-	-	-	2	7	14
Dsl - Railway Maintenance	-	-	-	-	-	-	-	-	-	12	2	2	-	-	1	-	17
Dsl – Rollers	-	-	-	1	-	-	-	-	28	8	46	-	-	-	-	-	83
Dsl - Rubber Tire Loaders	-	-	1	-	6	3	25	45	263	438	180	22	37	3	25	2	1,050
Dsl – Scrapers	-	-	-	-	-	-	-	-	1	-	18	4	-	-	-	-	23
Dsl - Shredders > 6 HP	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
Dsl - Skid Steer Loaders	-	-	-	3	15	78	18	10	5	-	-	-	-	-	-	-	129
Dsl - Sweepers/Scrubbers	-	-	1	2	8	-	3	-	32	2	-	-	-	-	-	-	48
Dsl - Tractors/Loaders/Backhoes	-	-	6	2	8	22	33	57	20	8	-	-	-	-	-	-	156
LPG – Forklifts	-	-	-	-	41	105	737	56	50	6	-	-	-	-	-	-	995
LPG - Other General Industrial Eqp	-	-	-	-	-	-	4	-	1	6	-	-	-	-	-	-	11
LPG - Rubber Tire Loaders	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
LPG - Skid Steer Loaders	-	-	-	-		-	1	-	-	-	-	-	-	-	-	-	1

Equipment description	2008 equipment population																
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp	Grand Total
LPG - Sweepers/Scrubbers	-	-	-	-	3	-	5	2	-	-	-	-	-	-	-	-	10
LPG - Tractors/Loaders/Backhoes			-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Grand Total	82	5	57	16	168	434	1,365	536	1,277	1,148	1,073	197	304	56	244	317	7,279

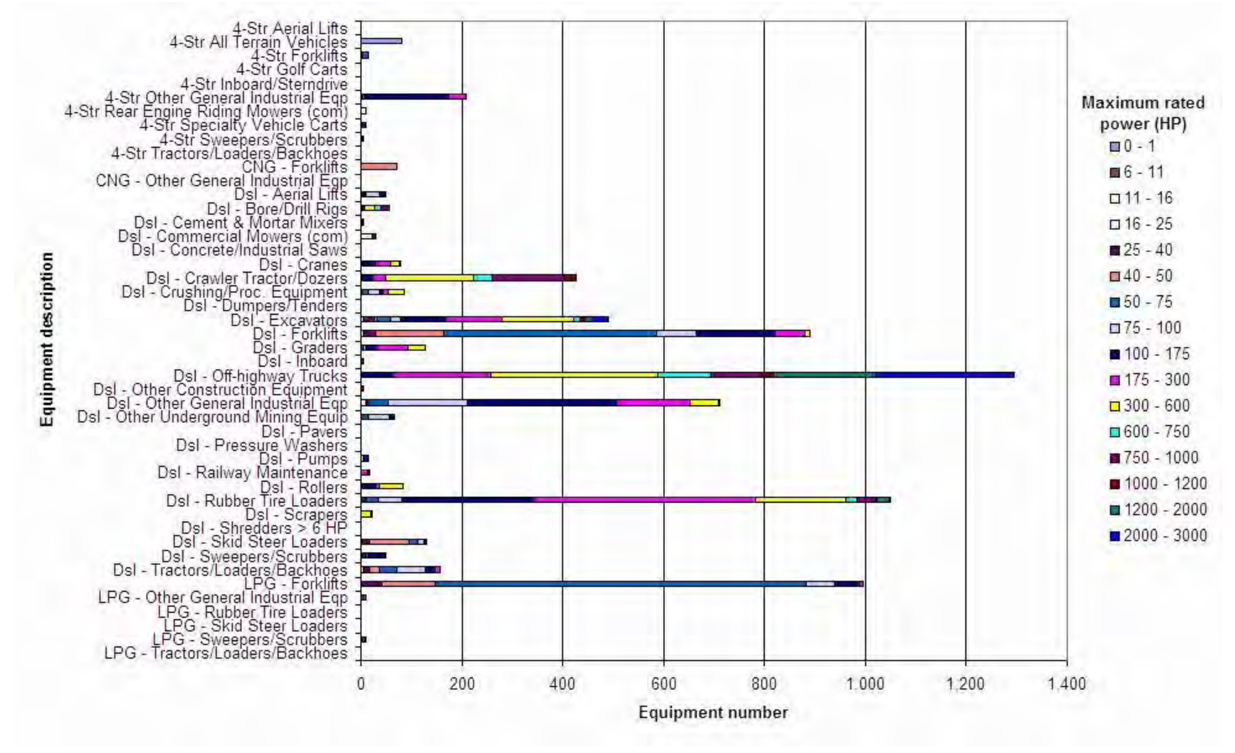

Figure 3-67: Industrial off-road vehicles and equipment population in the GMR

The annual operating time of industrial off-road vehicles and equipment has been estimated from the industrial survey (DECCW, 2009). In-service industrial vehicles and equipment annual operating time by engine description for the GMR is presented in Table 3-93 and shown in Figure 3-68.

Table 3-93: Industrial off-road vehicles and equipment annual operating time in the GMR

Equipment description	Annual operating time (h/year)															
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp
4-Stroke Aerial Lifts	-	-	-	-	-	-	59.7	-	-	-	-	-	-	-	-	-
4-Stroke All Terrain Vehicles	1,042.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Stroke Forklifts	-	-	-	-	-	425.1	2,973.3	-	-	-	-	-	-	-	-	-
4-Stroke Golf Carts	-	520.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Stroke Other General Industrial Equipm	-	-	-	-	5.5	-	409.4	32.5	338.6	16.1	-	-	-	-	-	-
4-Stroke Rear Engine Riding Mowers (Commercial)	-	-	351.7	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Stroke Specialty Vehicle Carts	-	-	268.3	-	175.2	-	-	-	-	-	-	-	-	-	-	-
4-Stroke Sweepers/Scrubbers	-	197.7	-	1,300.9	-	-	176.1	-	-	-	-	-	-	-	-	-
4-Stroke Tractors/Loaders/Backhoes	-	-	-	-	340.5	-	-	-	-	-	-	-	-	-	-	-
CNG Forklifts	-	-	-	-	-	3,720.6	-	-	-	-	-	-	-	-	-	-
CNG Other General Industrial Equipment	-	-	-	-	-	-	-	3,500.0	-	-	-	-	-	-	-	-
Diesel Aerial Lifts	-	65.9	-	-	91.6	21.7	1,482.0	2,890.6	918.6	-	-	-	-	-	-	-
Diesel Bore/Drill Rigs	-	-	-	-	-	-	710.5	28.0	120.4	763.3	1,875.7	2,969.1	3,687.7	-	-	-
Diesel Cement & Mortar Mixers	-	-	-	-	-	-	-	-	-	304.3	53.1	-	-	-	-	-
Diesel Concrete/Industrial	-	-	-	-	-	-	169.2	-	-	-	-	-	-	-	-	-

Equipment description	Annual operating time (h/year)															
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp
Saws																
Diesel Cranes	-	-	-	-	219.7	1,553.8	37.3	493.9	1,629.0	731.0	1,627.0	1,576.7	-	-	-	-
Diesel Crawler Tractors	-	-	-	-	-	-	-	856.9	495.2	682.1	1,848.2	3,175.6	2,817.2	4,342.9	-	-
Diesel Crushing/Proc. Equipment	-	-	-	-	1,347.1	237.6	310.6	650.5	1,057.4	899.7	864.2	-	-	-	-	-
Diesel Dumpers/Tenders	-	-	-	-	264.4	-	-	-	-	-	-	-	-	-	-	-
Diesel Excavators	-	-	-	1,039.0	995.9	231.9	556.2	981.1	1,042.4	940.4	1,342.6	1,768.9	1,867.9	1,283.9	2,635.7	2,715.6
Diesel Forklifts	-	-	362.6	-	1,138.2	798.9	835.1	1,223.5	687.4	560.1	1,292.0	-	-	-	-	-
Diesel Front Mowers (Commercial)	-	-	907.1	-	508.4	-	-	-	-	-	-	-	-	-	-	-
Diesel Graders	-	-	-	-	-	-	441.8	519.0	791.1	2,230.8	3,321.4	-	-	-	-	-
Diesel Inboards	-	-	-	-	713.3	-	-	-	-	-	-	-	-	-	-	-
Diesel Light Commercial Pressure Washer	-	-	-	-	-	-	-	-	540.0	25.0	-	-	-	-	-	-
Diesel Light Commercial Pumps	-	-	-	-	-	11.0	-	-	-	-	912.6	-	-	-	711.7	2,847.2
Diesel Logging Equipment Shredders > 6	-	-	-	-	-	2,007.2	-	-	-	-	-	-	-	-	-	-
Diesel Off-highway Trucks	-	-	-	-	-	-	-	-	1,066.0	1,347.0	1,210.3	1,525.7	3,561.8	2,251.5	2,681.3	3,916.9
Diesel Other Construction Equipment	-	-	-	-	-	-	-	-	-	525.6	-	-	346.7	-	-	-
Diesel Other General Industrial Equipment	-	-	1,931.4	7.1	643.4	158.3	1,055.4	749.6	790.6	982.6	2,244.9	716.6	-	-	-	-
Diesel Other Underground Mining Equipment	-	-	-	-	-	-	1,105.7	1,340.3	1,331.4	-	-	-	-	-	-	-

Equipment description	Annual operating time (h/year)															
	0 to 1 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	175 to 300 hp	300 to 600 hp	600 to 750 hp	750 to 1000 hp	1000 to 1200 hp	1200 to 2000 hp	2000 to 3000 hp
Diesel Pavers	-	-	-	-	-	-	-	-	429.3	-	-	-	-	-	-	-
Diesel Railway Maintenance	-	-	-	-	-	-	-	-	-	635.9	567.5	95.4	-	-	427.4	-
Diesel Rollers	-	-	-	55.1	-	-	-	-	1,207.4	700.1	957.7	-	-	-	-	-
Diesel Rubber Tire Loaders	-	-	13.5	-	1,484.6	290.7	634.0	900.8	1,236.6	1,294.4	1,422.9	1,181.4	2,655.0	1,217.8	2,626.3	4,380.0
Diesel Scrapers	-	-	-	-	-	-	-	-	223.9	-	672.0	608.2	-	-	-	-
Diesel Skid Steer Loaders	-	-	-	130.2	316.2	729.6	753.8	1,503.8	828.8	-	-	-	-	-	-	-
Diesel Sweepers/Scrubbers	-	-	219.7	141.8	226.8	-	371.9	-	794.5	866.1	-	-	-	-	-	-
Diesel Tractors/Loaders/Backhoes	-	-	1,566.0	142.5	211.0	927.4	2,064.1	783.8	744.4	489.7	-	-	-	-	-	-
Gas Inboards	-	11,014.9	-	-	-	-	97.9	-	-	-	-	-	-	-	-	-
LPG Forklifts	-	-	-	-	1,583.7	895.2	2,373.2	835.7	3,569.6	1,968.7	-	-	-	-	-	-
LPG Other General Industrial Equipment	-	-	-	-	-	-	250.0	-	43.7	60.0	-	-	-	-	-	-
LPG Rubber Tire Loaders	-	-	-	-	29.1	-	-	-	-	-	-	-	-	-	-	-
LPG Skid Steer Loaders	-	-	-	-	-	-	53.3	-	-	-	-	-	-	-	-	-
LPG Sweepers/Scrubbers	-	-	-	-	29.0	-	258.8	562.8	-	-	-	-	-	-	-	-
LPG Tractors/Loaders/Backhoes	-	-	-	-	-	-	-	858.0	-	-	-	-	-	-	-	-

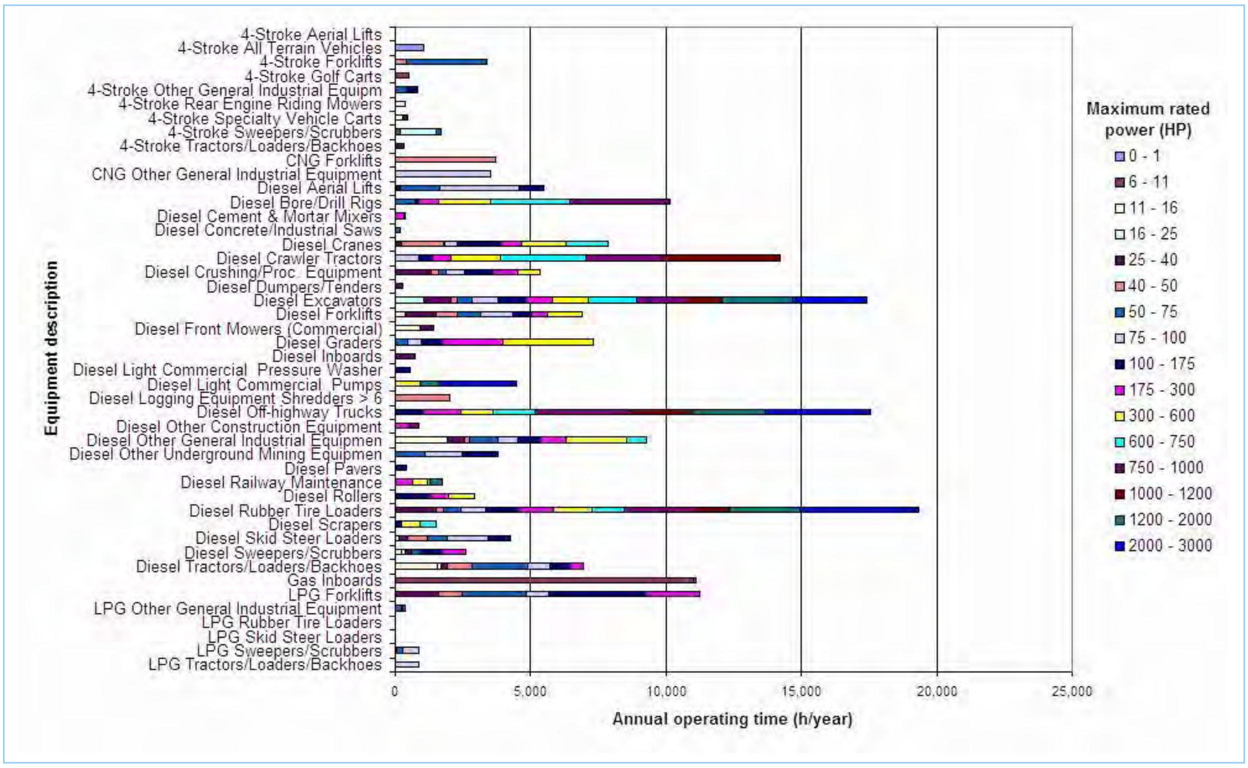

Figure 3-68: Industrial off-road vehicles and equipment annual operating time in the GMR

Exhaust and evaporative emissions from industrial off-road vehicles and equipment have been estimated using equipment population (DECCW, 2009), annual operating time (DECCW, 2009), fuel properties (Attorney-General's Department, 2003; Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECCW, 2009) data within the *NONROAD2008a Model* (USEPA, 2009a).

Figure 3-69 shows the NonRoad Model splash screen for the industrial off-road vehicles and equipment emission estimation simulation.

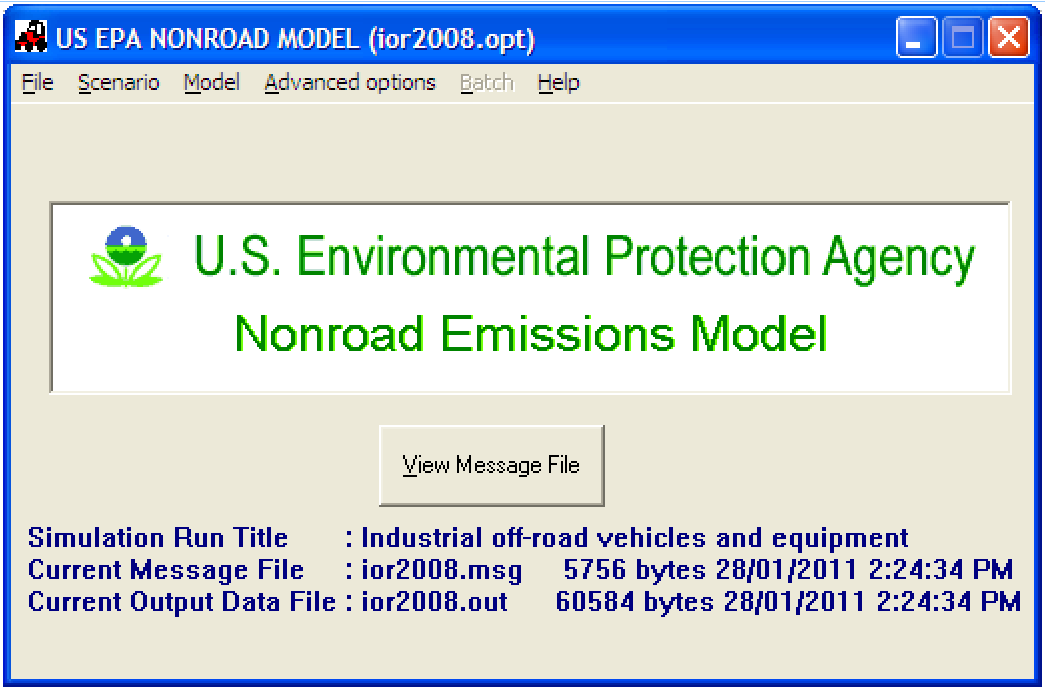

Figure 3-69: Industrial off-road vehicles and equipment NonRoad Model splash screen

Figure 3-70 shows the NonRoad Model options screen for the industrial off-road vehicles and equipment emission estimation simulation.

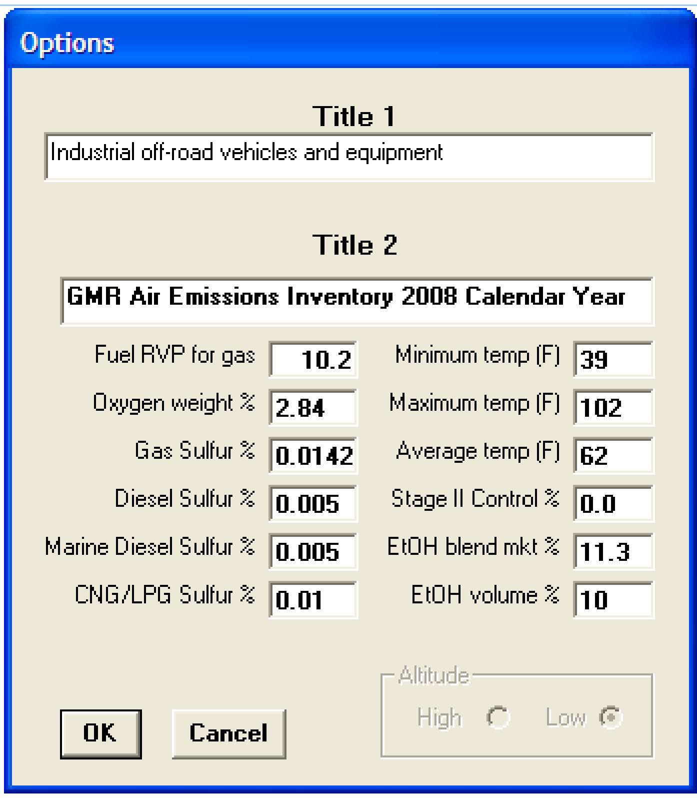

Figure 3-70: Industrial off-road vehicles and equipment NonRoad Model options

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).

Since there is little monthly temporal variation in industrial off-road vehicles and equipment use, the NonRoad Model has been run with average daily minimum, maximum and average ambient temperature (Hurley, 2005) and petrol RVP (PCO, 2011), which are shown in the NonRoad Model options screen in Figure 3-70.

Table 3-94 presents industrial off-road vehicles and equipment power rating (DECCW, 2009), useful life (USEPA, 2009a) and population (DECCW, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-94: Industrial off-road vehicles and equipment NonRoad Model population

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2265003010	4-Str Aerial Lifts	50	75	53.6	3000	1
2265001030	4-Str All Terrain Vehicles	0	1	1	20410	82
2265003020	4-Str Forklifts	40	50	40.1	4500	3
2265003020	4-Str Forklifts	50	75	60	4500	11
2265001050	4-Str Golf Carts	6	11	11.4	400	1
2282010005	4-Str Inboard/Sterndrive	50	75	60	197	1
2282010005	4-Str Inboard/Sterndrive	6	11	8	197	2
2265003040	4-Str Other General Industrial Eqp	100	175	156	3000	164
2265003040	4-Str Other General Industrial Eqp	175	300	232.6	3000	33
2265003040	4-Str Other General Industrial Eqp	25	40	27	1500	2
2265003040	4-Str Other General Industrial Eqp	50	75	63.6	3000	5
2265003040	4-Str Other General Industrial Eqp	75	100	95.9	3000	4
2265004041	4-Str Rear Engine Riding Mowers (com)	11	16	13.6	627	11
2265001060	4-Str Specialty Vehicle Carts	11	16	14.8	400	3
2265001060	4-Str Specialty Vehicle Carts	25	40	26.7	942	7
2265003030	4-Str Sweepers/Scrubbers	16	25	20	750	2
2265003030	4-Str Sweepers/Scrubbers	50	75	67.1	3000	1
2265003030	4-Str Sweepers/Scrubbers	6	11	10	400	1
2265002066	4-Str Tractors/Loaders/Backhoes	25	40	28	1500	2
2268003020	CNG - Forklifts	40	50	40	4500	72
2268003040	CNG - Other General Industrial Eqp	75	100	100	3000	2
2270003010	Dsl - Aerial Lifts	100	175	113.2	4667	12
2270003010	Dsl - Aerial Lifts	25	40	35.4	2500	3
2270003010	Dsl - Aerial Lifts	40	50	46.3	2500	3
2270003010	Dsl - Aerial Lifts	50	75	60	4667	4
2270003010	Dsl - Aerial Lifts	6	11	10	2500	1
2270003010	Dsl - Aerial Lifts	75	100	75.1	4667	26
2270002033	Dsl - Bore/Drill Rigs	100	175	108.7	4667	3
2270002033	Dsl - Bore/Drill Rigs	175	300	271.6	4667	2
2270002033	Dsl - Bore/Drill Rigs	300	600	506.6	7000	21
2270002033	Dsl - Bore/Drill Rigs	50	75	53.5	4667	1

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270002033	Dsl - Bore/Drill Rigs	600	750	703.9	7000	12
2270002033	Dsl - Bore/Drill Rigs	750	1000	842	7000	17
2270002033	Dsl - Bore/Drill Rigs	75	100	95	4667	1
2270002042	Dsl - Cement & Mortar Mixers	175	300	240	4667	3
2270002042	Dsl - Cement & Mortar Mixers	300	600	335.3	7000	1
2270004046	Dsl - Commercial Mowers (com)	11	16	12.3	2500	21
2270004046	Dsl - Commercial Mowers (com)	25	40	31.8	2500	8
2270002039	Dsl - Concrete/Industrial Saws	50	75	58	4667	1
2270002045	Dsl - Cranes	100	175	153.1	4667	23
2270002045	Dsl - Cranes	175	300	226.3	4667	28
2270002045	Dsl - Cranes	25	40	26.8	2500	1
2270002045	Dsl - Cranes	300	600	450.1	7000	19
2270002045	Dsl - Cranes	40	50	45	2500	2
2270002045	Dsl - Cranes	50	75	50	4667	1
2270002045	Dsl - Cranes	600	750	650	7000	1
2270002045	Dsl - Cranes	75	100	89.4	4667	3
2270002069	Dsl - Crawler Tractor/Dozers	1000	1200	1097	7000	23
2270002069	Dsl - Crawler Tractor/Dozers	100	175	142	4667	23
2270002069	Dsl - Crawler Tractor/Dozers	175	300	227.9	4667	23
2270002069	Dsl - Crawler Tractor/Dozers	300	600	481.7	7000	176
2270002069	Dsl - Crawler Tractor/Dozers	600	750	642.7	7000	36
2270002069	Dsl - Crawler Tractor/Dozers	750	1000	849.3	7000	143
2270002069	Dsl - Crawler Tractor/Dozers	75	100	83.5	4667	2
2270002054	Dsl - Crushing/Proc. Equipment	100	175	120.2	4667	8
2270002054	Dsl - Crushing/Proc. Equipment	175	300	234.8	4667	8
2270002054	Dsl - Crushing/Proc. Equipment	25	40	33.5	2500	2
2270002054	Dsl - Crushing/Proc. Equipment	300	600	411.1	7000	32
2270002054	Dsl - Crushing/Proc. Equipment	40	50	45.6	2500	1
2270002054	Dsl - Crushing/Proc. Equipment	50	75	62.1	4667	11
2270002054	Dsl - Crushing/Proc. Equipment	75	100	86	4667	23
2270002078	Dsl - Dumpers/Tenders	25	40	26.8	2500	3
2270002036	Dsl - Excavators	1000	1200	1077	7000	7
2270002036	Dsl - Excavators	100	175	139.6	4667	90
2270002036	Dsl - Excavators	1200	2000	1535	7000	15
2270002036	Dsl - Excavators	16	25	19.7	2500	5
2270002036	Dsl - Excavators	175	300	227.2	4667	112
2270002036	Dsl - Excavators	2000	3000	2782	7000	32
2270002036	Dsl - Excavators	25	40	31.5	2500	21
2270002036	Dsl - Excavators	300	600	369.4	7000	142
2270002036	Dsl - Excavators	40	50	41.6	2500	5
2270002036	Dsl - Excavators	50	75	59.2	4667	27
2270002036	Dsl - Excavators	600	750	600.1	7000	11
2270002036	Dsl - Excavators	750	1000	885.4	7000	3
2270002036	Dsl - Excavators	75	100	88.6	4667	20
2270003020	Dsl - Forklifts	100	175	137.3	4667	158

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270003020	Dsl - Forklifts	11	16	15	2500	4
2270003020	Dsl - Forklifts	175	300	216.5	4667	59
2270003020	Dsl - Forklifts	25	40	32.2	2500	25
2270003020	Dsl - Forklifts	300	600	384.8	7000	9
2270003020	Dsl - Forklifts	40	50	41.3	2500	135
2270003020	Dsl - Forklifts	50	75	53.4	4667	421
2270003020	Dsl - Forklifts	75	100	83.7	4667	79
2270002048	Dsl - Graders	100	175	136.6	4667	24
2270002048	Dsl - Graders	175	300	257.5	4667	61
2270002048	Dsl - Graders	300	600	453.2	7000	34
2270002048	Dsl - Graders	50	75	63.7	4667	4
2270002048	Dsl - Graders	75	100	84.7	4667	5
2282020005	Dsl - Inboard	25	40	30	1400	5
2270002051	Dsl - Off-highway Trucks	1000	1200	1102	7000	23
2270002051	Dsl - Off-highway Trucks	100	175	134	4667	64
2270002051	Dsl - Off-highway Trucks	1200	2000	1747	7000	201
2270002051	Dsl - Off-highway Trucks	175	300	232.6	4667	193
2270002051	Dsl - Off-highway Trucks	2000	3000	2408	7000	276
2270002051	Dsl - Off-highway Trucks	300	600	382.5	7000	331
2270002051	Dsl - Off-highway Trucks	600	750	689	7000	107
2270002051	Dsl - Off-highway Trucks	750	1000	873.2	7000	100
2270002081	Dsl - Other Construction Equipment	175	300	187	4667	1
2270002081	Dsl - Other Construction Equipment	750	1000	844.8	7000	4
2270003040	Dsl - Other General Industrial Eqp	100	175	131.9	4667	295
2270003040	Dsl - Other General Industrial Eqp	11	16	11.9	2500	10
2270003040	Dsl - Other General Industrial Eqp	16	25	20	2500	1
2270003040	Dsl - Other General Industrial Eqp	175	300	206.7	4667	144
2270003040	Dsl - Other General Industrial Eqp	25	40	36.1	2500	6
2270003040	Dsl - Other General Industrial Eqp	300	600	402	7000	58
2270003040	Dsl - Other General Industrial Eqp	40	50	46.9	2500	1
2270003040	Dsl - Other General Industrial Eqp	50	75	70.6	4667	36
2270003040	Dsl - Other General Industrial Eqp	600	750	658.5	7000	2
2270003040	Dsl - Other General Industrial Eqp	75	100	83	4667	158
2270009010	Dsl - Other Underground Mining Equip	100	175	110	4667	11
2270009010	Dsl - Other Underground Mining Equip	50	75	68.6	4667	14
2270009010	Dsl - Other Underground Mining Equip	75	100	84.6	4667	42
2270002003	Dsl - Pavers	100	175	150	4667	1
2270006030	Dsl - Pressure Washers	100	175	150	4667	1
2270006030	Dsl - Pressure Washers	175	300	210.5	4667	1
2270006010	Dsl - Pumps	1200	2000	1810	7000	2
2270006010	Dsl - Pumps	2000	3000	2714	7000	7
2270006010	Dsl - Pumps	300	600	455	7000	4

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270006010	Dsl - Pumps	40	50	40	2500	1
2285002015	Dsl - Railway Maintenance	1200	2000	1475	7000	1
2285002015	Dsl - Railway Maintenance	175	300	200	4667	12
2285002015	Dsl - Railway Maintenance	300	600	482.8	7000	2
2285002015	Dsl - Railway Maintenance	600	750	600	7000	2
2270002015	Dsl - Rollers	100	175	145	4667	28
2270002015	Dsl - Rollers	16	25	20	2500	1
2270002015	Dsl - Rollers	175	300	219.2	4667	8
2270002015	Dsl - Rollers	300	600	392.8	7000	46
2270002060	Dsl - Rubber Tire Loaders	1000	1200	1000	7000	3
2270002060	Dsl - Rubber Tire Loaders	100	175	135.5	4667	263
2270002060	Dsl - Rubber Tire Loaders	11	16	13	2500	1
2270002060	Dsl - Rubber Tire Loaders	1200	2000	1479	7000	25
2270002060	Dsl - Rubber Tire Loaders	175	300	226	4667	438
2270002060	Dsl - Rubber Tire Loaders	2000	3000	2414	7000	2
2270002060	Dsl - Rubber Tire Loaders	25	40	28	2500	6
2270002060	Dsl - Rubber Tire Loaders	300	600	387.4	7000	180
2270002060	Dsl - Rubber Tire Loaders	40	50	44.7	2500	3
2270002060	Dsl - Rubber Tire Loaders	50	75	62.6	4667	25
2270002060	Dsl - Rubber Tire Loaders	600	750	669.5	7000	22
2270002060	Dsl - Rubber Tire Loaders	750	1000	849.5	7000	37
2270002060	Dsl - Rubber Tire Loaders	75	100	87.6	4667	45
2270002018	Dsl - Scrapers	100	175	135	4667	1
2270002018	Dsl - Scrapers	300	600	459.8	7000	18
2270002018	Dsl - Scrapers	600	750	699.3	7000	4
2270007010	Dsl - Shredders > 6 HP	40	50	40	2500	3
2270002072	Dsl - Skid Steer Loaders	100	175	111.8	4667	5
2270002072	Dsl - Skid Steer Loaders	16	25	20	2500	3
2270002072	Dsl - Skid Steer Loaders	25	40	30.6	2500	15
2270002072	Dsl - Skid Steer Loaders	40	50	41.2	2500	78
2270002072	Dsl - Skid Steer Loaders	50	75	57.6	4667	18
2270002072	Dsl - Skid Steer Loaders	75	100	80.6	4667	10
2270003030	Dsl - Sweepers/Scrubbers	100	175	133.7	4667	32
2270003030	Dsl - Sweepers/Scrubbers	11	16	13.4	2500	1
2270003030	Dsl - Sweepers/Scrubbers	16	25	20.9	2500	2
2270003030	Dsl - Sweepers/Scrubbers	175	300	186.4	4667	2
2270003030	Dsl - Sweepers/Scrubbers	25	40	31.8	2500	8
2270003030	Dsl - Sweepers/Scrubbers	50	75	69	4667	3
2270002066	Dsl - Tractors/Loaders/Backhoes	100	175	113	4667	20
2270002066	Dsl - Tractors/Loaders/Backhoes	11	16	14	2500	6
2270002066	Dsl - Tractors/Loaders/Backhoes	16	25	17	2500	2
2270002066	Dsl - Tractors/Loaders/Backhoes	175	300	208.8	4667	8
2270002066	Dsl - Tractors/Loaders/Backhoes	25	40	33.3	2500	8
2270002066	Dsl - Tractors/Loaders/Backhoes	40	50	40.4	2500	22
2270002066	Dsl - Tractors/Loaders/Backhoes	50	75	60.1	4667	33

SCC	Equipment description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Equipment population
2270002066	Dsl - Tractors/Loaders/Backhoes	75	100	88.2	4667	57
2267003020	LPG - Forklifts	100	175	112.3	4500	50
2267003020	LPG - Forklifts	175	300	233.8	4500	6
2267003020	LPG - Forklifts	25	40	32.1	4500	41
2267003020	LPG - Forklifts	40	50	43.6	4500	105
2267003020	LPG - Forklifts	50	75	64.5	4500	737
2267003020	LPG - Forklifts	75	100	89.1	4500	56
2267003040	LPG - Other General Industrial Eqp	100	175	160.9	3000	1
2267003040	LPG - Other General Industrial Eqp	175	300	232	3000	6
2267003040	LPG - Other General Industrial Eqp	50	75	52	3000	4
2267002060	LPG - Rubber Tire Loaders	25	40	26.8	1500	2
2267002072	LPG - Skid Steer Loaders	50	75	53.6	3000	1
2267003030	LPG - Sweepers/Scrubbers	25	40	27.8	1500	3
2267003030	LPG - Sweepers/Scrubbers	50	75	52	3000	5
2267003030	LPG - Sweepers/Scrubbers	75	100	79.1	3000	2
2267002066	LPG - Tractors/Loaders/Backhoes	75	100	93.9	3000	1

Table 3-95 presents the industrial off-road vehicles and equipment load factor (USEPA, 2009a) and annual operating time (DECCW, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-95: Industrial off-road vehicles and equipment NonRoad Model load factor and annual operating time

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2265003010	4-Stroke Aerial Lifts	50	75	0.46	59.7
2265001030	4-Stroke All Terrain Vehicles	0	1	1.00	1042.3
2265003020	4-Stroke Forklifts	40	50	0.30	425.1
2265003020	4-Stroke Forklifts	50	75	0.30	2973.3
2265001050	4-Stroke Golf Carts	6	11	0.46	520.0
2282010005	Gas Inboards	50	75	0.21	97.9
2282010005	Gas Inboards	6	11	0.21	11014.9
2265003040	4-Stroke Other General Industrial Equipm	100	175	0.54	338.6
2265003040	4-Stroke Other General Industrial Equipm	175	300	0.54	16.1
2265003040	4-Stroke Other General Industrial Equipm	25	40	0.54	5.5
2265003040	4-Stroke Other General Industrial Equipm	50	75	0.54	409.4
2265003040	4-Stroke Other General Industrial Equipm	75	100	0.54	32.5
2265004041	4-Stroke Rear Engine Riding Mowers (Commercial)	11	16	0.38	351.7
2265001060	4-Stroke Specialty Vehicle Carts	11	16	0.58	268.3
2265001060	4-Stroke Specialty Vehicle Carts	25	40	0.58	175.2
2265003030	4-Stroke Sweepers/Scrubbers	16	25	0.71	1300.9
2265003030	4-Stroke Sweepers/Scrubbers	50	75	0.71	176.1
2265003030	4-Stroke Sweepers/Scrubbers	6	11	0.71	197.7
2265002066	4-Stroke Tractors/Loaders/Backhoes	25	40	0.48	340.5

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2268003020	CNG Forklifts	40	50	0.30	3720.6
2268003040	CNG Other General Industrial Equipment	75	100	0.54	3500.0
2270003010	Diesel Aerial Lifts	100	175	0.21	918.6
2270003010	Diesel Aerial Lifts	25	40	0.21	91.6
2270003010	Diesel Aerial Lifts	40	50	0.21	21.7
2270003010	Diesel Aerial Lifts	50	75	0.21	1482.0
2270003010	Diesel Aerial Lifts	6	11	0.21	65.9
2270003010	Diesel Aerial Lifts	75	100	0.21	2890.6
2270002033	Diesel Bore/Drill Rigs	100	175	0.43	120.4
2270002033	Diesel Bore/Drill Rigs	175	300	0.43	763.3
2270002033	Diesel Bore/Drill Rigs	300	600	0.43	1875.7
2270002033	Diesel Bore/Drill Rigs	50	75	0.43	710.5
2270002033	Diesel Bore/Drill Rigs	600	750	0.43	2969.1
2270002033	Diesel Bore/Drill Rigs	750	1000	0.43	3687.7
2270002033	Diesel Bore/Drill Rigs	75	100	0.43	28.0
2270002042	Diesel Cement & Mortar Mixers	175	300	0.43	304.3
2270002042	Diesel Cement & Mortar Mixers	300	600	0.43	53.1
2270004046	Diesel Front Mowers (Commercial)	11	16	0.43	907.1
2270004046	Diesel Front Mowers (Commercial)	25	40	0.43	508.4
2270002039	Diesel Concrete/Industrial Saws	50	75	0.59	169.2
2270002045	Diesel Cranes	100	175	0.43	1629.0
2270002045	Diesel Cranes	175	300	0.43	731.0
2270002045	Diesel Cranes	25	40	0.43	219.7
2270002045	Diesel Cranes	300	600	0.43	1627.0
2270002045	Diesel Cranes	40	50	0.43	1553.8
2270002045	Diesel Cranes	50	75	0.43	37.3
2270002045	Diesel Cranes	600	750	0.43	1576.7
2270002045	Diesel Cranes	75	100	0.43	493.9
2270002069	Diesel Crawler Tractors	1000	1200	0.59	4342.9
2270002069	Diesel Crawler Tractors	100	175	0.59	495.2
2270002069	Diesel Crawler Tractors	175	300	0.59	682.1
2270002069	Diesel Crawler Tractors	300	600	0.59	1848.2
2270002069	Diesel Crawler Tractors	600	750	0.59	3175.6
2270002069	Diesel Crawler Tractors	750	1000	0.59	2817.2
2270002069	Diesel Crawler Tractors	75	100	0.59	856.9
2270002054	Diesel Crushing/Proc. Equipment	100	175	0.43	1057.4
2270002054	Diesel Crushing/Proc. Equipment	175	300	0.43	899.7
2270002054	Diesel Crushing/Proc. Equipment	25	40	0.43	1347.1
2270002054	Diesel Crushing/Proc. Equipment	300	600	0.43	864.2
2270002054	Diesel Crushing/Proc. Equipment	40	50	0.43	237.6
2270002054	Diesel Crushing/Proc. Equipment	50	75	0.43	310.6
2270002054	Diesel Crushing/Proc. Equipment	75	100	0.43	650.5
2270002078	Diesel Dumpers/Tenders	25	40	0.21	264.4
2270002036	Diesel Excavators	1000	1200	0.59	1283.9
2270002036	Diesel Excavators	100	175	0.59	1042.4

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2270002036	Diesel Excavators	1200	2000	0.59	2635.7
2270002036	Diesel Excavators	16	25	0.59	1039.0
2270002036	Diesel Excavators	175	300	0.59	940.4
2270002036	Diesel Excavators	2000	3000	0.59	2715.6
2270002036	Diesel Excavators	25	40	0.59	995.9
2270002036	Diesel Excavators	300	600	0.59	1342.6
2270002036	Diesel Excavators	40	50	0.59	231.9
2270002036	Diesel Excavators	50	75	0.59	556.2
2270002036	Diesel Excavators	600	750	0.59	1768.9
2270002036	Diesel Excavators	750	1000	0.59	1867.9
2270002036	Diesel Excavators	75	100	0.59	981.1
2270003020	Diesel Forklifts	100	175	0.59	687.4
2270003020	Diesel Forklifts	11	16	0.59	362.6
2270003020	Diesel Forklifts	175	300	0.59	560.1
2270003020	Diesel Forklifts	25	40	0.59	1138.2
2270003020	Diesel Forklifts	300	600	0.59	1292.0
2270003020	Diesel Forklifts	40	50	0.59	798.9
2270003020	Diesel Forklifts	50	75	0.59	835.1
2270003020	Diesel Forklifts	75	100	0.59	1223.5
2270002048	Diesel Graders	100	175	0.59	791.1
2270002048	Diesel Graders	175	300	0.59	2230.8
2270002048	Diesel Graders	300	600	0.59	3321.4
2270002048	Diesel Graders	50	75	0.59	441.8
2270002048	Diesel Graders	75	100	0.59	519.0
2282020005	Diesel Inboards	25	40	0.35	713.3
2270002051	Diesel Off-highway Trucks	1000	1200	0.59	2251.5
2270002051	Diesel Off-highway Trucks	100	175	0.59	1066.0
2270002051	Diesel Off-highway Trucks	1200	2000	0.59	2681.3
2270002051	Diesel Off-highway Trucks	175	300	0.59	1347.0
2270002051	Diesel Off-highway Trucks	2000	3000	0.59	3916.9
2270002051	Diesel Off-highway Trucks	300	600	0.59	1210.3
2270002051	Diesel Off-highway Trucks	600	750	0.59	1525.7
2270002051	Diesel Off-highway Trucks	750	1000	0.59	3561.8
2270002081	Diesel Other Construction Equipment	175	300	0.59	525.6
2270002081	Diesel Other Construction Equipment	750	1000	0.59	346.7
2270003040	Diesel Other General Industrial Equipment	100	175	0.43	790.6
2270003040	Diesel Other General Industrial Equipment	11	16	0.43	1931.4
2270003040	Diesel Other General Industrial Equipment	16	25	0.43	7.1
2270003040	Diesel Other General Industrial Equipment	175	300	0.43	982.6
2270003040	Diesel Other General Industrial Equipment	25	40	0.43	643.4
2270003040	Diesel Other General Industrial Equipment	300	600	0.43	2244.9
2270003040	Diesel Other General Industrial Equipment	40	50	0.43	158.3
2270003040	Diesel Other General Industrial Equipment	50	75	0.43	1055.4
2270003040	Diesel Other General Industrial Equipment	600	750	0.43	716.6
2270003040	Diesel Other General Industrial Equipment	75	100	0.43	749.6

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2270009010	Diesel Other Underground Mining Equipment	100	175	0.21	1331.4
2270009010	Diesel Other Underground Mining Equipment	50	75	0.21	1105.7
2270009010	Diesel Other Underground Mining Equipment	75	100	0.21	1340.3
2270002003	Diesel Pavers	100	175	0.59	429.3
2270006030	Diesel Light Commercial Pressure Washer	100	175	0.43	540.0
2270006030	Diesel Light Commercial Pressure Washer	175	300	0.43	25.0
2270006010	Diesel Light Commercial Pumps	1200	2000	0.43	711.7
2270006010	Diesel Light Commercial Pumps	2000	3000	0.43	2847.2
2270006010	Diesel Light Commercial Pumps	300	600	0.43	912.6
2270006010	Diesel Light Commercial Pumps	40	50	0.43	11.0
2285002015	Diesel Railway Maintenance	1200	2000	0.21	427.4
2285002015	Diesel Railway Maintenance	175	300	0.21	635.9
2285002015	Diesel Railway Maintenance	300	600	0.21	567.5
2285002015	Diesel Railway Maintenance	600	750	0.21	95.4
2270002015	Diesel Rollers	100	175	0.59	1207.4
2270002015	Diesel Rollers	16	25	0.59	55.1
2270002015	Diesel Rollers	175	300	0.59	700.1
2270002015	Diesel Rollers	300	600	0.59	957.7
2270002060	Diesel Rubber Tire Loaders	1000	1200	0.59	1217.8
2270002060	Diesel Rubber Tire Loaders	100	175	0.59	1236.6
2270002060	Diesel Rubber Tire Loaders	11	16	0.59	13.5
2270002060	Diesel Rubber Tire Loaders	1200	2000	0.59	2626.3
2270002060	Diesel Rubber Tire Loaders	175	300	0.59	1294.4
2270002060	Diesel Rubber Tire Loaders	2000	3000	0.59	4380.0
2270002060	Diesel Rubber Tire Loaders	25	40	0.59	1484.6
2270002060	Diesel Rubber Tire Loaders	300	600	0.59	1422.9
2270002060	Diesel Rubber Tire Loaders	40	50	0.59	290.7
2270002060	Diesel Rubber Tire Loaders	50	75	0.59	634.0
2270002060	Diesel Rubber Tire Loaders	600	750	0.59	1181.4
2270002060	Diesel Rubber Tire Loaders	750	1000	0.59	2655.0
2270002060	Diesel Rubber Tire Loaders	75	100	0.59	900.8
2270002018	Diesel Scrapers	100	175	0.59	223.9
2270002018	Diesel Scrapers	300	600	0.59	672.0
2270002018	Diesel Scrapers	600	750	0.59	608.2
2270007010	Diesel Logging Equipment Shredders > 6	40	50	0.59	2007.2
2270002072	Diesel Skid Steer Loaders	100	175	0.21	828.8
2270002072	Diesel Skid Steer Loaders	16	25	0.21	130.2
2270002072	Diesel Skid Steer Loaders	25	40	0.21	316.2
2270002072	Diesel Skid Steer Loaders	40	50	0.21	729.6
2270002072	Diesel Skid Steer Loaders	50	75	0.21	753.8
2270002072	Diesel Skid Steer Loaders	75	100	0.21	1503.8
2270003030	Diesel Sweepers/Scrubbers	100	175	0.43	794.5

SCC	Activity	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2270003030	Diesel Sweepers/Scrubbers	11	16	0.43	219.7
2270003030	Diesel Sweepers/Scrubbers	16	25	0.43	141.8
2270003030	Diesel Sweepers/Scrubbers	175	300	0.43	866.1
2270003030	Diesel Sweepers/Scrubbers	25	40	0.43	226.8
2270003030	Diesel Sweepers/Scrubbers	50	75	0.43	371.9
2270002066	Diesel Tractors/Loaders/Backhoes	100	175	0.21	744.4
2270002066	Diesel Tractors/Loaders/Backhoes	11	16	0.21	1566.0
2270002066	Diesel Tractors/Loaders/Backhoes	16	25	0.21	142.5
2270002066	Diesel Tractors/Loaders/Backhoes	175	300	0.21	489.7
2270002066	Diesel Tractors/Loaders/Backhoes	25	40	0.21	211.0
2270002066	Diesel Tractors/Loaders/Backhoes	40	50	0.21	927.4
2270002066	Diesel Tractors/Loaders/Backhoes	50	75	0.21	2064.1
2270002066	Diesel Tractors/Loaders/Backhoes	75	100	0.21	783.8
2267003020	LPG Forklifts	100	175	0.30	3569.6
2267003020	LPG Forklifts	175	300	0.30	1968.7
2267003020	LPG Forklifts	25	40	0.30	1583.7
2267003020	LPG Forklifts	40	50	0.30	895.2
2267003020	LPG Forklifts	50	75	0.30	2373.2
2267003020	LPG Forklifts	75	100	0.30	835.7
2267003040	LPG Other General Industrial Equipment	100	175	0.54	43.7
2267003040	LPG Other General Industrial Equipment	175	300	0.54	60.0
2267003040	LPG Other General Industrial Equipment	50	75	0.54	250.0
2267002060	LPG Rubber Tire Loaders	25	40	0.71	29.1
2267002072	LPG Skid Steer Loaders	50	75	0.58	53.3
2267003030	LPG Sweepers/Scrubbers	25	40	0.71	29.0
2267003030	LPG Sweepers/Scrubbers	50	75	0.71	258.8
2267003030	LPG Sweepers/Scrubbers	75	100	0.71	562.8
2267002066	LPG Tractors/Loaders/Backhoes	75	100	0.48	858.0

Table 3-96 presents the industrial off-road vehicles and equipment fuel consumption estimates by equipment description from the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-96: Industrial off-road vehicles and equipment NonRoad Model fuel consumption by equipment description in the GMR

Equipment description	2008 fuel consumption (kL/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Aerial Lifts	1	-	-	384	385
ATVs	9	-	-	-	9
Bore/Drill Rigs	-	-	-	8,274	8,274
Cement & Mortar Mixers	-	-	-	20	20
Concrete/Industrial Saws	-	-	-	1	1
Cranes	-	-	-	2,156	2,156
Crawler Tractor/Dozers	-	-	-	80,220	80,220

Equipment description	2008 fuel consumption (kL/year)				
	4-stroke petrol	LPG	CNG	Diesel	Grand Total
Crushing/Proc. Equipment	-	-	-	1,334	1,334
Dumpers/Tenders	-	-	-	1	1
Excavators	-	-	-	51,365	51,365
Forklifts	224	18,652	1,550	7,279	27,705
Front Mowers	-	-	-	34	34
Golf Carts	2	-	-	-	2
Graders	-	-	-	10,410	10,410
Inboard/Sterndrive	15	-	-	8	24
Off-highway Trucks	-	-	-	495,877	495,877
Other Construction Equipment	-	-	-	148	148
Other General Industrial Eqp	1,790	-	-	10,740	12,531
Other General Industrial Equipm	-	33	-	-	33
Other General Industrial Equipment	-	-	182	-	182
Other Underground Mining Equipment	-	-	-	392	392
Pavers	-	-	-	8	8
Pressure Washers	-	-	-	7	7
Pumps	-	-	-	4,909	4,909
Railway Maintenance	-	-	-	137	137
Rear Engine Riding Mowers	11	-	-	-	11
Rollers	-	-	-	2,736	2,736
Rubber Tire Loaders	-	1	-	58,814	58,815
Scrapers	-	-	-	851	851
Shredders > 6 HP	-	-	-	31	31
Skid Steer Loaders	-	1	-	264	265
Specialty Vehicles/Carts	11	-	-	-	11
Sweepers/Scrubbers	25	48	-	327	400
Tractors/Loaders/Backhoes	3	16	-	609	629
Grand Total	2,092	18,750	1,732	737,337	759,911

Industrial off-road vehicles and equipment fuel consumption estimates by POEO scheduled activity from the *NONROAD2008a Model* (USEPA, 2009a) are presented in Table 3-97 for all POEO scheduled activities and shown in Figure 3-71 for the top 30 POEO scheduled activities.

Table 3-97: Industrial off-road vehicles and equipment NonRoad Model fuel consumption by POEO scheduled activity in the GMR

POEO scheduled activity	2008 fuel consumption (kL/year)			
	4-stroke petrol	LPG and CNG[23]	Diesel	Grand Total
Agricultural fertiliser (phosphate) production	-	-	42.27	42.27
Aluminium production (alumina)	-	-	4,449.15	4,449.15
Aluminium production (scrap metal)	-	9.17	480.75	489.92
Ammonium nitrate production	-	176.97	83.57	260.54
Animal accommodation	1.27	-	7.18	8.44
Battery production	-	3,586.98	-	3,586.98
Bird accommodation	0.97	-	275.49	276.46
Bitumen mixing	-	0.58	451.71	452.29
Boat construction/maintenance (dry/float)	2.78	-	50.63	53.42
Boat construction/maintenance (general)	33.50	48.45	35.35	117.31
Boat mooring and storage	1.51	-	1.38	2.89
Brewing and distilling	-	340.04	-	340.04
Cement or lime handling	0.49	24.14	568.39	593.02
Cement or lime production	-	468.99	1,260.27	1,729.26
Ceramics production	-	208.61	1,245.89	1,454.50
Chemical production	32.44	3,924.58	1,118.62	5,075.65
Chemical storage	-	6.69×10^{-2}	0.98	1.05
Coal washery reject or slag landfilling	-	-	7.37	7.37
Coal works	67.16	-	9,024.66	9,091.82
Coke production	-	-	107.16	107.16
Composting	-	79.55	4,902.23	4,981.78
Concrete works	26.26	893.81	2,526.18	3,446.24
Container reconditioning	0.49	88.01	0.98	89.48
Contaminated soil treatment	5.45	9.53	937.52	952.50
Crushing, grinding or separating	3.05	67.89	3,923.97	3,994.90
Dairy animal accommodation	-	-	56.82	56.82
Dairy processing	-	57.05	3.97	61.02
Explosives production	-	-	27.79	27.79
General agricultural processing	-	323.34	23.14	346.48
General animal products production	-	148.24	0.74	148.98
General chemicals storage	4.87	190.79	4,262.88	4,458.54
Generation of electrical power from coal	140.20	0.26	2,167.17	2,307.63
Generation of electrical power from gas	-	0.24	-	0.24

[23] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

POEO scheduled activity	2008 fuel consumption (kL/year)			
	4-stroke petrol	LPG and CNG[23]	Diesel	Grand Total
Generation of electricity not coal or gas	-	-	8.76	8.76
Glass production (container)	-	100.63	46.21	146.84
Glass production (float)	-	21.14	35.69	56.83
Hazardous, industrial or group A waste D	0.13	-	24.95	25.08
Hazardous, industrial or group A waste G	-	1.91	3.93	5.84
Helicopter-related activity	9.74×10^{-2}	-	0.20	0.29
Inert waste landfilling	-	-	73.05	73.05
Iron or steel production (iron ore)	-	-	8,666.24	8,666.24
Iron or steel production (scrap metal)	5.61	232.03	688.29	925.93
Land-based extractive activity	158.02	-	12,562.23	12,720.26
Metal plating or coating	97.48	1,819.72	557.03	2,474.23
Metal processing	93.65	6.04	243.80	343.48
Mining for coal	446.82	3,346.26	637,584.81	641,377.89
Mining for minerals	-	-	1,118.89	1,118.89
Miscellaneous licensed discharges to waters (at any time)	8.28×10^{-2}	-	3,120.56	3,120.65
Non-ferrous metal production (scrap)	-	-	49.16	49.16
Non-thermal treatment of waste	0.45	150.46	2,855.38	3,006.29
Other land-based extraction	-	-	8,666.24	8,666.24
Paints/polishes/adhesives production	-	111.88	118.34	230.22
Paper or pulp production	-	185.30	507.29	692.60
Paper production using recycle materials	-	802.34	-	802.34
Pesticides and related products production	-	5.17	0.59	5.76
Petrochemical production	456.66	153.31	159.09	769.05
Petroleum products and fuel production	55.50	1,814.59	274.79	2,144.88
Petroleum products storage	-	28.81	42.0	70.81
Pharmaceutical and veterinary products production	0.25	22.40	106.69	129.34
Pig accommodation	-	-	0.25	0.25
Plastics resins production	0.19	198.81	2.36	201.37
Printing, packaging and visual media production	-	388.66	3.34	392.0
Railway systems activities	389.44	-	2,241.52	2,630.96
Recovery of waste	-	19.18	1,807.46	1,826.64
Recovery of waste oil	-	6.64	1.57	8.21
Recovery of waste tyres	-	7.26	-	7.26
Rendering or fat extraction	2.51	13.07	64.87	80.44
Road construction	-	-	838.60	838.60
Rubber products/tyre production	-	21.97	-	21.97
Scrap metal processing	-	51.96	1,960.35	2,012.31
Sewage treatment - large plants	22.40	8.61	125.83	156.84
Sewage treatment - small plants	40.13	13.35	171.45	224.93
Shipping in bulk	1.51	1.98	800.49	803.98
Slaughtering or processing of animals	-	166.80	210.85	377.65

POEO scheduled activity	2008 fuel consumption (kL/year)			
	4-stroke petrol	LPG and CNG[23]	Diesel	Grand Total
Soap and detergent production	-	69.28	35.69	104.97
Solid waste landfilling	-	-	264.19	264.19
Sterilisation activities	-	0.35	-	0.35
Waste disposal (application to land)	-	-	8,063.43	8,063.43
Waste storage	5.84×10^{-2}	26.40	312.08	338.54
Water-based extractive activity	0.49	-	4,799.23	4,799.72
Wood or timber milling or processing	-	4.48	75.38	79.86
Grand Total	2,091.90	20,448.08	737,337.35	759,877.34

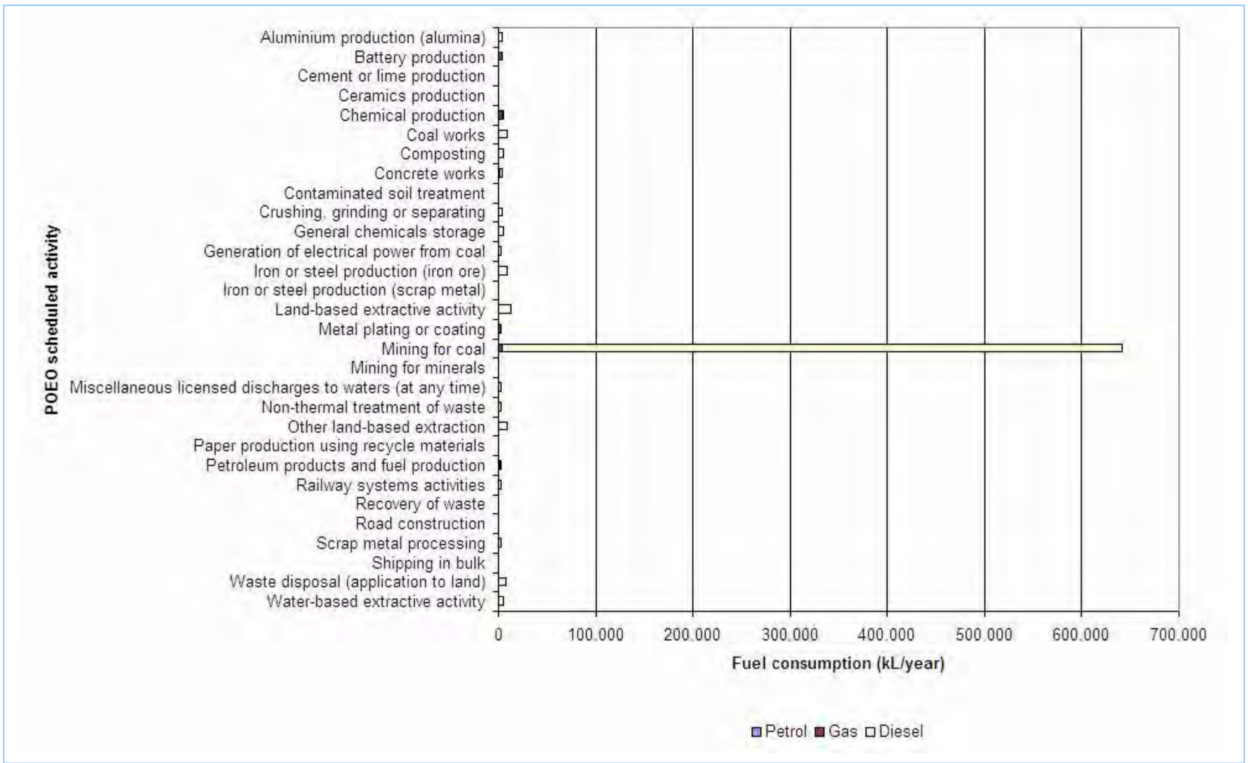

Figure 3-71: Industrial off-road vehicles and equipment NonRoad Model fuel consumption by POEO scheduled activity in the GMR

Figure 3-72 shows industrial off-road vehicles and equipment fuel consumption estimates by POEO scheduled activity from the *NONROAD2008a Model* (USEPA, 2009a) for the top 30 POEO scheduled activities except Mining for coal.

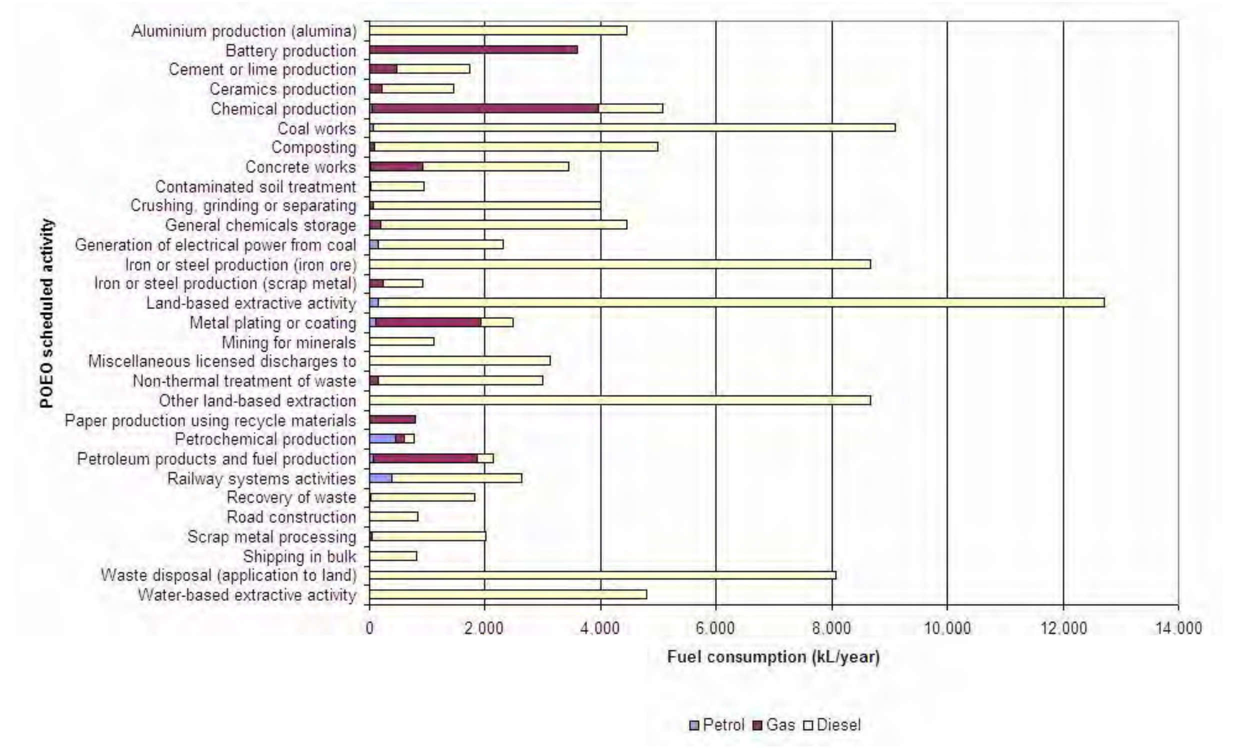

Figure 3-72: Industrial off-road vehicles and equipment NonRoad Model fuel consumption for selected POEO scheduled activity in the GMR

3.4.4 Emission and Speciation Factors

Table 3-98 summarises the emission and speciation factors used for industrial off-road vehicles and equipment.

Table 3-98: Industrial off-road vehicles and equipment 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	4-stroke petrol, LPG, CNG and diesel exhaust	- *NONROAD2008a Model* (USEPA, 2009a)
Criteria pollutants: VOC	4-stroke petrol, LPG, CNG and diesel exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009a)
Criteria pollutants: TSP	4-stroke petrol exhaust	- *PMPROF 400 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	LPG and CNG exhaust	- *PMPROF 120 - 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	4-stroke petrol, LPG, CNG and diesel	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)

Substance	Emission source	Emission and speciation factor source
	exhaust	
Speciated VOC	4-stroke petrol exhaust and evaporative	- *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)
	LPG and CNG exhaust and evaporative	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a) - *ORGPROF 719 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust and evaporative	- *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)
Organic air toxics	4-stroke petrol exhaust and evaporative	- *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)
	LPG and CNG exhaust and evaporative	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a) - *ORGPROF 719 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	diesel exhaust and evaporative	- *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)
Metal air toxics	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)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)

Substance	Emission source	Emission and speciation factor source
		- *PMPROF 123 - 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	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)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources, 3.2 Natural Gas-fired Reciprocating Engines* (USEPA, 2000a)
	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 and Polychlorinated dibenzofurans: PCDD and PCDF	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)
	LPG and CNG exhaust	- *Australian Inventory of Dioxin Emissions 2004, National Dioxins Program Technical Report No. 3* (Bawden et. al., 2004)
	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	4-stroke petrol and diesel exhaust	- *Table III-6 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	LPG and CNG exhaust	- *Table III-1 - 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, 2009a)
Greenhouse gases: N_2O	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)
	LPG and CNG exhaust	- *AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion* (USEPA, 1998)

Table 3-99 presents average activity weighted 4-stroke petrol, LPG, CNG and diesel exhaust and evaporative emission factors for industrial off-road vehicles and equipment.

Table 3-99: Industrial off-road vehicles and equipment 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
4-stroke petrol exhaust and evaporative	33.78	0.058	0.029	0.199	0.19	0.18	45.34	2.010	435.70	2,305.61	0.0202	3.29×10^{-12}
LPG and CNG[24] exhaust and evaporative	28.44	0.023	0.006	0.101	0.14	0.14	7.23	8.988	115.88	1,555.68	0.0038	1.28×10^{-11}
Diesel exhaust and evaporative	40.77	0.069	0.022	0.083	2.84	2.75	4.00	0.061	23.26	2,705.51	0.0029	4.57×10^{-9}

[24] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

3.4.5 Spatial Distribution of Emissions

Table 3-100 summarises the data used for spatially allocating emissions from industrial off-road vehicles and equipment.

Table 3-100: Industrial off-road vehicles and equipment spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from industrial off-road vehicles and equipment	Gridded 1 km x 1 km site-specific petrol, diesel and gas consumption estimates	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009) - *NONROAD2008a Model* (USEPA, 2009a)

Emissions from industrial off-road vehicles and equipment have been spatially distributed according to petrol, LPG, CNG and diesel consumption, which is based on site-specific fuel consumption estimated using industrial survey data (DECCW, 2009) within the *NONROAD2008a Model* (USEPA, 2009a).

EPA-licensed premises addresses have been geocoded to obtain the latitude and longitude (i.e. geographical coordinates). The geocoding process uses calibrated map layers to search for postcode, suburb, street name and street number in order to return the most accurate spatial coordinates for each EPA-licensed premises. Where the street number coordinate could not be found, the street centroid coordinate was used. Similarly, where the street name coordinate could not be found, the suburb centroid coordinate was used. Geographical coordinates have been converted to MGA easting and northing in km (i.e. gridded coordinates) using Redfearn's formula (ICSM, 2006).

Industrial off-road vehicles and equipment petrol, gas (i.e. LPG and CNG) and diesel consumption by LGA and region is presented in Table 3-101 and shown in Figure 3-73 for all LGA.

Table 3-101: Industrial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption by LGA and region

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[25]	Diesel	Grand Total
Newcastle	Cessnock	-	-	7,532.25	7,532.25
	Lake Macquarie	0.71	20.83	4,494.99	4,516.53
	Maitland	-	-	2,420.80	2,420.80
	Newcastle	78.63	307.23	15,274.99	15,660.85

[25] LPG equivalent based on effective heating value of 25.5 MJ/L for LPG and 25 MJ/L for CNG (ABARE, 2009b).

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[25]	Diesel	Grand Total
	Port Stephens	-	54.48	1,949.34	2,003.82
Newcastle Total		79.34	382.54	31,672.38	32,134.25
Non Urban	Blue Mountains	-	-	34.61	34.61
	Cessnock	6.86	1.67	5,773.20	5,781.73
	Dungog	8.28E-2	4.48	385.93	390.49
	Gosford	15.63	678.46	2,542.70	3,236.78
	Great Lakes	-	-	3,197.31	3,197.31
	Kiama	-	-	512.60	512.60
	Lake Macquarie	5.96	15.28	2,097.99	2,119.24
	Lithgow	3.14	18.25	15,179.18	15,200.58
	Maitland	1.20	40.52	379.01	420.73
	Mid-western Regional	-	-	15,338.95	15,338.95
	Muswellbrook	140.20	3.25	140,336.80	140,480.25
	N/A	-	-	10.79	10.79
	Oberon	-	-	0.49	0.49
	Port Stephens	21.88	-	2,135.55	2,157.43
	Shellharbour	-	1.82	3,111.21	3,113.03
	Singleton	448.44	8.25	447,841.06	448,297.75
	Wingecarribee	0.67	633.12	1,068.08	1,701.88
	Wyong	0.95	41.89	1,195.05	1,237.89
Non Urban Total		645.02	1,446.98	641,140.52	643,232.51
Sydney	Ashfield	-	81.06	0.35	81.42
	Auburn	-	665.27	109.57	774.84
	Bankstown	389.69	4,107.0	2,941.86	7,438.55
	Baulkham Hills	2.22	224.61	1,539.81	1,766.65
	Blacktown	1.58	442.83	8,700.12	9,144.53
	Blue Mountains	-	-	35.98	35.98
	Botany Bay	456.66	249.39	4,383.73	5,089.79
	Camden	16.80	9.36	1,248.40	1,274.56
	Campbelltown	1.37	271.82	1,431.39	1,704.59
	Canterbury	-	38.35	8.60	46.95
	Fairfield	0.27	1,279.07	2,716.70	3,996.04
	Gosford	-	-	413.65	413.65
	Hawkesbury	2.92	156.98	733.63	893.53
	Holroyd	19.82	676.60	769.30	1,465.72
	Hornsby	5.78	1.02	130.29	137.10
	Ku-ring-gai	-	38.21	79.28	117.49
	Lane Cove	-	240.70	6.59	247.28
	Leichhardt	-	13.54	43.65	57.19
	Liverpool	10.71	1,667.26	3,214.06	4,892.03
	Manly	-	-	2.13	2.13
	Marrickville	-	0.24	672.04	672.28
	N/A	-	4.34	-	4.34
	North Sydney	-	-	3.56	3.56

Region	LGA	2008 fuel consumption (kL/year)			
		4-stroke petrol	LPG and CNG[25]	Diesel	Grand Total
	Parramatta	55.69	1,877.55	1,402.96	3,336.20
	Penrith	2.02	581.52	6,848.42	7,431.96
	Pittwater	-	1.97	1.87	3.84
	Randwick	2.24	52.53	333.87	388.64
	Rockdale	-	-	65.32	65.32
	Ryde	32.44	1,873.41	447.44	2,353.29
	Strathfield	-	56.76	224.75	281.51
	Sutherland	128.28	16.63	6,165.29	6,310.19
	Sydney	0.19	43.91	281.10	325.21
	Unincorporated	37.19	-	1,012.89	1,050.08
	Warringah	0.45	61.34	694.89	756.68
	Willoughby	-	-	544.81	544.81
	Wollondilly	1.10	468.99	4,114.98	4,585.07
	Wollongong	-	-	867.78	867.78
Sydney Total		1,167.42	15,202.27	52,191.05	68,560.74
Wollongong	N/A	-	-	156.32	156.32
	Shellharbour	-	-	472.75	472.75
	Wollongong	200.12	3,416.30	11,704.35	15,320.77
Wollongong Total		200.12	3,416.30	12,333.41	15,949.83
Grand Total		2,091.90	20,448.08	737,337.35	759,877.34

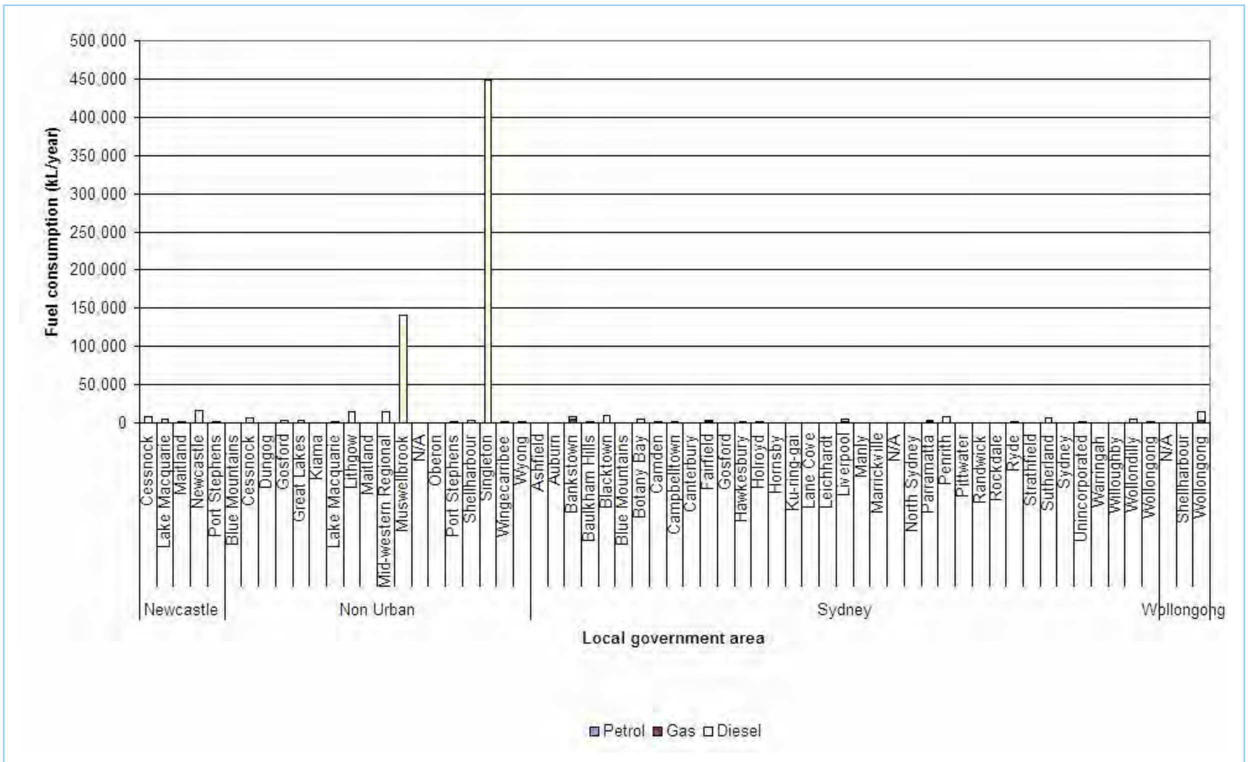

Figure 3-73: Industrial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption by LGA and region

Figure 3-74 shows industrial off-road vehicles and equipment petrol, gas (i.e. LPG and CNG) and diesel consumption by LGA and region for all LGA except Muswellbrook and Singleton.

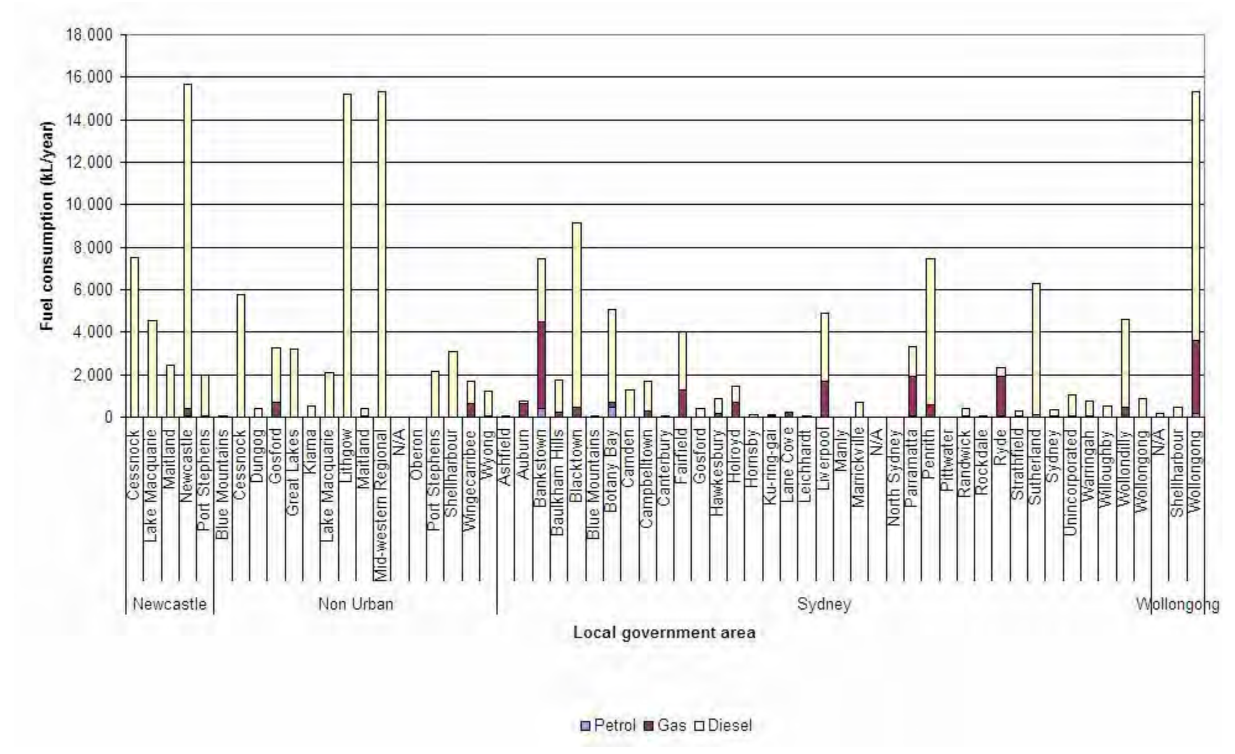

Figure 3-74: Industrial off-road vehicles and equipment spatial distribution of petrol, gas and diesel consumption for selected LGA and region

Figure 3-75 shows the spatial distribution of industrial off-road vehicles and equipment petrol exhaust and evaporative emissions.

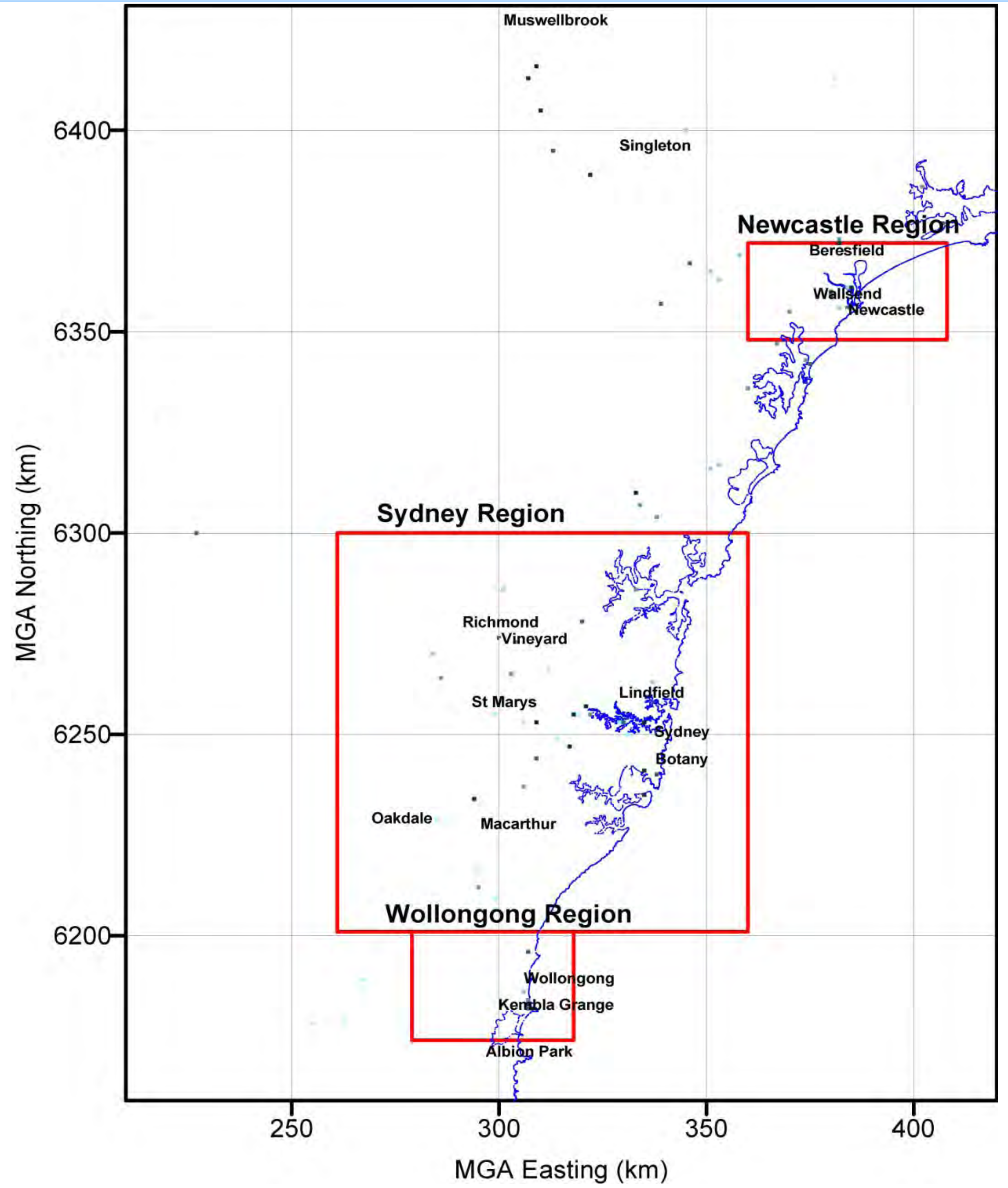

Figure 3-75: Industrial off-road vehicles and equipment petrol exhaust and evaporative emissions

Figure 3-76 shows the spatial distribution of industrial off-road vehicles and equipment gas (i.e. LPG and CNG) exhaust and evaporative emissions.

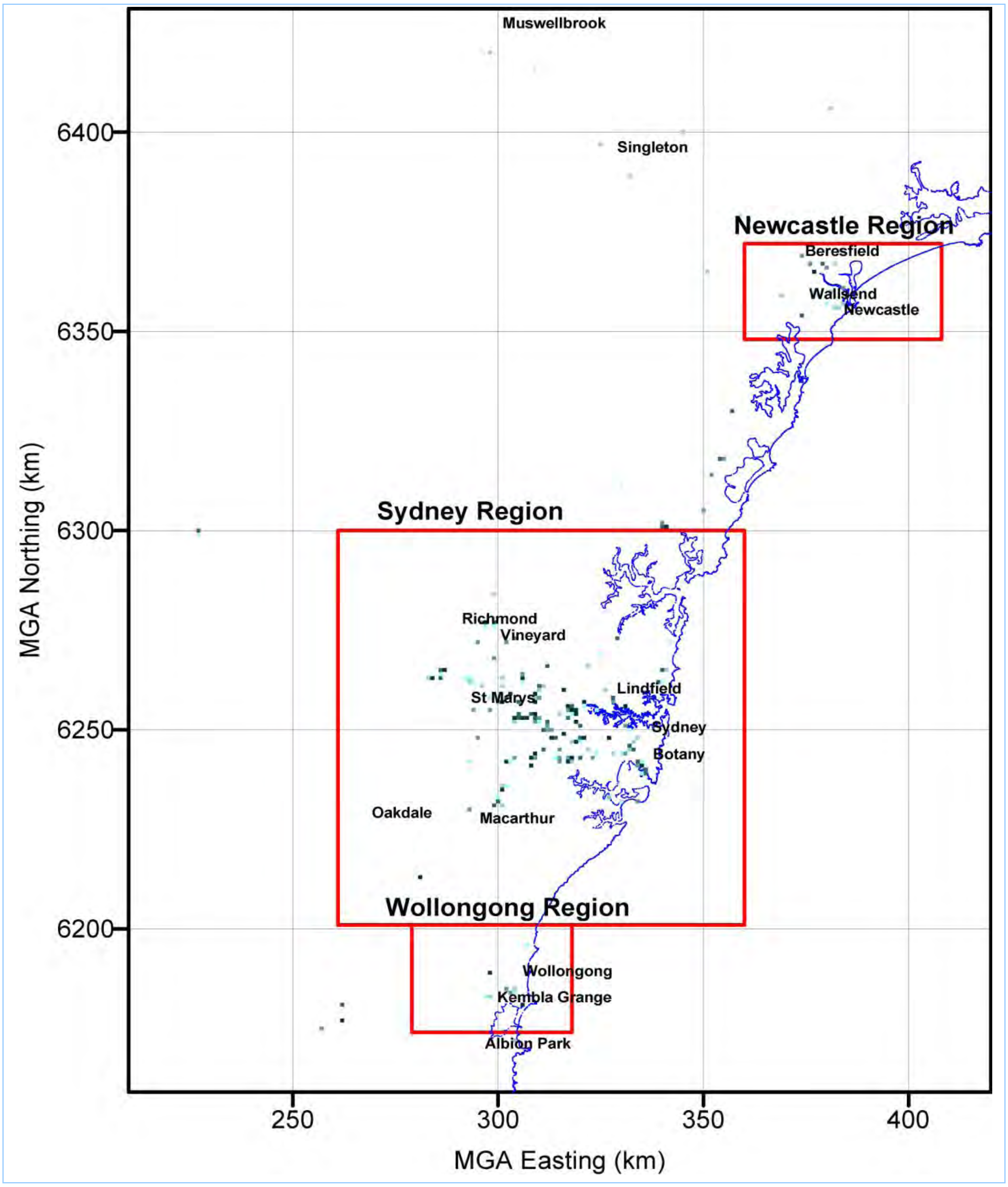

Figure 3-76: Industrial off-road vehicles and equipment gas exhaust and evaporative emissions

Figure 3-77 shows the spatial distribution of industrial off-road vehicles and equipment diesel exhaust and evaporative emissions.

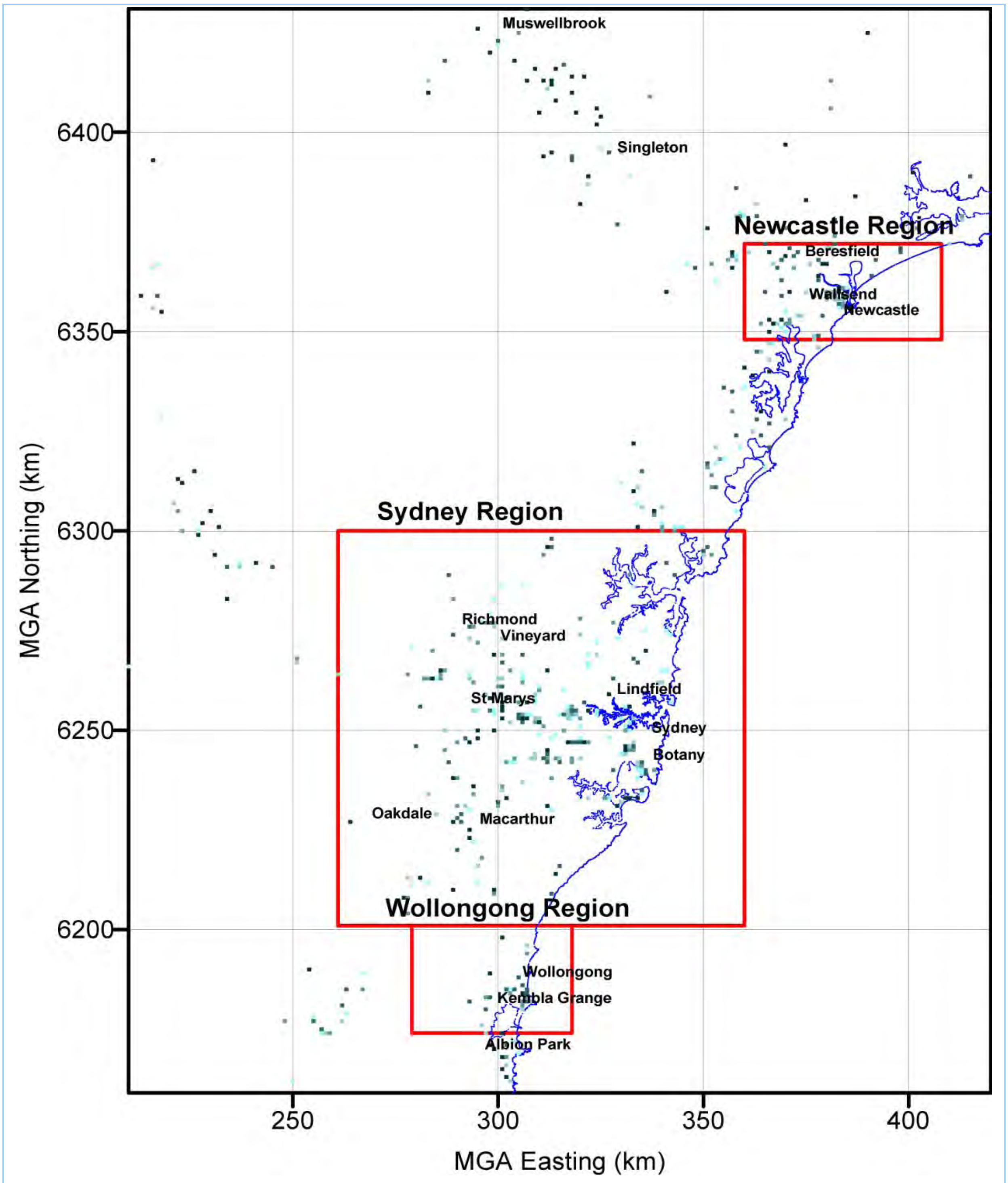

Figure 3-77: Industrial off-road vehicles and equipment diesel exhaust and evaporative emissions

3.4.6 Temporal Variation of Emissions

Table 3-102 summarises the data used to estimate the temporal variation in emissions from industrial off-road vehicles and equipment.

Table 3-102: Industrial off-road vehicles and equipment temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from industrial off-road vehicles and equipment	Monthly, daily and hourly: Derived from industrial off-road vehicles and equipment pollution survey	- *Industrial Off-Road Vehicles and Equipment Pollution Survey* (DECCW, 2009)

The temporal variation in exhaust and evaporative emissions from industrial off-road vehicles and equipment have been estimated using equipment population (DECCW, 2009), annual operating time (DECCW, 2009), fuel properties (Attorney-General's Department, 2003; Attorney-General's Department, 2008; Attorney-General's Department, 2009; and DRET, 2009), ambient temperature (Hurley, 2005) and daily and monthly temporal variation (DECCW, 2009) data within the *NONROAD2008a Model* (USEPA, 2009a). While the temporal variation in emissions is different for each of the 842 EPA-licensed premises, Figure 3-78, Figure 3-79 and Figure 3-80 show the hourly, daily and monthly variation in petrol, gas (i.e. LPG and CNG) and diesel consumption, respectively in the GMR for all 842 EPA-licensed premises.

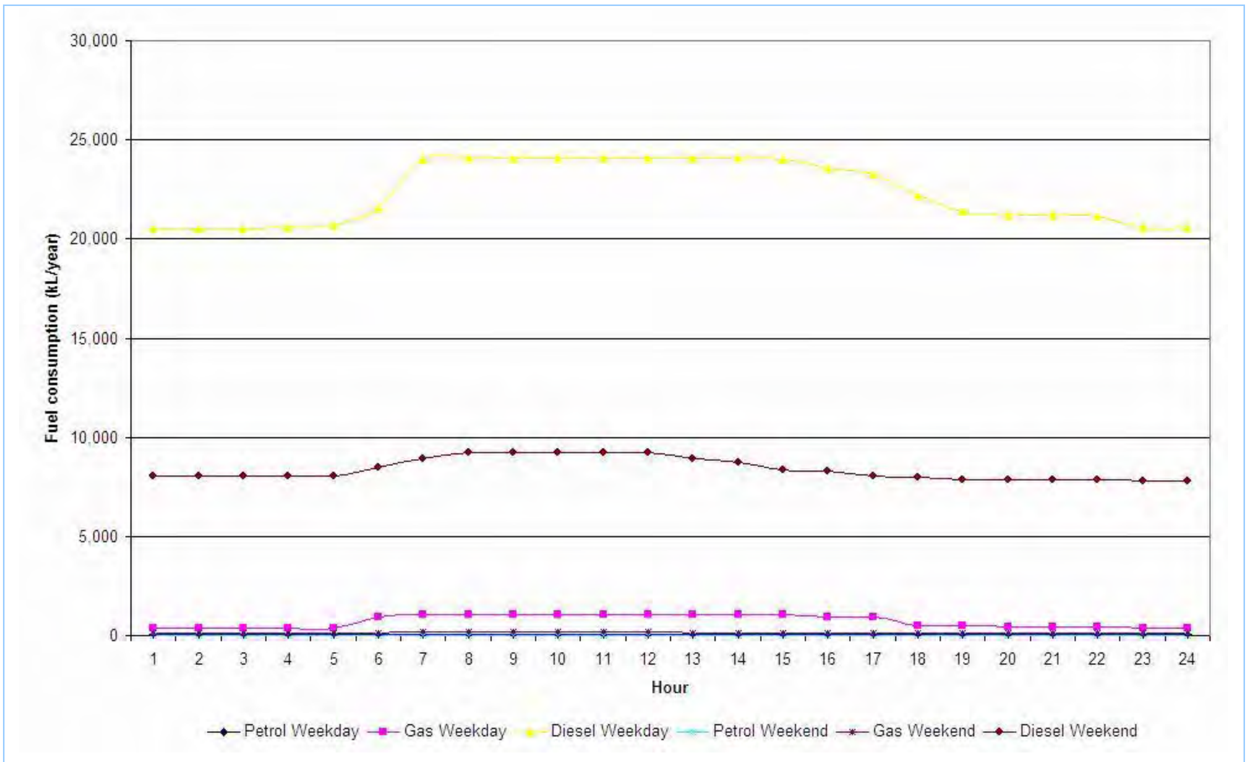

Figure 3-78: Industrial off-road vehicles and equipment hourly variation in petrol, gas and diesel consumption

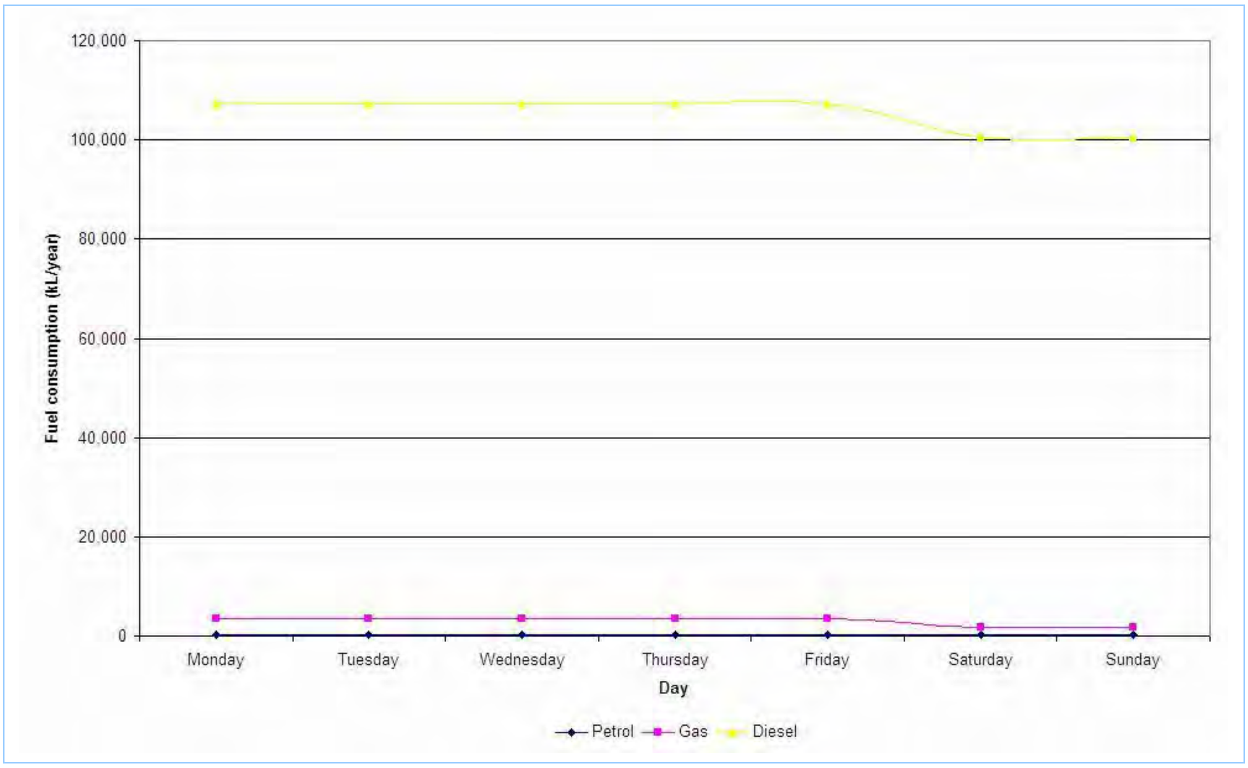

Figure 3-79: Industrial off-road vehicles and equipment daily variation in petrol, gas and diesel consumption

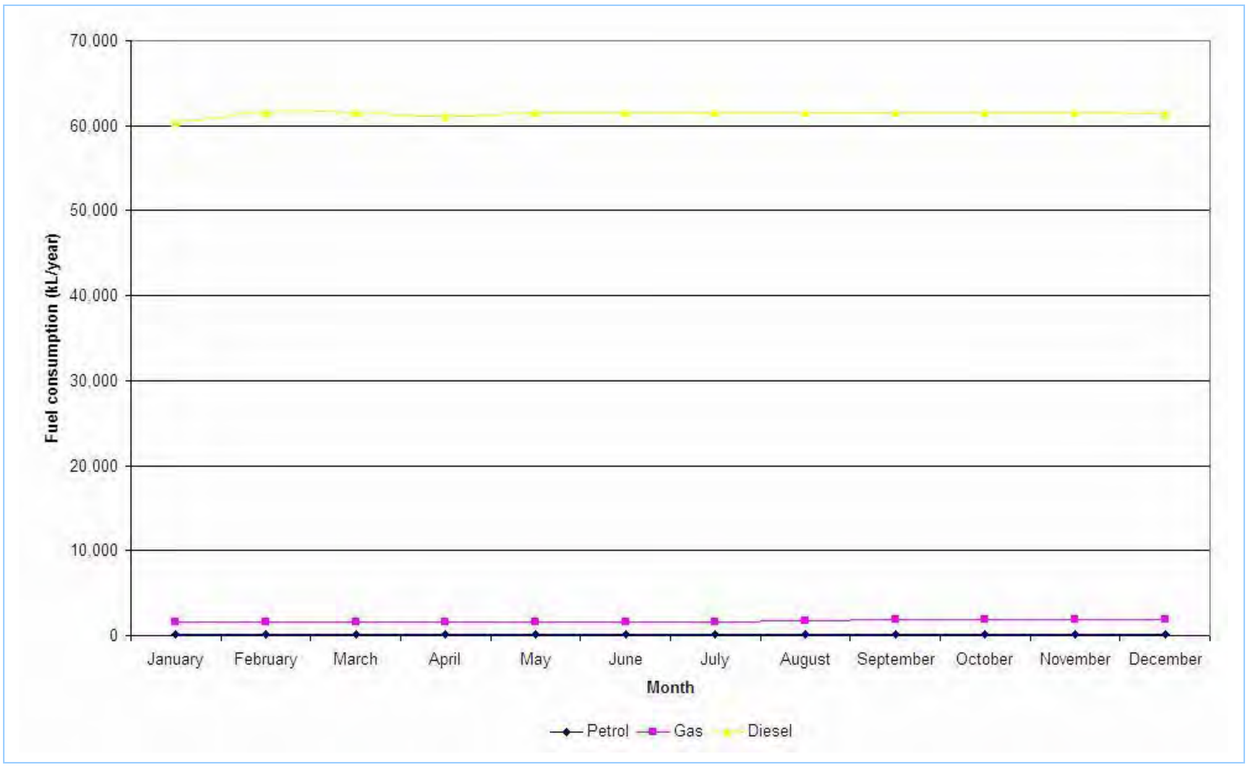

Figure 3-80: Industrial off-road vehicles and equipment monthly variation in petrol, gas and diesel consumption

3.4.7 Emission Estimates

Table 3-103 presents annual emissions of selected substances from industrial off-road vehicles and equipment by activity.

Table 3-103: Industrial off-road vehicles and equipment emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Industrial Vehicles and Equipment	1,3-BUTADIENE	272	5,063	952	192	6,478
	ACETALDEHYDE	6,792	136,552	13,162	3,075	159,581
	BENZENE	2,771	53,766	7,125	1,503	65,165
	CARBON MONOXIDE	815,569	15,361,071	3,484,256	769,950	20,430,847
	FORMALDEHYDE	15,339	304,905	37,300	8,620	366,164
	ISOMERS OF XYLENE	1,587	29,150	5,840	1,147	37,724
	LEAD & COMPOUNDS	3.09	58	10	2.05	73
	OXIDES OF NITROGEN	1,304,939	26,204,216	2,599,721	606,778	30,715,654
	PARTICULATE MATTER ≤ 10 µm	89,873	1,818,261	150,268	35,472	2,093,874
	PARTICULATE MATTER ≤ 2.5 µm	87,178	1,763,712	145,810	34,419	2,031,120
	PERCHLOROETHYLENE	1.38×10^{-2}	5.23×10^{-2}	0.55	0.12	0.74
	POLYCYCLIC AROMATIC HYDROCARBONS	96	1,900	235	53	2,284
	SULFUR DIOXIDE	2,676	53,346	6,095	1,407	63,525
	TOLUENE	2,159	40,530	7,020	1,411	51,120
	TOTAL SUSPENDED PARTICULATE	93,616	1,894,012	156,441	36,930	2,180,999
	TOTAL VOLATILE ORGANIC COMPOUNDS	133,174	2,606,702	371,875	83,170	3,194,920

Table 3-104 presents annual emissions of selected substances from industrial off-road vehicles and equipment by source type.

Table 3-104: Industrial off-road vehicles and equipment emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Petrol	1,3-BUTADIENE	34	278	504	86	903
	ACETALDEHYDE	15	120	217	37	389
	BENZENE	189	1,534	2,777	476	4,976
	CARBON MONOXIDE	34,568	281,035	508,650	87,194	911,447
	FORMALDEHYDE	62	502	908	156	1,626
	ISOMERS OF XYLENE	244	1,983	3,588	615	6,430
	LEAD & COMPOUNDS	0.40	3.23	5.84	1.00	10
	OXIDES OF NITROGEN	2,680	21,788	39,435	6,760	70,664
	PARTICULATE MATTER ≤	15	126	228	39	408

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	10 µm					
	PARTICULATE MATTER ≤ 2.5 µm	14	116	209	36	375
	POLYCYCLIC AROMATIC HYDROCARBONS	1.60	13	24	4.04	42
	SULFUR DIOXIDE	16	128	232	40	416
	TOLUENE	258	2,101	3,802	652	6,813
	TOTAL SUSPENDED PARTICULATE	16	130	235	40	420
	TOTAL VOLATILE ORGANIC COMPOUNDS	3,597	29,242	52,926	9,073	94,838
Diesel	1,3-BUTADIENE	236	4,779	389	92	5,496
	ACETALDEHYDE	6,731	136,256	11,092	2,621	156,700
	BENZENE	2,580	52,223	4,251	1,005	60,058
	CARBON MONOXIDE	736,671	14,912,355	1,213,917	286,864	17,149,807
	FORMALDEHYDE	14,983	303,290	24,689	5,834	348,796
	ISOMERS OF XYLENE	1,342	27,164	2,211	523	31,240
	LEAD & COMPOUNDS	2.69	55	4.44	1.05	63
	OXIDES OF NITROGEN	1,291,381	26,141,281	2,127,990	502,871	30,063,523
	PARTICULATE MATTER ≤ 10 µm	89,806	1,817,939	147,987	34,971	2,090,703
	PARTICULATE MATTER ≤ 2.5 µm	87,112	1,763,401	143,547	33,922	2,027,982
	POLYCYCLIC AROMATIC HYDROCARBONS	93	1,881	153	36	2,163
	SULFUR DIOXIDE	2,622	53,071	4,320	1,021	61,034
	TOLUENE	1,898	38,420	3,128	739	44,185
	TOTAL SUSPENDED PARTICULATE	93,548	1,893,687	154,153	36,428	2,177,816
	TOTAL VOLATILE ORGANIC COMPOUNDS	126,809	2,566,990	208,962	49,380	2,952,142
Gas	1,3-BUTADIENE	1.49	5.63	59	13	80
	ACETALDEHYDE	47	176	1,853	416	2,493
	BENZENE	2.45	9.28	98	22	131
	CARBON MONOXIDE	44,330	167,681	1,761,689	395,892	2,369,592
	FORMALDEHYDE	295	1,114	11,704	2,630	15,742
	ISOMERS OF XYLENE	1.03	3.88	41	9.17	55
	OXIDES OF NITROGEN	10,878	41,147	432,296	97,147	581,467
	PARTICULATE MATTER ≤ 10 µm	52	195	2,054	462	2,763
	PARTICULATE MATTER ≤ 2.5 µm	52	195	2,054	462	2,763
	PERCHLOROETHYLENE	1.38×10^{-2}	5.23×10^{-2}	0.55	0.12	0.74
	POLYCYCLIC AROMATIC HYDROCARBONS	1.47	5.55	58	13	78
	SULFUR DIOXIDE	39	147	1,543	347	2,075

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOLUENE	2.28	8.61	90	20	122
	TOTAL SUSPENDED PARTICULATE	52	195	2,054	462	2,763
	TOTAL VOLATILE ORGANIC COMPOUNDS	2,768	10,469	109,987	24,717	147,940

Table 3-105 presents annual emissions of selected substances from industrial off-road vehicles and equipment by POEO scheduled activity.

Table 3-105: Industrial off-road vehicles and equipment emissions by POEO scheduled activity

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
Newcastle	Industrial Vehicles and Equipment – Petrol	Boat construction/maintenance (dry/float)	1,213	94	0.54	0.50	0.55	126
		Cement or lime handling	212	16	9.49×10^{-2}	8.73×10^{-2}	9.69×10^{-2}	22
		Coal works	29,261	2,269	13	12	13	3,045
		Iron or steel production (scrap metal)	2,444	190	1.09	1.01	1.12	254
		Metal processing	928	72	0.42	0.38	0.42	97
		Sewage treatment - large plants	510	40	0.23	0.21	0.23	53
	Industrial Vehicles and Equipment - Petrol Total		34,568	2,680	15	14	16	3,597
	Industrial Vehicles and Equipment – Diesel	Agricultural fertiliser (phosphate) production	983	1,724	120	116	3.50	169
		Aluminium production (alumina)	25,382	44,494	3,094	3,001	90	4,369
		Ammonium nitrate production	1,944	3,407	237	230	6.92	335
		Bitumen mixing	2,378	4,169	290	281	8.46	409
		Boat construction/maintenance (dry/float)	1,148	2,012	140	136	4.09	198
		Boat construction/maintenance (general)	46	80	5.58	5.41	0.16	7.87
		Cement or lime handling	412	722	50	49	1.46	71
		Chemical production	22	38	2.68	2.60	7.81×10^{-2}	3.78
		Coal works	191,445	335,603	23,339	22,639	681	32,955
		Concrete works	10,443	18,306	1,273	1,235	37	1,798
		Contaminated soil treatment	3,833	6,719	467	453	14	660
		Crushing, grinding or	9,321	16,339	1,136	1,102	33	1,604

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		separating						
		Dairy processing	92	162	11	11	0.33	16
		General agricultural processing	77	135	9.42	9.14	0.28	13
		General chemicals storage	91	160	11	11	0.33	16
		Hazardous, industrial or group A waste G	91	160	11	11	0.33	16
		Iron or steel production (scrap metal)	11,685	20,483	1,424	1,382	42	2,011
		Land-based extractive activity	21,099	36,986	2,572	2,495	75	3,632
		Metal plating or coating	5,570	9,765	679	659	20	959
		Metal processing	2,756	4,831	336	326	9.81	474
		Mining for coal	307,108	538,358	37,439	36,316	1,093	52,865
		Non-thermal treatment of waste	3,948	6,922	481	467	14	680
		Other land-based extraction	7,523	13,188	917	890	27	1,295
		Petroleum products storage	133	233	16	16	0.47	23
		Recovery of waste	5,374	9,420	655	635	19	925
		Scrap metal processing	16,212	28,420	1,976	1,917	58	2,791
		Sewage treatment - large plants	14	25	1.72	1.66	5.01×10^{-2}	2.42
		Sewage treatment - small plants	160	281	20	19	0.57	28
		Shipping in bulk	10,788	18,912	1,315	1,276	38	1,857
		Slaughtering or processing of animals	1,493	2,618	182	177	5.31	257
		Waste disposal (application to land)	5,031	8,819	613	595	18	866
		Waste storage	309	541	38	37	1.10	53
		Water-based extractive activity	89,761	157,351	10,943	10,614	319	15,451
	Industrial Vehicles and Equipment - Diesel Total		736,671	1,291,381	89,806	87,112	2,622	126,809

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
	Industrial Vehicles and Equipment – Gas	Ammonium nitrate production	20,508	5,032	24	24	18	1,280
		Boat construction/maintenance (general)	518	127	0.60	0.60	0.45	32
		Chemical production	2,258	554	2.63	2.63	1.98	141
		Contaminated soil treatment	1,104	271	1.29	1.29	0.97	69
		Dairy processing	1,455	357	1.70	1.70	1.27	91
		General agricultural processing	2,930	719	3.42	3.42	2.57	183
		Metal plating or coating	11,726	2,877	14	14	10	732
		Non-thermal treatment of waste	343	84	0.40	0.40	0.30	21
		Printing, packaging and visual media production	669	164	0.78	0.78	0.59	42
		Sewage treatment - large plants	459	113	0.54	0.54	0.40	29
		Shipping in bulk	230	56	0.27	0.27	0.20	14
		Slaughtering or processing of animals	2,072	508	2.42	2.42	1.81	129
		Waste storage	55	14	6.45×10^{-2}	6.45×10^{-2}	4.85×10^{-2}	3.46
	Industrial Vehicles and Equipment - Gas Total		44,330	10,878	52	52	39	2,768
Newcastle Total			815,569	1,304,939	89,873	87,178	2,676	133,174
Non Urban	Industrial Vehicles and Equipment – Petrol	Animal accommodation	551	43	0.25	0.23	0.25	57
		Bird accommodation	424	33	0.19	0.17	0.19	44
		Boat mooring and storage	636	49	0.28	0.26	0.29	66
		Concrete works	170	13	7.59×10^{-2}	6.98×10^{-2}	7.75×10^{-2}	18
		Crushing, grinding or separating	1,327	103	0.59	0.55	0.61	138
		Generation of electrical power from coal	61,085	4,736	27	25	28	6,356
		Helicopter-related activity	42	3.29	1.90×10^{-2}	1.75×10^{-2}	1.94×10^{-2}	4.41

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Land-based extractive activity	12,749	988	5.70	5.25	5.82	1,327
		Mining for coal	194,682	15,094	87	80	89	20,257
		Miscellaneous licensed discharges to waters (at any time)	36	2.80	1.61×10^{-2}	1.48×10^{-2}	1.65×10^{-2}	3.75
		Rendering or fat extraction	175	14	7.84×10^{-2}	7.21×10^{-2}	8.0×10^{-2}	18
		Sewage treatment - large plants	1,653	128	0.74	0.68	0.75	172
		Sewage treatment - small plants	7,292	565	3.26	3.00	3.33	759
		Water-based extractive activity	212	16	9.49×10^{-2}	8.73×10^{-2}	9.69×10^{-2}	22
	Industrial Vehicles and Equipment - Petrol Total		281,035	21,788	126	116	128	29,242
	Industrial Vehicles and Equipment – Diesel	Aluminium production (alumina)	78,101	136,911	9,521	9,236	278	13,444
		Aluminium production (scrap metal)	3,682	6,454	449	435	13	634
		Animal accommodation	167	293	20	20	0.59	29
		Bird accommodation	384	673	47	45	1.37	66
		Bitumen mixing	336	589	41	40	1.20	58
		Cement or lime handling	4,253	7,456	518	503	15	732
		Cement or lime production	5,966	10,458	727	705	21	1,027
		Ceramics production	4,669	8,184	569	552	17	804
		Chemical production	2,791	4,892	340	330	9.93	480
		Coal works	14,824	25,987	1,807	1,753	53	2,552
		Composting	16,080	28,188	1,960	1,901	57	2,768
		Concrete works	20,539	36,005	2,504	2,429	73	3,536
		Crushing, grinding or separating	2,490	4,366	304	294	8.86	429
		Explosives production	646	1,133	79	76	2.30	111

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		General agricultural processing	450	789	55	53	1.60	77
		General animal products production	17	30	2.09	2.03	6.10×10^{-2}	2.95
		General chemicals storage	23	40	2.79	2.70	8.14×10^{-2}	3.94
		Generation of electrical power from coal	50,406	88,362	6,145	5,961	179	8,677
		Helicopter-related activity	4.57	8.02	0.56	0.54	1.63×10^{-2}	0.79
		Inert waste landfilling	1,699	2,978	207	201	6.05	292
		Land-based extractive activity	226,410	396,896	27,601	26,773	806	38,974
		Metal plating or coating	186	326	23	22	0.66	32
		Mining for coal	14,414,417	25,268,398	1,757,237	1,704,520	51,299	2,481,276
		Mining for minerals	26,024	45,620	3,173	3,077	93	4,480
		Miscellaneous licensed discharges to waters (at any time)	26	45	3.15	3.06	9.20×10^{-2}	4.45
		Non-thermal treatment of waste	306	537	37	36	1.09	53
		Other land-based extraction	6,288	11,023	767	744	22	1,082
		Pesticides and related products production	9.15	16	1.12	1.08	3.26×10^{-2}	1.57
		Petroleum products and fuel production	11	20	1.39	1.35	4.07×10^{-2}	1.97
		Pharmaceutical and veterinary products production	9.15	16	1.12	1.08	3.26×10^{-2}	1.57
		Recovery of waste	1,162	2,036	142	137	4.13	200
		Rendering or fat extraction	76	134	9.31	9.03	0.27	13
		Sewage treatment - large plants	72	127	8.83	8.57	0.26	12
		Sewage treatment - small plants	978	1,715	119	116	3.48	168

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Slaughtering or processing of animals	11	20	1.39	1.35	4.07×10^{-2}	1.97
		Solid waste landfilling	5,962	10,451	727	705	21	1,026
		Waste disposal (application to land)	13,406	23,500	1,634	1,585	48	2,308
		Water-based extractive activity	7,717	13,529	941	913	27	1,328
		Wood or timber milling or processing	1,753	3,074	214	207	6.24	302
	Industrial Vehicles and Equipment - Diesel Total		14,912,355	26,141,281	1,817,939	1,763,401	53,071	2,566,990
	Industrial Vehicles and Equipment – Gas	Ceramics production	2,228	547	2.60	2.60	1.95	139
		Chemical production	3,091	759	3.60	3.60	2.71	193
		Composting	1,001	246	1.17	1.17	0.88	62
		Concrete works	76,548	18,784	89	89	67	4,779
		Crushing, grinding or separating	2,096	514	2.44	2.44	1.83	131
		General agricultural processing	2,601	638	3.03	3.03	2.28	162
		General animal products production	1,185	291	1.38	1.38	1.04	74
		General chemicals storage	1,198	294	1.40	1.40	1.05	75
		Generation of electrical power from coal	30	7.46	3.54×10^{-2}	3.54×10^{-2}	2.66×10^{-2}	1.90
		Metal plating or coating	70,139	17,211	82	82	61	4,379
		Mining for coal	366	90	0.43	0.43	0.32	23
		Non-thermal treatment of waste	2,936	720	3.42	3.42	2.57	183
		Recovery of waste	1,771	435	2.06	2.06	1.55	111
		Recovery of waste oil	5.53	1.36	6.45×10^{-3}	6.45×10^{-3}	4.85×10^{-3}	0.35
		Rendering or fat extraction	421	103	0.49	0.49	0.37	26

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Sewage treatment - small plants	1,547	380	1.80	1.80	1.35	97
		Wood or timber milling or processing	519	127	0.60	0.60	0.45	32
	Industrial Vehicles and Equipment – Gas Total		167,681	41,147	195	195	147	10,469
Non Urban Total			15,361,071	26,204,216	1,818,261	1,763,712	53,346	2,606,702
Sydney	Industrial Vehicles and Equipment – Petrol	Boat construction/maintenance (general)	14,596	1,132	6.53	6.01	6.67	1,519
		Boat mooring and storage	21	1.64	9.49×10^{-3}	8.73×10^{-3}	9.69×10^{-3}	2.21
		Chemical production	14,135	1,096	6.32	5.82	6.45	1,471
		Concrete works	9,150	709	4.09	3.77	4.18	952
		Container reconditioning	212	16	9.49×10^{-2}	8.73×10^{-2}	9.69×10^{-2}	22
		Contaminated soil treatment	2,376	184	1.06	0.98	1.08	247
		Hazardous, industrial or group A waste D	55	4.28	2.47×10^{-2}	2.27×10^{-2}	2.52×10^{-2}	5.74
		Land-based extractive activity	56,102	4,350	25	23	26	5,838
		Metal plating or coating	53	4.11	2.37×10^{-2}	2.18×10^{-2}	2.42×10^{-2}	5.52
		Non-thermal treatment of waste	196	15	8.77×10^{-2}	8.07×10^{-2}	8.95×10^{-2}	20
		Petrochemical production	198,968	15,426	89	82	91	20,703
		Petroleum products and fuel production	24,179	1,875	11	9.95	11	2,516
		Pharmaceutical and veterinary products production	109	8.42	4.86×10^{-2}	4.47×10^{-2}	4.96×10^{-2}	11
		Plastics resins production	85	6.58	3.80×10^{-2}	3.49×10^{-2}	3.87×10^{-2}	8.83
		Railway systems activities	169,680	13,155	76	70	77	17,656
		Rendering or fat extraction	916	71	0.41	0.38	0.42	95
		Sewage treatment - large plants	7,596	589	3.40	3.13	3.47	790
		Sewage treatment - small plants	10,194	790	4.56	4.20	4.66	1,061

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Waste storage	25	1.97	1.14×10^{-2}	1.05×10^{-2}	1.16×10^{-2}	2.65
	Industrial Vehicles and Equipment - Petrol Total		508,650	39,435	228	209	232	52,926
	Industrial Vehicles and Equipment – Diesel	Aluminium production (scrap metal)	7,500	13,148	914	887	27	1,291
		Bird accommodation	6,024	10,559	734	712	21	1,037
		Bitumen mixing	5,378	9,428	656	636	19	926
		Boat construction/maintenance (dry/float)	30	52	3.62	3.52	0.11	5.12
		Boat construction/maintenance (general)	777	1,361	95	92	2.76	134
		Boat mooring and storage	32	56	3.90	3.79	0.11	5.51
		Cement or lime handling	8,400	14,725	1,024	993	30	1,446
		Cement or lime production	22,592	39,604	2,754	2,672	80	3,889
		Ceramics production	24,310	42,615	2,964	2,875	87	4,185
		Chemical production	23,205	40,679	2,829	2,744	83	3,995
		Chemical storage	23	40	2.79	2.70	8.14×10^{-2}	3.94
		Coke production	1,692	2,966	206	200	6.02	291
		Composting	97,941	171,691	11,940	11,582	349	16,859
		Concrete works	20,523	35,977	2,502	2,427	73	3,533
		Container reconditioning	23	40	2.79	2.70	8.14×10^{-2}	3.94
		Contaminated soil treatment	17,584	30,825	2,144	2,079	63	3,027
		Crushing, grinding or separating	78,314	137,283	9,547	9,261	279	13,481
		Dairy animal accommodation	1,322	2,317	161	156	4.70	228
		General agricultural processing	11	19	1.34	1.30	3.91×10^{-2}	1.89
		General chemicals storage	98,917	173,402	12,059	11,697	352	17,028
		Generation of electricity not coal	204	357	25	24	0.73	35

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		or gas						
		Glass production (container)	1,075	1,884	131	127	3.82	185
		Glass production (float)	830	1,455	101	98	2.95	143
		Hazardous, industrial or group A waste D	580	1,017	71	69	2.07	100
		Iron or steel production (scrap metal)	4,324	7,580	527	511	15	744
		Land-based extractive activity	44,678	78,320	5,447	5,283	159	7,691
		Metal plating or coating	455	797	55	54	1.62	78
		Metal processing	1,943	3,406	237	230	6.92	334
		Mining for coal	73,383	128,640	8,946	8,678	261	12,632
		Miscellaneous licensed discharges to waters (at any time)	72,556	127,190	8,845	8,580	258	12,490
		Non-ferrous metal production (scrap)	1,143	2,004	139	135	4.07	197
		Non-thermal treatment of waste	62,159	108,964	7,578	7,350	221	10,700
		Other land-based extraction	187,758	329,138	22,889	22,203	668	32,320
		Paints/polishes/adhesives production	2,752	4,825	336	325	9.80	474
		Paper or pulp production	11,799	20,684	1,438	1,395	42	2,031
		Pesticides and related products production	4.57	8.02	0.56	0.54	1.63×10^{-2}	0.79
		Petrochemical production	3,700	6,486	451	438	13	637
		Petroleum products and fuel production	6,380	11,184	778	754	23	1,098
		Petroleum products storage	844	1,480	103	100	3.00	145

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Pharmaceutical and veterinary products production	2,472	4,334	301	292	8.80	426
		Pig accommodation	5.72	10	0.70	0.68	2.03×10^{-2}	0.98
		Plastics resins production	55	96	6.69	6.49	0.20	9.45
		Printing, packaging and visual media production	78	136	9.48	9.19	0.28	13
		Railway systems activities	52,136	91,394	6,356	6,165	186	8,975
		Recovery of waste	35,505	62,239	4,328	4,198	126	6,112
		Recovery of waste oil	37	64	4.46	4.33	0.13	6.30
		Rendering or fat extraction	1,432	2,511	175	169	5.10	247
		Road construction	8,598	15,072	1,048	1,017	31	1,480
		Scrap metal processing	27,188	47,661	3,314	3,215	97	4,680
		Sewage treatment - large plants	2,806	4,918	342	332	9.99	483
		Sewage treatment - small plants	2,849	4,995	347	337	10	490
		Shipping in bulk	986	1,728	120	117	3.51	170
		Slaughtering or processing of animals	3,399	5,959	414	402	12	585
		Soap and detergent production	830	1,455	101	98	2.95	143
		Solid waste landfilling	183	321	22	22	0.65	31
		Waste disposal (application to land)	165,076	289,378	20,124	19,520	587	28,416
		Waste storage	6,813	11,943	831	806	24	1,173
		Water-based extractive activity	12,303	21,568	1,500	1,455	44	2,118
	Industrial Vehicles and Equipment - Diesel Total		1,213,917	2,127,990	147,987	143,547	4,320	208,962
	Industrial Vehicles and Equipment - Gas	Aluminium production (scrap metal)	1,063	261	1.24	1.24	0.93	66
		Battery production	415,671	102,000	485	485	364	25,951

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Bitumen mixing	68	17	7.90×10^{-2}	7.90×10^{-2}	5.94×10^{-2}	4.23
		Boat construction/maintenance (general)	5,097	1,251	5.94	5.94	4.46	318
		Brewing and distilling	39,405	9,670	46	46	35	2,460
		Cement or lime handling	2,797	686	3.26	3.26	2.45	175
		Cement or lime production	54,348	13,336	63	63	48	3,393
		Ceramics production	21,947	5,386	26	26	19	1,370
		Chemical production	449,365	110,268	524	524	393	28,055
		Chemical storage	7.75	1.90	9.03×10^{-3}	9.03×10^{-3}	6.78×10^{-3}	0.48
		Composting	8,218	2,017	9.58	9.58	7.20	513
		Concrete works	27,030	6,633	32	32	24	1,688
		Container reconditioning	10,109	2,481	12	12	8.85	631
		Crushing, grinding or separating	5,772	1,416	6.73	6.73	5.05	360
		Dairy processing	5,156	1,265	6.01	6.01	4.52	322
		General agricultural processing	31,938	7,837	37	37	28	1,994
		General animal products production	15,994	3,925	19	19	14	999
		General chemicals storage	20,911	5,131	24	24	18	1,306
		Generation of electrical power from gas	28	6.79	3.23×10^{-2}	3.23×10^{-2}	2.42×10^{-2}	1.73
		Glass production (container)	11,661	2,862	14	14	10	728
		Glass production (float)	2,450	601	2.86	2.86	2.15	153
		Hazardous, industrial or group A waste G	221	54	0.26	0.26	0.19	14
		Iron or steel production (scrap metal)	26,888	6,598	31	31	24	1,679

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Metal plating or coating	122,788	30,131	143	143	108	7,666
		Metal processing	677	166	0.79	0.79	0.59	42
		Non-thermal treatment of waste	12,087	2,966	14	14	11	755
		Paints/polishes/adhesives production	12,965	3,182	15	15	11	809
		Paper or pulp production	21,474	5,269	25	25	19	1,341
		Paper production using recycle materials	92,978	22,816	108	108	81	5,805
		Pesticides and related products production	599	147	0.70	0.70	0.52	37
		Petrochemical production	17,766	4,359	21	21	16	1,109
		Petroleum products and fuel production	210,281	51,600	245	245	184	13,128
		Petroleum products storage	3,338	819	3.89	3.89	2.92	208
		Pharmaceutical and veterinary products production	2,595	637	3.03	3.03	2.27	162
		Plastics resins production	23,039	5,654	27	27	20	1,438
		Printing, packaging and visual media production	44,369	10,888	52	52	39	2,770
		Recovery of waste	452	111	0.53	0.53	0.40	28
		Recovery of waste oil	764	187	0.89	0.89	0.67	48
		Recovery of waste tyres	841	206	0.98	0.98	0.74	53
		Rendering or fat extraction	1,094	268	1.27	1.27	0.96	68
		Rubber products/tyre production	2,546	625	2.97	2.97	2.23	159
		Scrap metal processing	6,022	1,478	7.02	7.02	5.27	376
		Sewage treatment - large plants	539	132	0.63	0.63	0.47	34

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 μm	PARTICULATE MATTER ≤ 2.5 μm	SULFUR DIOXIDE	TOTAL VOC
		Slaughtering or processing of animals	17,257	4,235	20	20	15	1,077
		Soap and detergent production	8,029	1,970	9.36	9.36	7.03	501
		Sterilisation activities	40	9.91	4.71×10^{-2}	4.71×10^{-2}	3.54×10^{-2}	2.52
		Waste storage	3,004	737	3.50	3.50	2.63	188
	Industrial Vehicles and Equipment - Gas Total		1,761,689	432,296	2,054	2,054	1,543	109,987
Sydney Total			3,484,256	2,599,721	150,268	145,810	6,095	371,875
Wollongong	Industrial Vehicles and Equipment – Petrol	Concrete works	2,121	164	0.95	0.87	0.97	221
		General chemicals storage	2,121	164	0.95	0.87	0.97	221
		Metal plating or coating	42,420	3,289	19	17	19	4,414
		Metal processing	39,875	3,091	18	16	18	4,149
		Shipping in bulk	658	51	0.29	0.27	0.30	68
	Industrial Vehicles and Equipment - Petrol Total		87,194	6,760	39	36	40	9,073
	Industrial Vehicles and Equipment – Diesel	Bitumen mixing	2,414	4,231	294	285	8.59	416
		Cement or lime handling	155	273	19	18	0.55	27
		Cement or lime production	755	1,323	92	89	2.69	130
		Coal washery reject or slag landfilling	171	301	21	20	0.61	30
		Coal works	3,636	6,374	443	430	13	626
		Coke production	800	1,403	98	95	2.85	138
		Concrete works	7,252	12,713	884	858	26	1,248
		Contaminated soil treatment	389	681	47	46	1.38	67
		Crushing, grinding or separating	1,143	2,004	139	135	4.07	197
		General chemicals storage	119	208	14	14	0.42	20
		Iron or steel production (iron ore)	201,569	353,349	24,573	23,836	717	34,698

Region	Source type	POEO scheduled activity	Emissions (kg/year)					
			CARBON MONOXIDE	OXIDES OF NITROGEN	PARTICULATE MATTER ≤ 10 µm	PARTICULATE MATTER ≤ 2.5 µm	SULFUR DIOXIDE	TOTAL VOC
		Metal plating or coating	6,745	11,824	822	798	24	1,161
		Metal processing	972	1,704	118	115	3.46	167
		Mining for coal	34,745	60,908	4,236	4,109	124	5,981
		Road construction	10,907	19,121	1,330	1,290	39	1,878
		Scrap metal processing	2,195	3,848	268	260	7.81	378
		Sewage treatment - large plants	34	60	4.19	4.06	0.12	5.92
		Shipping in bulk	6,845	11,999	834	809	24	1,178
		Waste disposal (application to land)	4,036	7,075	492	477	14	695
		Waste storage	137	241	17	16	0.49	24
		Water-based extractive activity	1,844	3,232	225	218	6.56	317
	Industrial Vehicles and Equipment - Diesel Total		286,864	502,871	34,971	33,922	1,021	49,380
	Industrial Vehicles and Equipment - Gas	Chemical production	79	19	9.24×10^{-2}	9.24×10^{-2}	6.94×10^{-2}	4.95
		Container reconditioning	90	22	0.11	0.11	7.91×10^{-2}	5.64
		Metal plating or coating	6,221	1,526	7.25	7.25	5.45	388
		Metal processing	22	5.43	2.58×10^{-2}	2.58×10^{-2}	1.94×10^{-2}	1.38
		Mining for coal	387,410	95,065	452	452	339	24,187
		Non-thermal treatment of waste	2,070	508	2.41	2.41	1.81	129
	Industrial Vehicles and Equipment - Gas Total		395,892	97,147	462	462	347	24,717
Wollongong Total			769,950	606,778	35,472	34,419	1,407	83,170
Grand Total			20,430,847	30,715,654	2,093,874	2,031,120	63,525	3,194,920

3.4.8 Emission Projection Methodology

Table 3-106 summarises the data used to estimate the emission projection factors for industrial off-road vehicles and equipment, while Figure 3-81 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-106: Industrial off-road vehicles and equipment emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from industrial off-road vehicles and equipment	Final energy consumption for manufacturing & construction and mining using liquid petroleum gas, petroleum and natural gas	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

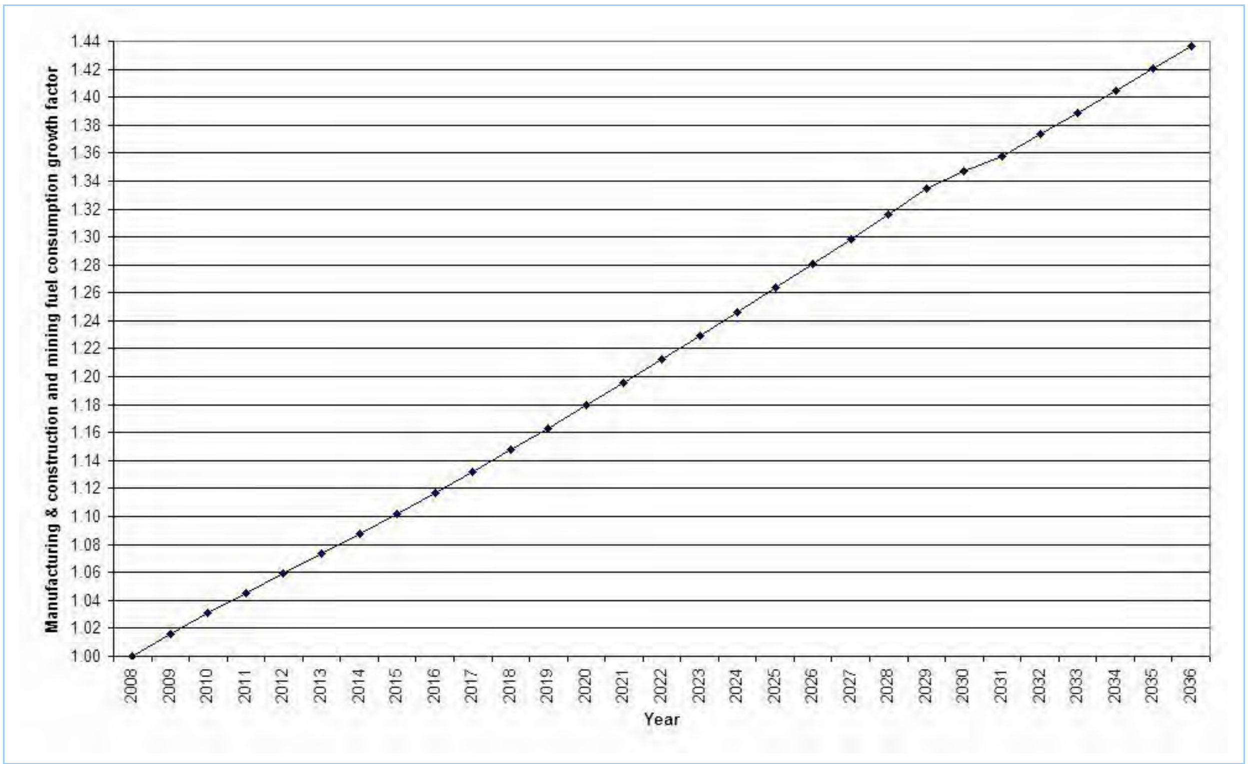

Figure 3-81: Industrial off-road vehicles and equipment emission projection factors

3.5 Locomotives

3.5.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of combustion products (i.e. exhaust) from diesel fuelled:

- Large line-hail locomotives; and
- Passenger locomotives.

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

- *Locomotive type, gross tonne kilometres and diesel consumption*

While locomotives include large line-haul, passenger, small line-hail and switching services (USEPA, 2009b), the inventory allocates all gross tonne kilometre (GTK) (ARTC, 2009) and automotive diesel oil (ADO) consumption for railway transport (ABARE, 2006; ABARE, 2009a; RailCorp, 2009a; and RailCorp, 2009b) to large line-haul and passenger services.

Electric locomotives have not been included, since emissions from electricity generation have been separately estimated as part of the industrial air emissions inventory. Also, steam locomotives have not been included since their use is limited primarily for tourist attractions, so they are considered to be a minor source of air emissions. Figure 3-82 shows historical black coal, ADO and electricity consumption for the period 1973-74 to 2007-08 in NSW for railway transport (ABARE, 2009a) and confirms that ADO consumption is the primary source of direct emissions from locomotives.

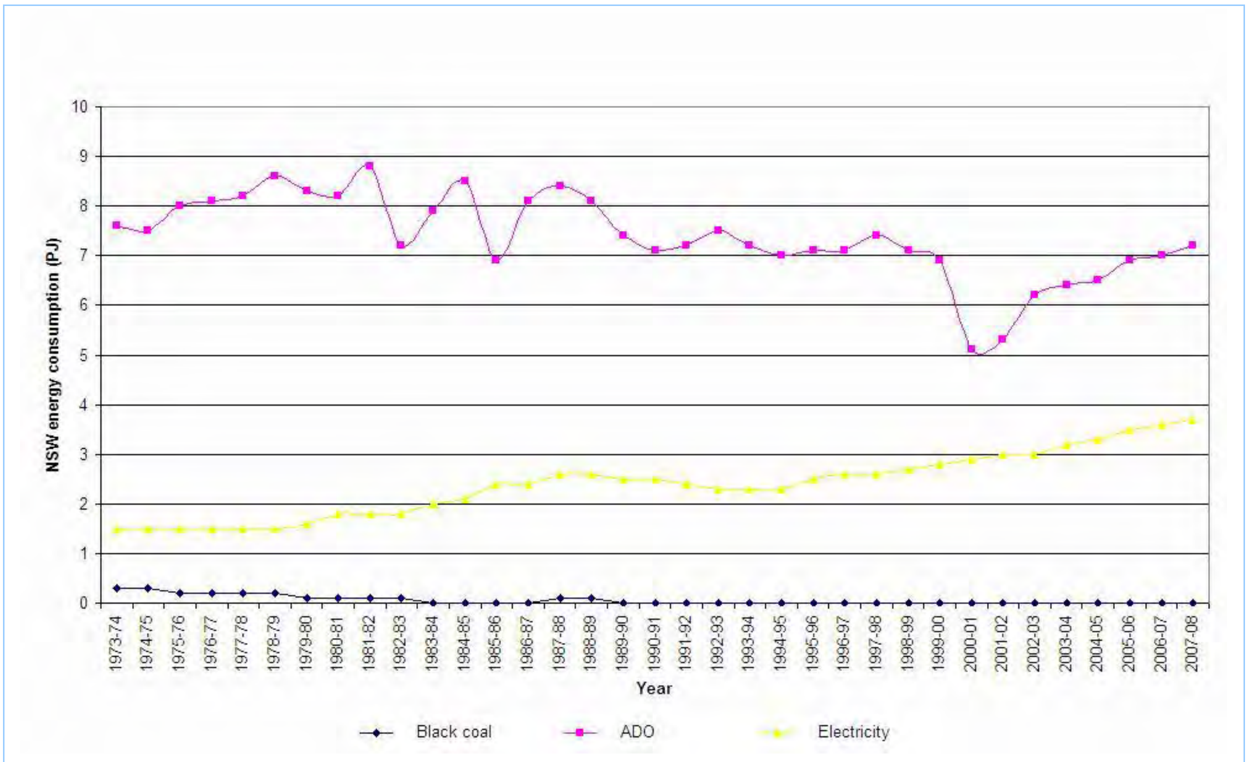

Figure 3-82: Locomotives fuel type historical NSW energy consumption

- *Engine type*

The inventory includes locomotives powered by diesel-electric engines. A diesel-electric locomotive uses either 2-stroke or 4-stroke compression ignition (CI) diesel engines and an alternator or generator to produce the electricity required to power its traction motors.

Since there are no NSW or Australian emission standards, the inventory considers all locomotives have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009b).

- *Fuel type*

The inventory includes locomotives that use ADO.

Table 3-107 presents the locomotive fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). The sulfur content is a requirement of the *Fuel Standard (Automotive Diesel) Determination 2001* (Attorney-General's Department, 2009), which is relevant for the 2008 calendar year.

Table 3-107: Locomotives fuel type and properties

Fuel type	Sulfur content (ppm)	Density (kg/L)	Effective heating value (MJ/L)	Carbon content (%)
Automotive diesel oil (ADO)	50	0.845	38.6	87

3.5.2 *Emission Estimation Methodology*

Table 3-108 summarises the emission estimation methodology used for locomotives.

Table 3-108: Locomotives emission estimation methodology

Emission source	Emission estimation methodology source
Exhaust emissions from large line-haul and passenger locomotives	- *Documentation for Locomotive Component of the National Emissions Inventory Methodology* (ERG, 2011b)

Exhaust emissions from locomotives have been estimated using fuel consumption based emission factors combined with activity rates. Activity rates include GTK and ADO consumption for large line-haul and passenger locomotives in NSW and the GMR. Emissions have been determined using Equation 10 (ERG, 2011b):

$$E_{i,j} = A_j \times EF_i \qquad \textbf{Equation 10}$$

where:			
$E_{i,j}$	=	Emissions of substance i from locomotive type j	(kg/year)
A_j	=	ADO consumption for locomotive type j	(kL/year)
EF_i	=	Emission factor for substance i	(kg/kL)

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	=	Locomotive type (either "large line-haul" or "passenger")	(-)

3.5.3 *Activity Data*

Table 3-109 summarises the activity data used for locomotives.

Table 3-109: Locomotives activity data

Activity data	Activity data source
Large line-haul and passenger gross tonne kilometre (GTK) data for GMR and NSW	- *GMR and NSW GTK 2008* (ARTC, 2009)
Large line-haul and passenger ADO consumption data for NSW	- *Energy Update 2009* (ABARE, 2009a)
Passenger ADO consumption data for NSW	- *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2007-2008* (RailCorp, 2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2008-2009* (RailCorp, 2009b)

For locomotives, GTK in NSW and the GMR (ARTC, 2009) and ADO consumption in NSW (ABARE, 2006; ABARE, 2009a; RailCorp, 2009a; and RailCorp, 2009b) have been used to establish ADO consumption in the GMR for large line-haul and passenger services.

Table 3-110 presents GTK for NSW and the GMR, which includes bulk, intermodal, Country Link, City Rail and other interstate passenger services (ARTC, 2009). Gross tonne kilometres in the GMR are 68.4% of the NSW total.

Table 3-110: Locomotive GTK

Region	2008 GTK (gross tonne.km/year)
GMR	31,940,182,000
NSW	46,697,863,000

Table 3-111 presents the NSW total (ABARE, 2006; and ABARE, 2009a) and NSW passenger (RailCorp, 2009a; and RailCorp, 2009b) ADO consumption. Large line-haul ADO consumption in NSW has been calculated from the difference between passenger and total ADO consumption. To establish ADO consumption for large line-haul and passenger services in the GMR, the NSW ADO consumption for each locomotive type has been multiplied by the proportion of GTK in the GMR to the NSW total (i.e. 68.4%) (ARTC, 2009).

Table 3-111: Locomotives diesel consumption

Locomotive	2008 diesel consumption (kL/year)	
	NSW	GMR
Large line-haul	166,922	114,170
Passenger	21,443	14,666
Grand Total	188,365	128,837

3.5.4 Emission and Speciation Factors

Table 3-112 summarises the emission and speciation factors used for locomotives.

Table 3-112: Locomotives emission and speciation factors

Emission source	Substance	Emission and speciation factor source
Exhaust emissions from large line-haul and passenger locomotives	Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	- *Emission Factors for Locomotives* (USEPA, 2009b) - *NONROAD2008a Model* (USEPA, 2009a)
	Criteria pollutants: TSP	- *PMPROF 116 - 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	- *Table C-3 (California low sulphur diesel) and Table C-4 - 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)
	Organic air toxics	- *Table C-3 (California low sulphur diesel) and Table C-4 - 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)
	Metal air toxics	- *Table C-2, Table C-3 (California low sulfur diesel) and Table C-4 - 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	- *Table C-5 (California low sulfur 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	- *Table D-1 - Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and other NonRoad Components of the*

Emission source	Substance	Emission and speciation factor source
	and Polychlorinated dibenzofurans: PCDD and PCDF	*National Emissions Inventory, Volume I – Methodology* (Pechan, 2005)
	Ammonia	- *Table III-5 - Estimating Ammonia Emissions from Anthropogenic Non-Agricultural Sources – Draft Final Report* (Pechan, 2004)
	Greenhouse gases: CH_4	- *Emission Factors for Locomotives* (USEPA, 2009b) - *NONROAD2008a Model* (USEPA, 2009a)
	Greenhouse gases: CO_2	- *Emission Factors for Locomotives* (USEPA, 2009b) - *NONROAD2008a Model* (USEPA, 2009a)
	Greenhouse gases: N_2O	- *Table A-6 - Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobile Combustion Sources* (USEPA, 2008a)

Emission factors for large line-haul and passenger locomotives are expressed in g/bhp.h (USEPA, 2009b) and these have been converted to kg/kL using Equation 11 (USEPA, 2009b):

$$EF_{kg\,/\,kL} = \frac{EF_{g\,/\,bhp.h} \times CF \times 1000}{3.7862 \times 1000} \qquad \textbf{Equation 11}$$

where:			
$EF_{kg/kL}$	=	Emission factor for large line-haul and passenger locomotives	(kg/kL)
$EF_{g/bhp.h}$	=	Emission factor for large line-haul and passenger locomotives	(g/bhp.h)
CF	=	Conversion factor for large line-haul and passenger locomotives (Table 3; USEPA, 2009b) – 20.8	(bhp.h/US gal)
3.7862	=	Conversion factor	(L/US gal)
1000	=	Conversion factor	(L/kL)
1000	=	Conversion factor	(g/kg)

Brake specific fuel consumption (BSFC) for large line-haul and passenger locomotives has been estimated using Equation 12 (USEPA, 2009b):

$$BSFC = \frac{\rho_{ADO}}{CF \times 0.7457} \qquad \textbf{Equation 12}$$

where:			
BSFC	=	Brake specific fuel consumption for large line-haul and passenger locomotives	(kg/kW.h)
ρ_{ADO}	=	Density of ADO (Table A-6; USEPA,2008a) – 3.2	(kg/US gal)
CF	=	Conversion factor for large line-haul and passenger locomotives (Table 3; USEPA, 2009b) – 20.8	(bhp.h/US gal)
0.7457	=	Conversion factor	(kW/bhp)

Since PM_{10} emissions are dependent on the sulfur content of the fuel, an adjustment has been made to the baseline PM_{10} emission factors (USEPA, 2009b) for large line-haul and passenger locomotives using Equation 13 (USEPA, 2009a):

$$EF_{PM10} = EF_{PM10BAS} - \frac{\rho_{ADO}}{3.7862} \times 1000 \times 7 \times 0.02247 \times 0.01 \times (0.33 - 0.005) \qquad \textbf{Equation 13}$$

where:			
EF_{PM10}	=	Adjusted PM_{10} emission factor for large line-haul and passenger locomotives at 0.005% (50 ppm) sulfur content of ADO	(kg/kL)
$EF_{PM10BAS}$	=	Baseline PM_{10} emission factor for large line-haul and passenger locomotives at 0.33% (3300 ppm) default certification sulfur content of fuel (USEPA, 2009b) - 1.7579	(kg/kL)
ρ_{ADO}	=	Density of ADO (Table A-6; USEPA,2008a) – 3.2	(kg/US gal)
7	=	PM_{10} sulfate/PM_{10} sulfur	(kg/kg)
0.02247	=	Fractional sulfur in fuel converted to PM_{10} sulfate	(-)
0.01	=	Conversion factor from percent to fraction	(-)
0.33	=	Default certification sulfur content of fuel (USEPA, 2009a) – 3300 ppm	(%)
0.005	=	Sulfur content of ADO (Attorney-General's Department, 2009) – 50 ppm	(%)
3.7862	=	Conversion factor	(L/US gal)
1000	=	Conversion factor	(L/kL)

Exhaust $PM_{2.5}$ emissions from large line-haul and passenger locomotives are 97% of PM_{10} emissions (USEPA, 2009b).

Exhaust SO_2 emissions from large line-haul and passenger locomotives vary according to fuel sulfur content and THC emissions and have been estimated using Equation 14 (USEPA, 2009a):

$$EF_{SO2} = (\frac{\rho_{ADO}}{3.7862} \times 1000 \times 0.97753 - THC) \times 0.01 \times 0.005 \times 2 \qquad \textbf{Equation 14}$$

where:			
EF_{SO2}	=	SO_2 emission factor for large line-haul and passenger locomotives	(kg/kL)
ρ_{ADO}	=	Density of ADO (Table A-6; USEPA,2008a) – 3.2	(kg/US gal)
0.97753	=	Fractional sulfur in fuel converted to sulfur dioxide	(-)
THC	=	THC emission factor for large line-haul and passenger locomotives (Table 1; USEPA, 2009b) – 2.6369	(kg/kL)
0.01	=	Conversion factor from percent to fraction	(-)
0.005	=	Sulfur content of ADO (Attorney-General's Department, 2009) – 50 ppm	(%)
2	=	Molecular weight of sulfur dioxide divided by molecular weight sulfur	(-)
3.7862	=	Conversion factor	(L/US gal)
1000	=	Conversion factor	(L/kL)

Exhaust VOC emissions from large line-haul and passenger locomotives have been estimated from THC emissions (USEPA, 2009b) using the conversion factors in Table 3-113 (USEPA, 2009a).

Table 3-113: Locomotives exhaust hydrocarbon conversion factors

TOG/THC	NMOG/THC	NMHC/THC	VOC/THC
1.070	1.054	0.984	1.053

Figure 3-83 shows the individual and groups of organic gases included in each defined set/subset of organic gases (FAA, 2009) presented in Table 3-113.

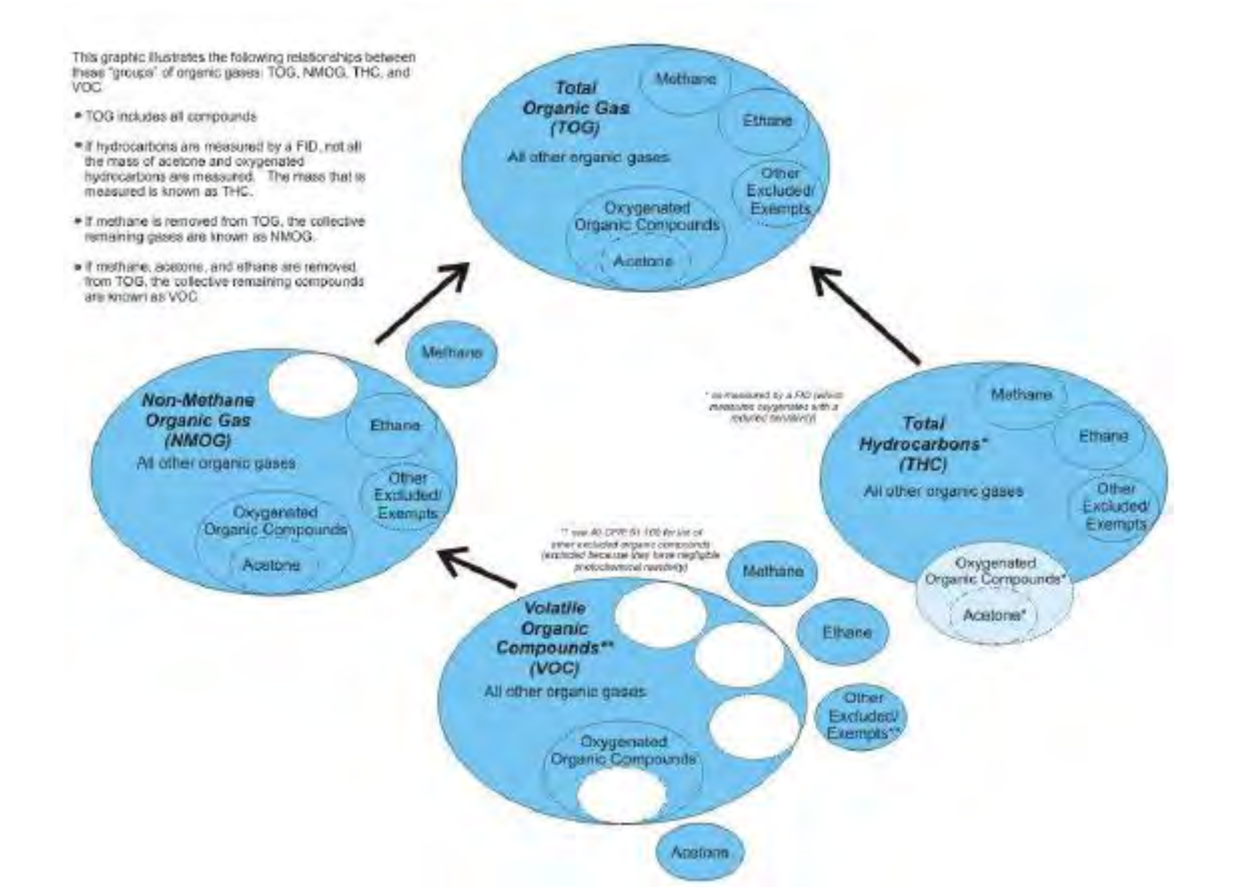

Figure 3-83: Groups of organic gases

Emission factors for some organic and metal air toxics are specific to either 2-stroke or 4-stroke diesel engines, so the emission factors have been weighted according to the proportion of each engine type. The proportion of ADO consumed in 2-stroke and 4-stroke large line-haul and passenger locomotives is 68.4% and 31.6%, respectively (Pechan, 2005).

Exhaust CH_4 emissions from large line-haul and passenger locomotives have been estimated from THC emissions (USEPA, 2009b) minus NMHC emissions using the conversion factors in Table 3-113 (USEPA, 2009a).

Exhaust CO_2 emissions from large line-haul and passenger locomotives vary according to fuel carbon content and THC emissions and have been estimated using Equation 15 (USEPA, 2009a):

$$EF_{CO2} = \left(\frac{\rho_{ADO}}{3.7862} \times 1000 - THC\right) \times CC \times 44/12 \qquad \textbf{Equation 15}$$

where:			
EF_{CO2}	=	SO_2 emission factor for large line-haul and passenger locomotives	(kg/kL)
ρ_{ADO}	=	Density of ADO (Table A-6; USEPA,2008a) – 3.2	(kg/US gal)
THC	=	THC emission factor for large line-haul and passenger locomotives (Table 1; USEPA, 2009b) – 2.6369	(kg/kL)
CC	=	Fractional carbon content of ADO (USEPA, 2009a) – 0.87	(-)
44	=	Molecular weight of carbon dioxide	(kg/kg.mol)
12	=	Molecular weight of carbon	(kg/kg.mol)
3.7862	=	Conversion factor	(L/US gal)
1000	=	Conversion factor	(L/kL)

Table 3-114 presents the key engine parameters and emission factors used for locomotives.

Table 3-114: Locomotives engine parameters and emission factors

Engine parameters (kg/kW.h)	Engine emission factors (kg/kL)											
BSFC	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDF and PCDF
0.2063	47.24	0.069	0.022	0.082	1.33	1.29	2.78	0.042	7.03	2,687.67	0.0036	4.57×10^{-09}

3.5.5 *Spatial Distribution of Emissions*

Table 3-115 summarises the data used for spatially allocating emissions from locomotives.

Table 3-115: Locomotives spatial data

Emission source	Spatial data	Spatial data source
Exhaust emissions from large line-haul and passenger locomotives	Gridded 1 km x 1 km diesel consumption estimates allocated to rail network	- *GMR and NSW GTK 2008* (ARTC, 2009) - *Energy Update 2009* (ABARE, 2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2007-2008* (RailCorp, 2009a) - *CountryLink and CityRail Diesel Train Distance, Passengers and Fuel Consumption 2008-2009* (RailCorp, 2009b) - *Rail Movement Data in NSW Broken Down by Region 2003* (Pacific National, 2005)

Emissions from large line-haul and passenger locomotives have been spatially distributed according to ADO consumption, which is proportional to GTK (ERG, 2011b). The proportion of ADO consumption by rail link and region using rail movement data by each NSW region is presented in Table 3-116 and shown in Figure 3-84 (Pacific National, 2005).

Table 3-116: Locomotives spatial distribution of diesel consumption by rail link and region

Rail link	2008 proportion of diesel consumption by region (%)				
	Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Illawarra	-	1.67	0.10	4.13	5.91
Newcastle Metropolitan	3.88	1.25	-	-	5.13
Outer Newcastle	-	10.29	-	-	10.29
Short North	1.14	5.49	1.22	-	7.86
Short South	-	12.02	0.32	-	12.34
Short West	-	12.02	1.38	-	13.40
Sydney Metropolitan	-	-	45.07	-	45.07
Grand Total	5.03	42.75	48.09	4.13	100.00

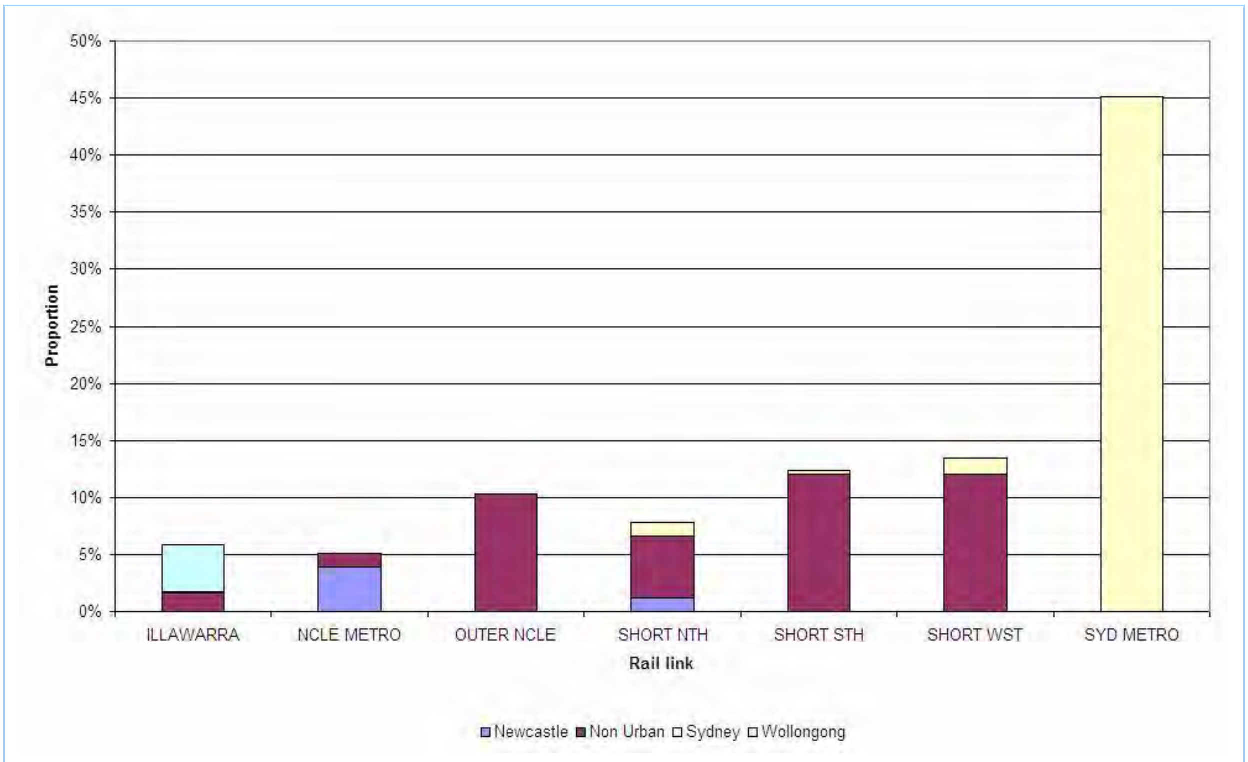

Figure 3-84: Locomotives spatial distribution of diesel consumption by rail link and region

Figure 3-85 shows the spatial distribution of large line-haul and passenger locomotive emissions.

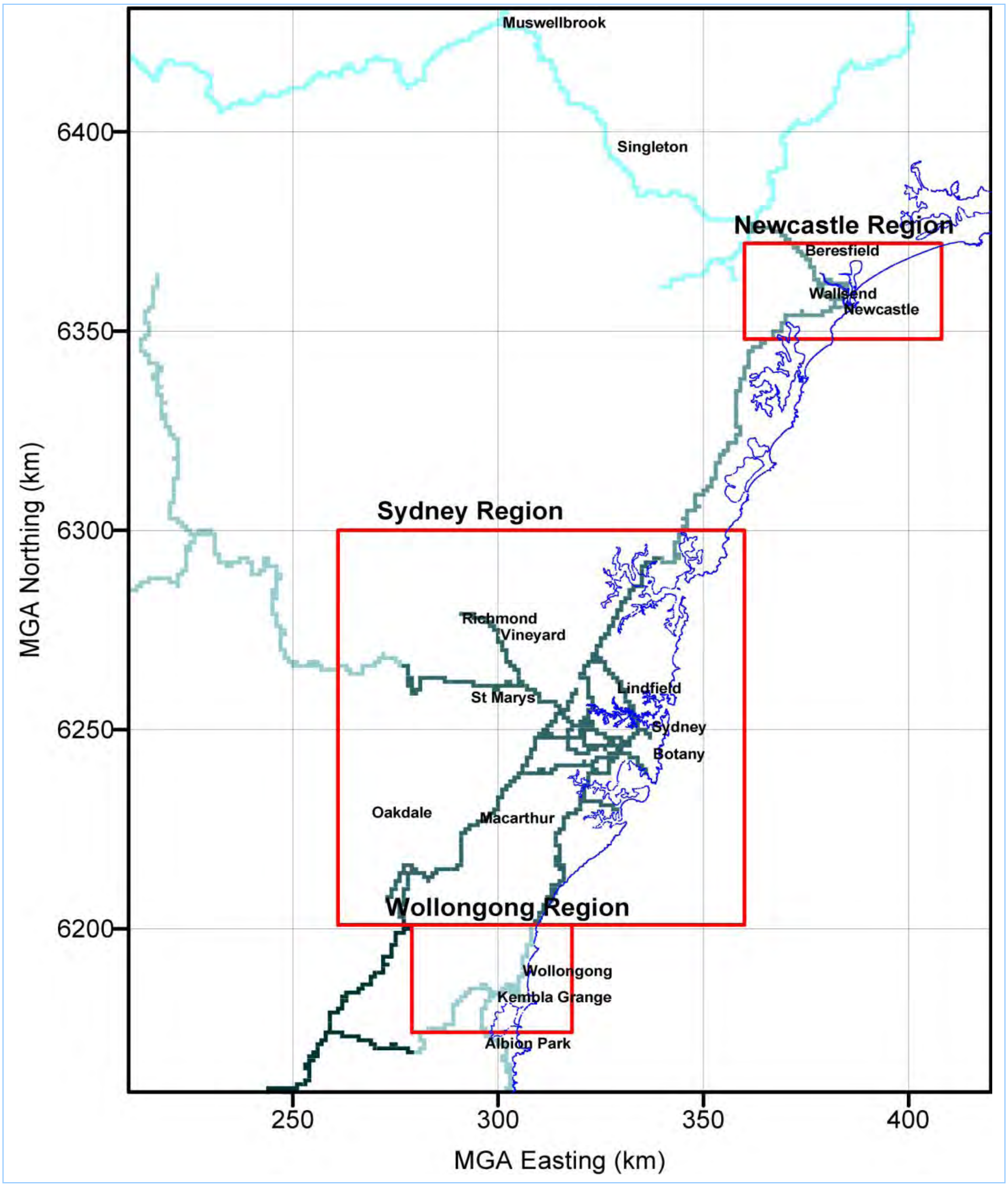

Figure 3-85: Locomotives spatial distribution of emissions

3.5.6 *Temporal Variation of Emissions*

Table 3-117 summarises the data used to estimate the temporal variation in emissions from locomotives.

Table 3-117: Locomotives temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from large line-haul and passenger locomotives	Monthly: Derived from Australian Rail Track Corporation gross tonne kilometre data for the GMR	- *GMR and NSW GTK 2008* (ARTC, 2009)
	Daily: Derived from Pacific National gross tonne kilometre data by NSW region	- *Rail Movement Data in NSW Broken Down by Region 2003* (Pacific National, 2005)
	Hourly: Derived from inverse of hourly passenger train volumes	- *Analysis of Peak Hour Travel Using the Sydney Household Travel Survey Data* (TPDC, 2006)

Since electric passenger trains have priority during peak hours and large line-haul locomotives rarely operate during these times, approximately 5% of GTK occurs from 5 am to 10 am and 3 pm to 7 pm, while approximately 95% of GTK occurs during the remaining hours (Pacific National, 2005). The inverse of hourly passenger train volumes has been used to establish locomotive operating frequency and duration by hour (TPDC, 2006) and then adjusted so that 5% of GTK occurs during peak hours.

Hourly temporal variation profiles are presented in Table 3-118 and shown in Figure 3-86.

Table 3-118: Locomotives hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	8.16	13	4.21
2	8.34	14	4.05
3	8.37	15	3.43
4	8.35	16	0.36
5	7.91	17	0.31
6	1.38	18	0.27
7	0.95	19	0.72
8	0.28	20	5.46
9	0.04	21	6.70
10	0.69	22	7.10
11	4.12	23	7.10
12	3.90	24	7.81

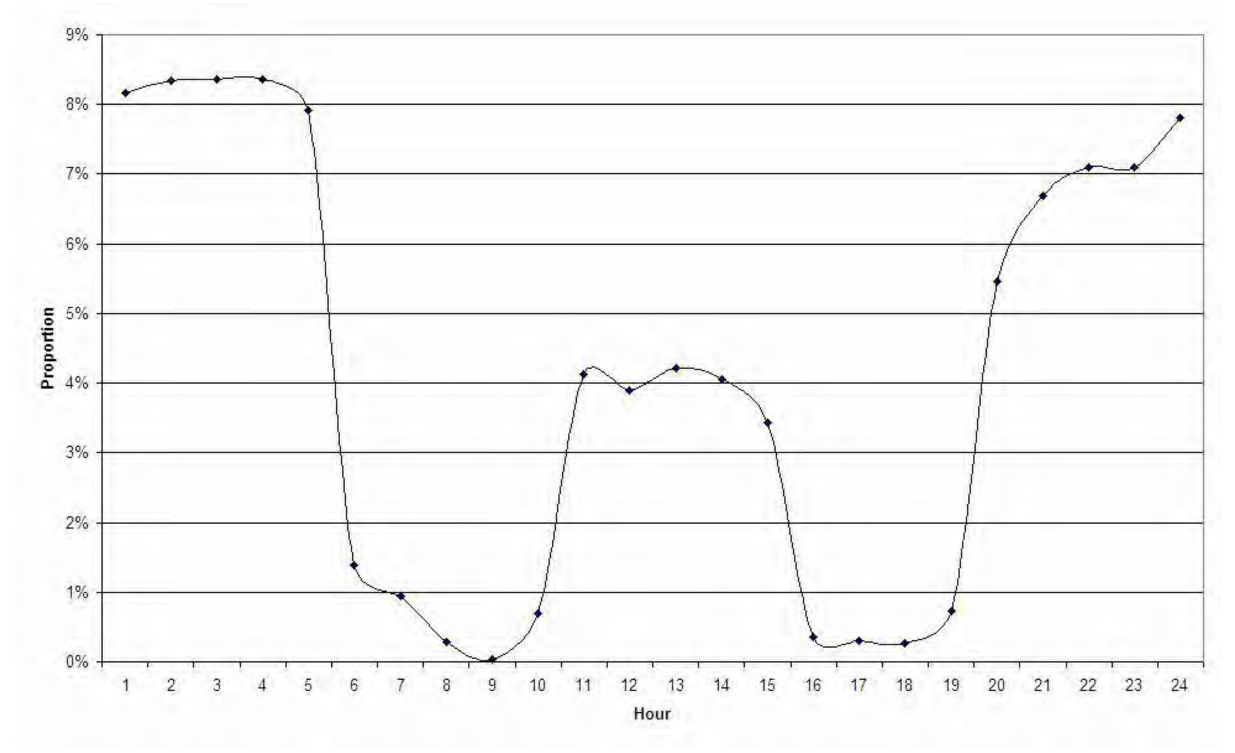

Figure 3-86: Locomotives hourly temporal profile

Daily GTK data for the GMR has been used to establish locomotive operating frequency and duration by day (Pacific National, 2005).

Daily temporal variation profiles are presented in Table 3-119 and shown in Figure 3-87.

Table 3-119: Locomotives daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.60	16.90	16.52	16.27	15.81	10.80	9.09

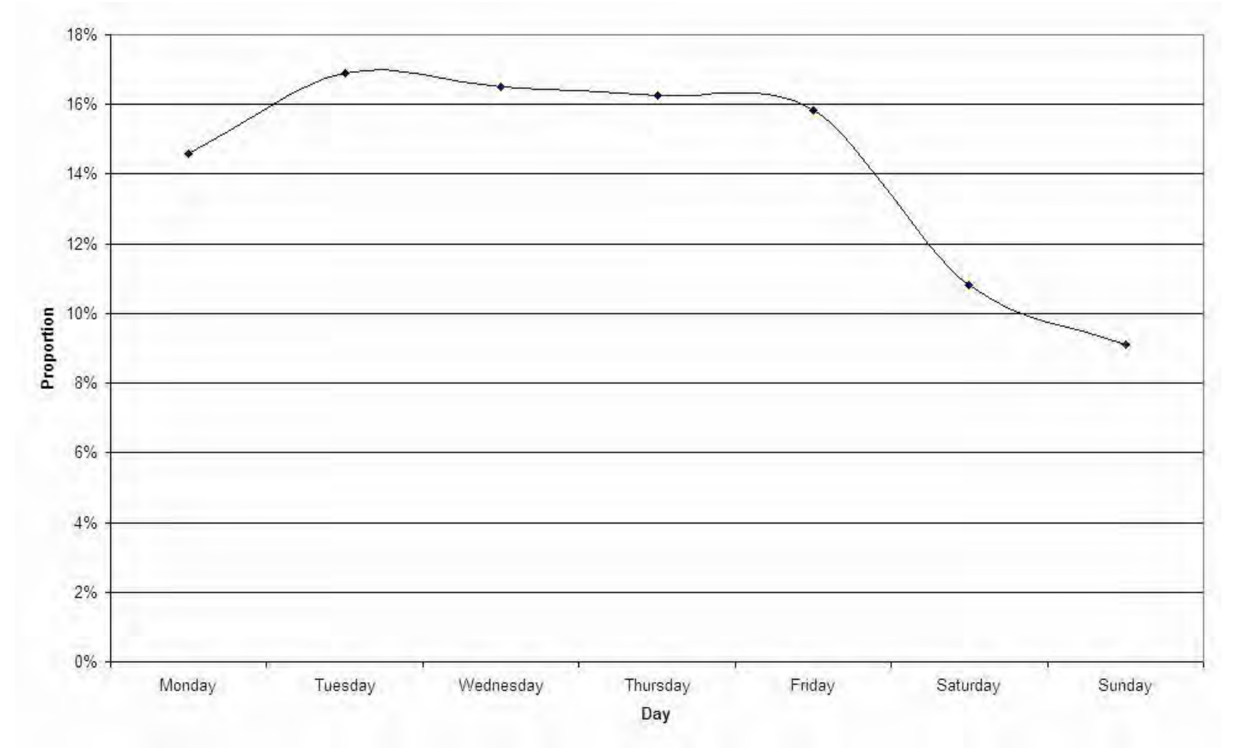

Figure 3-87: Locomotives daily temporal profile

Monthly GTK data for the GMR has been used to establish locomotive operating frequency and duration by month (ARTC, 2009).

Monthly temporal variation profiles are presented in Table 3-120 and shown in Figure 3-88.

Table 3-120: Locomotives monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.26	July	8.59
February	7.79	August	8.28
March	8.02	September	8.51
April	8.41	October	8.70
May	8.68	November	8.18
June	8.11	December	8.48

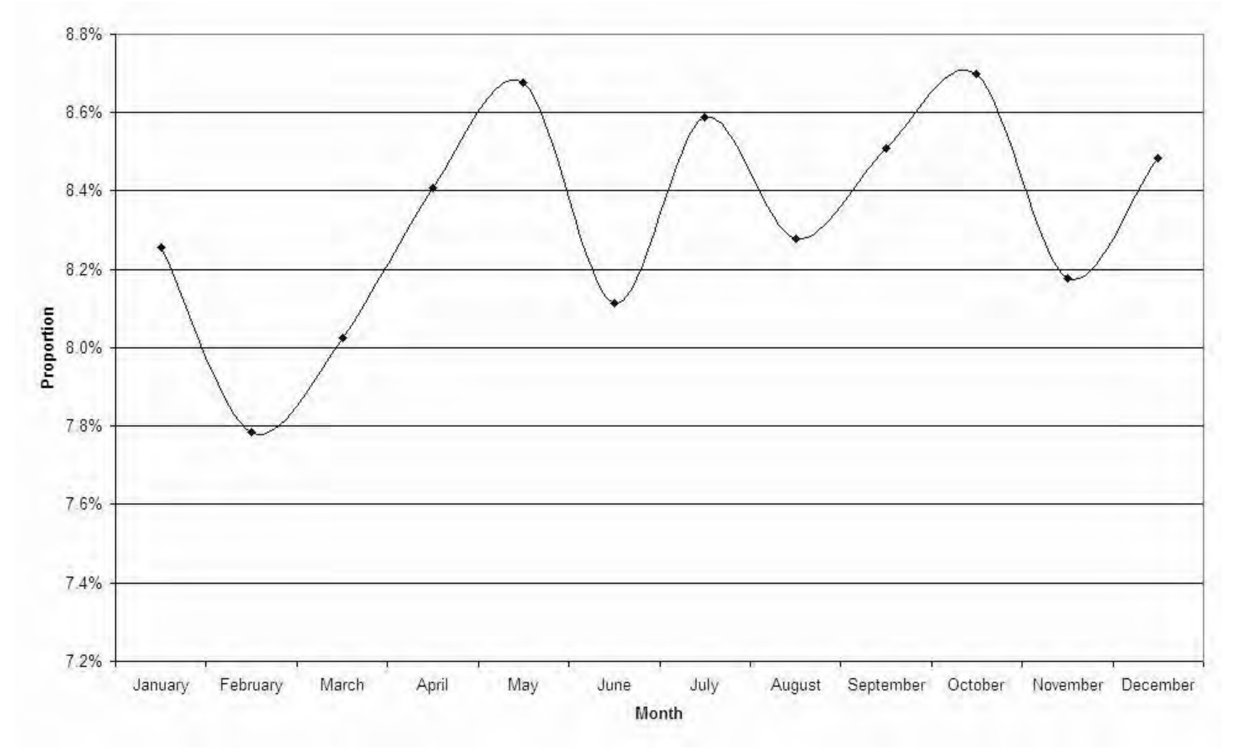

Figure 3-88: Locomotives monthly temporal profile

3.5.7 *Emission Estimates*

Table 3-121 presents annual emissions of selected substances from locomotives by activity.

Table 3-121: Locomotives emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Locomotives	1,3-BUTADIENE	48	406	456	39	949
	ACETALDEHYDE	348	2,963	3,334	287	6,932
	BENZENE	40	341	384	33	799
	CARBON MONOXIDE	45,530	387,262	435,705	37,455	905,953
	FORMALDEHYDE	733	6,236	7,016	603	14,588
	ISOMERS OF XYLENE	86	734	826	71	1,717
	LEAD & COMPOUNDS	1.01	8.58	9.65	0.83	20
	OXIDES OF NITROGEN	305,907	2,601,916	2,927,394	251,653	6,086,871
	PARTICULATE MATTER ≤ 10 µm	8,585	73,022	82,156	7,063	170,825
	PARTICULATE MATTER ≤ 2.5 µm	8,328	70,831	79,691	6,851	165,700
	POLYCYCLIC AROMATIC HYDROCARBONS	23	194	218	19	453
	SULFUR DIOXIDE	533	4,535	5,103	439	10,610
	TOLUENE	58	489	551	47	1,145
	TOTAL SUSPENDED	9,212	78,352	88,153	7,578	183,295

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	PARTICULATE					
	TOTAL VOLATILE ORGANIC COMPOUNDS	17,979	152,920	172,049	14,790	357,738

Table 3-122 presents annual emissions of selected substances from locomotives by source type.

Table 3-122: Locomotives emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Line Haul	1,3-BUTADIENE	42	359	404	35	841
	ACETALDEHYDE	309	2,626	2,955	254	6,143
	BENZENE	36	302	340	29	708
	CARBON MONOXIDE	40,347	343,177	386,106	33,192	802,822
	FORMALDEHYDE	650	5,526	6,217	534	12,927
	ISOMERS OF XYLENE	76	650	732	63	1,522
	LEAD & COMPOUNDS	0.89	7.60	8.55	0.74	18
	OXIDES OF NITROGEN	271,083	2,305,722	2,594,148	223,006	5,393,959
	PARTICULATE MATTER ≤ 10 µm	7,608	64,709	72,804	6,259	151,379
	PARTICULATE MATTER ≤ 2.5 µm	7,380	62,768	70,619	6,071	146,838
	POLYCYCLIC AROMATIC HYDROCARBONS	20	172	193	17	402
	SULFUR DIOXIDE	473	4,019	4,522	389	9,402
	TOLUENE	51	434	488	42	1,014
	TOTAL SUSPENDED PARTICULATE	8,163	69,433	78,118	6,715	162,429
	TOTAL VOLATILE ORGANIC COMPOUNDS	15,932	135,512	152,464	13,107	317,014
Passenger	1,3-BUTADIENE	5.43	46	52	4.46	108
	ACETALDEHYDE	40	337	380	33	789
	BENZENE	4.57	39	44	3.76	91
	CARBON MONOXIDE	5,183	44,085	49,599	4,264	103,131
	FORMALDEHYDE	83	710	799	69	1,661
	ISOMERS OF XYLENE	9.82	84	94	8.08	195
	LEAD & COMPOUNDS	0.11	0.98	1.10	9.44×10^{-2}	2.28
	OXIDES OF NITROGEN	34,824	296,194	333,246	28,647	692,911
	PARTICULATE MATTER ≤ 10 µm	977	8,313	9,352	804	19,446
	PARTICULATE MATTER ≤ 2.5 µm	948	8,063	9,072	780	18,863
	POLYCYCLIC AROMATIC HYDROCARBONS	2.59	22	25	2.13	52
	SULFUR DIOXIDE	61	516	581	50	1,208

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOLUENE	6.55	56	63	5.39	130
	TOTAL SUSPENDED PARTICULATE	1,049	8,919	10,035	863	20,866
	TOTAL VOLATILE ORGANIC COMPOUNDS	2,047	17,408	19,586	1,684	40,724

3.5.8 *Emission Projection Methodology*

Table 3-123 summarises the data used to estimate the emission projection factors for locomotives, while Figure 3-89 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-123: Locomotives emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from large line-haul and passenger locomotives	Final energy consumption for rail transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

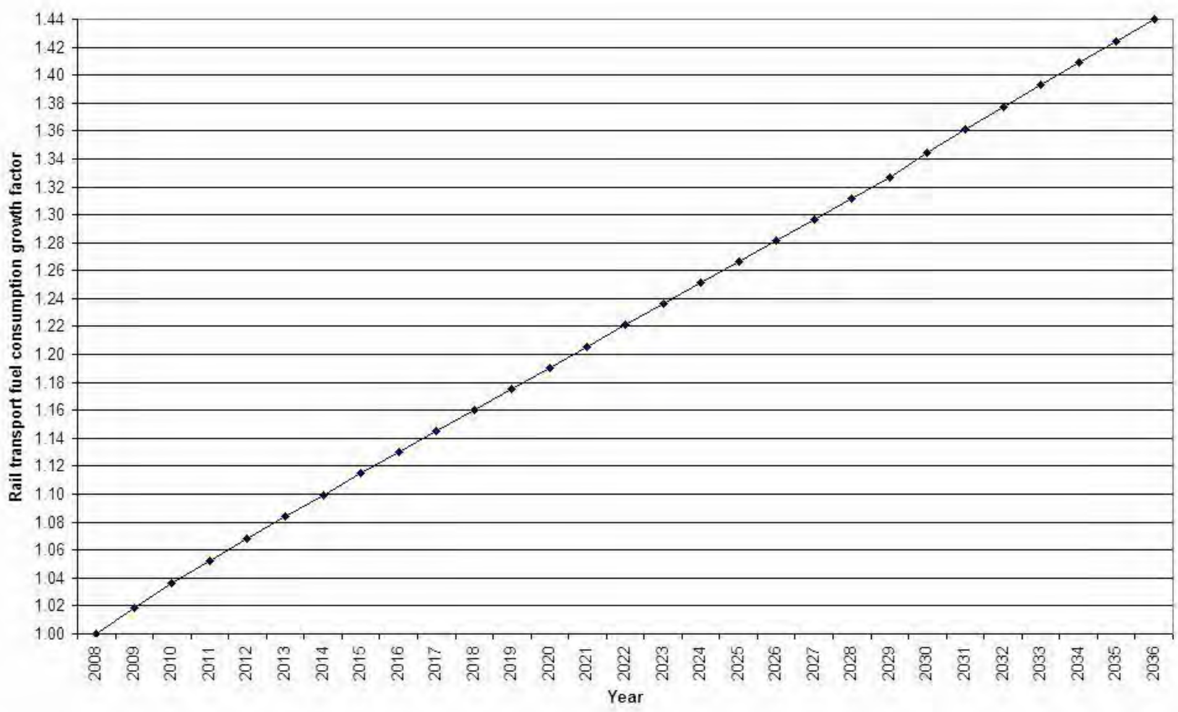

Figure 3-89: Locomotives emission projection factors

3.6 Recreational Boats

3.6.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from recreational boat (i.e. harbour vessels) 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:

- *Recreational boat operating area and survey data*

The inventory includes recreational boats that operate within estuaries, ports or harbours, which are located in the GMR.

Recreational boat operating areas include Botany Bay, Broken Bay, Hawkesbury River, Hunter River, Lake Illawarra, Lake Macquarie, Nepean River, Open Ocean, Parramatta River, Port Hacking, Port Jackson, Port Stephens and Tuggerah Lakes (TR, 2009).

Recreational boat survey data include a domestic survey of recreational boat ownership and usage for each of the 64 local government areas (LGA)[26] located in the GMR. The survey results include data about: boat type and number; engine type, size, power, fuel used and age; and boat operating area, frequency and duration of use by hour, day and month (TR, 2009).

Figure 3-90 shows how the domestic survey results have been combined with emission factor and load factor data from the technical literature (USEPA, 2009a) to develop an inventory of recreational boat emissions.

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[26] 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.

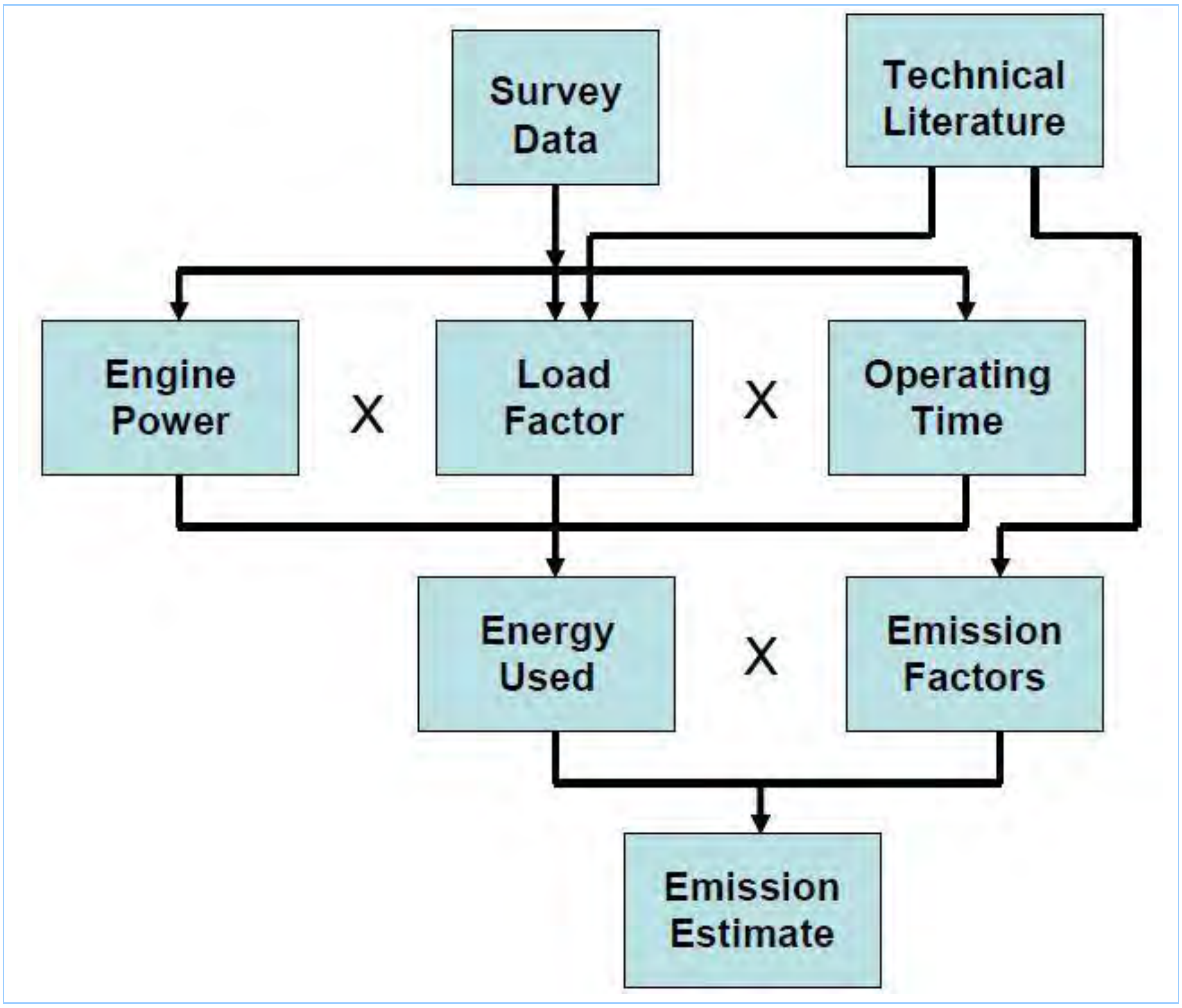

Figure 3-90: Recreational boats - use of survey data

- *Recreational boat type*

The inventory includes privately owned recreational boats, including powerboats and sailboats, as follows:

- *Dinghy with outboard motor;*
- *Boat with outboard motor;*
- *Boat with inboard motor; and*
- *Jet ski.*

- *Engine type*

The inventory includes recreational boats powered by 2-stroke and 4-stroke spark ignition (SI) petrol engines and diesel compression ignition (CI) engines. 2-stroke petrol engines are all outboard and range from 1 to 175 horsepower (hp)[27]. 4-stroke petrol engines are either inboard or outboard and range from 3 to 175 hp. All diesel engines are inboard and range from 6 to 175 hp.

Since there are no NSW or Australian emission standards, the inventory considers all recreational boats have emissions control technology consistent with USEPA Tier 0 (USEPA, 2009a).

- *Fuel type*

The inventory includes recreational boats that use automotive gasoline (petrol) and automotive diesel oil (ADO).

Table 3-124 presents the recreational boat fuel type and properties used in the inventory (ABARE, 2009b; and USEPA, 2009a). 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.

Table 3-124: Recreational boats 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[28]	2.7 - All grades (no ethanol)	0.740	34.2	87
	50 – PULP	3.9 - All grades (with ethanol)			
	142 – Weighted average[29]	2.84 – Weighted average[30]			
Automotive diesel oil (ADO)	50	-	0.845	38.6	87

[27] 1 horsepower (hp) is equivalent to 0.7457 kilowatts (kW) (USEPA, 1995a).
[28] Includes lead replacement petrol (LRP), unleaded petrol (ULP) and premium unleaded petrol (PULP).
[29] 5,509,243 kL (All grades) and 500,756 kL (PULP) (DRET, 2009).
[30] 5,332,615 kl (no ethanol) and 677,384 kL (with ethanol) (DRET, 2009).

➢ *Source type*

The inventory includes emissions of combustion products and evaporation from recreational boat 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
- *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).

3.6.2 Emission Estimation Methodology

Table 3-125 summarises the emission estimation methodologies used for recreational boats.

Table 3-125: Recreational boats emission estimation methodologies

Emission source	Emission estimation methodology source
Exhaust and evaporative emissions from recreational boats	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *NONROAD2008a Model* (USEPA, 2009a)

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

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, 2009a).

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, 2009a).

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, 2009a).

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, 2009a).

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, 2009a).

Engine population is defined by fuel type, application and power, while activity rates include frequency and duration of use on an hourly, daily and monthly basis. Engine population and activity rates have been derived from recreational boat survey data (TR, 2009) and sales data (OEDA, 2005). Emissions have been determined using Equation 16 within the *NONROAD2008a Model* (USEPA, 2009a):

$$\mathbf{E_{i,j,k,l,m} = P_{j,k,l} \times A_{j,k,l} \times HP_{j,k,l} \times LF_{j,k,l} \times TAF_{j,k,l} \times DF_{j,k,l} \times EF_{i,j,k,l,m} / 1000} \qquad \textbf{Equation 16}$$

where:			
$E_{i,j,k,l,m}$	=	Emissions of substance i from recreational boat type j, engine type k, engine power range l and source type m	(kg/year)
$P_{j,k,l}$	=	Population of recreational boat type j, engine type k and engine power range l	(number)
$A_{j,k,l}$	=	Activity of recreational boat type j, engine type k and engine power range l	(h/year)
$HP_{j,k,l}$	=	Maximum rated power of recreational boat type j, engine type k and engine power range l	(hp)
$LF_{j,k,l}$	=	Fractional load factor for recreational boat type j, engine type k and engine power range l	(hp/hp)

where:			
$TAF_{j,k,l}$	=	Fractional transient adjustment factor for recreational boat 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 recreational boat 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 recreational boat 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	=	Recreational boat type (either "dinghy with outboard motor', "boat with outboard motor", "boat with inboard motor' or "jet ski")	(-)
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)

3.6.3 Activity Data

Table 3-126 summarises the activity data used for recreational boats.

Table 3-126: Recreational boats activity data

Activity data	Activity data source
Recreational boat type/number and monthly usage frequency/duration/location	- *Recreational Boat 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)
Recreational boat fleet composition	- *The Outboard Motor Market in NSW, Actual Sales Data 2003 to 2005 and Projected Sales Data 2006 to 2010 for NSW and the GMR* (OEDA, 2005)

A domestic survey of recreational boat 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: boat type and number; engine type, size, power, fuel used and age; and boat operating area, frequency and duration of 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 recreational boat 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 recreational boats 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 3-127 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 3-127: Confidence intervals at 95% confidence level by sample size for recreational boats 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 recreational boats 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: boat type and number; engine type, size, power, fuel used and age; and boat operating area, frequency and duration of use by hour, day and month. The domestic survey questionnaire form is included at Appendix C. Domestic Survey Questionnaire 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 3-128.

Table 3-128: Recreational boats 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 recreational boat survey results (TR, 2009). Table 3-129 presents a summary of the population and dwelling by LGA data used to scale-up the domestic survey results to the GMR.

Table 3-129: Population and dwelling by LGA used to scale-up recreational boats survey

LGA	2008 population and dwelling					
	Population	Flat, unit or apartment	Semi-detached, row, terrace or town house	Separate house	Other dwelling[31]	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

[31] 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[31]	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[31]	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

Outboard engine sales data for the 2003 and 2004 calendar years (OEDA, 2005) have been used to estimate the proportion of 2-stroke/4-stroke petrol and inboard/outboard engines with a given maximum power rating, while the recreational boat survey results (TR, 2009) have been used to estimate the total number of in-service recreational boat engines. Since sales data for diesel engines is not available, the proportion of 4-stroke petrol engines with a given maximum power rating has been assumed for diesel recreational boat engines up to 175 hp. Table 3-130 presents a summary of outboard engine sales data for NSW.

Table 3-130: Outboard engine sales data for NSW

Maximum rated power (hp)	2003 calendar year		2004 calendar year		2003 and 2004 calendar years			
	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke sales	4-stroke sales	2-stroke proportion (%)	4-stroke proportion (%)
≤ 10	1,503	490	1,455	544	2,958	1,034	14.79	15.63
11 to 25	3,246	1,058	3,143	1,176	6,389	2,234	31.95	33.77
26 to 50	2,203	719	2,134	798	4,337	1,517	21.69	22.93
51 to 90	1,681	498	1,633	553	3,314	1,051	16.57	15.89
91 to 150	1,254	314	1,224	349	2,478	663	12.39	10.02
≥ 151	264	55	258	62	522	117	2.61	1.77
Grand Total	10,151	3,134	9,847	3,482	19,998	6,616	100.00	100.00

The total population of recreational boat engines has been estimated by combining the domestic survey results (TR, 2009), gridded 1 km by 1 km dwelling estimates (TDC, 2009) and outboard engine sales data (OEDA, 2005). In-service recreational boat engine population by engine description and maximum rated power range data for the GMR is presented in Table 3-131 and shown in Figure 3-91.

Table 3-131: Recreational boats engine population in the GMR

Engine description	2008 engine population										
	1 to 3 hp	3 to 6 hp	6 to 11 hp	11 to 16 hp	16 to 25 hp	25 to 40 hp	40 to 50 hp	50 to 75 hp	75 to 100 hp	100 to 175 hp	Grand Total
2-Str Outboard	6,592	6,592	6,592	21,358	21,358	14,498	14,498	11,078	11,078	20,057	133,702
2-Str Personal Water Craft	239	239	239	-	1,546	525	525	401	401	726	4,838
4-Str Inboard	-	941	941	4,066	-	2,761	-	956	956	1,420	12,041
4-Str Outboard	-	2,630	2,630	11,365	-	7,717	-	2,673	2,673	3,968	33,657
4-Str Personal Water Craft	-	378	378	1,634	-	1,109	-	384	384	570	4,838
Dsl – Inboard	-	-	1,255	1,355	1,355	920	920	638	638	946	8,027
Grand Total	6,831	10,780	12,034	39,777	24,259	27,531	15,943	16,131	16,131	27,687	197,104

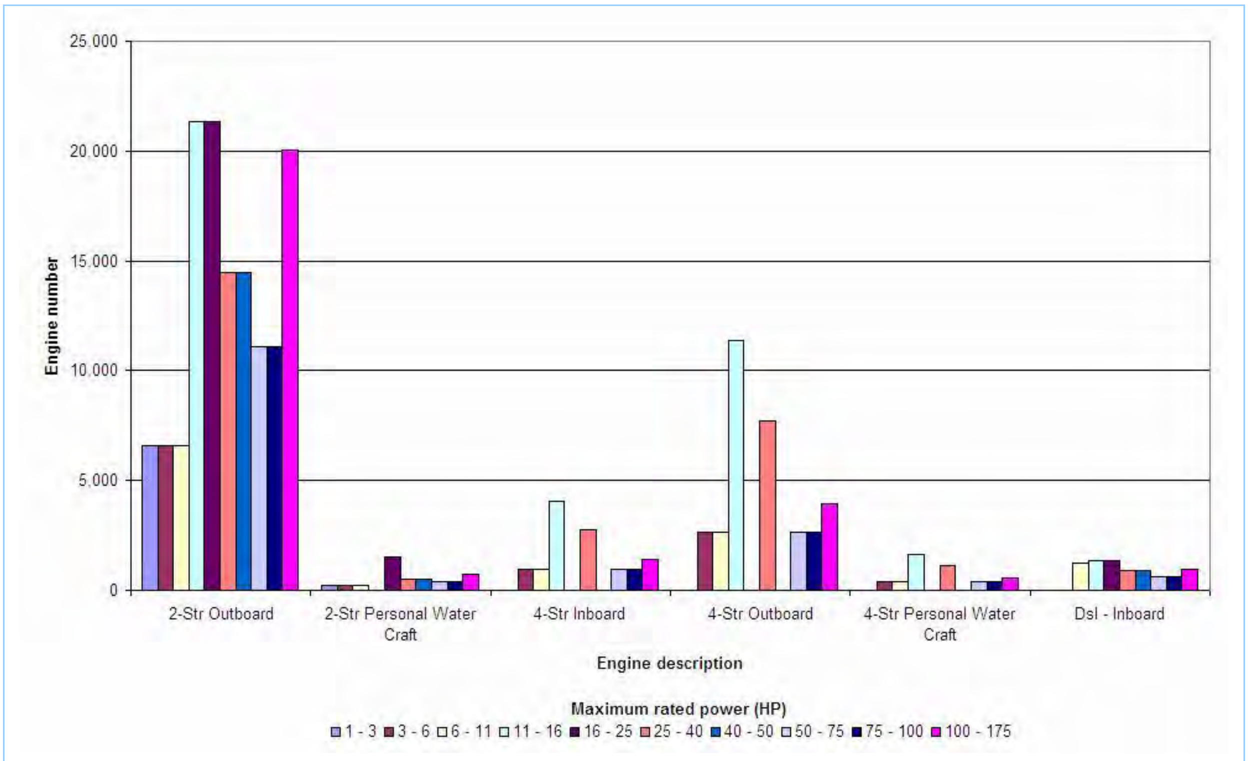

Figure 3-91: Recreational boats engine population in the GMR

The annual operating time of in-service recreational boat engines has been estimated from the domestic survey results (TR, 2009). In-service recreational boat engine annual operating time by engine description for the GMR is presented in Table 3-132 and shown in Figure 3-92.

Table 3-132: Recreational boats engine annual operating time in the GMR

Engine description	Annual operating time (h/year)
2-Str Outboard	44.5
2-Str Personal Water Craft	10.1
4-Str Inboard	31.3
4-Str Outboard	44.5
4-Str Personal Water Craft	10.1
Dsl – Inboard	31.3

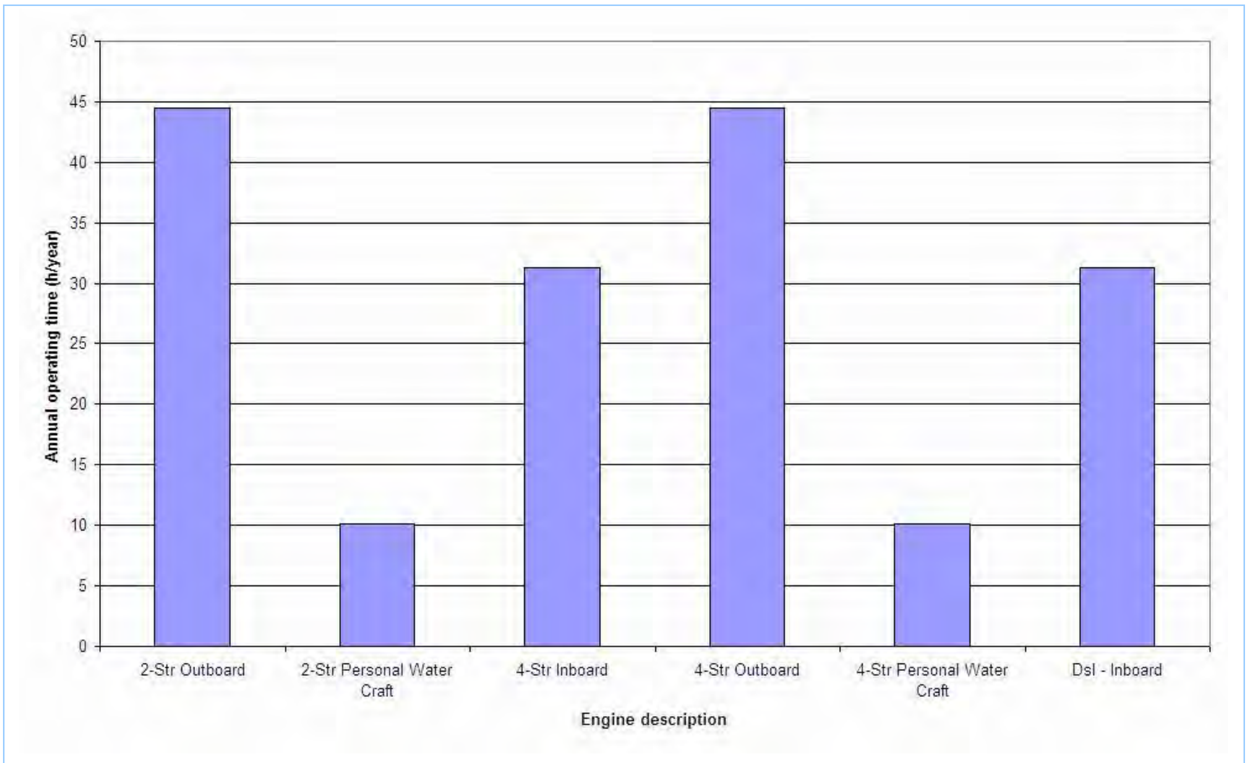

Figure 3-92: Recreational boats engine annual operating time in the GMR

Exhaust and evaporative emissions from recreational boat engines have been estimated using engine population (TR, 2009), annual operating time (TR, 2009), 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 (TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009a).

Figure 3-93 shows the NonRoad Model splash screen for the recreational boats emission estimation simulation.

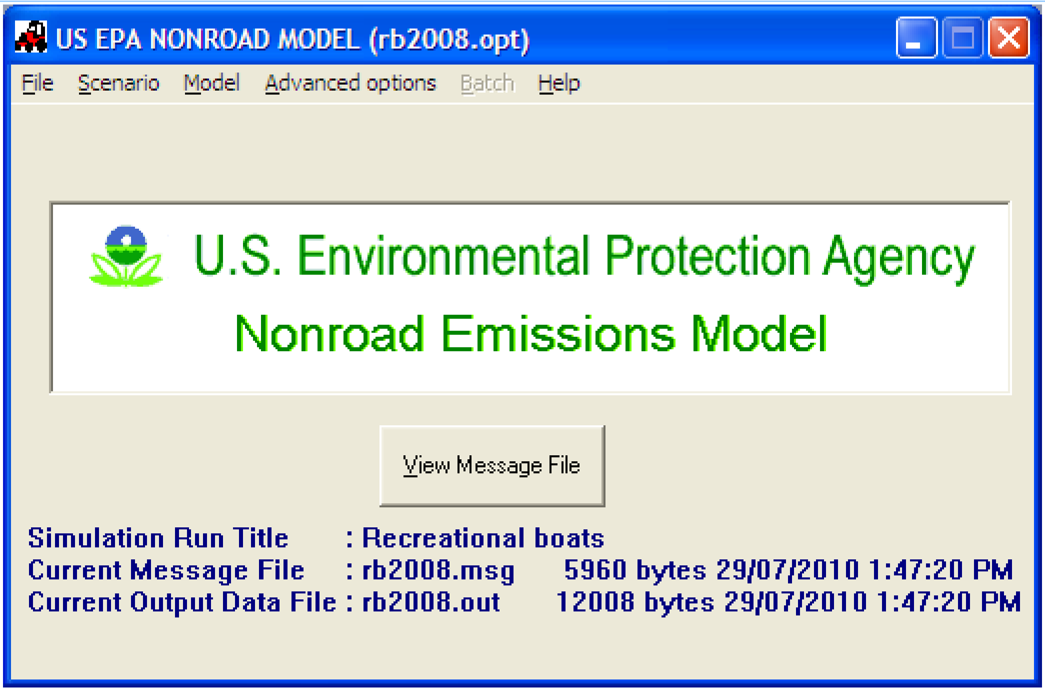

Figure 3-93: Recreational boats NonRoad Model splash screen

Figure 3-94 shows the NonRoad Model options screen for the recreational boats emission estimation simulation.

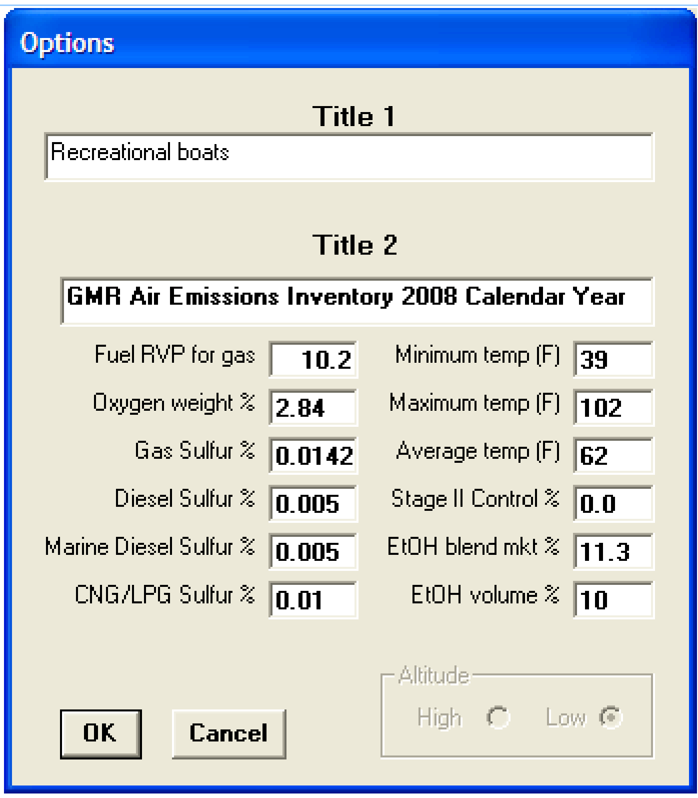

Figure 3-94: Recreational boats NonRoad Model options

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 3-133 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, 2009a).

Table 3-133: Recreational boats 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 3-134 presents the recreational boat engine power rating (OEDA, 2005), useful life (USEPA, 2009a) and population (TR, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-134: Recreational boats NonRoad Model population

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282010005	4-Str Inboard	3	6	5	197	940.9
2282010005	4-Str Inboard	6	11	10	197	940.9
2282010005	4-Str Inboard	11	16	15	197	4065.8
2282010005	4-Str Inboard	25	40	30.47	197	2760.9
2282010005	4-Str Inboard	50	75	59.55	197	956.4
2282010005	4-Str Inboard	75	100	94.22	197	956.4
2282010005	4-Str Inboard	100	175	149.7	197	1419.6
2282020005	Dsl - Inboard	6	11	9.736	1400	1254.6
2282020005	Dsl - Inboard	11	16	14.92	1400	1355.3
2282020005	Dsl - Inboard	16	25	21.41	1400	1355.3
2282020005	Dsl - Inboard	25	40	31.2	1400	920.3
2282020005	Dsl - Inboard	40	50	42.4	1400	920.3
2282020005	Dsl - Inboard	50	75	56.19	1400	637.6
2282020005	Dsl - Inboard	75	100	94.22	1400	637.6
2282020005	Dsl - Inboard	100	175	144.9	1400	946.4
2282005010	2-Str Outboard	1	3	2.08	194	6592.1
2282005010	2-Str Outboard	3	6	4.43	194	6592.1

SCC	Engine description	hp_{min}	hp_{max}	hp_{avg}	Life (h)	Engine population
2282005010	2-Str Outboard	6	11	9.07	191	6592.1
2282005010	2-Str Outboard	11	16	14.83	177	21357.6
2282005010	2-Str Outboard	16	25	22.76	162	21357.6
2282005010	2-Str Outboard	25	40	32.01	148	14498.0
2282005010	2-Str Outboard	40	50	45.58	140	14498.0
2282005010	2-Str Outboard	50	75	63.58	126	11078.3
2282005010	2-Str Outboard	75	100	85.05	126	11078.3
2282005010	2-Str Outboard	100	175	127.8	108	20057.3
2282010005	4-Str Outboard	3	6	4.43	194	2630.1
2282010005	4-Str Outboard	6	11	9.07	191	2630.1
2282010005	4-Str Outboard	11	16	14.83	177	11364.9
2282010005	4-Str Outboard	25	40	32.01	148	7717.3
2282010005	4-Str Outboard	50	75	63.58	126	2673.3
2282010005	4-Str Outboard	75	100	85.05	126	2673.3
2282010005	4-Str Outboard	100	175	127.8	108	3968.0
2282005015	2-Str Personal Water Craft	1	3	2.01	160	238.6
2282005015	2-Str Personal Water Craft	3	6	4.96	160	238.6
2282005015	2-Str Personal Water Craft	6	11	9.12	160	238.6
2282005015	2-Str Personal Water Craft	16	25	25	160	1545.7
2282005015	2-Str Personal Water Craft	25	40	29.59	160	524.6
2282005015	2-Str Personal Water Craft	40	50	46.59	160	524.6
2282005015	2-Str Personal Water Craft	50	75	61.51	160	400.9
2282005015	2-Str Personal Water Craft	75	100	88.85	160	400.9
2282005015	2-Str Personal Water Craft	100	175	130	160	725.8
2282010005	4-Str Personal Water Craft	3	6	4.96	160	378.1
2282010005	4-Str Personal Water Craft	6	11	9.12	160	378.1
2282010005	4-Str Personal Water Craft	11	16	14.83	177	1633.7
2282010005	4-Str Personal Water Craft	25	40	29.59	160	1109.4
2282010005	4-Str Personal Water Craft	50	75	61.51	160	384.3
2282010005	4-Str Personal Water Craft	75	100	88.85	160	384.3
2282010005	4-Str Personal Water Craft	100	175	130	160	570.4

Table 3-135 presents the recreational boat engine load factor (USEPA, 2009a) and annual operating time (TR, 2009) data used within the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-135: Recreational boats NonRoad Model load factor and annual operating time

SCC	Engine description	hp_{min}	hp_{max}	LF	Annual operating time (h/year)
2282010005	4-Str Inboard	0	9999	0.21	31.3
2282020005	Dsl – Inboard	0	9999	0.35	31.3
2282005010	2-Str Outboard	0	9999	0.21	44.5
2282010005	4-Str Outboard	0	9999	0.21	44.5
2282005015	2-Str Personal Water Craft	0	9999	0.21	10.1
2282010005	4-Str Personal Water Craft	0	9999	0.21	10.1

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 recreational boats.

Table 3-136 presents the recreational boats fuel consumption estimates from the *NONROAD2008a Model* (USEPA, 2009a).

Table 3-136: Recreational boats NonRoad Model fuel consumption in the GMR

Engine description	2008 fuel consumption (kL/year)			
	2-stroke petrol	4-stroke petrol	Diesel	Grand Total
Inboard/Sterndrive	-	7,871	831	8,701
Outboard	37,963	-	-	37,963
Personal Water Craft	312	-	-	312
Grand Total	38,275	7,871	831	46,976

3.6.4 *Emission and Speciation Factors*

Table 3-137 summarises the emission and speciation factors used for recreational boat engines.

Table 3-137: Recreational boats 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, 2009a)
Criteria pollutants: VOC	2-stroke /4-stroke petrol and diesel exhaust and evaporative	- *NONROAD2008a Model* (USEPA, 2009a)
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,*

Substance	Emission source	Emission and speciation factor source
		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 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)
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*

Substance	Emission source	Emission and speciation factor source
		(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 and Polychlorinated dibenzofurans: PCDD and PCDF	2-stroke petrol 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 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, 2009a)
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 3-138 presents average activity weighted 2-stroke/4-stroke petrol and diesel exhaust and evaporative emission factors for recreational boats.

Table 3-138: Recreational boats 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	3.18	0.058	0.029	0.152	3.67	3.38	183.60	1.598	305.15	1,781.73	0.0053	3.29×10^{-12}
4-stroke petrol exhaust	19.26	0.058	0.029	0.199	0.17	0.16	13.79	1.478	367.95	2,305.10	0.0175	3.29×10^{-12}
Diesel exhaust	33.88	0.069	0.022	0.083	1.61	1.56	3.84	0.058	11.65	2,701.78	0.0017	4.57×10^{-9}
2-stroke petrol evaporative	-	-	-	-	-	-	28.90	-	-	-	-	-
4-stroke petrol evaporative	-	-	-	-	-	-	29.26	-	-	-	-	-
Diesel evaporative	-	-	-	-	-	-	0.08	1.17×10^{-3}	-	-	-	-

3.6.5 Spatial Distribution of Emissions

Table 3-139 summarises the data used for spatially allocating emissions from recreational boat engines.

Table 3-139: Recreational boats spatial data

Emission source	Spatial data	Spatial data source
Exhaust and evaporative emissions from recreational boats	Gridded 1 km x 1 km petrol and diesel consumption estimates allocated to water bodies	- *Recreational Boat Pollution Survey* (TR, 2009) - *NONROAD2008a Model* (USEPA, 2009a)

Emissions from recreational boats have been spatially distributed according to petrol and diesel consumption, which is proportional to annual operating time within each water body. Recreational boat operating area data has been combined with recreational boat survey data to estimate petrol and diesel consumption for recreational boats in each 1 km by 1 km grid cell using the following data:

➢ *Recreational boat operating areas* - include Botany Bay, Broken Bay, Hawkesbury River, Hunter River, Lake Illawarra, Lake Macquarie, Nepean River, Open Ocean, Parramatta River, Port Hacking, Port Jackson, Port Stephens and Tuggerah Lakes (TR, 2009).

➢ *Recreational boat survey data* - include a domestic survey of recreational boat ownership and usage for each of the 64 local government areas (LGA) located in the GMR. The survey results include data about: boat type and number; engine type, size, power, fuel used and age; and boat operating area, frequency and duration of use by hour, day and month (TR, 2009).

The proportion of petrol and diesel consumption by LGA, water body and region is presented in Table 3-140 and shown in Figure 3-95 and Figure 3-96.

Table 3-140: Recreational boats spatial distribution of petrol and diesel consumption by LGA, water body and region

LGA	Water body	2008 proportion of annual petrol and diesel consumption (%)				
		Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Ashfield	Port Jackson	-	-	5.91×10^{-2}	-	5.91×10^{-2}
Ashfield Total		-	-	5.91×10^{-2}	-	5.91×10^{-2}
Auburn	Parramatta River	-	-	0.32	-	0.32
	Port Jackson	-	-	0.18	-	0.18
Auburn Total		-	-	0.50	-	0.50
Baulkham Hills	Hawkesbury River	-	0.66	-	-	0.66
Baulkham Hills Total		-	0.66	-	-	0.66
Blacktown	Other Rivers	-	-	0.36	-	0.36
Blacktown Total		-	-	0.36	-	0.36
Blue Mountains	Nepean River	-	-	0.39	-	0.39
Blue Mountains Total		-	-	0.39	-	0.39
Botany Bay	Botany Bay	-	-	0.42	-	0.42
Botany Bay Total		-	-	0.42	-	0.42

LGA	Water body	2008 proportion of annual petrol and diesel consumption (%)				
		Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Camden	Nepean River	-	-	0.69	-	0.69
Camden Total		-	-	0.69	-	0.69
Campbelltown	Nepean River	-	-	0.17	-	0.17
	Other Rivers	-	-	0.20	-	0.20
Campbelltown Total		-	-	0.37	-	0.37
Canada Bay	Parramatta River	-	-	0.16	-	0.16
	Port Jackson	-	-	0.53	-	0.53
Canada Bay Total		-	-	0.69	-	0.69
Dungog	Other Rivers	-	0.40	-	-	0.40
Dungog Total		-	0.40	-	-	0.40
Fairfield	Other Rivers	-	-	0.12	-	0.12
Fairfield Total		-	-	0.12	-	0.12
Gosford	Broken Bay	-	-	5.01	-	5.01
	Hawkesbury River	-	1.32	4.46	-	5.78
	Other Rivers	-	0.65	-	-	0.65
Gosford Total		-	1.97	9.47	-	11.43
Great Lakes	Port Stephens	-	0.51	-	-	0.51
Great Lakes Total		-	0.51	-	-	0.51
Hawkesbury	Hawkesbury River	-	1.16	-	-	1.16
	Nepean River	-	-	0.19	-	0.19
Hawkesbury Total		-	1.16	0.19	-	1.35
Hornsby	Broken Bay	-	-	2.15	-	2.15
	Hawkesbury River	-	0.66	5.78	-	6.44
Hornsby Total		-	0.66	7.93	-	8.59
Hunters Hill	Port Jackson	-	-	0.18	-	0.18
Hunters Hill Total		-	-	0.18	-	0.18
Lake Macquarie	Lake Macquarie	1.65	13.13	-	-	14.78
	Other Rivers	-	0.12	-	-	0.12
Lake Macquarie Total		1.65	13.25	-	-	14.90
Leichhardt	Port Jackson	-	-	0.30	-	0.30
Leichhardt Total		-	-	0.30	-	0.30
Lithgow	Other Rivers	-	0.69	-	-	0.69
Lithgow Total		-	0.69	-	-	0.69
Liverpool	Nepean River	-	-	0.19	-	0.19
Liverpool Total		-	-	0.19	-	0.19
Maitland	Hunter River	-	0.40	-	-	0.40
	Other Rivers	0.12	0.12	-	-	0.24
Maitland Total		0.12	0.52	-	-	0.64
Manly	Port Jackson	-	-	0.24	-	0.24
Manly Total		-	-	0.24	-	0.24
Mosman	Port Jackson	-	-	0.18	-	0.18
Mosman Total		-	-	0.18	-	0.18
Muswellbrook	Hunter River	-	0.50	-	-	0.50
	Other Rivers	-	1.01	-	-	1.01

LGA	Water body	2008 proportion of annual petrol and diesel consumption (%)				
		Newcastle	Non Urban	Sydney	Wollongong	Grand Total
Muswellbrook Total		-	1.51	-	-	1.51
N/A	Broken Bay	-	-	0.82	-	0.82
	Other Rivers	4.03×10^{-2}	-	-	-	4.03×10^{-2}
	Port Jackson	-	-	0.18	-	0.18
N/A Total		4.03×10^{-2}	-	0.99	-	1.04
Newcastle	Other Rivers	2.30	-	-	-	2.30
Newcastle Total		2.30	-	-	-	2.30
North Sydney	Port Jackson	-	-	0.18	-	0.18
North Sydney Total		-	-	0.18	-	0.18
Parramatta	Parramatta River	-	-	0.85	-	0.85
Parramatta Total		-	-	0.85	-	0.85
Penrith	Nepean River	-	-	0.89	-	0.89
Penrith Total		-	-	0.89	-	0.89
Pittwater	Broken Bay	-	-	2.55	-	2.55
Pittwater Total		-	-	2.55	-	2.55
Port Stephens	Hunter River	-	5.26×10^{-2}	-	-	5.26×10^{-2}
	Other Rivers	0.81	2.62	-	-	3.43
	Port Stephens	-	6.51	-	-	6.51
Port Stephens Total		0.81	9.19	-	-	9.99
Randwick	Botany Bay	-	-	0.12	-	0.12
Randwick Total		-	-	0.12	-	0.12
Rockdale	Botany Bay	-	-	0.24	-	0.24
Rockdale Total		-	-	0.24	-	0.24
Ryde	Parramatta River	-	-	0.16	-	0.16
	Port Jackson	-	-	0.12	-	0.12
Ryde Total		-	-	0.28	-	0.28
Shellharbour	Lake Illawarra	-	0.15	-	0.35	0.50
Shellharbour Total		-	0.15	-	0.35	0.50
Singleton	Hunter River	-	0.81	-	-	0.81
	Other Rivers	-	2.42	-	-	2.42
Singleton Total		-	3.23	-	-	3.23
Sutherland	Botany Bay	-	-	1.07	-	1.07
	Other Rivers	-	-	0.20	-	0.20
	Port Hacking	-	-	5.26	-	5.26
Sutherland Total		-	-	6.54	-	6.54
Sydney	Port Jackson	-	-	0.30	-	0.30
Sydney Total		-	-	0.30	-	0.30
Unincorporated	Botany Bay	-	-	1.67	-	1.67
	Parramatta River	-	-	0.27	-	0.27
	Port Jackson	-	-	2.60	-	2.60
Unincorporated Total		-	-	4.53	-	4.53
Warringah	Other Rivers	-	-	0.32	-	0.32
Warringah Total		-	-	0.32	-	0.32
Wingecarribee	Nepean River	-	0.61	-	8.31×10^{-2}	0.69

LGA	Water body	2008 proportion of annual petrol and diesel consumption (%)				
		Newcastle	Non Urban	Sydney	Wollongong	Grand Total
	Other Rivers	-	1.53	-	1.61	3.15
Wingecarribee Total		-	2.14	-	1.70	3.84
Wollondilly	Nepean River	-	-	2.02	2.77×10^{-2}	2.05
	Other Rivers	-	4.36	4.07	4.03×10^{-2}	8.47
Wollondilly Total		-	4.36	6.10	6.80×10^{-2}	10.52
Wollongong	Lake Illawarra	-	-	-	1.26	1.26
	Other Rivers	-	-	1.01	1.86	2.86
Wollongong Total		-	-	1.01	3.11	4.12
Woollahra	Port Jackson	-	-	0.24	-	0.24
Woollahra Total		-	-	0.24	-	0.24
Wyong	Lake Macquarie	-	1.01	-	-	1.01
	Other Rivers	-	1.09	-	-	1.09
Wyong Total		-	2.10	-	-	2.10
Grand Total		4.92	42.47	47.39	5.23	100.00

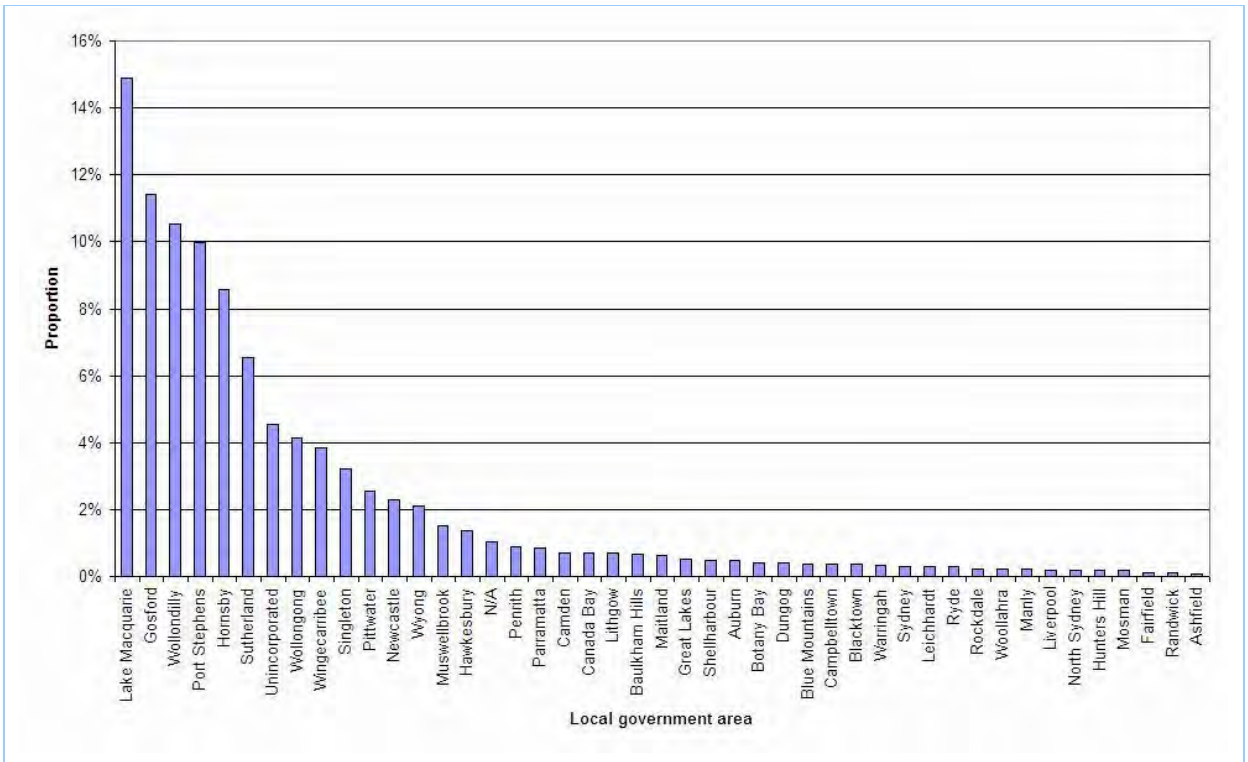

Figure 3-95: Recreational boats spatial distribution of petrol and diesel consumption by LGA

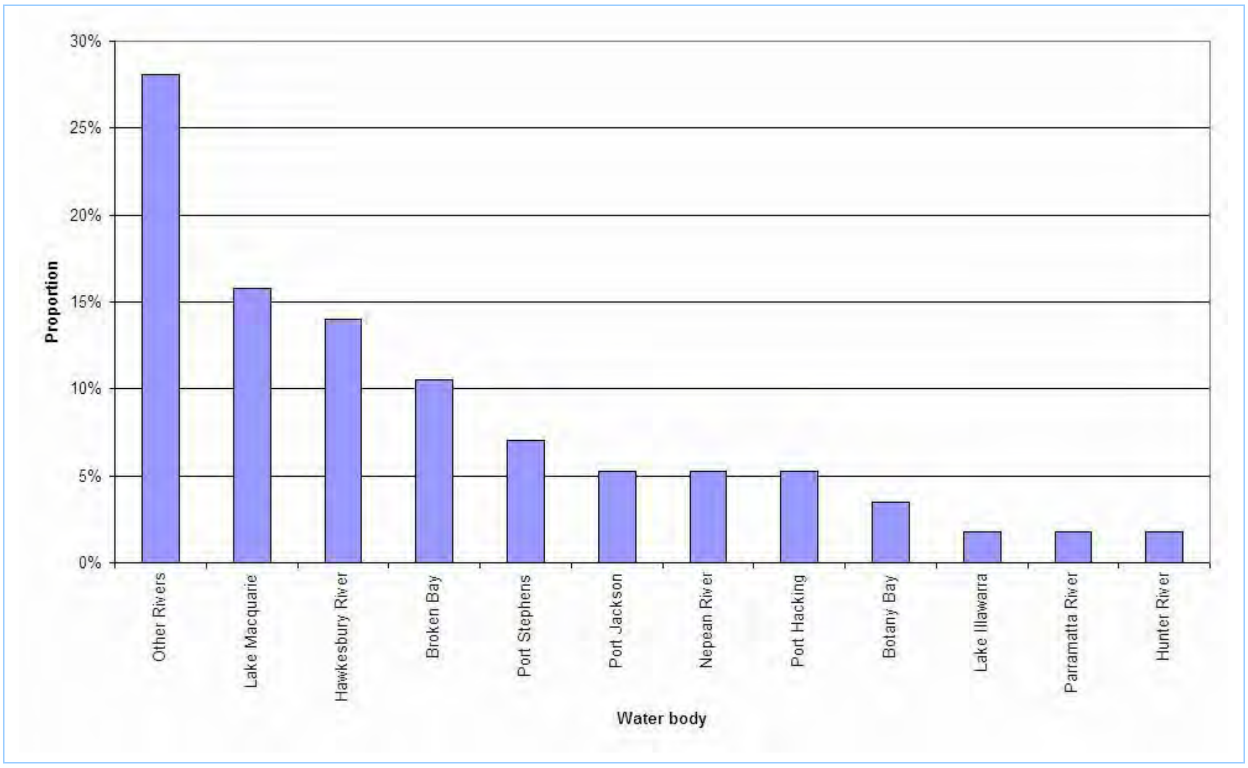

Figure 3-96: Recreational boats spatial distribution of petrol and diesel consumption by water body

Figure 3-97 shows the spatial distribution of recreational boat emissions.

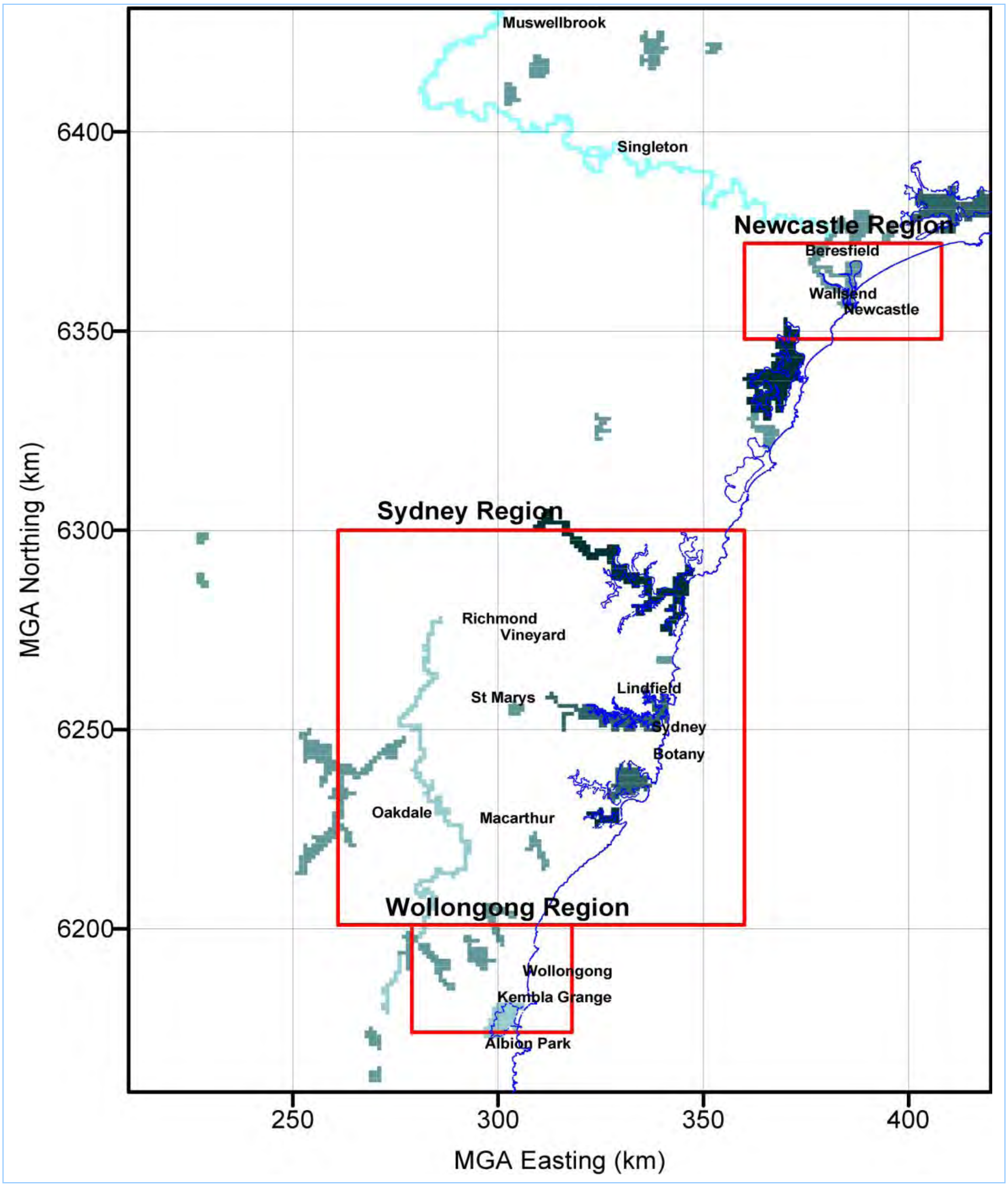

Figure 3-97: Recreational boats spatial distribution of emissions

3.6.6 *Temporal Variation of Emissions*

Table 3-141 summarises the data used to estimate the temporal variation in emissions from recreational boat engines.

Table 3-141: Recreational boats temporal data

Emission source	Temporal data	Temporal data source
Exhaust and evaporative emissions from recreational boats	Monthly, daily and hourly: Derived from domestic survey	- *Recreational Boat Pollution Survey* (TR, 2009)

The temporal variation in exhaust and evaporative emissions from recreational boat engines have been estimated using engine population (TR, 2009), annual operating time (TR, 2009), 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 (TR, 2009) data within the *NONROAD2008a Model* (USEPA, 2009a). Hourly temporal variation profiles for exhaust emissions are presented in Table 3-142 and shown in Figure 3-98.

Table 3-142: Recreational boats exhaust hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	-	13	9.47
2	-	14	9.05
3	-	15	9.47
4	0.41	16	6.58
5	0.41	17	4.53
6	1.23	18	3.29
7	3.70	19	2.88
8	4.53	20	0.82
9	7.41	21	0.41
10	11.11	22	0.41
11	12.35	23	-
12	11.93	24	-

Hourly temporal variation profiles for evaporative emissions are presented in Table 3-143 (weighted hourly composite) and shown in Figure 3-99 (weighted hourly composite by source type).

Table 3-143: Recreational boats evaporative hourly temporal profile

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
1	3.00	2.66	13	6.29	6.73
2	2.96	2.62	14	6.20	6.59
3	2.93	2.59	15	5.95	6.40
4	2.92	2.62	16	5.49	5.63
5	2.90	2.60	17	4.90	4.84
6	2.96	2.73	18	4.22	4.08
7	3.32	3.30	19	3.69	3.56
8	3.95	3.97	20	3.35	3.04
9	4.77	5.04	21	3.20	2.87
10	5.51	6.17	22	3.13	2.81
11	5.99	6.78	23	3.07	2.72

Hour	Week day proportion (%)	Weekend proportion (%)	Hour	Week day proportion (%)	Weekend proportion (%)
12	6.25	6.99	24	3.03	2.68

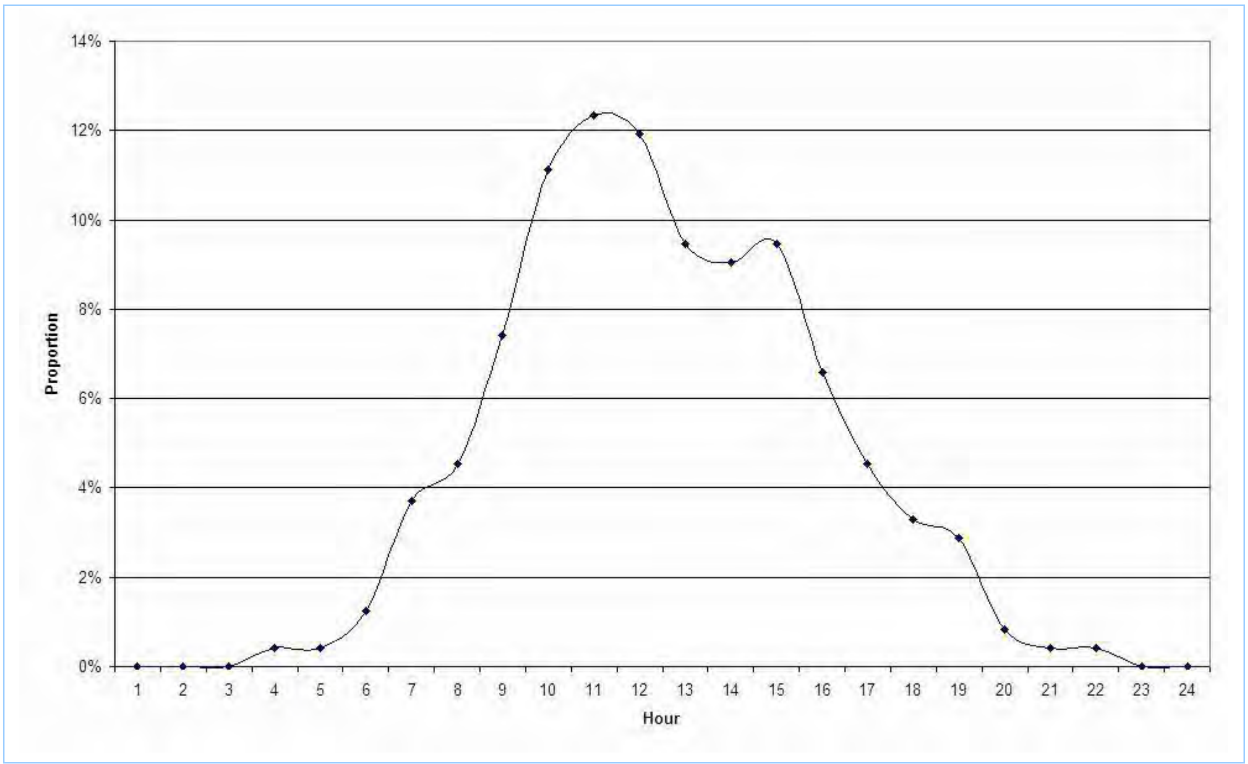

Figure 3-98: Recreational boats exhaust hourly temporal profile

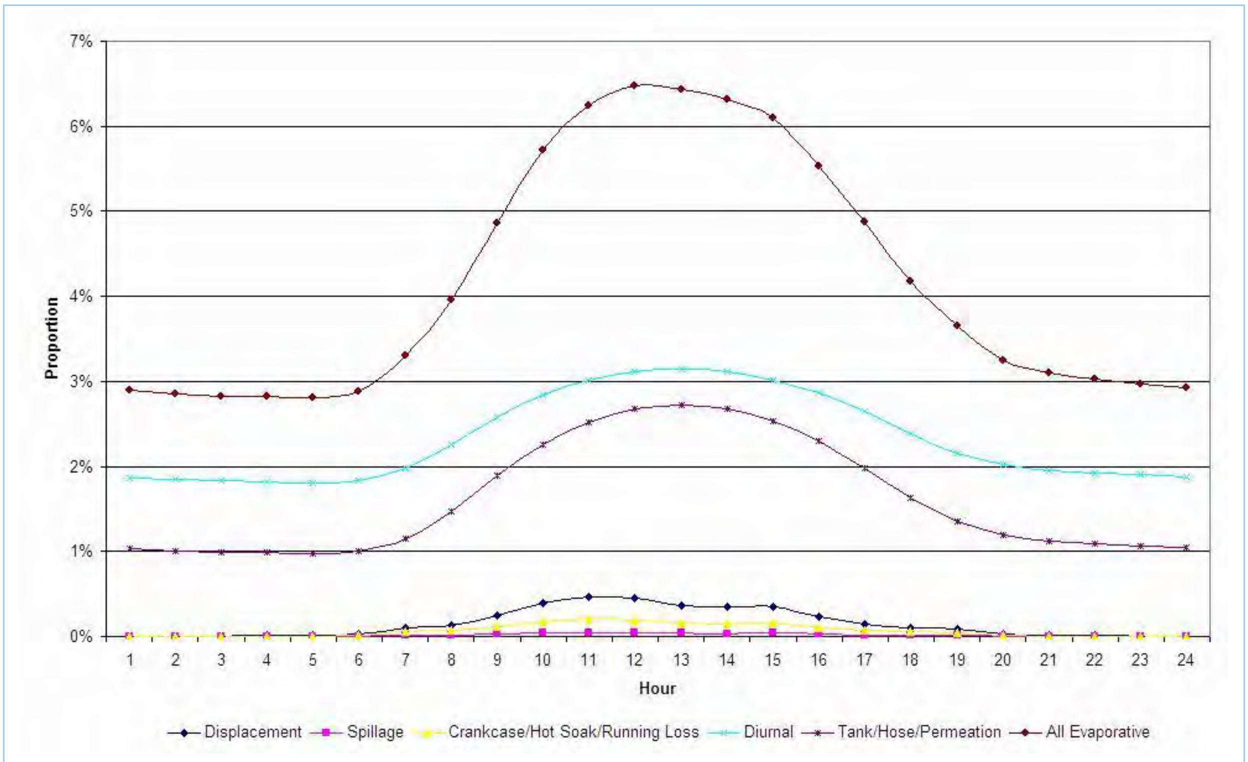

Figure 3-99: Recreational boats evaporative hourly temporal profile

Daily temporal variation profiles for exhaust emissions are presented in Table 3-144 and shown in Figure 3-100.

Table 3-144: Recreational boats exhaust daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	5.00	5.00	5.00	5.00	5.00	37.50	37.50

Daily temporal variation profiles for evaporative emissions are presented in Table 3-145 (weighted daily composite) and shown in Figure 3-101 (weighted daily composite by source type).

Table 3-145: Recreational boats evaporative daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	13.77	13.77	13.77	13.77	13.77	15.57	15.57

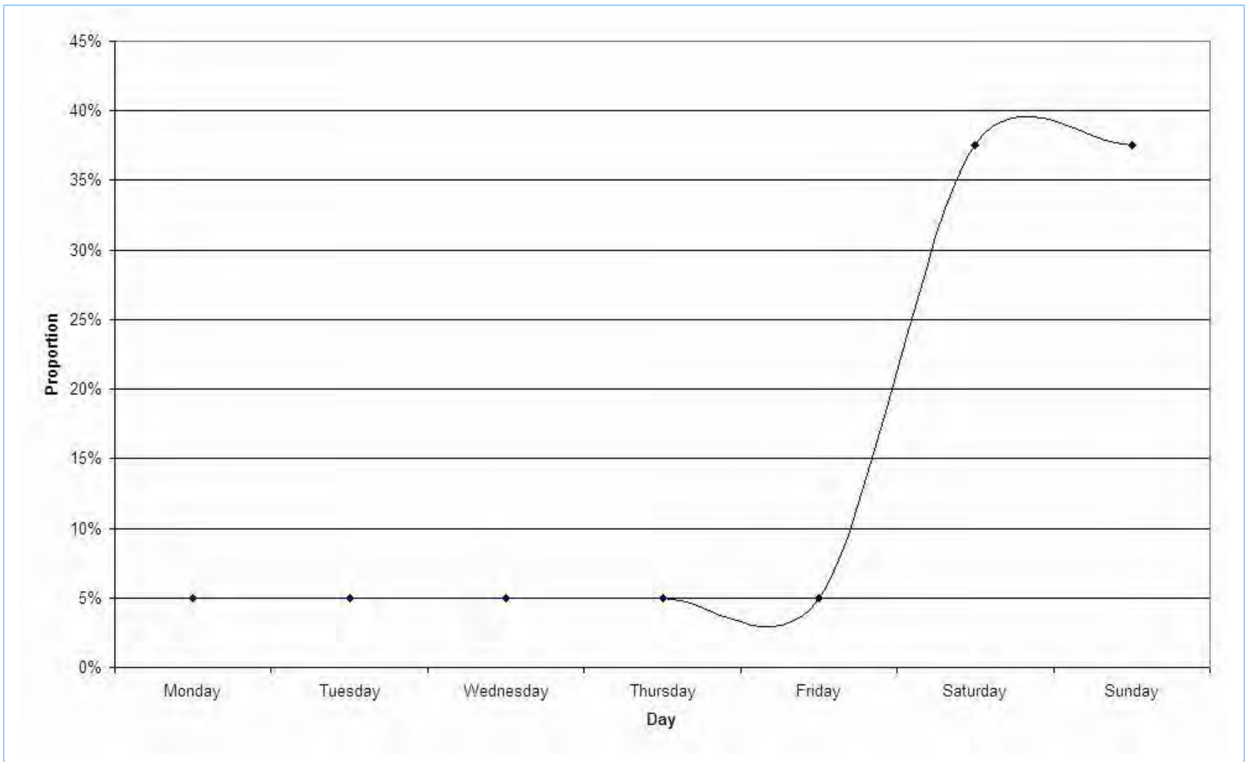

Figure 3-100: Recreational boats exhaust daily temporal profile

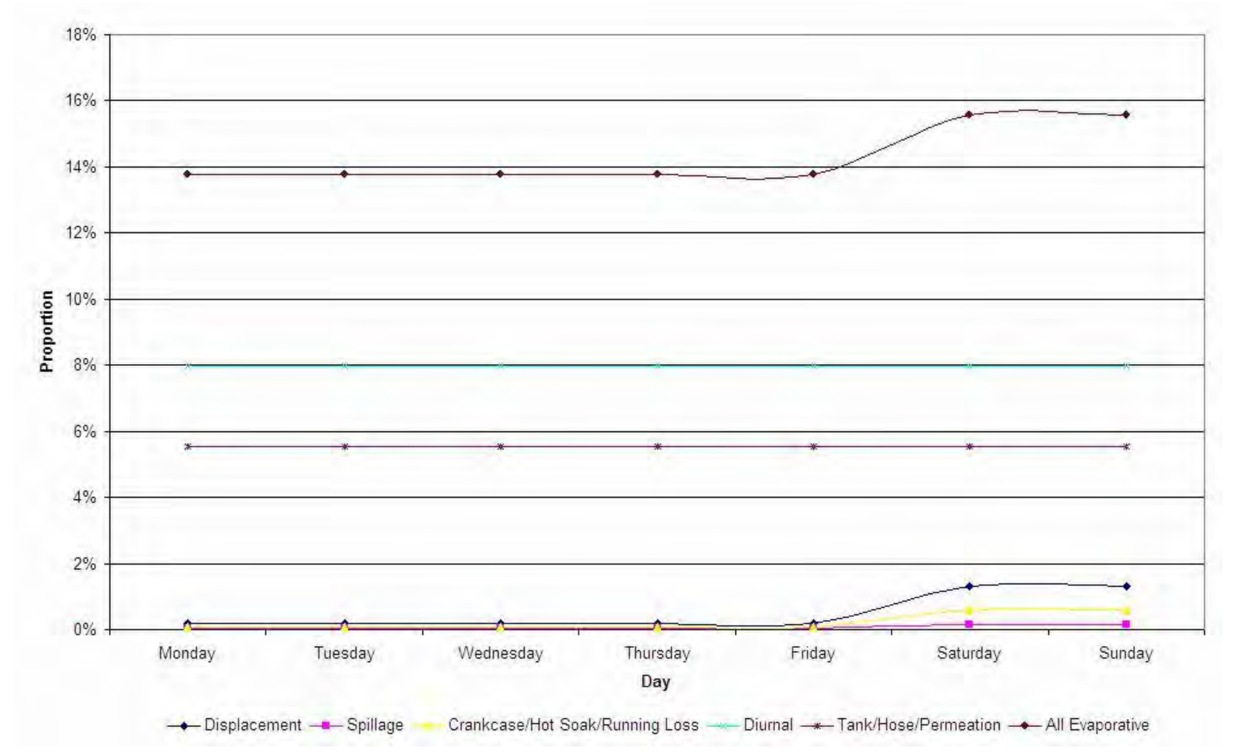

Figure 3-101: Recreational boats evaporative daily temporal profile

Monthly temporal variation profiles for exhaust emissions are presented in Table 3-146 and shown in Figure 3-102.

Table 3-146: Recreational boats exhaust monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	13.42	July	3.46
February	13.85	August	3.46
March	11.69	September	5.19
April	7.36	October	9.09
May	3.90	November	12.55
June	3.46	December	12.55

Monthly temporal variation profiles for evaporative emissions are presented in Table 3-147 (weighted monthly composite) and shown in Figure 3-103 (weighted monthly composite by source type).

Table 3-147: Recreational boats evaporative monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	10.97	July	6.01
February	10.48	August	6.18
March	9.32	September	7.03
April	8.08	October	8.23
May	6.97	November	9.53
June	6.35	December	10.86

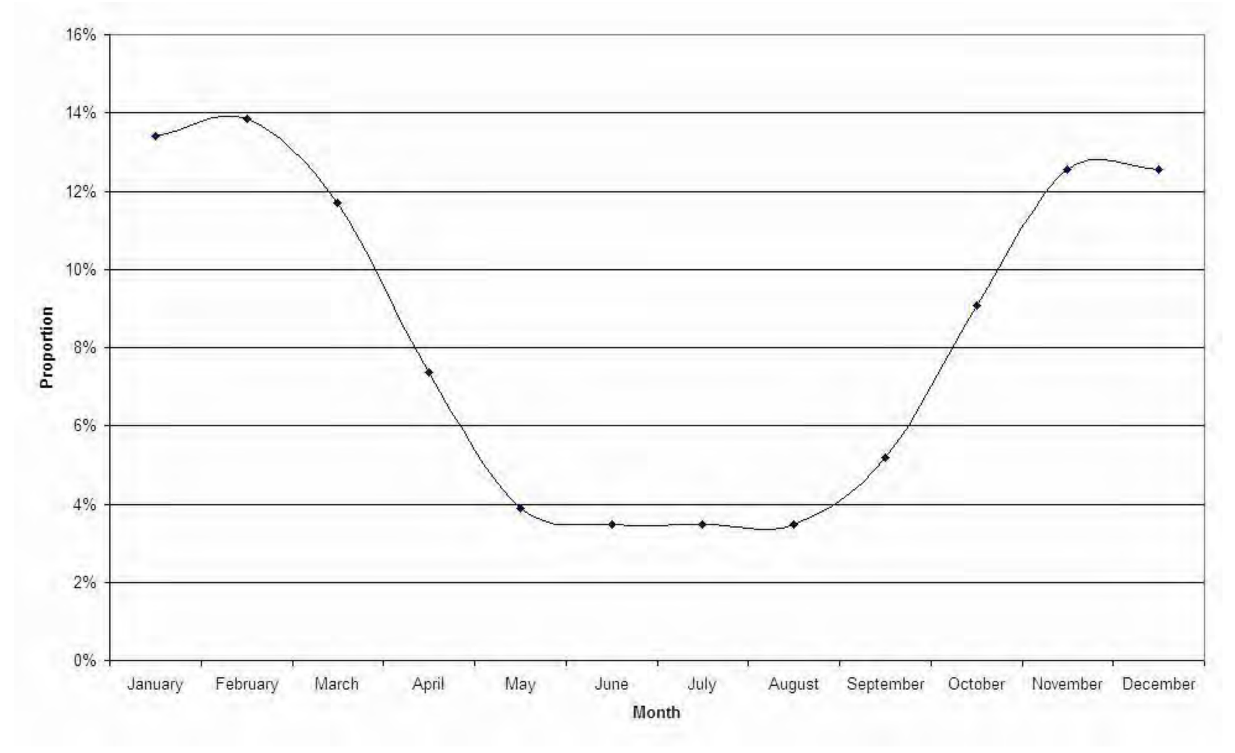

Figure 3-102: Recreational boats exhaust monthly temporal profile

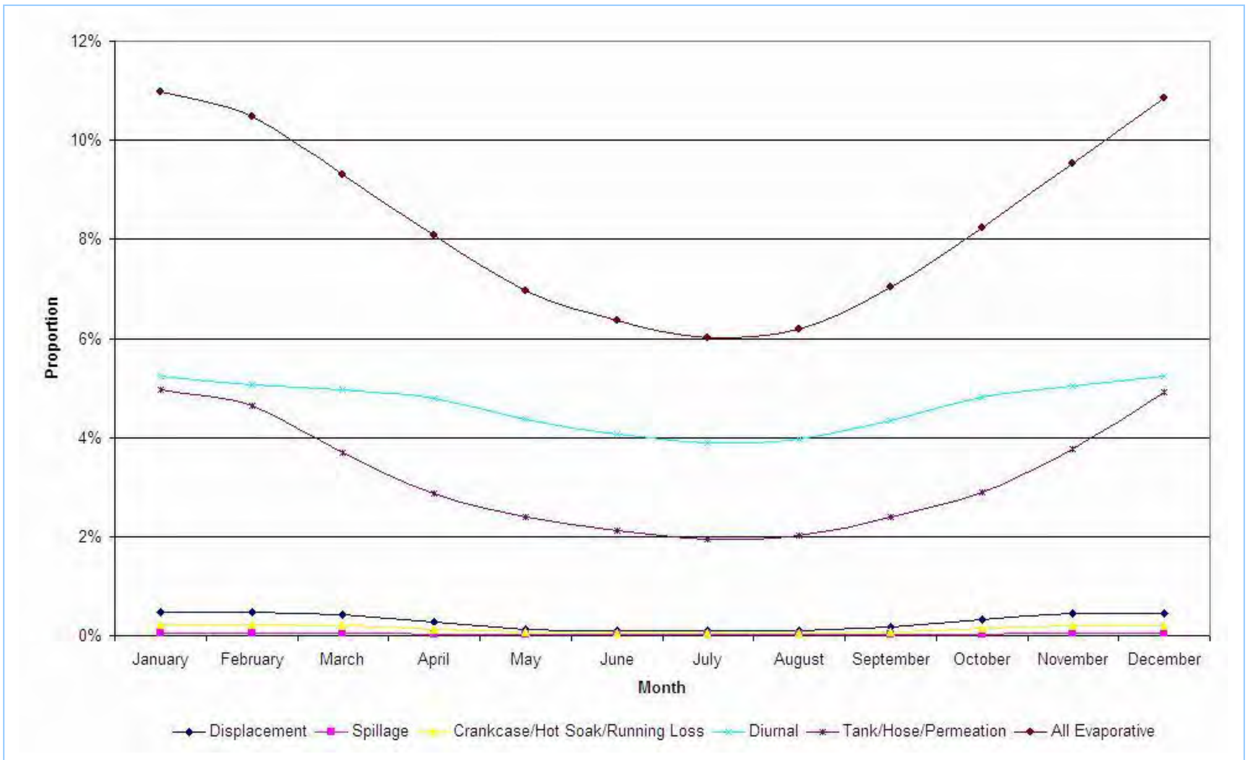

Figure 3-103: Recreational boats evaporative monthly temporal profile

3.6.7 Emission Estimates

Table 3-148 presents annual emissions of selected substances from recreational boat engines by activity.

Table 3-148: Recreational boats emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Recreational Boats Exhaust	1,3-BUTADIENE	793	6,844	7,638	843	16,117
	ACETALDEHYDE	605	5,227	5,833	643	12,309
	BENZENE	8,980	77,522	86,508	9,544	182,554
	CARBON MONOXIDE	717,473	6,193,675	6,911,599	762,481	14,585,228
	FORMALDEHYDE	987	8,524	9,512	1,049	20,074
	ISOMERS OF XYLENE	37,522	323,912	361,458	39,876	762,768
	LEAD & COMPOUNDS	11	98	109	12	231
	OXIDES OF NITROGEN	14,818	127,918	142,746	15,748	301,229
	PARTICULATE MATTER ≤ 10 µm	7,042	60,790	67,837	7,484	143,152
	PARTICULATE MATTER ≤ 2.5 µm	6,482	55,955	62,441	6,888	131,767
	POLYCYCLIC AROMATIC HYDROCARBONS	17	145	162	18	342
	SULFUR DIOXIDE	367	3,170	3,537	390	7,465
	TOLUENE	34,193	295,179	329,394	36,338	695,104
	TOTAL SUSPENDED PARTICULATE	7,260	62,676	69,941	7,716	147,594
	TOTAL VOLATILE ORGANIC COMPOUNDS	351,186	3,031,658	3,383,065	373,217	7,139,125
Recreational Boats Evaporative	BENZENE	513	4,427	4,940	545	10,424
	ISOMERS OF XYLENE	362	3,121	3,483	384	7,350
	TOLUENE	1,249	10,783	12,033	1,327	25,392
	TOTAL VOLATILE ORGANIC COMPOUNDS	65,741	567,520	633,303	69,865	1,336,430

Table 3-149 presents annual emissions of selected substances from recreational boat engines by source type.

Table 3-149: Recreational boats emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Exhaust - Petrol 2 Stroke	1,3-BUTADIENE	742	6,403	7,145	788	15,078
	ACETALDEHYDE	575	4,966	5,542	611	11,694
	BENZENE	8,697	75,077	83,779	9,242	176,796
	CARBON MONOXIDE	574,535	4,959,749	5,534,645	610,577	11,679,506
	FORMALDEHYDE	877	7,574	8,452	932	17,836
	ISOMERS OF XYLENE	37,158	320,773	357,955	39,489	755,376
	LEAD & COMPOUNDS	9.41	81	91	10	191

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	OXIDES OF NITROGEN	5,979	51,610	57,593	6,354	121,535
	PARTICULATE MATTER ≤ 10 µm	6,911	59,657	66,572	7,344	140,484
	PARTICULATE MATTER ≤ 2.5 µm	6,358	54,885	61,246	6,757	129,246
	POLYCYCLIC AROMATIC HYDROCARBONS	9.99	86	96	11	203
	SULFUR DIOXIDE	287	2,476	2,763	305	5,830
	TOLUENE	33,807	291,847	325,676	35,928	687,259
	TOTAL SUSPENDED PARTICULATE	7,124	61,502	68,631	7,571	144,829
	TOTAL VOLATILE ORGANIC COMPOUNDS	345,690	2,984,217	3,330,125	367,376	7,027,408
Exhaust - Petrol 4 Stroke	1,3-BUTADIENE	51	439	490	54	1,033
	ACETALDEHYDE	22	189	211	23	445
	BENZENE	280	2,418	2,698	298	5,694
	CARBON MONOXIDE	142,462	1,229,817	1,372,369	151,398	2,896,046
	FORMALDEHYDE	92	790	882	97	1,861
	ISOMERS OF XYLENE	362	3,125	3,487	385	7,358
	LEAD & COMPOUNDS	1.94	17	19	2.06	39
	OXIDES OF NITROGEN	7,455	64,359	71,819	7,923	151,556
	PARTICULATE MATTER ≤ 10 µm	66	565	631	70	1,332
	PARTICULATE MATTER ≤ 2.5 µm	60	520	581	64	1,225
	POLYCYCLIC AROMATIC HYDROCARBONS	6.78	59	65	7.21	138
	SULFUR DIOXIDE	77	665	742	82	1,566
	TOLUENE	384	3,311	3,695	408	7,797
	TOTAL SUSPENDED PARTICULATE	68	583	651	72	1,373
	TOTAL VOLATILE ORGANIC COMPOUNDS	5,339	46,087	51,429	5,674	108,528
Exhaust – Diesel	1,3-BUTADIENE	0.29	2.52	2.81	0.31	5.94
	ACETALDEHYDE	8.33	72	80	8.85	169
	BENZENE	3.19	28	31	3.39	65
	CARBON MONOXIDE	476	4,109	4,585	506	9,676
	FORMALDEHYDE	19	160	179	20	377
	ISOMERS OF XYLENE	1.66	14	16	1.76	34
	LEAD & COMPOUNDS	2.05×10^{-3}	1.77×10^{-2}	1.98×10^{-2}	2.18×10^{-3}	4.18×10^{-2}
	OXIDES OF NITROGEN	1,384	11,949	13,334	1,471	28,138
	PARTICULATE MATTER ≤ 10 µm	66	568	633	70	1,336
	PARTICULATE MATTER	64	550	614	68	1,296

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	≤ 2.5 µm					
	POLYCYCLIC AROMATIC HYDROCARBONS	6.80×10^{-2}	0.59	0.66	7.23×10^{-2}	1.38
	SULFUR DIOXIDE	3.38	29	33	3.59	69
	TOLUENE	2.35	20	23	2.50	48
	TOTAL SUSPENDED PARTICULATE	68	591	660	73	1,392
	TOTAL VOLATILE ORGANIC COMPOUNDS	157	1,354	1,511	167	3,190
Evaporative	BENZENE	513	4,427	4,940	545	10,424
	ISOMERS OF XYLENE	362	3,121	3,483	384	7,350
	TOLUENE	1,249	10,783	12,033	1,327	25,392
	TOTAL VOLATILE ORGANIC COMPOUNDS	65,741	567,520	633,303	69,865	1,336,430

3.6.8 *Emission Projection Methodology*

Table 3-150 summarises the data used to estimate the emission projection factors for recreational boat engines, while Figure 3-104 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-150: Recreational boats emission projection factors

Emissions source	Projection factor surrogate	Projection factor source
Exhaust and evaporative emissions from recreational boats	Total dwelling growth	- *Forecasts for Total Dwelling from 2006 to 2036* (TDC, 2009)

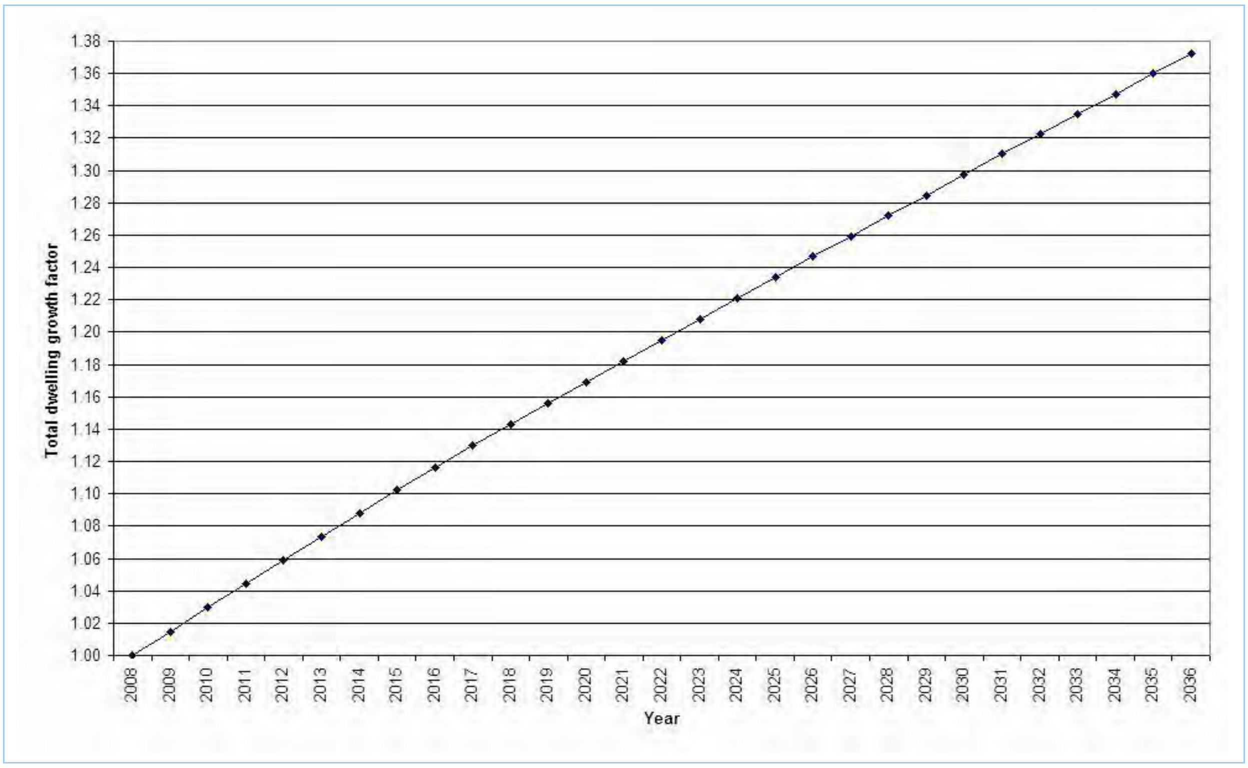

Figure 3-104: Recreational boats emission projection factors

3.7 Ships

3.7.1 Emission Source Description

The off-road mobile air emissions inventory includes emissions of:

- Combustion products (i.e. exhaust) from ocean going vessel (OGV):
    - Main engines;
    - Auxiliary engines; and
    - Auxiliary boilers.
- Evaporative VOC from refuelling OGV.

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

- *Port location, shipping logs, pilot data and Lloyd's Register of Ships*

There are four ports considered in this inventory, including Newcastle, Sydney, Port Botany and Port Kembla.

For each OGV entering and exiting the four ports, shipping logs have been obtained from port authorities, which contain amongst other data, international maritime organisation (IMO) number, vessel name, dead weight tonnage (DWT) and time and date of arrival and departure (NPC, 2009; SPC, 2009; and PKPC, 2009).

Pilot data obtained from port authorities includes anchorage and dock coordinates, shipping lanes and speed limits within the port boundaries (NPC, 2009; SPC, 2009; and PKPC, 2009).

The shipping logs and pilot data have been used to establish main engine, auxiliary engine and auxiliary boiler operating times during cruise, reduced speed zone (RSZ), manoeuvre and hotel (i.e. anchorage and dock) modes of operation.

Each OGV listed in the shipping log has been matched with data from the Lloyd's Register of Ships to establish detailed vessel, engine and fuel characteristics (LR, 2010).

Figure 3-105 shows how pilot data, shipping logs and Lloyd's Register of Ships information have been used to calculate average vessel movements and characteristics. This information is then combined with emission factor data to develop an inventory of ocean going vessel emissions (ICF, 2009).

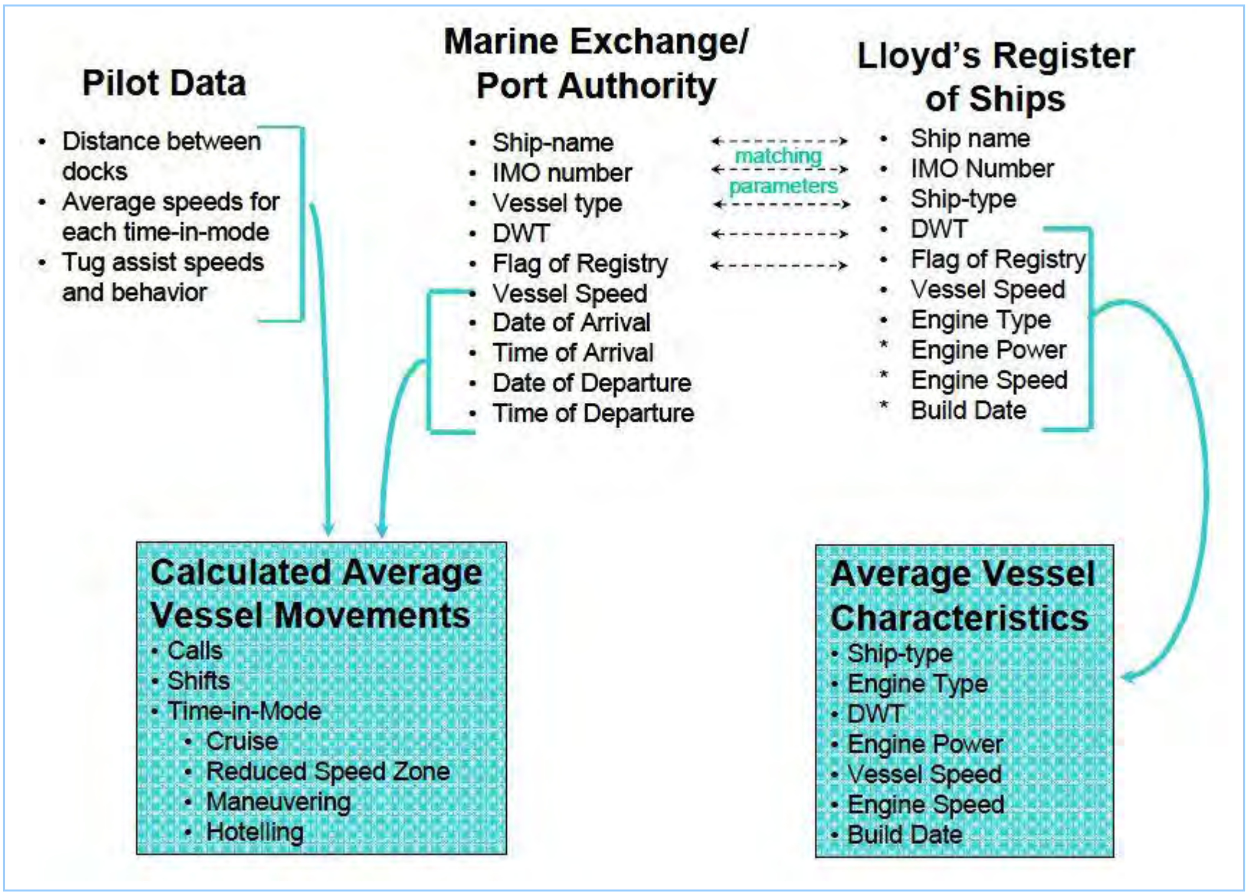

Figure 3-105: Ocean going vessel – use of pilot data, shipping logs and Lloyd's Register of Ships

➢ *Ship type*

The engine size and speed of OGVs varies according to ship type, so it is appropriate to describe them by the type of cargo they carry (ICF, 2009).

Table 3-151 presents the various OGVs included in the inventory, including ship category, description and ship type for the four ports considered (NPC, 2009; SPC, 2009; PKPC, 2009; and LR, 2010).

Table 3-151: Ocean going vessel ship category, description and ship type

Ship category	Description	Ship type
Auto Carrier	Self-propelled dry-cargo vessels that carry containerised automobiles	Vehicles Carrier
Bulk Carrier	Self-propelled dry-cargo ship that carries loose cargo	Aggregates Carrier
		Bulk Carrier
		Bulk Carrier, Self-discharging
		Cement Carrier
		Ore Carrier
		Wood Chips Carrier
Container	Self-propelled dry-cargo vessel that carries containerised cargo	Container Ship (Fully Cellular)
Cruise	Self-propelled cruise ships	Passenger/Cruise
General	Self-propelled cargo vessel that carries a variety of dry cargo	Barge Carrier

Ship category	Description	Ship type
Cargo		General Cargo Ship
		General Cargo Ship (with Ro-Ro facility)
		General Cargo Ship, Self-discharging
		General Cargo/Passenger Ship
		Heavy Load Carrier
		Livestock Carrier
		Open Hatch Cargo Ship
Miscellaneous	Category for those vessels that do not fit into one of the other categories or are unidentified	Cable Layer
		Crane Pontoon
		Cutter Suction Dredger
		Deck Cargo Pontoon, semi submersible
		Fishery Patrol Vessel
		Fishery Research Vessel
		Fishing Vessel
		Passenger Ship, Inland Waterways
		Research Survey Vessel
		Restaurant Vessel, Stationary
		Trailing Suction Hopper Dredger
		Trawler
		Utility Vessel
		Weapons Trials Vessel
		Yacht
Ocean Tug	Self-propelled tugboats and towboats that tow/push cargo or barges in the open ocean	Offshore Tug/Supply Ship
		Pusher Tug
		Tug
Reefer	Self-propelled dry-cargo vessels that often carry perishable items	Refrigerated Cargo Ship
RORO	Self-propelled vessel that handles cargo that is rolled on and off the ship, including ferries	Passenger/Ro-Ro Ship (Vehicles)
		Ro-Ro Cargo Ship
Tanker	Self-propelled liquid-cargo vessels including chemical tankers, petroleum product tankers, liquid food product tankers	Bunkering Tanker
		Chemical Tanker
		Chemical/Products Tanker
		Crude Oil Tanker
		Crude/Oil Products Tanker
		LPG Tanker
		Oil Tanker, Inland Waterways
		Products Tanker

- *Engine type*

Ocean going vessels generally include three engine types, including, main engine (ME), auxiliary engine (AE) and auxiliary boiler (AB). Reciprocating compression ignition (CI) main and auxiliary engines are normally classified by their crankshaft engine speed, namely, high speed (HSD), medium speed (MSD) and slow speed (SSD) diesel. Main engines in OGVs are largely slow and medium speed diesel. For auxiliary engines, high and medium speed diesels are more common. Steam turbine (ST) propulsion (i.e. using a boiler to generate steam, which then drives a turbine geared to the propeller shaft) has a relatively low efficiency and is largely being replaced by diesel engines (Entec, 2002; and ICF, 2009). Gas turbines (GT) are also used as main engines in some applications.

Main engines provide the main propulsion power for the OGV while in motion and are normally shut down when at anchorage or at dock. Modifications include addition of a shaft generator (i.e. to provide electric power at sea instead of auxiliary engines) and addition of an exhaust boiler (i.e. to provide steam for heating purposes). Main engines are largely compression ignition diesels and mostly medium speed 4-stroke or slow speed 2-stroke. In general, the main engine drives the propeller axle (either with or without a gear system) but in some cases, diesel-electric operation is used (i.e. the generator is used to drive an electric motor for propellers). The main engine load varies according to cruise, RSZ and manoeuvre modes of operation (Entec, 2002; and ICF, 2009).

Auxiliary engines drive a generator unit to provide electrical power for the OGV while in motion, at anchorage or at dock. Electrical power generation is used for on board lighting, ventilation, cranes and pumps etc. Auxiliary engines are normally shut down when a shaft generator is used on the main engine or when diesel-electric operation is used. Auxiliary engines are largely compression ignition diesels and mostly high speed 4-stroke or medium speed 4-stroke. The auxiliary engine load varies according to cruise, RSZ, manoeuvre and hotel (i.e. anchorage and dock) modes of operation (Entec, 2002; and ICF, 2009).

Table 3-152 presents the OGV main engine and auxiliary engine speed designations used in the inventory for reciprocating compression ignition diesels (ICF, 2009).

Table 3-152: Ocean going vessel main engine and auxiliary engine speed designations for reciprocating compression ignition diesels

Speed category	Engine RPM	Engine stroke type
Slow	< 130	2
Medium	130 – 1,400	4
High	> 1,400	4

Auxiliary boilers are used to heat fuel so it is fluid and to provide hot water for the vessel. They are generally used when the vessel is stationary, since most main engines are fitted with exhaust heat recovery systems (i.e. economisers) that use waste heat from the main engine exhaust. The auxiliary boiler load varies according to manoeuvre and hotel (i.e. anchorage and dock) modes of operation (Entec, 2002; and ICF, 2009).

- *Fuel type*

Ships consume a variety of fuels classed primarily by their viscosity, ranging from distillate through to heavier residual oil (RO). Within the distillate classification, a further division is normally made between marine gas oil (MGO) and marine diesel oil (MDO). Marine fuel used in OGVs is often referred to as bunker fuel or by its industrial name, intermediate fuel oil (IFO) (ICCT, 2007).

Residual oil is the heavy oil product remaining after distillation in a refinery. It is very viscous, so it is partially solid at low ambient temperatures and requires heating to turn it into a liquid state before it is delivered to the engine. Intermediate fuel oil is mainly composed of RO, the lowest grade of fuel oil available, mixed with varying levels of distillate oil. Marine diesel oil is a distillate which often contains traces of RO and is used to blend RO to produce IFO, while MGO is pure distillate (ICCT, 2007).

In this inventory, fuels with viscosity at 50°C ranging from 55 to 810, 5.5 to 50 and 1 to 5.5 Centistokes (mm^2/s) are classified as RO, MDO and MGO, respectively (Entec, 2002). Intermediate fuel oil is generally available in two grades, including IFO380 (world average 98% RO and 2% distillate oil) or IFO180 (world average 88% RO and 12% distillate oil), with viscosities at 50°C of 380 and 180 mm^2/s, respectively (ICCT, 2007).

Table 3-153 presents the OGV fuel types and properties used in the inventory (Entec, 2002). The sulfur content for each OGV fuel type used in the inventory is the world average (ICCT, 2007).

Table 3-153: Ocean going vessel fuel types and properties

Fuel type	Viscosity (mm^2/s)	Sulfur content (%)	Density (kg/L)	Effective heating value (MJ/kg)	Carbon content (%)
Residual Oil (RO)	55 to 810	2.67	0.965	40.96	86.61
Intermediate fuel oil (IFO)	55 to 810	2.67	0.965	40.96	86.61
Marine diesel oil (MDO)	5.5 to 50	0.65	0.900	42.19	86.68
Marine gas oil (MGO)	1 to 5.5	0.38	0.852	42.65	86.74

Figure 3-106 shows the fractional distillation of crude oil and the end use of each product. In general, RO is typically C_{20} to C_{70} fuel oil, IFO ranges from C_{20} to C_{50} lubricating oil to C_{20} to C_{70} fuel oil, MDO ranges from C_{14} to C_{20} diesel oils to C_{20} to C_{50} lubricating oil, while MGO is typically C_{14} to C_{20} diesel oils.

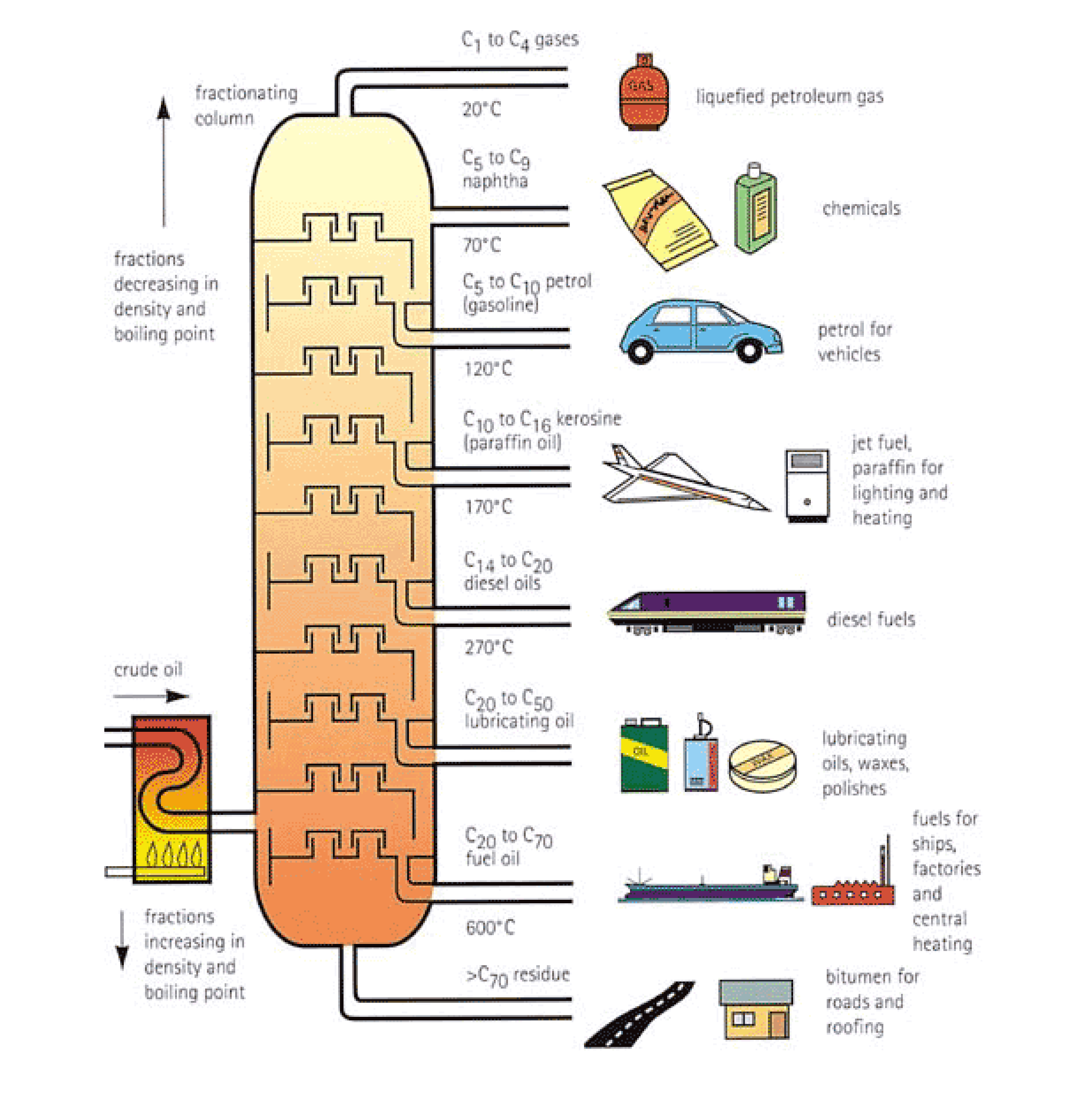

Figure 3-106: Fractional distillation of crude oil and the end use of each product

➢ *Mode of operation*

To describe an OGV's movements during a call, the transit route has been split into discrete sections which have similar average speed, engine load and emission characteristics. Vessel movements for each call have been described for four distinct modes of operation, including cruise, RSZ, manoeuvring and hotelling (i.e. anchorage and dock).

Cruise time-in-mode (TIM) has been estimated using average ship speed and distance. During cruise mode (i.e. cruise speed), OGVs travel at 94% (ICF, 2009) of the maximum service speed listed in Lloyd's Register of Ships (LR, 2010). For each port, the distance from the GMR boundary (i.e. north, south or west exit, depending on the origin and destination of the vessel) to the anchorage point has been used along with the cruise speed to calculate inbound and outbound cruise times.

Reduced speed zone time-in-mode (TIM) has been estimated using time elapsed from shipping logs. For each port, the inbound RSZ time starts when the OGV arrives at the anchorage point and ends at the pier/wharf/dock (PWD), while the outbound RSZ time starts when the OGV departs from the PWD and ends at the port boundary off the coast.

Manoeuvring time-in-mode (TIM) has been estimated using time elapsed from shipping logs. Since the OGV does not need to dock, outbound speeds are greater than inbound speeds. Manoeuvring time has been estimated using the difference between the inbound and outbound RSZ time.

Hotelling time-in-mode (TIM) has been estimated using time elapsed from shipping logs. There are two components to hotelling, including anchorage and dock. Anchorage time starts at the anchorage point and ends at the port boundary off the coast, while dock time has been estimated by subtracting the time spent manoeuvring into and out of a PWD from the departure time minus the arrival time at the PWD.

Table 3-154 presents a description of each ocean going vessel movement and mode of operation (ICF, 2009).

Table 3-154: Ocean going vessel movement and mode of operation description

Vessel movement	Description
Call	A call is one entrance and one clearance from the port area
Shift	A shift is a vessel movement within the port area. Since shifts are contained in calls, more than one shift is possible
Cruise (h/call)	Time at cruise speed (also called sea speed or service speed) is considered to be 94% of maximum vessel speed and 83% of engine power at maximum continuous rating (MCR). This is calculated for each port from the GMR boundary to the anchorage point. It includes both the inbound and outbound OGV movements. For the ports of Newcastle, Sydney, Port Botany and Port Kembla, typical one way inbound and outbound movements in cruise mode are 92, 106, 108 and 117 km, respectively
Reduced Speed Zone (RSZ) (h/call)	Time in the port area at less than cruise speed and greater than manoeuvring speed is the RSZ. This is the maximum safe speed the OGV uses to traverse distances within the waterway leading to a port. For the ports of Newcastle, Sydney, Port Botany and Port Kembla, typical speeds in the RSZ are 11, 17, 15 and 7 km/h, respectively
Manoeuvre (h/call)	Time in the port area within the RSZ and close to the dock. Manoeuvring speeds within the port area are generally slower than the RSZ speed. Manoeuvring time has been estimated using the difference between the inbound and outbound RSZ time
Hotelling (h/call)	Hotelling is the time at anchorage or dock when the OGV is operating auxiliary engines and boilers only. Auxiliary engines and boilers operate at varying load conditions the entire time the vessel is manned but peak loads occur after the main engines are shut down. The auxiliary engines and boilers are then responsible for all onboard power and hot water

3.7.2 *Emission Estimation Methodology*

Table 3-155 summarises the emission estimation methodologies used for OGVs.

Table 3-155: Ocean going vessel emission estimation methodologies

Emission source	Emission estimation methodology source
Exhaust emissions from main engine, auxiliary engine and auxiliary boiler	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009)
Evaporative emissions from refuelling OGVs with RO, IFO, MDO and MGO	- *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)

➢ *Ocean going vessel engine exhaust*

Exhaust emissions from OGVs have been estimated using energy based emission factors combined with activity rates. Activity rates include representative engine load factors for each OGV and operating times for each ship call and mode of operation. Emissions have been determined using Equation 17 (ICF, 2009):

$$\mathbf{E_{i,j,k,l} = P_j \times LF_{j,l} \times A_{j,k,l} \times EF_{i,j,k,l} / 1000}$$ **Equation 17**

where:			
$E_{i,j,k,l}$	=	Emissions of substance i, from engine type j, using fuel type k during mode of operation l	(kg/year)
P_j	=	Power (at maximum continuous rating (MCR)) for engine type j	(kW)
$LF_{j,l}$	=	Fractional load factor for engine type j during mode of operation l	(-)
$A_{j,k,l}$	=	Operating time for engine type j, using fuel type k during mode of operation l	(h/year)
$EF_{i,j,k,l}$	=	Emission factor for substance i, from engine type j, using fuel type k during mode of operation l	(g/kW.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	=	Engine type (either “main engine - slow speed”, “main engine – medium speed”, “main engine – high speed”, “main engine – gas turbine”, “main engine – steam turbine”, “auxiliary engine – medium speed”, “auxiliary engine – high speed” or “auxiliary boiler”)	(-)
k	=	Fuel type (either “RO”, “IFO”, “MDO” or “MGO”)	(-)
l	=	Mode of operation (either “cruise”, “RSZ”, “manoeuvre”, “hotel – anchorage” or “hotel – dock”)	(-)
1000	=	Conversion factor	(g/kg)

Load factors are expressed as a proportion of the OGV main propulsion or auxiliary power. To estimate OGV main propulsion load factors, the propeller law (i.e. propulsion power varies by the cube of speed) has been applied using Equation 18 (ICF, 2009):

$$\mathbf{LF_{i,j} = AS_{i,j} / MS_i}$$ **Equation 18**

where:

$LF_{i,j}$	=	Fractional load factor for OGV i during mode of operation j	(-)
$AS_{i,j}$	=	Actual speed for OGV i during mode of operation j	(km/h)
MS_i	=	Maximum service speed for OGV i	(km/h)
i	=	OGV (each unique vessel identified by IMO number)	(-)
j	=	Mode of operation (either "cruise", "RSZ" or "manoeuvre")	(-)

At service or cruise speed, the OGV travels at 94% of maximum service speed (ICF, 2009), so the main propulsion load factor has been estimated to be 83% during the cruise mode of operation using Equation 18.

Auxiliary engine and auxiliary boiler load factors have been estimated from contemporary OGV emission inventories (SCG, 2010a; and SCG, 2010b).

- *Transfer of fuel to ocean going vessels*

Evaporative VOC emissions from refuelling OGVs have been estimated using emission factors combined with RO, IFO, MDO and MGO fuel sales data within Equation 19 (USEPA, 2008b):

$$E_{VOC,i} = EF_{VOC,i} \times A_i \qquad \textbf{Equation 19}$$

where:

$E_{VOC,i}$	=	Emissions of VOC from fuel type i	(kg/year)
$EF_{VOC,i}$	=	VOC emission factor for fuel type i (Equation 20)	(kg/kL)
A_i	=	Amount of fuel type i loaded	(kL/year)
i	=	Fuel type (either "RO", "IFO", "MDO" or "MGO")	(-)

Emission factors for the transfer of fuels have been estimated using Equation 20 (USEPA, 2008b):

$$EF_{VOC,i} = 12.46 \times \frac{S \times P_i \times M_i}{T} \times \frac{0.4536}{3.7862} \qquad \textbf{Equation 20}$$

where:

$EF_{VOC,i}$	=	VOC emission factor for fuel type i	(kg/kL)
S	=	Saturation factor for submerged loading to barges (Table 5.2-1; USEPA, 2008b) - 0.5	(-)
P_i	=	True vapour pressure of fuel type i (Table 7.1-2; USEPA, 2006) - 0.00004, 0.00004, 0.0065 and 0.0065 for RO, IFO, MDO and MGO, respectively	(psia)
M_i	=	Molecular weight of vapour for fuel type i (Table 7.1-2; USEPA, 2006) - 190, 190, 130 and 130 for RO, IFO, MDO and MGO, respectively	(lb/lb.mol)
T	=	Temperature of bulk liquid loaded (Table 7.1-2; USEPA, 2006) – 520	(°R)
i	=	Fuel type (either "RO", "IFO", "MDO" or "MGO")	(-)
0.4536	=	Conversion factor	(lb/kg)
3.7862	=	Conversion factor	(L/US gal)

3.7.3 Activity Data

Table 3-156 summarises the activity data used for OGVs.

Table 3-156: Ocean going vessel activity data

Activity data	Activity data source
Ship logs and pilot data for Botany, Newcastle, Sydney and Kembla ports	- *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009)
Main engine, auxiliary engine and auxiliary boiler specifications and fuel type	- *LRF Bespoke Data Catalogue (APS)* (LR, 2010) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b)
Gas oil, intermediate fuel oil, marine diesel oil and residual oil sales data to estimate refuelling emissions	- *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)

For each OGV call, shipping logs and pilot data have been used to establish main engine, auxiliary engine and auxiliary boiler operating times during cruise, RSZ, manoeuvre and hotel (i.e. anchorage and dock) modes of operation (NPC, 2009; SPC, 2009; and PKPC, 2009). Table 3-157, Table 3-158, Table 3-159 and Table 3-160 present the number of calls and average time-in-mode (TIM) by ship category for the four ports, Newcastle, Port Botany, Sydney and Port Kembla.

Table 3-157: Ocean going vessel call and average time-in-mode – Newcastle

Ship category	Call	Cruise (h/call)	RSZ (h/call)	Manoeuvre (h/call)	Anchorage (h/call)[32]	Dock (h/call)
Bulk Carrier	1,212	7.2	1.5	0.4	14.7	39.3
Container	10	6.4	1.0	0.2	14.7	41.5
Cruise	4	5.0	1.2	0.2	14.7	9.1
General Cargo	246	6.7	1.0	0.4	14.7	56.6
Miscellaneous	22	6.8	1.0	0.3	14.7	1,085.7
Ocean Tug	23	9.4	0.9	0.5	14.7	876.0
Reefer	2	4.9	0.9	0.1	14.7	17.2
Tanker	94	7.4	1.2	0.3	14.7	31.2
Grand Total	1,613	7.1	1.4	0.4	14.7	67.6

[32] Data for Newcastle port not available so average anchorage time for Port Botany, Sydney and Port Kembla ports has been used (NPC, 2009; SPC, 2009; and PKPC, 2009).

Table 3-158: Ocean going vessel call and average time-in-mode – Port Botany

Ship category	Call	Cruise (h/call)	RSZ (h/call)	Manoeuvre (h/call)	Anchorage (h/call)	Dock (h/call)
Bulk Carrier	1	8.2	0.8	0.7	1.5	6.0
Container	1,288	5.6	1.0	0.4	7.9	30.2
General Cargo	42	6.9	0.9	0.5	7.0	17.5
Ocean Tug	2	8.1	0.6	1.0	2.4	270.4
Reefer	1	8.2	0.7	0.3	2.4	4.0
Tanker	441	8.2	0.7	1.1	32.6	30.9
Grand Total	1,775	6.3	0.9	0.6	14.0	30.3

Table 3-159: Ocean going vessel call and average time-in-mode – Sydney

Ship category	Call	Cruise (h/call)	RSZ (h/call)	Manoeuvre (h/call)	Anchorage (h/call)	Dock (h/call)
Auto Carrier	220	6.2	2.1	0.3	2.7	20.1
Bulk Carrier	158	9.2	1.9	0.4	3.4	75.8
Container	20	6.0	1.4	0.4	4.3	64.1
Cruise	114	5.9	1.8	0.3	0.9	17.9
General Cargo	299	12.4	1.2	1.1	13.3	9.3
Miscellaneous	68	10.4	1.2	0.6	5.1	225.5
Ocean Tug	26	10.0	1.3	2.8	12.1	69.9
Reefer	1	6.8	0.7	0.3	15.1	4.9
RORO	2	5.2	1.5	0.8	0.8	375.4
Tanker	336	10.2	1.7	0.8	42.1	21.8
Grand Total	1,244	9.4	1.7	0.7	16.2	38.4

Table 3-160: Ocean going vessel call and average time-in-mode – Port Kembla

Ship category	Call	Cruise (h/call)	RSZ (h/call)	Manoeuvre (h/call)	Anchorage (h/call)	Dock (h/call)
Auto Carrier	122	6.6	0.8	0.5	2.3×10^{-2}	14.3
Bulk Carrier	360	9.2	0.9	0.5	29.4	52.2
Container	10	7.8	0.8	0.4	-	73.8
General Cargo	192	8.3	0.7	0.3	3.7	52.6
Miscellaneous	5	10.4	0.5	0.2	-	1083.5
Ocean Tug	3	11.3	0.3	0.2	-	3.7
Reefer	1	6.2	0.4	5.0×10^{-2}	-	63.7
RORO	76	7.7	0.7	0.5	-	30.4
Tanker	34	9.3	0.4	0.5	1.8	21.2
Grand Total	803	8.4	0.8	0.5	14.1	49.7

Each OGV listed in the shipping log has been matched with data from the Lloyd's Register of Ships to establish detailed vessel, engine and fuel characteristics (LR, 2010). Table 3-161 presents the number of OGV and averages of maximum speed, main engine, auxiliary engine and auxiliary boiler power by ship category and ship type for the four ports, Newcastle, Port Botany, Sydney and Port Kembla.

Table 3-161: Ocean going vessel averages of maximum speed, main engine, auxiliary engine and auxiliary boiler power

Ship category	Ship type	Number	Maximum speed (kn)	Main engine (kW)	Auxiliary engine (kW)	Auxiliary boiler (kW)[33]
Auto Carrier	Vehicles Carrier	174	19.4	13,298	3,762	252
Auto Carrier Total		174	19.4	13,298	3,762	252
Bulk Carrier	Aggregates Carrier	1	12.0	1,840	832	132
	Bulk Carrier	711	14.4	10,163	1,812	132
	Bulk Carrier, Self-discharging	4	14.8	6,606	2,459	132
	Cement Carrier	6	14.2	5,441	701	132
	Ore Carrier	2	14.2	10,554	1,927	132
	Wood Chips Carrier	4	14.0	8,043	1,468	132
Bulk Carrier Total		728	14.4	10,083	1,803	132
Container	Container Ship (Fully Cellular)	248	21.6	24,408	6,832	516
Container Total		248	21.6	24,408	6,832	516
Cruise	Passenger/Cruise	35	20.8	33,584	3,515	1,452
Cruise Total		35	20.8	33,584	3,515	1,452
General Cargo	Barge Carrier	1	13.7	3,162	796	133
	General Cargo Ship	104	15.1	6,454	1,629	133
	General Cargo Ship (with Ro-Ro facility)	1	17.0	15,446	3,843	133
	General Cargo Ship, Self-discharging	3	14.9	9,617	2,435	133
	General Cargo/Passenger Ship	1	13.0	5,958	1,499	133
	Heavy Load Carrier	1	15.0	4,900	2,155	133
	Livestock Carrier	1	23.3	10,922	7,695	133
	Open Hatch Cargo Ship	21	14.4	9,068	1,963	133
General Cargo Total		133	15.0	6,999	1,759	133
Miscellaneous	Cable Layer	1	15.4	17,280	1,360	137
	Crane Pontoon	1	6.0	5,400	218	137
	Cutter Suction Dredger	1	13.5	7,400	880	137
	Deck Cargo Pontoon, semi submersible	1	13.8	-	-	137
	Fishery Patrol Vessel	2	13.9	2,465	553	137

[33] Lloyd's Register of Ships does not contain auxiliary boiler power so these have been calculated from *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a); and *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b).

Ship category	Ship type	Number	Maximum speed (kn)	Main engine (kW)	Auxiliary engine (kW)	Auxiliary boiler (kW)[33]
	Fishery Research Vessel	1	14.0	2,200	3,127	137
	Fishing Vessel	1	12.2	1,140	503	137
	Passenger Ship, Inland Waterways	1	5.0	596	522	137
	Research Survey Vessel	1	15.9	5,148	1,155	137
	Restaurant Vessel, Stationary	1	12.5	302	68	137
	Trailing Suction Hopper Dredger	3	9.3	402	79	137
	Trawler	1	12.8	1,770	382	137
	Utility Vessel	1	12.0	1,640	368	137
	Weapons Trials Vessel	18	20.9	16,119	4,620	137
	Yacht	4	15.9	2,598	601	137
Miscellaneous Total		38	16.6	9,198	2,513	137
Ocean Tug	Offshore Tug/Supply Ship	1	10.0	764	94	-
	Pusher Tug	1	10.0	1,516	187	-
	Tug	17	11.9	2,086	233	-
Ocean Tug Total		19	11.7	1,986	224	-
Reefer	Refrigerated Cargo Ship	3	17.6	5,869	1,583	363
Reefer Total		3	17.6	5,869	1,583	363
RORO	Passenger/Ro-Ro Ship (Vehicles)	1	27.5	42,240	15,910	64
	Ro-Ro Cargo Ship	3	18.3	12,991	3,277	64
RORO Total		4	20.6	20,304	6,435	64
Tanker	Bunkering Tanker	1	9.0	814	91	2,797
	Chemical Tanker	12	13.6	4,966	1,470	2,797
	Chemical/Products Tanker	84	14.4	7,088	2,549	2,797
	Crude Oil Tanker	45	14.8	12,745	2,402	2,797
	Crude/Oil Products Tanker	31	14.8	10,274	2,331	2,797
	LPG Tanker	21	15.3	7,615	2,640	2,797
	Oil Tanker, Inland Waterways	1	14.0	544	161	2,797
	Products Tanker	40	14.6	8,888	3,032	2,797
Tanker Total		235	14.6	8,782	2,507	2,797
Grand Total		1,617	16.3	12,593	2,930	618

Table 3-162 presents the number of OGV and averages of main engine power by ship category, ship type and engine type (i.e. gas turbine (GT), high-speed diesel (HSD), medium-speed diesel (MSD), slow-speed diesel (SSD) and steam turbine (ST)) for the four ports, Newcastle, Port Botany, Sydney and Port Kembla. For auxiliary engines, 58% and 42% are estimated to be MSD and HSD, respectively (Entec, 2002). For each OGV, auxiliary engines and auxiliary boilers consume RO, IFO, MDO and MGO in the same proportions as main engines.

Table 3-162: Ocean going vessel averages of main engine power and fuel type by ship type and main engine type

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
Auto Carrier	Vehicles Carrier	Number	-	-	14	-	160	-	174
		Main engine (kW)	-	-	9,205	-	13,656	-	13,298
		RO (%)	-	-	66.8	-	64.4	-	64.6
		IFO (%)	-	-	25.7	-	29.6	-	29.3
		MDO (%)	-	-	7.5	-	6.0	-	6.1
		MGO (%)	-	-	-	-	-	-	-
Bulk Carrier	Aggregates Carrier	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	1,840	-	-	-	1,840
		RO (%)	-	-	85.6	-	-	-	85.6
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	14.4	-	-	-	14.4
		MGO (%)	-	-	-	-	-	-	-
	Bulk Carrier	Number	-	-	4	-	707	-	711
		Main engine (kW)	-	-	4,432	-	10,196	-	10,163
		RO (%)	-	-	72.3	-	60.5	-	60.6
		IFO (%)	-	-	10.7	-	32.7	-	32.5
		MDO (%)	-	-	16.5	-	5.4	-	5.5
		MGO (%)	-	-	0.5	-	1.4	-	1.4
	Bulk Carrier, Self-discharging	Number	-	-	1	-	3	-	4
		Main engine (kW)	-	-	2,500	-	7,975	-	6,606
		RO (%)	-	-	-	-	76.6	-	57.5
		IFO (%)	-	-	81.0	-	10.2	-	27.9
		MDO (%)	-	-	19.0	-	13.1	-	14.6
		MGO (%)	-	-	-	-	-	-	-
	Cement Carrier	Number	-	-	3	-	3	-	6
		Main engine (kW)	-	-	5,143	-	5,738	-	5,441

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		RO (%)	-	-	80.8	-	82.3	-	81.6
		IFO (%)	-	-	5.2	-	5.2	-	5.2
		MDO (%)	-	-	14.0	-	12.5	-	13.3
		MGO (%)	-	-	-	-	-	-	-
	Ore Carrier	Number	-	-	-	-	2	-	2
		Main engine (kW)	-	-	-	-	10,554	-	10,554
		RO (%)	-	-	-	-	95.6	-	95.6
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	4.4	-	4.4
		MGO (%)	-	-	-	-	-	-	-
	Wood Chips Carrier	Number	-	-	-	-	4	-	4
		Main engine (kW)	-	-	-	-	8,043	-	8,043
		RO (%)	-	-	-	-	51.0	-	51.0
		IFO (%)	-	-	-	-	42.6	-	42.6
		MDO (%)	-	-	-	-	4.3	-	4.3
		MGO (%)	-	-	-	-	2.2	-	2.2
Container	Container Ship (Fully Cellular)	Number	-	-	13	-	235	-	248
		Main engine (kW)	-	-	11,916	-	25,099	-	24,408
		RO (%)	-	-	54.9	-	61.7	-	61.3
		IFO (%)	-	-	36.8	-	31.5	-	31.8
		MDO (%)	-	-	5.4	-	5.5	-	5.5
		MGO (%)	-	-	2.9	-	1.3	-	1.4
Cruise	Passenger/Cruise	Number	1	1	28	-	4	1	35
		Main engine (kW)	50,000	1,566	36,520	-	19,816	22,066	33,584
		RO (%)	-	33.2	64.0	-	91.5	93.4	65.2
		IFO (%)	-	37.6	17.3	-	-	-	14.9
		MDO (%)	-	5.8	11.8	-	8.5	6.6	10.8
		MGO	100.0	23.4	6.9	-	-	-	9.1

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		(%)							
General Cargo	Barge Carrier	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	3,162	-	-	-	3,162
		RO (%)	-	-	45.0	-	-	-	45.0
		IFO (%)	-	-	44.3	-	-	-	44.3
		MDO (%)	-	-	6.2	-	-	-	6.2
		MGO (%)	-	-	4.5	-	-	-	4.5
	General Cargo Ship	Number	-	-	55	-	49	-	104
		Main engine (kW)	-	-	4,731	-	8,389	-	6,454
		RO (%)	-	-	43.7	-	50.2	-	46.8
		IFO (%)	-	-	35.2	-	33.5	-	34.4
		MDO (%)	-	-	17.4	-	13.7	-	15.6
		MGO (%)	-	-	3.7	-	2.6	-	3.2
	General Cargo Ship (with Ro-Ro facility)	Number	-	-	-	-	1	-	1
		Main engine (kW)	-	-	-	-	15,446	-	15,446
		RO (%)	-	-	-	-	82.7	-	82.7
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	17.3	-	17.3
		MGO (%)	-	-	-	-	-	-	-
	General Cargo Ship, Self-discharging	Number	-	-	-	-	3	-	3
		Main engine (kW)	-	-	-	-	9,617	-	9,617
		RO (%)	-	-	-	-	92.0	-	92.0
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	8.0	-	8.0
		MGO (%)	-	-	-	-	-	-	-
	General Cargo/Passenger Ship	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	5,958	-	-	-	5,958
		RO (%)	-	-	63.1	-	-	-	63.1

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	36.9	-	-	-	36.9
		MGO (%)	-	-	-	-	-	-	-
	Heavy Load Carrier	Number	-	-	-	-	1	-	1
		Main engine (kW)	-	-	-	-	4,900	-	4,900
		RO (%)	-	-	-	-	87.4	-	87.4
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	12.6	-	12.6
		MGO (%)	-	-	-	-	-	-	-
	Livestock Carrier	Number	-	-	-	-	1	-	1
		Main engine (kW)	-	-	-	-	10,922	-	10,922
		RO (%)	-	-	-	-	89.5	-	89.5
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	10.5	-	10.5
		MGO (%)	-	-	-	-	-	-	-
	Open Hatch Cargo Ship	Number	-	-	-	-	21	-	21
		Main engine (kW)	-	-	-	-	9,068	-	9,068
		RO (%)	-	-	-	-	52.3	-	52.3
		IFO (%)	-	-	-	-	41.1	-	41.1
		MDO (%)	-	-	-	-	6.6	-	6.6
		MGO (%)	-	-	-	-	-	-	-
Miscellaneous	Cable Layer	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	17,280	-	-	-	17,280
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO	-	-	100.0	-	-	-	100.0

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		(%)							
		MGO (%)	-	-	-	-	-	-	-
	Crane Pontoon	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	5,400	-	-	-	5,400
		RO (%)	-	-	47.3	-	-	-	47.3
		IFO (%)	-	-	25.7	-	-	-	25.7
		MDO (%)	-	-	7.3	-	-	-	7.3
		MGO (%)	-	-	19.7	-	-	-	19.7
	Cutter Suction Dredger	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	7,400	-	-	-	7,400
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Deck Cargo Pontoon, semi submersible	Number	-	-	-	1	-	-	1
		Main engine (kW)	-	-	-	-	-	-	-
		RO (%)	-	-	-	47.3	-	-	47.3
		IFO (%)	-	-	-	25.7	-	-	25.7
		MDO (%)	-	-	-	7.3	-	-	7.3
		MGO (%)	-	-	-	19.7	-	-	19.7
	Fishery Patrol Vessel	Number	-	-	2	-	-	-	2
		Main engine (kW)	-	-	2,465	-	-	-	2,465
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	100.0	-	-	-	100.0
		MDO (%)	-	-	-	-	-	-	-
		MGO (%)	-	-	-	-	-	-	-
	Fishery Research Vessel	Number	-	-	1	-	-	-	1
		Main engine	-	-	2,200	-	-	-	2,200

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		(kW)							
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Fishing Vessel	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	1,140	-	-	-	1,140
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Passenger Ship, Inland Waterways	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	596	-	-	-	-	596
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	100.0	-	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Research Survey Vessel	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	5,148	-	-	-	5,148
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Restaurant Vessel, Stationary	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	302	-	-	-	302
		RO (%)	-	-	100.0	-	-	-	100.0

Ship category	Ship type	Data	Main engine type GT	HSD	MSD	NIL	SSD	ST	Grand Total
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	-	-	-	-	-
		MGO (%)	-	-	-	-	-	-	-
	Trailing Suction Hopper Dredger	Number	-	2	-	-	1	-	3
		Main engine (kW)	-	272	-	-	662	-	402
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	100.0	-	-	100.0	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Trawler	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	1,770	-	-	-	1,770
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	-	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Utility Vessel	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	1,640	-	-	-	-	1,640
		RO (%)	-	47.3	-	-	-	-	47.3
		IFO (%)	-	25.7	-	-	-	-	25.7
		MDO (%)	-	7.3	-	-	-	-	7.3
		MGO (%)	-	19.7	-	-	-	-	19.7
	Weapons Trials Vessel	Number	3	5	9	-	1	-	18
		Main engine (kW)	66,600	3,116	7,342	-	8,680	-	16,119
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	100.0	100.0	100.0	-	100.0	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Yacht	Number	-	3	1	-	-	-	4

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		Main engine (kW)	-	1,365	6,297	-	-	-	2,598
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	100.0	100.0	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
Ocean Tug	Offshore Tug/Supply Ship	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	764	-	-	-	-	764
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	100.0	-	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Pusher Tug	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	1,516	-	-	-	-	1,516
		RO (%)	-	87.5	-	-	-	-	87.5
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	12.5	-	-	-	-	12.5
		MGO (%)	-	-	-	-	-	-	-
	Tug	Number	-	3	14	-	-	-	17
		Main engine (kW)	-	1,050	2,307	-	-	-	2,086
		RO (%)	-	88.4	50.3	-	-	-	57.0
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	11.6	49.7	-	-	-	43.0
		MGO (%)	-	-	-	-	-	-	-
Reefer	Refrigerated Cargo Ship	Number	-	-	-	-	3	-	3
		Main engine (kW)	-	-	-	-	5,869	-	5,869

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		RO (%)	-	-	-	-	58.2	-	58.2
		IFO (%)	-	-	-	-	29.7	-	29.7
		MDO (%)	-	-	-	-	10.8	-	10.8
		MGO (%)	-	-	-	-	1.4	-	1.4
RORO	Passenger/Ro-Ro Ship (Vehicles)	Number	-	-	1	-	-	-	1
		Main engine (kW)	-	-	42,240	-	-	-	42,240
		RO (%)	-	-	89.5	-	-	-	89.5
		IFO (%)	-	-	0.0	-	-	-	0.0
		MDO (%)	-	-	10.5	-	-	-	10.5
		MGO (%)	-	-	-	-	-	-	-
	Ro-Ro Cargo Ship	Number	-	-	2	-	1	-	3
		Main engine (kW)	-	-	11,690	-	15,594	-	12,991
		RO (%)	-	-	45.5	-	90.9	-	60.6
		IFO (%)	-	-	41.4	-	0.0	-	27.6
		MDO (%)	-	-	13.1	-	9.1	-	11.7
		MGO (%)	-	-	-	-	-	-	-
Tanker	Bunkering Tanker	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	814	-	-	-	-	814
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-
		MDO (%)	-	100.0	-	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Chemical Tanker	Number	-		1	-	11	-	12
		Main engine (kW)	-		2,574	-	5,184	-	4,966
		RO (%)	-	-	-	-	43.8	-	40.1
		IFO (%)	-	-	83.8	-	44.8	-	48.1
		MDO (%)	-	-	16.2	-	11.4	-	11.8
		MGO (%)	-	-	-	-	-	-	-

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
	Chemical/Products Tanker	Number	-	-	5	-	79	-	84
		Main engine (kW)	-	-	7,014	-	7,093	-	7,088
		RO (%)	-	-	76.3	-	68.8	-	69.3
		IFO (%)	-	-	18.5	-	18.9	-	18.8
		MDO (%)	-	-	3.7	-	10.3	-	9.9
		MGO (%)	-	-	1.5	-	2.0	-	2.0
	Crude Oil Tanker	Number	-	-	-	-	45	-	45
		Main engine (kW)	-	-	-	-	12,745	-	12,745
		RO (%)	-	-	-	-	56.0	-	56.0
		IFO (%)	-	-	-	-	38.4	-	38.4
		MDO (%)	-	-	-	-	5.6	-	5.6
		MGO (%)	-	-	-	-	-	-	-
	Crude/Oil Products Tanker	Number	-	-	-	-	31	-	31
		Main engine (kW)	-	-	-	-	10,274	-	10,274
		RO (%)	-	-	-	-	60.0	-	60.0
		IFO (%)	-	-	-	-	32.5	-	32.5
		MDO (%)	-	-	-	-	7.4	-	7.4
		MGO (%)	-	-	-	-	-	-	-
	LPG Tanker	Number	-	-	3	-	18	-	21
		Main engine (kW)	-	-	3,492	-	8,302	-	7,615
		RO (%)	-	-	28.5	-	69.1	-	63.3
		IFO (%)	-	-	29.2	-	15.6	-	17.6
		MDO (%)	-	-	37.5	-	12.7	-	16.2
		MGO (%)	-	-	4.8	-	2.6	-	2.9
	Oil Tanker, Inland Waterways	Number	-	1	-	-	-	-	1
		Main engine (kW)	-	544	-	-	-	-	544
		RO (%)	-	-	-	-	-	-	-
		IFO (%)	-	-	-	-	-	-	-

Ship category	Ship type	Data	Main engine type						Grand Total
			GT	HSD	MSD	NIL	SSD	ST	
		MDO (%)	-	100.0	-	-	-	-	100.0
		MGO (%)	-	-	-	-	-	-	-
	Products Tanker	Number	-	-	-	-	40	-	40
		Main engine (kW)	-	-	-	-	8,888	-	8,888
		RO (%)	-	-	-	-	52.2	-	52.2
		IFO (%)	-	-	-	-	38.3	-	38.3
		MDO (%)	-	-	-	-	7.1	-	7.1
		MGO (%)	-	-	-	-	2.4	-	2.4
Total Number			4	20	167	1	1,424	1	1,617
Total Main engine (kW)			62,450	1,541	11,240	-	12,770	22,066	12,593
Total RO (%)			-	21.7	48.3	-	61.0	93.4	59.0
Total IFO (%)			-	3.2	24.0	-	31.3	-	30.1
Total MDO (%)			75.0	73.0	24.8	-	6.5	6.6	9.4
Total MGO (%)			25.0	2.2	2.9	-	1.2	-	1.5

Table 3-163 presents the number of OGV and averages of main engine power by ship category and engine type for the four ports, Newcastle, Port Botany, Sydney and Port Kembla.

Table 3-163: Ocean going vessel averages of main engine power and fuel type by ship category and main engine type

Ship category	Data	Main engine type						Grand Total
		GT	HSD	MSD	NIL	SSD	ST	
Auto Carrier	Number	-	-	14	-	160	-	174
	Main engine (kW)	-	-	9,205	-	13,656	-	13,298
	RO (%)	-	-	66.7	-	64.3	-	64.5
	IFO (%)	-	-	25.6	-	29.6	-	29.3
	MDO (%)	-	-	7.7	-	6.1	-	6.2
	MGO (%)	-	-	-	-	-	-	-
Bulk Carrier	Number	-	-	9	-	719	-	728
	Main engine (kW)	-	-	4,166	-	10,157	-	10,083
	RO (%)	-	-	68.2	-	60.6	-	60.7
	IFO (%)	-	-	15.4	-	32.4	-	32.1
	MDO (%)	-	-	16.1	-	5.6	-	5.8
	MGO (%)	-	-	0.2	-	1.4	-	1.4
Container	Number	-	-	13	-	235	-	248

Ship category	Data	Main engine type						Grand Total
		GT	HSD	MSD	NIL	SSD	ST	
	Main engine (kW)	-	-	11,916	-	25,099	-	24,408
	RO (%)	-	-	54.7	-	61.6	-	61.2
	IFO (%)	-	-	36.7	-	31.4	-	31.7
	MDO (%)	-	-	5.6	-	5.7	-	5.7
	MGO (%)	-	-	3.0	-	1.4	-	1.5
Cruise	Number	1	1	28	-	4	1	35
	Main engine (kW)	50,000	1,566	36,520	-	19,816	22,066	33,584
	RO (%)	-	32.8	63.7	-	91.3	93.2	65.0
	IFO (%)	-	37.2	17.2	-	-	-	14.8
	MDO (%)	-	5.9	12.0	-	8.7	6.8	11.0
	MGO (%)	100.0	24.1	7.1	-	-	-	9.2
General Cargo	Number	-	-	57	-	76	-	133
	Main engine (kW)	-	-	4,725	-	8,706	-	6,999
	RO (%)	-	-	43.9	-	53.7	-	49.5
	IFO (%)	-	-	34.6	-	32.9	-	33.6
	MDO (%)	-	-	17.7	-	11.7	-	14.3
	MGO (%)	-	-	3.8	-	1.7	-	2.6
Miscellaneous	Number	3	12	20	1	2	-	38
	Main engine (kW)	66,600	1,871	5,897	-	4,671	-	9,198
	RO (%)	-	3.9	7.3	46.8	-	-	6.3
	IFO (%)	-	2.1	11.3	25.4	-	-	7.3
	MDO (%)	100.0	92.3	80.4	7.5	100.0	-	84.8
	MGO (%)	-	1.7	1.0	20.3	-	-	1.6
Ocean Tug	Number	-	5	14	-	-	-	19
	Main engine (kW)	-	1,086	2,307	-	-	-	1,986
	RO (%)	-	70.3	50.1	-	-	-	55.4
	IFO (%)	-	-	-	-	-	-	-
	MDO (%)	-	29.7	49.9	-	-	-	44.6
	MGO (%)	-	-	-	-	-	-	-
Reefer	Number	-	-	-	-	3	-	3
	Main engine (kW)	-	-	-	-	5,869	-	5,869
	RO (%)	-	-	-	-	58.0	-	58.0
	IFO (%)	-	-	-	-	29.6	-	29.6
	MDO (%)	-	-	-	-	11.1	-	11.1
	MGO (%)	-	-	-	-	1.4	-	1.4
RORO	Number	-	-	3	-	1	-	4
	Main engine (kW)	-	-	21,873	-	15,594	-	20,304
	RO (%)	-	-	60.0	-	90.7	-	67.7

Ship category	Data	Main engine type						Grand Total
		GT	HSD	MSD	NIL	SSD	ST	
	IFO (%)	-	-	27.5	-	-	-	20.6
	MDO (%)	-	-	12.5	-	9.3	-	11.7
	MGO (%)	-	-	-	-	-	-	-
Tanker	Number	-	2	9	-	224	-	235
	Main engine (kW)	-	679	5,347	-	8,993	-	8,782
	RO (%)	-	-	51.8	-	60.7	-	59.8
	IFO (%)	-	-	29.2	-	29.1	-	28.8
	MDO (%)	-	100.0	16.5	-	8.9	-	9.9
	MGO (%)	-	-	2.5	-	1.4	-	1.4
Total Number		4	20	167	1	1,424	1	1,617
Total Main engine (kW)		62,450	1,541	11,240	-	12,770	22,066	12,593
Total RO (%)		-	21.6	48.1	-	60.8	93.2	58.9
Total IFO (%)		-	3.1	23.9	-	31.2	-	30.0
Total MDO (%)		75.0	73.1	24.9	-	6.7	6.8	9.5
Total MGO (%)		25.0	2.2	3.0	-	1.3	-	1.5

For each OGV call, shipping logs and pilot data have been used to establish main engine load factors during cruise, RSZ, manoeuvre and hotel (i.e. anchorage and dock) modes of operation (NPC, 2009; SPC, 2009; and PKPC, 2009). Auxiliary engine and auxiliary boiler load factors during cruise, RSZ, manoeuvre and hotel modes of operation have been calculated from *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a); and *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b). Table 3-164, Table 3-165, Table 3-166 and Table 3-167 present the average load factors by ship category and engine type for the four ports, Newcastle, Port Botany, Sydney and Port Kembla.

Table 3-164: Ocean going vessel average load factors by engine type and mode of operation - Newcastle

Ship category	Cruise LF			RSZ LF			Manoeuvre LF			Hotel LF		AB LF	
	ME	AE	AB	ME	AE	AB	ME	AE	AB	ME	AE	Anchorage	Dock
Bulk Carrier	0.83	0.17	-	0.07	0.27	-	0.07	0.45	1.00	-	0.10	1.00	1.00
Container	0.83	0.13	-	0.05	0.25	-	0.05	0.48	1.00	-	0.19	1.00	1.00
Cruise	0.83	0.80	-	0.03	0.80	-	0.03	0.80	1.00	-	0.64	1.00	1.00
General Cargo	0.83	0.17	-	0.06	0.27	-	0.06	0.45	1.00	-	0.22	1.00	1.00
Miscellaneous	0.83	0.17	-	0.08	0.27	-	0.08	0.45	1.00	-	0.22	1.00	1.00
Ocean Tug	0.83	0.17	-	0.17	0.27	-	0.17	0.45	-	-	0.22	-	-
Reefer	0.83	0.20	-	0.02	0.34	-	0.02	0.67	1.00	-	0.32	1.00	1.00
Tanker	0.83	0.24	-	0.08	0.28	-	0.08	0.33	0.13	-	0.26	0.13	1.00
Grand Total	0.83	0.18	-	0.07	0.27	-	0.07	0.44	0.94	-	0.13	0.94	0.99

Table 3-165: Ocean going vessel average load factors by engine type and mode of operation – Port Botany

Ship category	Cruise LF			RSZ LF			Manoeuvre LF			Hotel LF		AB LF	
	ME	AE	AB	ME	AE	AB	ME	AE	AB	ME	AE	Anchorage	Dock
Bulk Carrier	0.83	0.17	-	0.17	0.27	-	0.17	0.45	1.00	-	0.10	1.00	1.00
Container	0.83	0.13	-	0.05	0.25	-	0.05	0.48	1.00	-	0.19	1.00	1.00
General Cargo	0.83	0.17	-	0.10	0.27	-	0.10	0.45	1.00	-	0.22	1.00	1.00
Ocean Tug	0.83	0.17	-	0.16	0.27	-	0.16	0.45	-	-	0.22	-	-
Reefer	0.83	0.20	-	0.17	0.34	-	0.17	0.67	1.00	-	0.32	1.00	1.00
Tanker	0.83	0.24	-	0.17	0.28	-	0.17	0.33	0.13	-	0.26	0.13	1.00
Grand Total	0.83	0.16	-	0.08	0.26	-	0.08	0.44	0.78	-	0.21	0.78	1.00

Table 3-166: Ocean going vessel average load factors by engine type and mode of operation - Sydney

Ship category	Cruise LF			RSZ LF			Manoeuvre LF			Hotel LF		AB LF	
	ME	AE	AB	ME	AE	AB	ME	AE	AB	ME	AE	Anchorage	Dock
Auto Carrier	0.83	0.15	-	0.11	0.30	-	0.11	0.45	1.00	-	0.26	1.00	1.00
Bulk Carrier	0.83	0.17	-	0.35	0.27	-	0.35	0.45	1.00	-	0.10	1.00	1.00
Container	0.83	0.13	-	0.10	0.25	-	0.10	0.48	1.00	-	0.19	1.00	1.00
Cruise	0.83	0.80	-	0.10	0.80	-	0.10	0.80	1.00	-	0.64	1.00	1.00
General Cargo	0.83	0.17	-	0.89	0.27	-	0.89	0.45	1.00	-	0.22	1.00	1.00
Miscellaneous	0.83	0.17	-	1.38	0.27	-	1.38	0.45	1.00	-	0.22	1.00	1.00
Ocean Tug	0.83	0.17	-	0.46	0.27	-	0.46	0.45	-	-	0.22	-	-
Reefer	0.83	0.20	-	0.14	0.34	-	0.14	0.67	1.00	-	0.32	1.00	1.00
RORO	0.83	0.15	-	0.07	0.30	-	0.07	0.45	1.00	-	0.26	1.00	1.00
Tanker	0.83	0.24	-	0.56	0.28	-	0.56	0.33	0.13	-	0.26	0.13	1.00
Grand Total	0.83	0.24	-	0.53	0.33	-	0.53	0.45	0.74	-	0.26	0.74	0.98

Table 3-167: Ocean going vessel average load factors by engine type and mode of operation – Port Kembla

Ship category	Cruise LF			RSZ LF			Manoeuvre LF			Hotel LF		AB LF	
	ME	AE	AB	ME	AE	AB	ME	AE	AB	ME	AE	Anchorage	Dock
Auto Carrier	0.83	0.15	-	0.01	0.30	-	0.01	0.45	1.00	-	0.26	1.00	1.00
Bulk Carrier	0.83	0.17	-	0.02	0.27	-	0.02	0.45	1.00	-	0.10	1.00	1.00
Container	0.83	0.13	-	0.01	0.25	-	0.01	0.48	1.00	-	0.19	1.00	1.00
General Cargo	0.83	0.17	-	0.02	0.27	-	0.02	0.45	1.00	-	0.22	1.00	1.00
Miscellaneous	0.83	0.17	-	0.04	0.27	-	0.04	0.45	1.00	-	0.22	1.00	1.00
Ocean Tug	0.83	0.17	-	0.04	0.27	-	0.04	0.45	-	-	0.22	-	-
Reefer	0.83	0.20	-	0.01	0.34	-	0.01	0.67	1.00	-	0.32	1.00	1.00
RORO	0.83	0.15	-	0.01	0.30	-	0.01	0.45	1.00	-	0.26	1.00	1.00
Tanker	0.83	0.24	-	0.02	0.28	-	0.02	0.33	0.13	-	0.26	0.13	1.00

Ship category	Cruise LF			RSZ LF			Manoeuvre LF			Hotel LF		AB LF	
	ME	AE	AB	ME	AE	AB	ME	AE	AB	ME	AE	Anchorage	Dock
Grand Total	0.83	0.17	-	0.02	0.28	-	0.02	0.45	0.96	-	0.18	0.96	1.00

Table 3-168 presents the estimated OGV consumption of RO, IFO, MDO and MGO by engine type for the four ports, Newcastle, Port Botany, Sydney and Port Kembla. The quantity of RO, IFO, MDO and MGO loaded to OGVs for refuelling is also presented (DRET, 2009).

Table 3-168: Ocean going vessel fuel consumption and fuel loaded in the GMR

Activity	Source	2008 fuel consumption/fuel loaded		
		RO and IFO (tonne/year)	MDO (tonne/year)	MGO (tonne/year)
OGV combustion - fuel consumption	Main engine	67,781	5,682	1,163
	Auxiliary engine	36,594	5,756	720
	Auxiliary boiler	35,959	5,292	718
	Grand Total	140,334	16,731	2,601
OGV refuelling – fuel loaded	Grand Total	414,709	41,224	7,010

Figure 3-107 shows how OGV fuel consumption compares with fuel loaded and demonstrates the proportions of RO, IFO, MDO and MGO used in main engines, auxiliary engines and auxiliary boilers are consistent with the proportion of marine fuels sold through NSW ports.

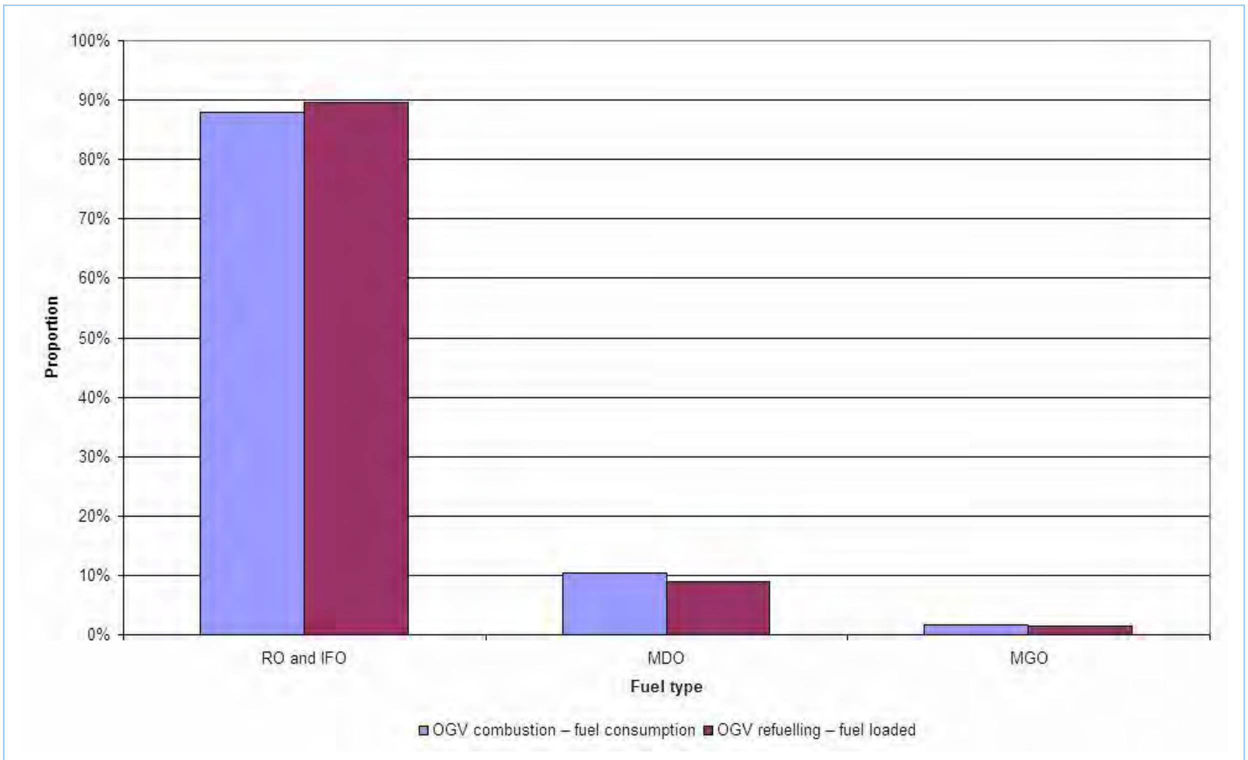

Figure 3-107: Ocean going vessel fuel consumption and fuel loaded

3.7.4 Emission and Speciation Factors

Table 3-169 summarises the emission and speciation factors used for OGVs.

Table 3-169: Ocean going vessel emission and speciation factors

Substance	Emission source	Emission and speciation factor source
Criteria pollutants: CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC	Main engine and auxiliary boiler: all fuel type	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009)
	Auxiliary engine: all fuel type	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community* (Entec, 2002) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009)
	Refuelling: all fuel type	- *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b)
Criteria pollutants: TSP	All engine type: RO and IFO	- *PMPROF 113 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
	All engine type: MDO and MGO	- *PMPROF 116 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2008b)
Speciated NO_x	All engine type and all fuel type	- *Technology Transfer Network - Clearinghouse for Inventories & Emissions Factors* (USEPA, 2003)
Speciated VOC	All engine type: RO and IFO	- *ORGPROF 504 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	All engine type: MDO and MGO	- *ORGPROF 818 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Refuelling: RO and IFO	- *ORGPROF 715 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Refuelling: MDO and MGO	- *ORGPROF 760 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Organic air toxics	All engine type: RO and IFO	- *ORGPROF 504 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	All engine type: MDO and MGO	- *ORGPROF 818 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
	Refuelling: RO and IFO	- *ORGPROF 715 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)

Substance	Emission source	Emission and speciation factor source
	Refuelling: MDO and MGO	- *ORGPROF 760 - California Emission Inventory and Reporting System (CEIDARS), Organic Gas Speciation Profiles* (CARB, 2005)
Metal air toxics	All engine type: RO and IFO	- *Table IV for RO - Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *PMPROF 113 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
	All engine type: MDO and MGO	- *Table IV for MDO- Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *PMPROF 425 - California Emission Inventory and Reporting System (CEIDARS), Particulate Matter (PM) Speciation Profiles* (CARB, 2007)
Polycyclic aromatic hydrocarbons: PAH	All engine type: RO and IFO	- *Table 6 for RO - Exhaust Emissions from Ships at Berth* (Cooper, 2003) - *Section 3.6.4 PAH, PCB, HCB and dioxin emissions footnote 10 for RO - Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
	All engine type: MDO and MGO	- *Table 8 and Table 9 for MGO - Exhaust Emissions from High Speed Passenger Ferries* (Cooper, 2001) - *Table 6 for MDO and MGO - Exhaust Emissions from Ships at Berth* (Cooper, 2003) - *Section 3.6.4 PAH, PCB, HCB and dioxin emissions footnote 10 for MDO - Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
Polychlorinated dibenzo-p-dioxins and Polychlorinated dibenzofurans: PCDD and PCDF	All engine type: RO and IFO	- *Table 6 for RO - HCB, PCB, PCDD and PCDF Emissions from Ships* (Cooper, 2004)
	All engine type: MDO and MGO	- *Table 6 for MDO - HCB, PCB, PCDD and PCDF Emissions from Ships* (Cooper, 2004)
Ammonia	All engine type: all fuel type	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
Greenhouse gases: CH_4 and N_2O	All engine type: all fuel type	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004)
Greenhouse gases: CO_2	All engine type: all fuel type	- *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009)

Exhaust PM_{10} emissions from OGVs vary according to fuel type, fuel sulfur content and brake specific fuel consumption (BSFC) and have been estimated using Equation 21 (ICF, 2009):

$$EF_{PM10,i,j} = FF1_i + BSFC_{i,j} \times 7 \times 0.02247 \times (SC_i - FF2_i) \qquad \textbf{Equation 21}$$

where:			
$EF_{PM10,i,j}$	=	PM_{10} emission factor for fuel type i and engine type j	(g/kW.h)
$FF1_i$	=	Fuel factor for fuel type i (ICF, 2009) - 1.35, 1.35, 0.23 and 0.23 for RO, IFO, MDO and MGO, respectively	(g/kW.h)
$BSFC_{i,j}$	=	Brake specific fuel consumption for fuel type i and engine type j (Table 3-171, Table 3-172 and Table 3-173)	(g/kW.h)

where:			
7	=	PM_{10} sulfate/PM_{10} sulfur	(kg/kg)
0.02247	=	Fractional sulfur in fuel converted to PM_{10} sulfate	(-)
SC_i	=	Fractional sulfur content for fuel type i (Table 3-171, Table 3-172 and Table 3-173)	(-)
$FF2_i$	=	Fuel factor for fuel type i (ICF, 2009) - 0.0246, 0.0246, 0.0024 and 0.0024 for RO, IFO, MDO and MGO, respectively	(g/kW.h)
i	=	Fuel type (either "RO", "IFO", "MDO" or "MGO")	(-)
j	=	Engine type (either "main engine - slow speed", "main engine – medium speed", "main engine – high speed", "main engine – gas turbine", "main engine – steam turbine", "auxiliary engine – medium speed", "auxiliary engine – high speed" or "auxiliary boiler")	(-)

Exhaust $PM_{2.5}$ emissions from OGVs are 92% of PM_{10} emissions (ICF, 2009).

Exhaust SO_2 emissions from OGVs vary according to fuel type, fuel sulfur content and BSFC and have been estimated using Equation 22 (ICF, 2009):

$$\mathbf{EF_{SO2,i,j} = BSFC_{i,j} \times 2 \times 0.97753 \times SC_i} \qquad \textbf{Equation 22}$$

where:			
$EF_{SO2,i,j}$	=	SO_2 emission factor for fuel type i and engine type j	(g/kW.h)
$BSFC_{i,j}$	=	Brake specific fuel consumption for fuel type i and engine type j (Table 3-171, Table 3-172 and Table 3-173)	(g/kW.h)
2	=	Molecular weight of sulfur dioxide divided by molecular weight sulfur	(-)
0.97753	=	Fractional sulfur in fuel converted to sulfur dioxide	(-)
SC_i	=	Fractional sulfur content for fuel type i (Table 3-171, Table 3-172 and Table 3-173)	(-)
i	=	Fuel type (either "RO", "IFO", "MDO" or "MGO")	(-)
j	=	Engine type (either "main engine - slow speed", "main engine – medium speed", "main engine – high speed", "main engine – gas turbine", "main engine – steam turbine", "auxiliary engine – medium speed", "auxiliary engine – high speed" or "auxiliary boiler")	(-)

Table 3-170 presents emission factors for total PAH (Cooper, 2001; Cooper, 2003; and Cooper et. al., 2004) and each of the 29 PAH compounds (Cooper, 2003).

Table 3-170: Ocean going vessel PAH emission factors

Substance	PAH emission factors (g/kW.h)	
	RO and IFO	MDO and MGO
1-Methylanthracene	1.36×10^{-05}	1.04×10^{-04}
1-Methylnaphthalene	3.50×10^{-04}	2.54×10^{-04}
1-Methylphenanthrene	4.95×10^{-05}	2.99×10^{-07}
2,3,5-Trimethylnaphthalene	1.96×10^{-05}	2.88×10^{-05}

Substance	PAH emission factors (g/kW.h)	
	RO and IFO	MDO and MGO
2,6-Dimethylnaphthalene	9.68×10^{-05}	7.60×10^{-05}
2-Methylanthracene	1.19×10^{-06}	5.38×10^{-07}
2-Methylnaphthalene	5.55×10^{-04}	3.10×10^{-04}
Acenaphthene	1.30×10^{-05}	2.91×10^{-05}
Acenaphthylene	1.68×10^{-06}	4.67×10^{-06}
Anthracene	3.47×10^{-06}	2.46×10^{-05}
Benz(a)anthracene	2.73×10^{-06}	1.59×10^{-05}
Benzo(a)pyrene	1.35×10^{-06}	4.04×10^{-06}
Benzo(b)fluoranthene	7.32×10^{-07}	1.76×10^{-05}
Benzo(e)pyrene	1.55×10^{-06}	9.69×10^{-06}
Benzo(g,h,i)perylene	5.74×10^{-06}	1.48×10^{-05}
Benzo(k)fluoranthene	7.05×10^{-07}	5.20×10^{-06}
Biphenyl	4.68×10^{-04}	8.44×10^{-05}
Chrysene	1.09×10^{-05}	3.43×10^{-05}
Coronene	9.93×10^{-06}	1.11×10^{-06}
Dibenzo(a,h)anthracene	5.84×10^{-06}	2.16×10^{-05}
Dibenzothiophene	3.99×10^{-05}	2.53×10^{-05}
Fluoranthene	2.06×10^{-05}	1.19×10^{-04}
Fluorene	8.18×10^{-05}	8.96×10^{-05}
Indeno(1,2,3-c,d)pyrene	5.93×10^{-06}	1.24×10^{-05}
Naphthalene	2.24×10^{-03}	6.10×10^{-04}
Perylene	1.13×10^{-06}	4.79×10^{-07}
Phenanthrene	3.82×10^{-04}	4.19×10^{-04}
Pyrene	1.64×10^{-05}	1.54×10^{-04}
Retene	3.20×10^{-07}	2.94×10^{-05}
Polycyclic Aromatic Hydrocarbons	0.0044	0.0025

Exhaust CO_2 emissions from OGVs vary according to fuel type, fuel carbon content and BSFC and have been estimated using Equation 23 (ICF, 2009):

$$\mathbf{EF_{CO2,i,j} = BSFC_{i,j} \times CC_i \times 44 / 12}$$ **Equation 23**

where:			
$EF_{CO2,i,j}$	=	CO_2 emission factor for fuel type i and engine type j	(g/kW.h)
$BSFC_{i,j}$	=	Brake specific fuel consumption for fuel type i and engine type j (Table 3-171, Table 3-172 and Table 3-173)	(g/kW.h)
CC_i	=	Fractional carbon content for fuel type i (Table 3-153)	(-)
44	=	Molecular weight of carbon dioxide	(g/g.mol)
12	=	Molecular weight of carbon	(g/g.mol)
i	=	Fuel type (either “RO”, “IFO”, “MDO” or “MGO”)	(-)

where:			
j	=	Engine type (either "main engine - slow speed", "main engine – medium speed", "main engine – high speed", "main engine – gas turbine", "main engine – steam turbine", "auxiliary engine – medium speed", "auxiliary engine – high speed" or "auxiliary boiler")	(-)

Table 3-171, Table 3-172 and Table 3-173 present the key main engine, auxiliary engine and auxiliary boiler parameters and emission factors used for OGVs.

Table 3-171: Ocean going vessel main engine parameters and emission factors

Engine type	Fuel type	Sulfur content (%)	Main engine parameters and emission factors (g/kW.h)												
			BSFC	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
SSD	RO	2.67	195	18.1	0.031	0.003	10.18	1.41	1.30	0.3	0.006	0.5	619.26	0.0044	1×10^{-10}
SSD	IFO	2.67	195	18.1	0.031	0.003	10.18	1.41	1.30	0.3	0.006	0.5	619.26	0.0044	1×10^{-10}
SSD	MDO	0.65	185	17.0	0.031	0.003	2.35	0.35	0.32	0.3	0.006	0.5	587.98	0.0025	3×10^{-11}
SSD	MGO	0.38	185	17.0	0.031	0.003	1.37	0.27	0.25	0.3	0.006	0.5	588.39	0.0025	3×10^{-11}
MSD	RO	2.67	215	14.0	0.031	0.003	11.22	1.42	1.31	0.2	0.004	1.1	682.78	0.0044	1×10^{-10}
MSD	IFO	2.67	215	14.0	0.031	0.003	11.22	1.42	1.31	0.2	0.004	1.1	682.78	0.0044	1×10^{-10}
MSD	MDO	0.65	205	13.2	0.031	0.003	2.61	0.36	0.33	0.2	0.004	1.1	651.54	0.0025	3×10^{-11}
MSD	MGO	0.38	205	13.2	0.031	0.003	1.52	0.28	0.25	0.2	0.004	1.1	652.00	0.0025	3×10^{-11}
HSD	RO	2.67	215	12.7	0.031	0.003	11.22	1.42	1.31	0.2	0.004	1.1	682.78	0.0044	1×10^{-10}
HSD	IFO	2.67	215	12.7	0.031	0.003	11.22	1.42	1.31	0.2	0.004	1.1	682.78	0.0044	1×10^{-10}
HSD	MDO	0.65	205	12.0	0.031	0.003	2.61	0.36	0.33	0.2	0.004	1.1	651.54	0.0025	3×10^{-11}
HSD	MGO	0.38	205	12.0	0.031	0.003	1.52	0.28	0.25	0.2	0.004	1.1	652.00	0.0025	3×10^{-11}
GT	RO	2.67	305	6.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.1	968.59	0.0044	1×10^{-10}
GT	IFO	2.67	305	6.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.1	968.59	0.0044	1×10^{-10}
GT	MDO	0.65	300	5.9	0.080	0.0004	3.81	0.42	0.39	0.1	0.002	0.1	953.48	0.0025	3×10^{-11}
GT	MGO	0.38	300	5.9	0.080	0.0004	2.23	0.30	0.27	0.1	0.002	0.1	954.14	0.0025	3×10^{-11}
ST	RO	2.67	305	2.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.2	968.59	0.0044	1×10^{-10}
ST	IFO	2.67	305	2.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.2	968.59	0.0044	1×10^{-10}
ST	MDO	0.65	300	2.0	0.080	0.0004	3.81	0.42	0.39	0.1	0.002	0.2	953.48	0.0025	3×10^{-11}
ST	MGO	0.38	300	2.0	0.080	0.0004	2.23	0.30	0.27	0.1	0.002	0.2	954.14	0.0025	3×10^{-11}

Table 3-172: Ocean going vessel auxiliary engine parameters and emission factors

Engine type	Fuel type	Sulfur content (%)	Auxiliary engine parameters and emission factors (g/kW.h)												
			BSFC	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
MSD	RO	2.67	227	14.7	0.031	0.003	11.85	1.42	1.31	0.4	0.004	1.1	720.88	0.0044	1×10^{-10}
MSD	IFO	2.67	227	14.7	0.031	0.003	11.85	1.42	1.31	0.4	0.004	1.1	720.88	0.0044	1×10^{-10}
MSD	MDO	0.65	217	13.9	0.031	0.003	2.76	0.37	0.34	0.4	0.004	1.1	689.68	0.0025	3×10^{-11}
MSD	MGO	0.38	217	13.9	0.031	0.003	1.61	0.28	0.26	0.4	0.004	1.1	690.16	0.0025	3×10^{-11}
HSD	RO	2.67	227	11.6	0.031	0.003	11.85	1.42	1.31	0.4	0.004	1.1	720.88	0.0044	1×10^{-10}
HSD	IFO	2.67	227	11.6	0.031	0.003	11.85	1.42	1.31	0.4	0.004	1.1	720.88	0.0044	1×10^{-10}
HSD	MDO	0.65	217	10.9	0.031	0.003	2.76	0.37	0.34	0.4	0.004	1.1	689.68	0.0025	3×10^{-11}
HSD	MGO	0.38	217	10.9	0.031	0.003	1.61	0.28	0.26	0.4	0.004	1.1	690.16	0.0025	3×10^{-11}

Table 3-173: Ocean going vessel auxiliary boiler parameters and emission factors

Engine type	Fuel type	Sulfur content (%)	Auxiliary boiler parameters and emission factors (g/kW.h)												
			BSFC	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
ST	RO	2.67	305	2.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.2	968.59	0.0044	1×10^{-10}
ST	IFO	2.67	305	2.1	0.080	0.0004	15.92	1.45	1.33	0.1	0.002	0.2	968.59	0.0044	1×10^{-10}
ST	MDO	0.65	300	2.0	0.080	0.0004	3.81	0.42	0.39	0.1	0.002	0.2	953.48	0.0025	3×10^{-11}
ST	MGO	0.38	300	2.0	0.080	0.0004	2.23	0.30	0.27	0.1	0.002	0.2	954.14	0.0025	3×10^{-11}

The OGV main engine emission factors presented in Table 3-171 are appropriate for loads from 100% down to 20%. For loads below 20%, emission factors tend to increase as the load decreases since engines become less efficient and the BSFC increases accordingly (ICF, 2009). For main engines with loads of 20% or less, low load adjustment factors have been applied to the emission factors presented in Table 3-171 using Equation 24 (USEPA, 2000b):

$$\mathbf{LAF_i = \left(a_i \times LF^{-x} + b_i \right) / \left(a_i \times 0.2^{-x} + b_i \right)} \qquad \textbf{Equation 24}$$

where:			
LAF_i	=	Low load adjustment factor for substance i	(g/kW.h)
a_i	=	Factor for substance i (Table 3-174)	(g/kW.h)
LF	=	Main engine fractional load factor	(-)
x_i	=	Factor for substance i (Table 3-174)	(-)
b_i	=	Factor for substance i (Table 3-174)	(g/kW.h)
j	=	Engine type (either "main engine - slow speed", "main engine – medium speed", "main engine – high speed", "main engine – gas turbine", "main engine – steam turbine", "auxiliary engine – medium speed", "auxiliary engine – high speed" or "auxiliary boiler")	(-)

Although Equation 24 has been derived specifically for HSD, MSD and SSD main propulsion engines, low load adjustment factors have been applied to GT and ST main propulsion engines since these are also less efficient at low loads (ICF, 2009).

For nitrous oxide (N_2O) and methane (CH_4), low load adjustment is consistent with NO_x and VOC, respectively (SCG, 2010a; and SCG, 2010b). For ammonia (NH_3), SO_2, polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF), low load adjustment is consistent with BSFC.

Table 3-174 presents the variables used to calculate low load adjustment factors using Equation 24. The low load adjustment factors are presented in Table 3-175 and shown in Figure 3-108 for each substance in increments of 1% which have been estimated for OGV main propulsion engines.

Table 3-174: Ocean going vessel main engine low load adjustment factor variables

Factor	BSFC, NH_3, PAH, PCDD and PCDF	NO_x and N_2O	SO_2	TSP, PM_{10} and $PM_{2.5}$	VOC and CH_4	CO	CO_2
a	14.1205	0.1255	14.1205	0.0059	0.0667	0.8378	44.10
x	1	1.5	1	1.5	1.5	1	1
b	205.7169	10.4496	205.7169	0.2551	0.3859	0.1548	648.6

Table 3-175: Ocean going vessel main engine low load adjustment factors

Load (%)	Ocean going vessel main engine low load adjustment factors											
	BSFC	NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
1	5.85	11.47	11.47	5.85	5.85	19.17	19.17	59.28	59.28	19.32	5.82	5.85	5.85
2	3.30	4.63	4.63	3.30	3.30	7.29	7.29	21.18	21.18	9.68	3.28	3.30	3.30
3	2.45	2.92	2.92	2.45	2.45	4.33	4.33	11.68	11.68	6.46	2.44	2.45	2.45
4	2.02	2.21	2.21	2.02	2.02	3.09	3.09	7.71	7.71	4.86	2.01	2.02	2.02
5	1.77	1.83	1.83	1.77	1.77	2.44	2.44	5.61	5.61	3.89	1.76	1.77	1.77
6	1.60	1.60	1.60	1.60	1.60	2.04	2.04	4.35	4.35	3.25	1.59	1.60	1.60
7	1.47	1.45	1.45	1.47	1.47	1.79	1.79	3.52	3.52	2.79	1.47	1.47	1.47
8	1.38	1.35	1.35	1.38	1.38	1.61	1.61	2.95	2.95	2.45	1.38	1.38	1.38
9	1.31	1.27	1.27	1.31	1.31	1.48	1.48	2.52	2.52	2.18	1.31	1.31	1.31
10	1.26	1.22	1.22	1.26	1.26	1.38	1.38	2.20	2.20	1.96	1.25	1.26	1.26
11	1.21	1.17	1.17	1.21	1.21	1.30	1.30	1.96	1.96	1.79	1.21	1.21	1.21
12	1.17	1.14	1.14	1.17	1.17	1.24	1.24	1.76	1.76	1.64	1.17	1.17	1.17
13	1.14	1.11	1.11	1.14	1.14	1.19	1.19	1.60	1.60	1.52	1.14	1.14	1.14
14	1.11	1.08	1.08	1.11	1.11	1.15	1.15	1.47	1.47	1.41	1.11	1.11	1.11
15	1.09	1.06	1.06	1.09	1.09	1.11	1.11	1.36	1.36	1.32	1.08	1.09	1.09
16	1.06	1.05	1.05	1.06	1.06	1.08	1.08	1.26	1.26	1.24	1.06	1.06	1.06
17	1.05	1.03	1.03	1.05	1.05	1.06	1.06	1.18	1.18	1.17	1.04	1.05	1.05
18	1.03	1.02	1.02	1.03	1.03	1.04	1.04	1.11	1.11	1.11	1.03	1.03	1.03
19	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.05	1.05	1.05	1.01	1.01	1.01
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

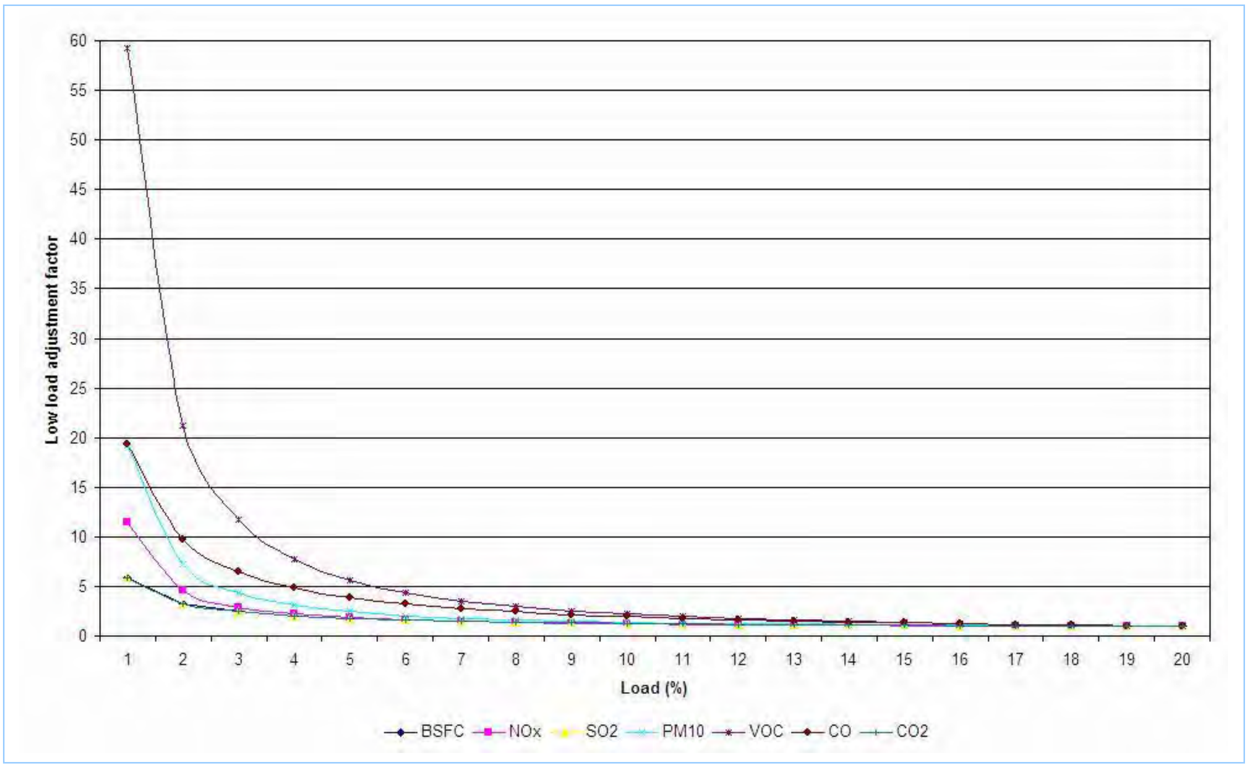

Figure 3-108: Ocean going vessel main engine low load adjustment factors

3.7.5 *Spatial Distribution of Emissions*

Table 3-176 summarises the data used for spatially allocating emissions from OGVs.

Table 3-176: Ocean going vessel spatial data

Emission source	Spatial data	Spatial data source
Main engine, auxiliary boiler: all fuel type	Gridded 1 km x 1 km main engine and auxiliary boiler gas oil, intermediate fuel oil, marine diesel oil and residual oil consumption allocated to port locations and water bodies	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009) - *LRF Bespoke Data Catalogue (APS)* (LR, 2010) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b) - *Geospatial Analysis, A Comprehensive Guide to Principles, Techniques and*

Emission source	Spatial data	Spatial data source
		Software Tools, Third Edition (De Smith et. al., 2009)
Auxiliary engine: all fuel type	Gridded 1 km x 1 km auxiliary engine gas oil, intermediate fuel oil, marine diesel oil and residual oil consumption allocated to port locations and water bodies	- *Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors* (Cooper et. al., 2004) - *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community* (Entec, 2002) - *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF, 2009) - *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009) - *LRF Bespoke Data Catalogue (APS)* (LR, 2010) - *The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2009* (SCG, 2010a) - *Port of Long Beach Air Emissions Inventory – 2009* (SCG, 2010b) - *Geospatial Analysis, A Comprehensive Guide to Principles, Techniques and Software Tools, Third Edition* (De Smith et. al., 2009)
Refuelling: all fuel type	Gridded 1 km x 1 km gas oil, intermediate fuel oil, marine diesel oil and residual oil fuel loaded estimates allocated to port locations and water bodies	- *AP 42, Fifth Edition, Volume I, Chapter 7: Liquid Storage Tanks, 7.1 Organic Liquid Storage Tanks* (USEPA, 2006) - *AP 42, Fifth Edition, Volume I, Chapter 5: Petroleum Industry, 5.2 Transportation and Marketing of Petroleum Liquids* (USEPA, 2008b) - *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009) - *Australian Petroleum Statistics – 2008, Issue 138 January 2008 to Issue 149 December 2008* (DRET, 2009)

All OGVs in the GMR travel through the four ports, Newcastle, Sydney, Port Botany and Port Kembla. Port authorities advise there are no preferred or usual routes that OGVs use when arriving and departing from a port (NPC, 2009; SPC, 2009; and PKPC, 2009). Therefore, a probabilistic spatial distribution of fuel consumption has been developed for cruise, RSZ and manoeuvre modes of operation, with each OGV being treated as equally likely to travel in any direction. The spatial distribution of fuel consumption is inversely proportional[34] to the distance squared for grid cells between lines connecting a port with the east, north and south exit points (De Smith et. al., 2009). For grid cells outside these routes, the spatial distribution of fuel consumption is inversely proportional to the distance squared according to a Gaussian[35] distribution (De Smith et. al., 2009). Using this methodology, the fuel consumption for each of the four ports has been allocated to each grid cell and then summed to allocate the total fuel consumption for all four ports in each grid cell.

Exhaust emissions from OGVs have been assigned to 1 km by 1 km grid cells as follows:

- *Cruise mode* - probabilistic spatial distribution of main engine and auxiliary engine fuel consumption estimates measured from port entry and exit (approximately 5.5 km from the coast) to open ocean within the GMR. An exclusion zone (approximately 9 km from the coast) applies (NPC, 2009; SPC, 2009; and PKPC, 2009);

- *RSZ mode* - probabilistic spatial distribution of main engine and auxiliary engine fuel consumption estimates measured from port entry (approximately 5.5 km from the coast) to dock and dock to port exit (NPC, 2009; SPC, 2009; and PKPC, 2009);

- *Manoeuvring mode* - probabilistic spatial distribution of main engine, auxiliary engine and auxiliary boiler fuel consumption estimates measured from port entry (approximately 5.5 km from the coast) to dock and dock to port exit (NPC, 2009; SPC, 2009; and PKPC, 2009); and

- *Hotel mode* (i.e. anchorage and dock) – auxiliary engine and auxiliary boiler fuel consumption estimates allocated to anchorage (approximately 5.5 km from the coast) and dock coordinates (NPC, 2009; SPC, 2009; and PKPC, 2009).

Evaporative emissions from refuelling OGVs have been assigned to 1 km by 1 km grid cells as follows:

- RO, IFO, MDO and MGO fuel loaded (DRET, 2009) allocated to dock coordinates (NPC, 2009; SPC, 2009; and PKPC, 2009).

Ocean going vessel fuel consumption by engine type, port, mode of operation and fuel type is presented in Table 3-177 and shown in Figure 3-109.

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[34] Technique adapted from the first law of geography (Tobler, 1970) and related to Newton's law of universal gravitation (Newton, 1687).
[35] Original formulation by Johann Carl Friedrich Gauss (Gauss, 1809).

Table 3-177: Ocean going vessel fuel consumption by engine type, port, mode of operation and fuel type

Fuel type	Mode of operation	Port	2008 fuel consumption (kL/year)			
			Auxiliary boiler	Auxiliary engine	Main engine	Grand Total
RO and IFO	Anchorage	Newcastle	1,019	1,301	-	2,320
		Sydney	1,411	1,981	-	3,393
		Port Botany	3,044	4,422	-	7,466
		Port Kembla	440	573	-	1,013
	Anchorage Total		5,914	8,277	-	14,191
	Berth	Newcastle	4,839	3,779	-	8,618
		Sydney	7,594	4,011	-	11,605
		Port Botany	16,757	13,122	-	29,879
		Port Kembla	1,946	3,015	-	4,961
	Berth Total		31,136	23,927	-	55,064
	Cruise	Newcastle	-	817	16,975	17,792
		Sydney	-	715	10,008	10,723
		Port Botany	-	1,727	30,749	32,476
		Port Kembla	-	553	10,150	10,702
	Cruise Total		-	3,812	67,881	71,693
	Manoeuvre	Newcastle	27	121	126	274
		Sydney	33	70	116	219
		Port Botany	135	456	375	966
		Port Kembla	17	90	45	152
	Manoeuvre Total		213	736	662	1,611
	RSZ	Newcastle	-	260	446	706
		Sydney	-	287	566	854
		Port Botany	-	525	604	1,129
		Port Kembla	-	96	79	175
	RSZ Total		-	1,169	1,695	2,864
RO and IFO Total			37,264	37,921	70,239	145,424
MDO	Anchorage	Newcastle	91	133	-	225
		Sydney	577	194	-	771
		Port Botany	286	355	-	641
		Port Kembla	35	45	-	80
	Anchorage Total		989	728	-	1,717
	Berth	Newcastle	1,341	1,515	-	2,855
		Sydney	1,575	2,511	-	4,086
		Port Botany	1,492	797	-	2,289
		Port Kembla	434	315	-	749
	Berth Total		4,842	5,138	-	9,980
	Cruise	Newcastle	-	66	1,271	1,337
		Sydney	-	134	1,972	2,105
		Port Botany	-	116	1,894	2,010
		Port Kembla	-	51	863	914
	Cruise Total		-	366	5,999	6,366
	Manoeuvre	Newcastle	2	10	9	21

Fuel type	Mode of operation	Port	2008 fuel consumption (kL/year)			
			Auxiliary boiler	Auxiliary engine	Main engine	Grand Total
		Sydney	37	18	75	130
		Port Botany	10	28	24	62
		Port Kembla	1	8	4	13
	Manoeuvre Total		50	63	112	225
	RSZ	Newcastle	-	20	31	51
		Sydney	-	42	128	169
		Port Botany	-	31	37	68
		Port Kembla	-	8	6	14
	RSZ Total		-	100	202	302
MDO Total			5,881	6,396	6,313	18,589
MGO	Anchorage	Newcastle	24	46	-	70
		Sydney	18	26	-	44
		Port Botany	47	72	-	119
		Port Kembla	6	8	-	14
	Anchorage Total		94	152	-	246
	Berth	Newcastle	185	92	-	277
		Sydney	206	166	-	373
		Port Botany	269	218	-	487
		Port Kembla	37	47	-	85
	Berth Total		698	523	-	1,221
	Cruise	Newcastle	-	22	294	316
		Sydney	-	28	348	376
		Port Botany	-	29	480	510
		Port Kembla	-	7	126	133
	Cruise Total		-	87	1,248	1,335
	Manoeuvre	Newcastle	1	2	2	5
		Sydney	2	2	5	9
		Port Botany	2	7	5	14
		Port Kembla	-	1	1	2
	Manoeuvre Total		5	13	13	30
	RSZ	Newcastle	-	7	7	14
		Sydney	-	8	14	23
		Port Botany	-	9	9	18
		Port Kembla	-	1	1	2
	RSZ Total		-	25	32	57
MGO Total			798	799	1,293	2,890
Grand Total			43,942	45,116	77,845	166,903

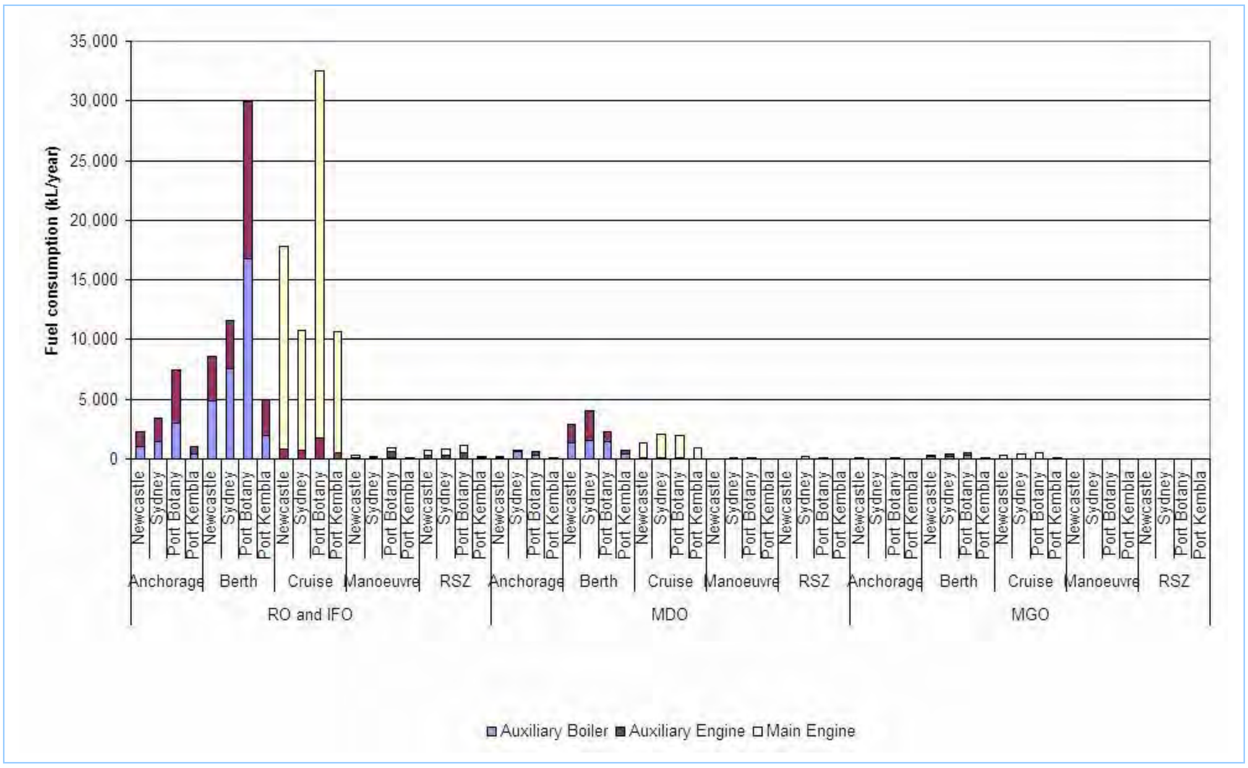

Figure 3-109: Ocean going vessel fuel consumption by engine, port, mode of operation and fuel type

Figure 3-110, Figure 3-111, Figure 3-112 and Figure 3-113 show the spatial distribution of OGV main engine, auxiliary engine, auxiliary boiler and refuelling emissions.

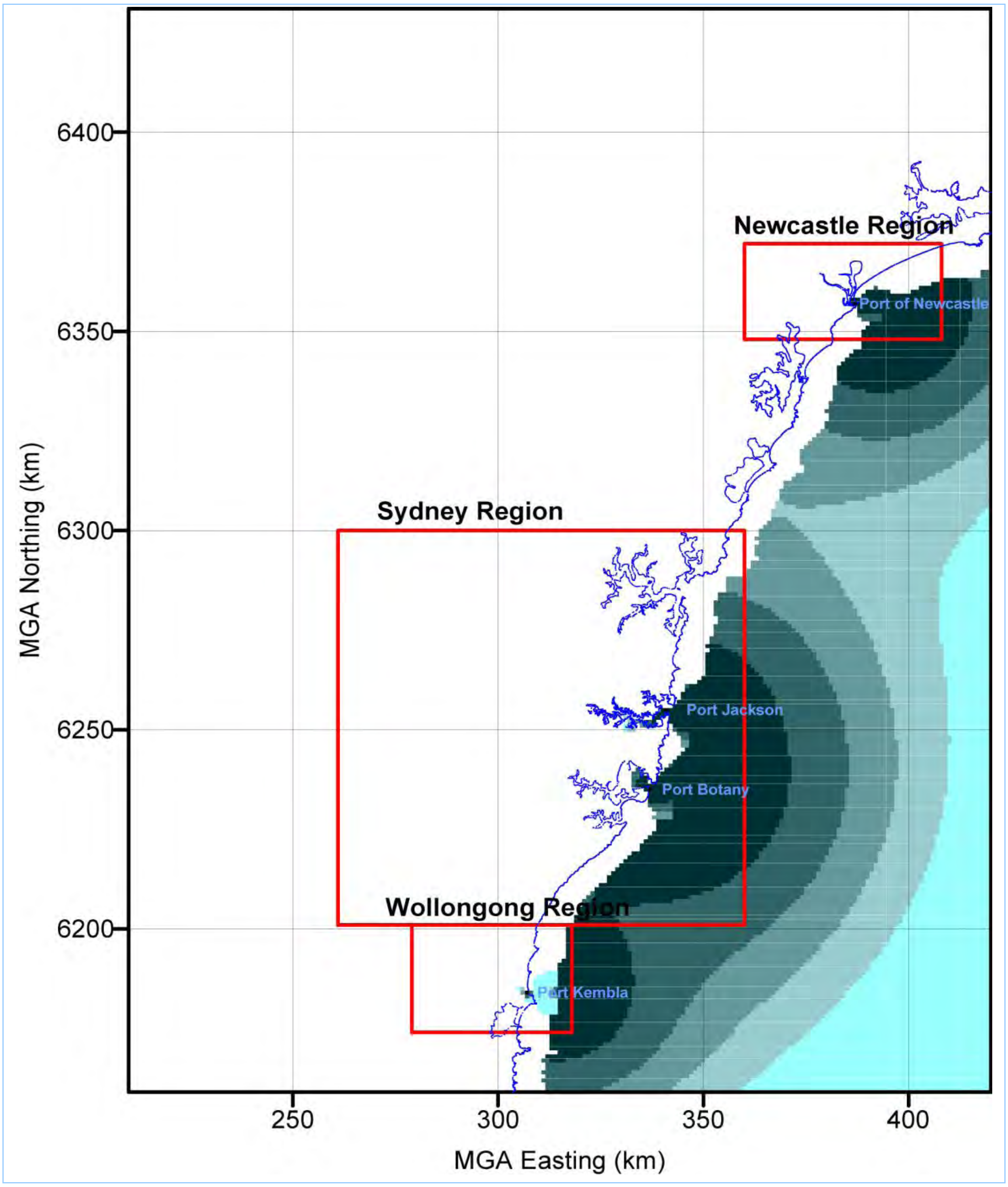

Figure 3-110: Ocean going vessel spatial distribution of main engine emissions

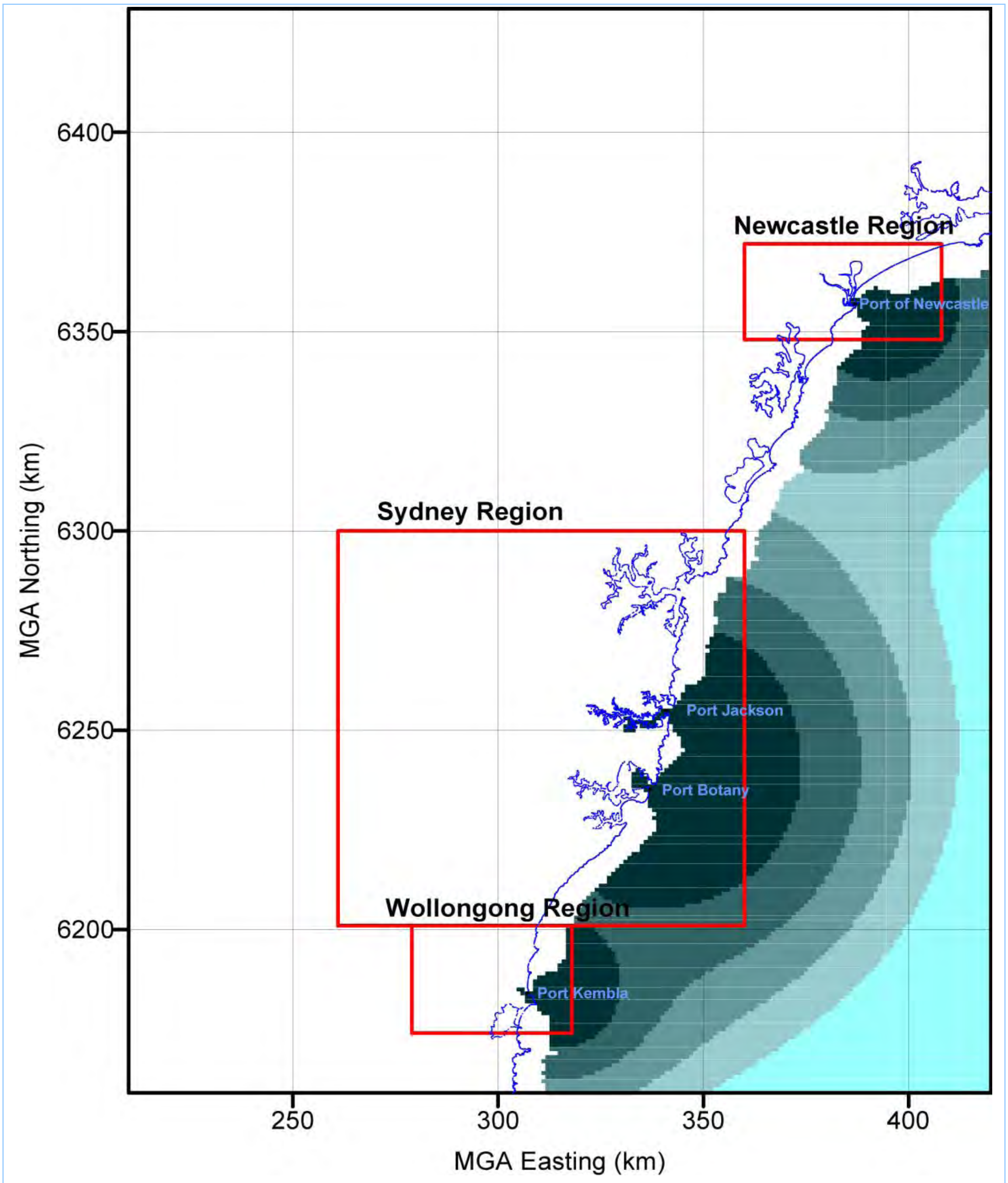

Figure 3-111: Ocean going vessel spatial distribution of auxiliary engine emissions

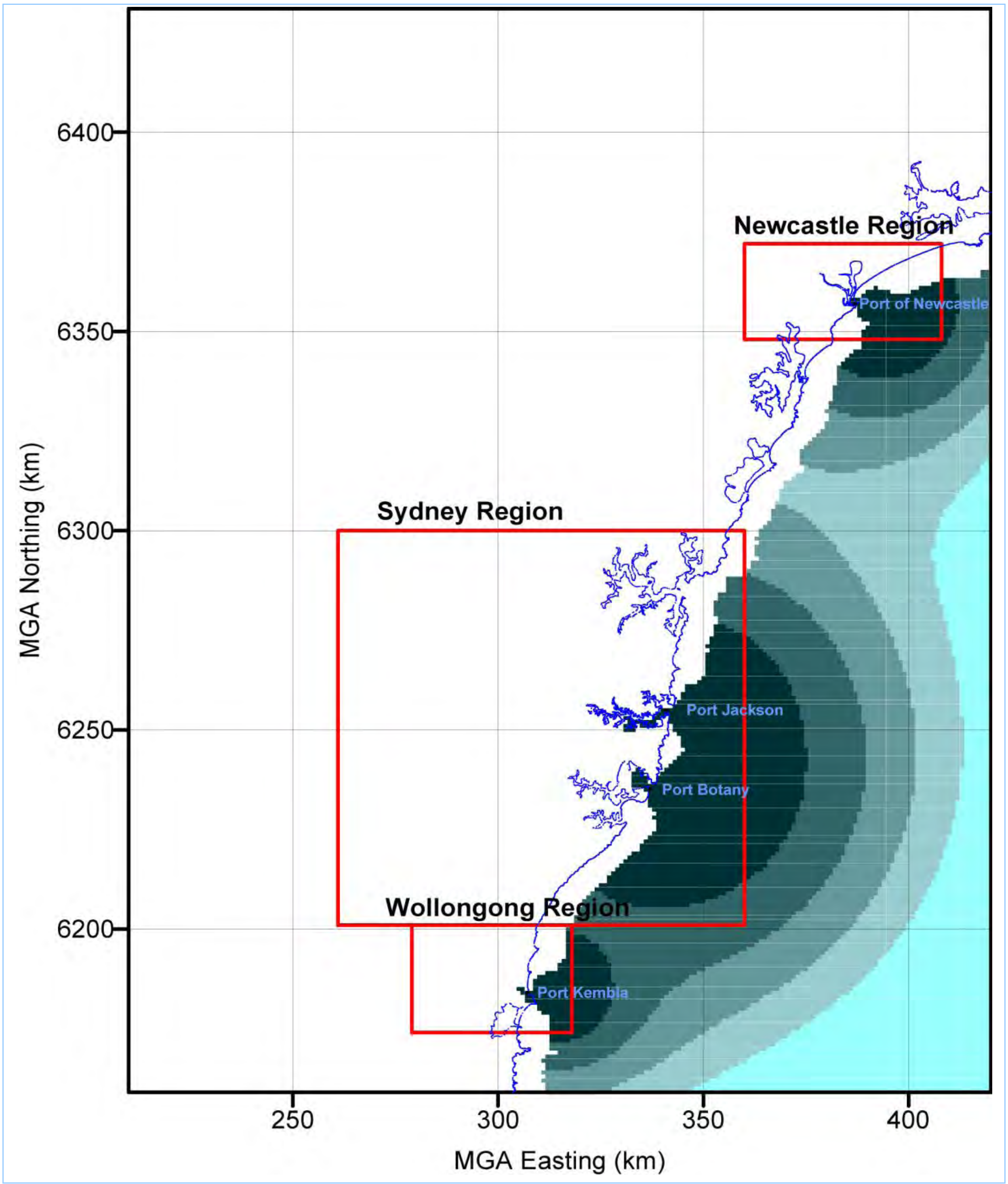

Figure 3-112: Ocean going vessel spatial distribution of auxiliary boiler emissions

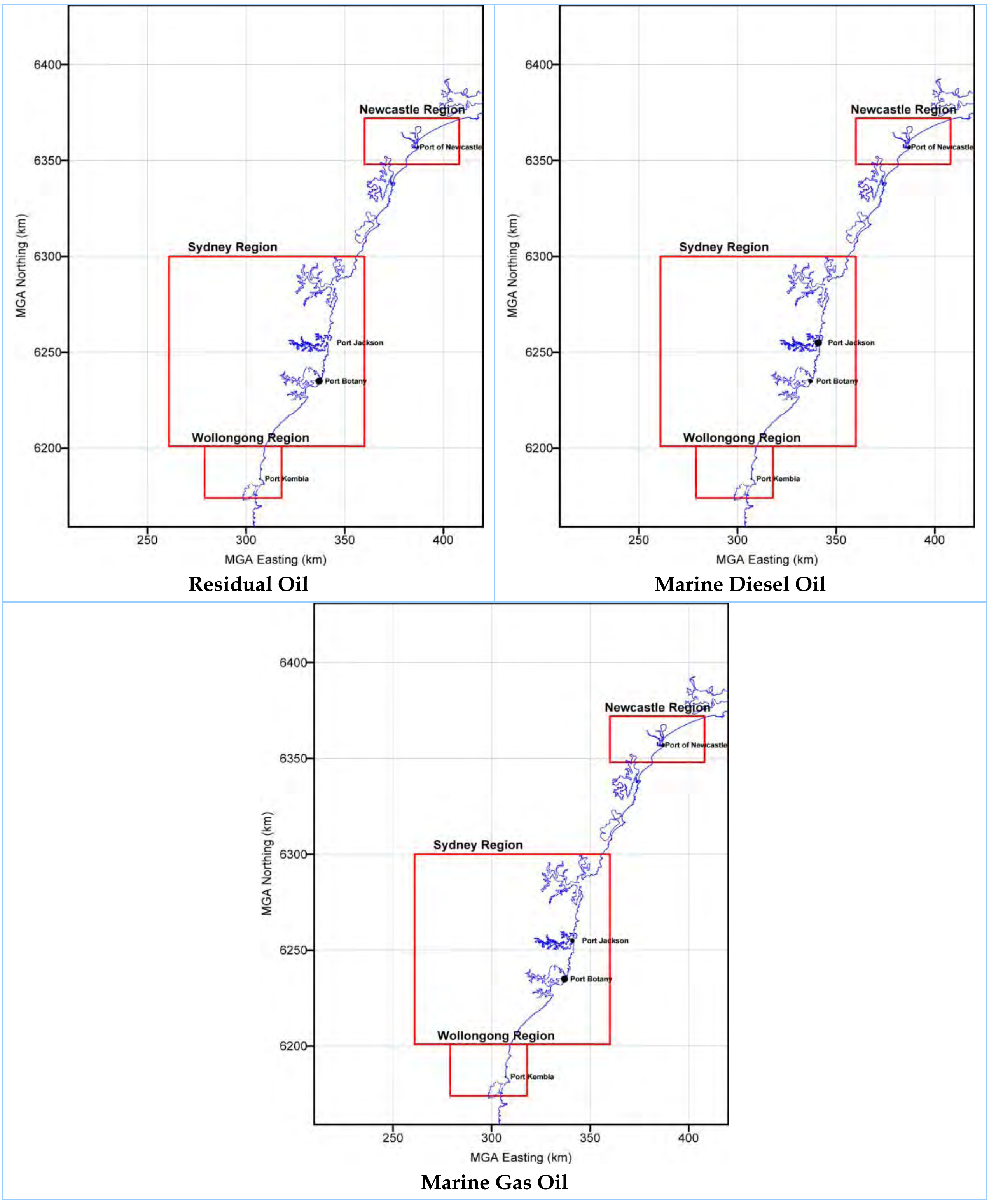

Figure 3-113: Ocean going vessel spatial distribution of refuelling emissions

3.7.6 Temporal Variation of Emissions

Table 3-178 summarises the data used to estimate the temporal variation in emissions from OGVs.

Table 3-178: Ocean going vessel temporal data

Emission source	Temporal data	Temporal data source
Exhaust emissions from main engine, auxiliary engine and auxiliary boilers and evaporative emissions from refuelling OGVs with RO, IFO, MDO and MGO	Monthly, daily and hourly: Derived from ship logs	- *Port Newcastle Vessel Visits for 2008* (NPC, 2009) - *Port Botany and Port of Sydney Vessel Visits for 2008* (SPC, 2009) - *Port Kembla Vessel Visits for 2008* (PKPC, 2009)

For each OGV call, shipping logs have been used to establish main engine, auxiliary engine and auxiliary boiler operating frequency and duration by hour, day and month (NPC, 2009; SPC, 2009; and PKPC, 2009). Hourly, daily and monthly temporal variation profiles are presented in Table 3-179, Table 3-180 and Table 3-181 and shown in Figure 3-114, Figure 3-115 and Figure 3-116.

Table 3-179: Ocean going vessel hourly temporal profile

Hour	Week day and weekend proportion (%)	Hour	Week day and weekend proportion (%)
1	4.07	13	4.21
2	4.11	14	4.17
3	4.14	15	4.16
4	4.17	16	4.16
5	4.18	17	4.15
6	4.20	18	4.15
7	4.23	19	4.13
8	4.26	20	4.12
9	4.28	21	4.11
10	4.28	22	4.09
11	4.26	23	4.08
12	4.24	24	4.06

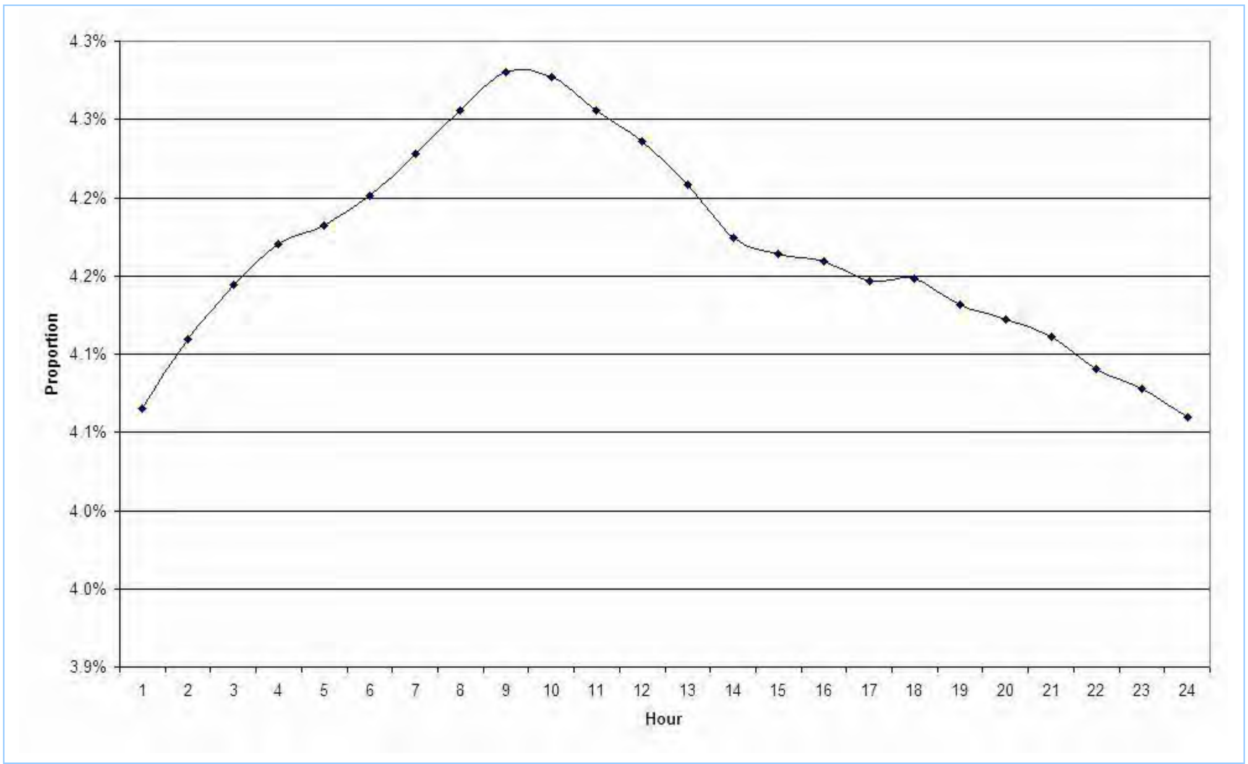

Figure 3-114: Ocean going vessel hourly temporal profile

Table 3-180: Ocean going vessel daily temporal profile

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Proportion (%)	14.14	14.46	14.47	14.26	14.66	14.31	13.70

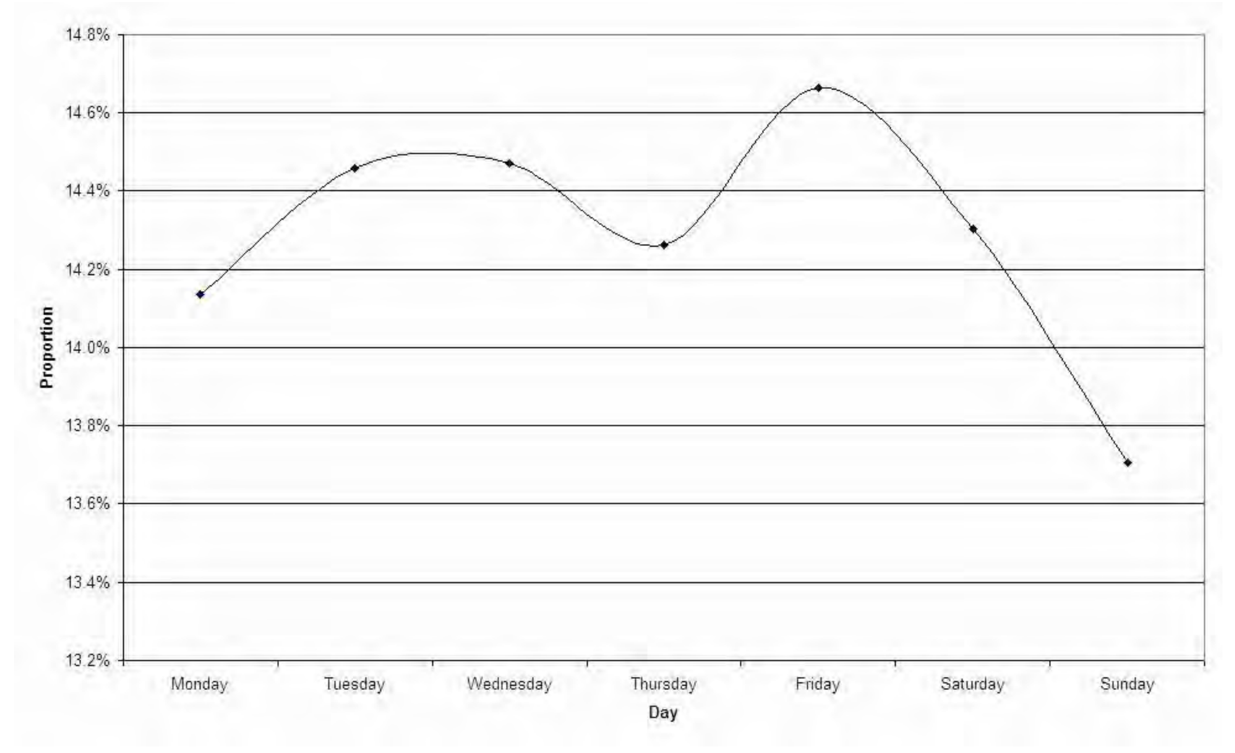

Figure 3-115: Ocean going vessel daily temporal profile

Table 3-181: Ocean going vessel monthly temporal profile

Month	Proportion (%)	Month	Proportion (%)
January	8.18	July	8.50
February	8.20	August	8.40
March	8.72	September	7.93
April	8.33	October	8.53
May	8.38	November	8.43
June	7.78	December	8.62

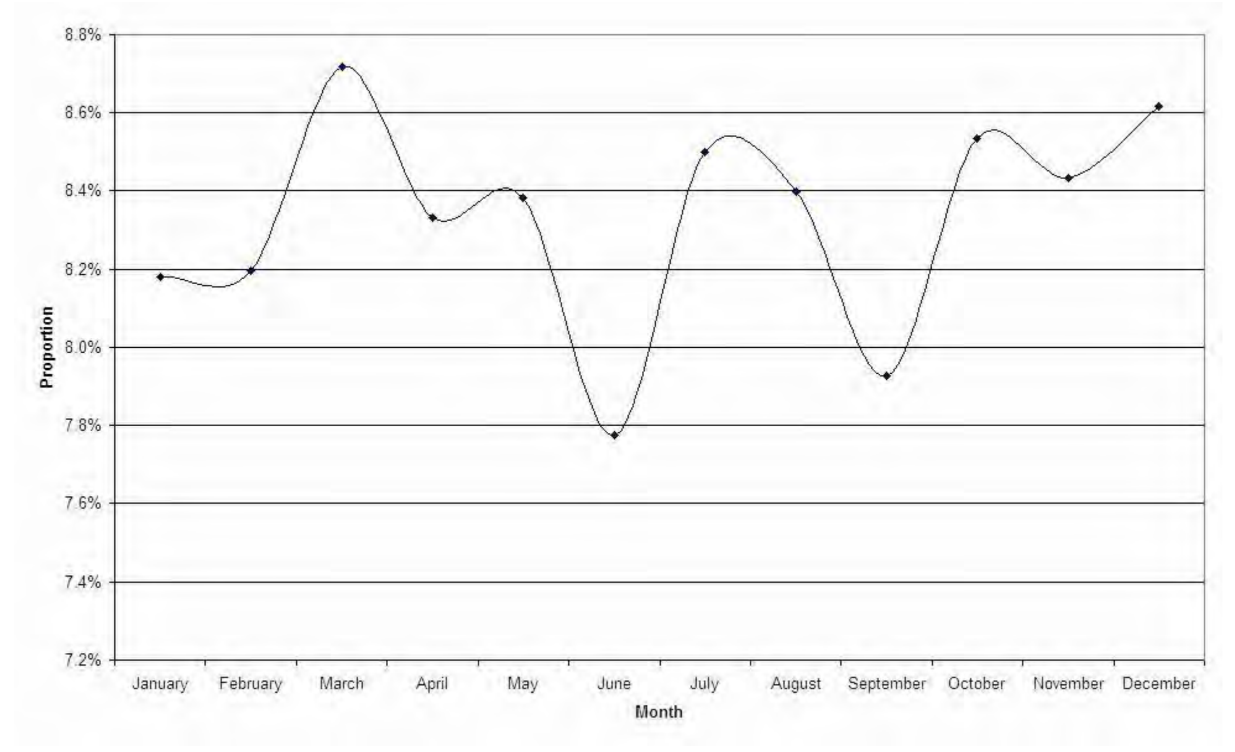

Figure 3-116: Ocean going vessel monthly temporal profile

3.7.7 *Emission Estimates*

Table 3-182 presents annual emissions of selected substances from OGVs by activity.

Table 3-182: Ocean going vessel emissions by activity

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Ships Exhaust	1,3-BUTADIENE	8.04	7.05	28	3.77	47
	ACETALDEHYDE	311	273	1,094	146	1,824
	BENZENE	793	818	2,634	355	4,600
	CARBON MONOXIDE	79,425	76,084	270,874	36,610	462,994
	FORMALDEHYDE	655	581	2,297	307	3,839
	ISOMERS OF XYLENE	405	417	1,345	181	2,348
	LEAD & COMPOUNDS	4.09	3.67	14	1.75	24
	OXIDES OF NITROGEN	1,643,026	1,937,834	5,138,456	705,798	9,425,114
	PARTICULATE MATTER ≤ 10 µm	158,627	157,162	538,935	67,646	922,370
	PARTICULATE MATTER ≤ 2.5 µm	145,937	144,589	495,820	62,234	848,580
	POLYCYCLIC AROMATIC HYDROCARBONS	507	501	1,726	217	2,951
	SULFUR DIOXIDE	1,292,254	1,176,035	4,538,324	550,755	7,557,368
	TOLUENE	768	795	2,545	343	4,450
	TOTAL SUSPENDED	163,590	162,069	555,809	69,763	951,230

Activity	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	PARTICULATE					
	TOTAL VOLATILE ORGANIC COMPOUNDS	35,195	36,225	116,948	15,737	204,106
Ships Evaporative	POLYCYCLIC AROMATIC HYDROCARBONS	0.16	-	0.53	9.20×10^{-2}	0.79
	TOTAL VOLATILE ORGANIC COMPOUNDS	17	-	47	6.65	70

Table 3-183 presents annual emissions of selected substances from OGVs by source type.

Table 3-183: Ocean gouging vessel emissions by source type

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
Main Engine - Residual Oil	BENZENE	422	623	1,160	163	2,368
	CARBON MONOXIDE	35,943	53,066	98,842	13,854	201,705
	FORMALDEHYDE	20	29	54	7.53	110
	ISOMERS OF XYLENE	215	317	591	83	1,206
	LEAD & COMPOUNDS	1.81	2.67	4.98	0.70	10
	OXIDES OF NITROGEN	1,078,329	1,592,044	2,965,401	415,646	6,051,420
	PARTICULATE MATTER ≤ 10 µm	87,415	129,060	240,392	33,695	490,561
	PARTICULATE MATTER ≤ 2.5 µm	80,422	118,735	221,160	30,999	451,316
	POLYCYCLIC AROMATIC HYDROCARBONS	269	397	740	104	1,510
	SULFUR DIOXIDE	630,481	930,842	1,733,822	243,022	3,538,167
	TOLUENE	420	620	1,155	162	2,357
	TOTAL SUSPENDED PARTICULATE	90,119	133,051	247,826	34,737	505,733
	TOTAL VOLATILE ORGANIC COMPOUNDS	18,544	27,378	50,996	7,148	104,066
Main Engine - Diesel Oil	1,3-BUTADIENE	2.89	4.27	7.96	1.12	16
	ACETALDEHYDE	112	165	308	43	628
	BENZENE	30	45	84	12	171
	CARBON MONOXIDE	3,548	5,238	9,757	1,368	19,910
	FORMALDEHYDE	224	331	616	86	1,257
	ISOMERS OF XYLENE	16	23	44	6.11	89
	LEAD & COMPOUNDS	0.15	0.22	0.42	5.85×10^{-2}	0.85
	OXIDES OF NITROGEN	81,693	120,611	224,655	31,489	458,448
	PARTICULATE MATTER ≤ 10 µm	1,873	2,766	5,152	722	10,513
	PARTICULATE MATTER	1,723	2,544	4,739	664	9,672

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	≤ 2.5 µm					
	POLYCYCLIC AROMATIC HYDROCARBONS	13	19	36	5.05	73
	SULFUR DIOXIDE	12,866	18,996	35,383	4,959	72,205
	TOLUENE	22	33	62	8.65	126
	TOTAL SUSPENDED PARTICULATE	1,951	2,881	5,366	752	10,951
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,459	2,154	4,013	562	8,189
Main Engine - Gas Oil	1,3-BUTADIENE	0.58	0.85	1.59	0.22	3.25
	ACETALDEHYDE	22	33	62	8.63	126
	BENZENE	6.10	9.00	17	2.35	34
	CARBON MONOXIDE	648	957	1,783	250	3,639
	FORMALDEHYDE	45	66	123	17	252
	ISOMERS OF XYLENE	3.17	4.68	8.72	1.22	18
	LEAD & COMPOUNDS	3.11×10^{-2}	4.59×10^{-2}	8.55×10^{-2}	1.20×10^{-2}	0.17
	OXIDES OF NITROGEN	16,136	23,824	44,375	6,220	90,555
	PARTICULATE MATTER ≤ 10 µm	290	428	797	112	1,627
	PARTICULATE MATTER ≤ 2.5 µm	267	394	733	103	1,496
	POLYCYCLIC AROMATIC HYDROCARBONS	2.62	3.87	7.21	1.01	15
	SULFUR DIOXIDE	1,540	2,274	4,235	594	8,643
	TOLUENE	4.49	6.63	12	1.73	25
	TOTAL SUSPENDED PARTICULATE	302	446	830	116	1,694
	TOTAL VOLATILE ORGANIC COMPOUNDS	292	431	803	113	1,638
Auxiliary Engine - Residual Oil	BENZENE	243	110	978	136	1,467
	CARBON MONOXIDE	29,350	13,303	118,244	16,428	177,326
	FORMALDEHYDE	11	5.10	45	6.29	68
	ISOMERS OF XYLENE	124	56	498	69	747
	LEAD & COMPOUNDS	0.91	0.41	3.66	0.51	5.49
	OXIDES OF NITROGEN	357,486	162,031	1,440,216	200,096	2,159,828
	PARTICULATE MATTER ≤ 10 µm	38,021	17,233	153,178	21,282	229,714
	PARTICULATE MATTER ≤ 2.5 µm	34,980	15,855	140,924	19,579	211,337
	POLYCYCLIC AROMATIC HYDROCARBONS	117	53	473	66	709

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	SULFUR DIOXIDE	316,167	143,303	1,273,752	176,968	1,910,190
	TOLUENE	242	110	974	135	1,461
	TOTAL SUSPENDED PARTICULATE	39,197	17,766	157,915	21,940	236,819
	TOTAL VOLATILE ORGANIC COMPOUNDS	10,673	4,837	42,998	5,974	64,482
Auxiliary Engine - Diesel Oil	1,3-BUTADIENE	3.48	1.58	14	1.95	21
	ACETALDEHYDE	135	61	543	75	814
	BENZENE	37	17	148	21	222
	CARBON MONOXIDE	4,830	2,189	19,457	2,703	29,179
	FORMALDEHYDE	270	122	1,086	151	1,629
	ISOMERS OF XYLENE	19	8.65	77	11	115
	LEAD & COMPOUNDS	0.14	6.48×10^{-2}	0.58	8.0×10^{-2}	0.86
	OXIDES OF NITROGEN	55,496	25,154	223,579	31,063	335,292
	PARTICULATE MATTER ≤ 10 µm	1,624	736	6,544	909	9,813
	PARTICULATE MATTER ≤ 2.5 µm	1,494	677	6,020	836	9,028
	POLYCYCLIC AROMATIC HYDROCARBONS	11	4.98	44	6.14	66
	SULFUR DIOXIDE	12,107	5,488	48,777	6,777	73,149
	TOLUENE	27	12	109	15	163
	TOTAL SUSPENDED PARTICULATE	1,692	767	6,816	947	10,222
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,756	796	7,075	983	10,611
Auxiliary Engine - Gas Oil	1,3-BUTADIENE	0.44	0.20	1.75	0.24	2.63
	ACETALDEHYDE	17	7.63	68	9.43	102
	BENZENE	4.58	2.08	18	2.57	28
	CARBON MONOXIDE	604	274	2,432	338	3,647
	FORMALDEHYDE	34	15	136	19	204
	ISOMERS OF XYLENE	2.38	1.08	9.61	1.33	14
	LEAD & COMPOUNDS	1.79×10^{-2}	8.10×10^{-3}	7.20×10^{-2}	1.0×10^{-2}	0.11
	OXIDES OF NITROGEN	6,937	3,144	27,948	3,883	41,913
	PARTICULATE MATTER ≤ 10 µm	152	69	614	85	921
	PARTICULATE MATTER ≤ 2.5 µm	140	64	565	79	847
	POLYCYCLIC AROMATIC HYDROCARBONS	1.37	0.62	5.53	0.77	8.29
	SULFUR DIOXIDE	885	401	3,565	495	5,346
	TOLUENE	3.37	1.53	14	1.89	20

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	TOTAL SUSPENDED PARTICULATE	159	72	640	89	959
	TOTAL VOLATILE ORGANIC COMPOUNDS	220	100	884	123	1,326
Auxiliary Boiler - Residual Oil	BENZENE	44	10	198	16	268
	CARBON MONOXIDE	3,848	904	17,401	1,426	23,580
	FORMALDEHYDE	2.03	0.48	9.17	0.75	12
	ISOMERS OF XYLENE	22	5.24	101	8.26	137
	LEAD & COMPOUNDS	0.88	0.21	3.98	0.33	5.39
	OXIDES OF NITROGEN	40,409	9,490	182,712	14,977	247,589
	PARTICULATE MATTER ≤ 10 µm	27,916	6,556	126,223	10,347	171,042
	PARTICULATE MATTER ≤ 2.5 µm	25,683	6,032	116,125	9,519	157,359
	POLYCYCLIC AROMATIC HYDROCARBONS	85	20	383	31	519
	SULFUR DIOXIDE	306,360	71,949	1,385,222	113,549	1,877,080
	TOLUENE	44	10	197	16	267
	TOTAL SUSPENDED PARTICULATE	28,779	6,759	130,127	10,667	176,332
	TOTAL VOLATILE ORGANIC COMPOUNDS	1,924	452	8,701	713	11,790
Auxiliary Boiler - Diesel Oil	1,3-BUTADIENE	0.57	0.13	2.58	0.21	3.50
	ACETALDEHYDE	22	5.19	100	8.19	135
	BENZENE	6.01	1.41	27	2.23	37
	CARBON MONOXIDE	576	135	2,604	213	3,528
	FORMALDEHYDE	44	10	200	16	271
	ISOMERS OF XYLENE	3.13	0.73	14	1.16	19
	LEAD & COMPOUNDS	0.13	3.04×10^{-2}	0.59	4.80×10^{-2}	0.79
	OXIDES OF NITROGEN	5,759	1,352	26,038	2,134	35,283
	PARTICULATE MATTER ≤ 10 µm	1,219	286	5,513	452	7,471
	PARTICULATE MATTER ≤ 2.5 µm	1,122	263	5,072	416	6,873
	POLYCYCLIC AROMATIC HYDROCARBONS	7.20	1.69	33	2.67	44
	SULFUR DIOXIDE	10,977	2,578	49,633	4,068	67,256
	TOLUENE	4.43	1.04	20	1.64	27
	TOTAL SUSPENDED PARTICULATE	1,270	298	5,743	471	7,782
	TOTAL VOLATILE ORGANIC	288	68	1,302	107	1,764

Source type	Substance	Emissions (kg/year)				
		Newcastle	Non Urban	Sydney	Wollongong	GMR
	COMPOUNDS					
Auxiliary Boiler - Gas Oil	1,3-BUTADIENE	7.74×10^{-2}	1.82×10^{-2}	0.35	2.87×10^{-2}	0.47
	ACETALDEHYDE	3.00	0.70	14	1.11	18
	BENZENE	0.82	0.19	3.69	0.30	5.00
	CARBON MONOXIDE	78	18	353	29	479
	FORMALDEHYDE	6.00	1.41	27	2.22	37
	ISOMERS OF XYLENE	0.42	9.96×10^{-2}	1.92	0.16	2.60
	LEAD & COMPOUNDS	1.76×10^{-2}	4.13×10^{-3}	7.95×10^{-2}	6.51×10^{-3}	0.11
	OXIDES OF NITROGEN	781	183	3,532	290	4,786
	PARTICULATE MATTER ≤ 10 µm	116	27	523	43	708
	PARTICULATE MATTER ≤ 2.5 µm	106	25	481	39	652
	POLYCYCLIC AROMATIC HYDROCARBONS	0.98	0.23	4.41	0.36	5.98
	SULFUR DIOXIDE	870	204	3,936	323	5,333
	TOLUENE	0.60	0.14	2.71	0.22	3.68
	TOTAL SUSPENDED PARTICULATE	120	28	545	45	738
	TOTAL VOLATILE ORGANIC COMPOUNDS	39	9.17	177	14	239
Evaporative - Residual Oil	POLYCYCLIC AROMATIC HYDROCARBONS	0.16	-	0.53	9.20×10^{-2}	0.79
	TOTAL VOLATILE ORGANIC COMPOUNDS	0.96	-	3.18	0.55	4.69
Evaporative - Diesel Oil	TOTAL VOLATILE ORGANIC COMPOUNDS	13	-	37	5.29	56
Evaporative - Gas Oil	TOTAL VOLATILE ORGANIC COMPOUNDS	2.36	-	6.81	0.81	9.98

Table 3-184 presents annual emissions of selected substances from OGVs by engine, mode of operation and port.

Table 3-184: Ocean going vessel emissions by engine, mode of operation and port

Port	Engine	Mode	Fuel (tonne/year)	Emissions (tonne/year)											
				NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
Newcastle	Main Engine	Cruise	17,789	1,622	2.83	0.27	872	121	111	27	0.54	48	56,498	0.39	8.59×10^{-9}
		RSZ	464	42	7.35×10^{-2}	7.14×10^{-3}	23	3.86	3.55	1.69	3.39×10^{-2}	2.33	1,472	1.01×10^{-2}	2.25×10^{-10}
		Manoeuvre	131	12	2.09×10^{-2}	2.01×10^{-3}	6.45	1.09	1.01	0.48	9.61×10^{-3}	0.66	416	2.86×10^{-3}	6.36×10^{-11}
		Anchorage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Berth	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Engine Total		18,385	1,676	2.93	0.28	901	126	116	29	0.58	51	58,385	0.40	8.88×10^{-9}
	Auxiliary Engine	Cruise	868	51	0.12	1.15×10^{-2}	42	5.08	4.67	1.54	1.54×10^{-2}	4.22	2,756	1.62×10^{-2}	3.58×10^{-10}
		RSZ	275	16	3.77×10^{-2}	3.65×10^{-3}	13	1.62	1.49	0.49	4.87×10^{-3}	1.34	873	5.14×10^{-3}	1.14×10^{-10}
		Manoeuvre	127	7.52	1.75×10^{-2}	1.69×10^{-3}	6.22	0.75	0.69	0.23	2.26×10^{-3}	0.62	405	2.39×10^{-3}	5.29×10^{-11}
		Anchorage	1,417	84	0.19	1.88×10^{-2}	67	8.14	7.49	2.51	2.51×10^{-2}	6.90	4,500	2.62×10^{-2}	5.75×10^{-10}
		Berth	5,092	299	0.70	6.82×10^{-2}	208	25	23	9.09	9.09×10^{-2}	25	16,176	8.73×10^{-2}	1.81×10^{-9}
	Auxiliary Engine Total		7,779	458	1.07	0.10	337	41	38	14	0.14	38	24,710	0.14	2.91×10^{-9}
	Auxiliary Boiler	Cruise	-	-	-	-	-	-	-	-	-	-	-	-	-
		RSZ	-	-	-	-	-	-	-	-	-	-	-	-	-
		Manoeuvre	29	0.20	7.59×10^{-3}	3.80×10^{-5}	1.41	0.13	0.12	9.49×10^{-3}	1.90×10^{-4}	1.90×10^{-2}	92	4.02×10^{-4}	8.91×10^{-12}
		Anchorage	1,087	7.46	0.29	1.43×10^{-3}	53	4.81	4.43	0.36	7.14×10^{-3}	0.71	3,453	1.50×10^{-2}	3.33×10^{-10}
		Berth	6,043	41	1.59	7.96×10^{-3}	260	24	22	1.99	3.98×10^{-2}	3.98	19,195	7.88×10^{-2}	1.67×10^{-9}
	Auxiliary Boiler Total		7,159	49	1.88	9.42×10^{-3}	314	29	27	2.36	4.71×10^{-2}	4.71	22,740	9.43×10^{-2}	2.01×10^{-9}
	All Engine	Cruise	18,657	1,673	2.95	0.28	914	126	116	28	0.55	52	59,254	0.40	8.95×10^{-9}
		RSZ	739	58	0.11	1.08×10^{-2}	36	5.48	5.04	2.18	3.87×10^{-2}	3.66	2,345	1.53×10^{-2}	3.39×10^{-10}
		Manoeuvre	288	20	4.60×10^{-2}	3.74×10^{-3}	14	1.97	1.81	0.72	1.21×10^{-2}	1.30	913	5.65×10^{-3}	1.25×10^{-10}
		Anchorage	2,504	91	0.48	2.03×10^{-2}	120	13	12	2.87	3.22×10^{-2}	7.62	7,953	4.12×10^{-2}	9.08×10^{-10}
		Berth	11,136	341	2.30	7.61×10^{-2}	469	49	45	11	0.13	29	35,371	0.17	3.47×10^{-9}

Port	Engine	Mode	Fuel (tonne/year)	Emissions (tonne/year)											
				NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
	All Engine Total		33,324	2,183	5.88	0.40	1,552	196	180	45	0.77	94	105,835	0.63	1.38×10^{-8}
Sydney	Main Engine	Cruise	11,745	902	1.83	0.17	529	71	65	14	0.28	45	37,305	0.23	5.03×10^{-9}
		RSZ	675	52	0.10	9.88×10^{-3}	30	4.34	3.99	1.24	2.47×10^{-2}	3.49	2,141	1.34×10^{-2}	2.88×10^{-10}
		Manoeuvre	184	14	2.85×10^{-2}	2.71×10^{-3}	6.72	0.96	0.88	0.29	5.83×10^{-3}	0.89	583	3.32×10^{-3}	6.60×10^{-11}
		Anchorage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Berth	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Engine Total		12,604	968	1.96	0.18	566	76	70	16	0.32	49	40,030	0.25	5.38×10^{-9}
	Auxiliary Engine	Cruise	835	49	0.12	1.11×10^{-2}	38	4.57	4.20	1.48	1.48×10^{-2}	4.08	2,654	1.50×10^{-2}	3.24×10^{-10}
		RSZ	322	19	4.43×10^{-2}	4.28×10^{-3}	15	1.81	1.67	0.57	5.71×10^{-3}	1.57	1,023	5.89×10^{-3}	1.28×10^{-10}
		Manoeuvre	85	5.02	1.18×10^{-2}	1.14×10^{-3}	3.72	0.45	0.42	0.15	1.52×10^{-3}	0.42	271	1.51×10^{-3}	3.21×10^{-11}
		Anchorage	2,110	124	0.29	2.80×10^{-2}	102	12	11	3.73	3.73×10^{-2}	10	6,702	3.93×10^{-2}	8.70×10^{-10}
		Berth	6,280	369	0.87	8.45×10^{-2}	232	28	26	11	0.11	31	19,951	0.10	2.04×10^{-9}
	Auxiliary Engine Total		9,633	566	1.33	0.13	391	48	44	17	0.17	47	30,600	0.16	3.39×10^{-9}
	Auxiliary Boiler	Cruise	-	-	-	-	-	-	-	-	-	-	-	-	-
		RSZ	-	-	-	-	-	-	-	-	-	-	-	-	-
		Manoeuvre	67	0.45	1.77×10^{-2}	8.86×10^{-5}	2.11	0.20	0.19	2.22×10^{-2}	4.43×10^{-4}	4.43×10^{-2}	213	7.55×10^{-4}	1.40×10^{-11}
		Anchorage	1,897	13	0.50	2.50×10^{-3}	78	7.23	6.65	0.62	1.25×10^{-2}	1.25	6,025	2.41×10^{-2}	5.0×10^{-10}
		Berth	8,932	61	2.35	1.17×10^{-2}	402	37	34	2.94	5.87×10^{-2}	5.87	28,368	0.12	2.56×10^{-9}
	Auxiliary Boiler Total		10,895	75	2.87	1.43×10^{-2}	482	44	41	3.58	7.17×10^{-2}	7.17	34,607	0.14	3.08×10^{-9}
	All Engine	Cruise	12,581	951	1.94	0.18	567	75	69	16	0.30	49	39,959	0.25	5.35×10^{-9}
		RSZ	997	71	0.15	1.42×10^{-2}	45	6.15	5.66	1.81	3.04×10^{-2}	5.06	3,164	1.93×10^{-2}	4.16×10^{-10}
		Manoeuvre	336	19	5.80×10^{-2}	3.94×10^{-3}	13	1.61	1.48	0.47	7.79×10^{-3}	1.35	1,067	5.59×10^{-3}	1.12×10^{-10}
		Anchorage	4,007	137	0.79	3.05×10^{-2}	180	20	18	4.36	4.98×10^{-2}	12	12,727	6.34×10^{-2}	1.37×10^{-9}
		Berth	15,212	430	3.22	9.62×10^{-2}	634	65	60	14	0.17	37	48,319	0.22	4.60×10^{-9}
	All Engine Total		33,132	1,609	6.16	0.33	1,438	168	154	37	0.56	104	105,236	0.56	1.19×10^{-8}

Port	Engine	Mode	Fuel (tonne/year)	Emissions (tonne/year)											
				NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
Port Botany	Main Engine	Cruise	31,809	2,890	5.04	0.49	1,574	218	200	48	0.96	87	101,022	0.69	1.55×10^{-8}
		RSZ	625	60	0.10	9.59×10^{-3}	31	5.92	5.44	2.92	5.83×10^{-2}	3.59	1,979	1.36×10^{-2}	3.04×10^{-10}
		Manoeuvre	388	36	6.31×10^{-2}	5.97×10^{-3}	19	3.31	3.05	1.40	2.80×10^{-2}	1.87	1,231	8.49×10^{-3}	1.89×10^{-10}
		Anchorage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Berth	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Engine Total		32,822	2,986	5.21	0.50	1,624	227	209	52	1.04	93	104,232	0.72	1.60×10^{-8}
	Auxiliary Engine	Cruise	1,798	106	0.25	2.38×10^{-2}	89	11	9.82	3.18	3.18×10^{-2}	8.74	5,710	3.38×10^{-2}	7.52×10^{-10}
		RSZ	542	32	7.42×10^{-2}	7.18×10^{-3}	27	3.24	2.98	0.96	9.58×10^{-3}	2.63	1,721	1.02×10^{-2}	2.28×10^{-10}
		Manoeuvre	472	28	6.46×10^{-2}	6.25×10^{-3}	23	2.81	2.59	0.83	8.34×10^{-3}	2.29	1,498	8.89×10^{-3}	1.98×10^{-10}
		Anchorage	4,651	274	0.64	6.17×10^{-2}	227	27	25	8.23	8.23×10^{-2}	23	14,773	8.71×10^{-2}	1.93×10^{-9}
		Berth	13,576	801	1.86	0.18	672	81	74	24	0.24	66	43,117	0.26	5.70×10^{-9}
	Auxiliary Engine Total		21,039	1,241	2.88	0.28	1,038	125	115	37	0.37	102	66,818	0.40	8.82×10^{-9}
	Auxiliary Boiler	Cruise	-	-	-	-	-	-	-	-	-	-	-	-	-
		RSZ	-	-	-	-	-	-	-	-	-	-	-	-	-
		Manoeuvre	141	0.97	3.70×10^{-2}	1.85×10^{-4}	6.93	0.63	0.58	4.63×10^{-2}	9.25×10^{-4}	9.25×10^{-2}	448	1.97×10^{-3}	4.38×10^{-11}
		Anchorage	3,237	22	0.85	4.25×10^{-3}	157	14	13	1.06	2.13×10^{-2}	2.13	10,282	4.49×10^{-2}	9.93×10^{-10}
		Berth	17,756	122	4.66	2.33×10^{-2}	863	79	73	5.83	0.12	12	56,391	0.25	5.46×10^{-9}
	Auxiliary Boiler Total		21,134	145	5.55	2.78×10^{-2}	1,027	94	87	6.94	0.14	14	67,120	0.29	6.50×10^{-9}
	All Engine	Cruise	33,607	2,996	5.29	0.51	1,662	228	210	51	0.99	96	106,732	0.73	1.62×10^{-8}
		RSZ	1,167	92	0.18	1.68×10^{-2}	58	9.15	8.42	3.87	6.79×10^{-2}	6.22	3,700	2.39×10^{-2}	5.32×10^{-10}
		Manoeuvre	1,001	65	0.16	1.24×10^{-2}	49	6.76	6.22	2.28	3.73×10^{-2}	4.26	3,177	1.93×10^{-2}	4.31×10^{-10}
		Anchorage	7,889	296	1.49	6.60×10^{-2}	384	42	38	9.29	0.10	25	25,054	0.13	2.93×10^{-9}
		Berth	31,332	922	6.52	0.20	1,535	160	147	30	0.36	78	99,508	0.50	1.12×10^{-8}
	All Engine Total		74,995	4,372	14	0.81	3,688	446	410	96	1.55	209	238,171	1.41	3.13×10^{-8}
Port	Main	Cruise	10,684	952	1.68	0.16	522	72	66	16	0.31	31	33,933	0.23	5.10×10^{-9}

Port	Engine	Mode	Fuel (tonne/year)	Emissions (tonne/year)											
				NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
Kembla	Engine	RSZ	83	12	2.14×10^{-2}	1.27×10^{-3}	4.07	1.49	1.37	0.97	1.95×10^{-2}	0.72	262	1.80×10^{-3}	3.99×10^{-11}
		Manoeuvre	48	7.01	1.24×10^{-2}	7.28×10^{-4}	2.33	0.86	0.79	0.56	1.12×10^{-2}	0.42	151	1.03×10^{-3}	2.28×10^{-11}
		Anchorage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Berth	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Engine Total		10,815	971	1.72	0.17	528	74	68	17	0.34	32	34,346	0.23	5.17×10^{-9}
	Auxiliary Engine	Cruise	586	35	8.03×10^{-2}	7.77×10^{-3}	28	3.44	3.16	1.04	1.04×10^{-2}	2.85	1,860	1.09×10^{-2}	2.42×10^{-10}
		RSZ	101	5.93	1.38×10^{-2}	1.33×10^{-3}	4.92	0.59	0.55	0.18	1.78×10^{-3}	0.49	320	1.89×10^{-3}	4.19×10^{-11}
		Manoeuvre	95	5.58	1.30×10^{-2}	1.26×10^{-3}	4.62	0.56	0.51	0.17	1.67×10^{-3}	0.46	300	1.77×10^{-3}	3.93×10^{-11}
		Anchorage	601	35	8.24×10^{-2}	7.97×10^{-3}	29	3.55	3.27	1.06	1.06×10^{-2}	2.92	1,909	1.13×10^{-2}	2.50×10^{-10}
		Berth	3,236	191	0.44	4.30×10^{-2}	156	19	17	5.73	5.73×10^{-2}	16	10,276	6.02×10^{-2}	1.33×10^{-9}
	Auxiliary Engine Total		4,618	272	0.63	6.13×10^{-2}	223	27	25	8.17	8.17×10^{-2}	22	14,665	8.60×10^{-2}	1.90×10^{-9}
	Auxiliary Boiler	Cruise	-	-	-	-	-	-	-	-	-	-	-	-	-
		RSZ	-	-	-	-	-	-	-	-	-	-	-	-	-
		Manoeuvre	18	0.12	4.66×10^{-3}	2.33×10^{-5}	0.86	7.92×10^{-2}	7.28×10^{-2}	5.83×10^{-3}	1.17×10^{-4}	1.17×10^{-2}	56	2.47×10^{-4}	5.47×10^{-12}
		Anchorage	461	3.17	0.12	6.05×10^{-4}	23	2.07	1.90	0.15	3.03×10^{-3}	0.30	1,464	6.43×10^{-3}	1.43×10^{-10}
		Berth	2,303	16	0.61	3.03×10^{-3}	103	9.52	8.76	0.76	1.51×10^{-2}	1.51	7,313	3.06×10^{-2}	6.58×10^{-10}
	Auxiliary Boiler Total		2,781	19	0.73	3.66×10^{-3}	127	12	11	0.91	1.83×10^{-2}	1.83	8,834	3.73×10^{-2}	8.06×10^{-10}
	All Engine	Cruise	11,270	986	1.77	0.17	550	75	69	17	0.32	34	35,794	0.24	5.35×10^{-9}
		RSZ	184	18	3.52×10^{-2}	2.61×10^{-3}	9.00	2.08	1.91	1.15	2.12×10^{-2}	1.21	582	3.68×10^{-3}	8.18×10^{-11}
		Manoeuvre	160	13	3.0×10^{-2}	2.01×10^{-3}	7.82	1.50	1.38	0.73	1.30×10^{-2}	0.89	507	3.05×10^{-3}	6.76×10^{-11}
		Anchorage	1,062	39	0.20	8.58×10^{-3}	52	5.62	5.17	1.21	1.37×10^{-2}	3.23	3,372	1.77×10^{-2}	3.93×10^{-10}
		Berth	5,538	206	1.05	4.60×10^{-2}	259	28	26	6.49	7.24×10^{-2}	17	17,589	9.08×10^{-2}	1.99×10^{-9}
	All Engine Total		18,214	1,262	3.08	0.23	878	113	104	26	0.44	57	57,845	0.36	7.87×10^{-9}
All Ports	Main Engine	Cruise	72,028	6,365	11	1.09	3,496	481	443	105	2.09	211	228,759	1.54	3.42×10^{-8}
		RSZ	1,847	167	0.30	2.79×10^{-2}	88	16	14	6.82	0.14	10	5,854	3.90×10^{-2}	8.57×10^{-10}

Port	Engine	Mode	Fuel (tonne/year)	Emissions (tonne/year)											
				NO_x	N_2O	NH_3	SO_2	PM_{10}	$PM_{2.5}$	VOC	CH_4	CO	CO_2	PAH	PCDD and PCDF
		Manoeuvre	751	69	0.12	1.14×10^{-2}	35	6.23	5.73	2.73	5.46×10^{-2}	3.84	2,381	1.57×10^{-2}	3.41×10^{-10}
		Anchorage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Berth	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Engine Total		74,626	6,601	12	1.13	3,619	503	463	114	2.28	225	236,994	1.60	3.54×10^{-8}
	Auxiliary Engine	Cruise	4,087	241	0.56	5.43×10^{-2}	197	24	22	7.23	7.23×10^{-2}	20	12,980	7.60×10^{-2}	1.68×10^{-9}
		RSZ	1,240	73	0.17	1.65×10^{-2}	60	7.26	6.68	2.19	2.19×10^{-2}	6.03	3,938	2.31×10^{-2}	5.12×10^{-10}
		Manoeuvre	779	46	0.11	1.03×10^{-2}	38	4.57	4.21	1.38	1.38×10^{-2}	3.79	2,474	1.46×10^{-2}	3.22×10^{-10}
		Anchorage	8,779	518	1.20	0.12	426	51	47	16	0.16	43	27,883	0.16	3.63×10^{-9}
		Berth	28,184	1,660	3.88	0.38	1,268	153	141	50	0.50	138	89,519	0.51	1.09×10^{-8}
	Auxiliary Engine Total		43,069	2,537	5.92	0.57	1,989	240	221	76	0.76	210	136,794	0.78	1.70×10^{-8}
	Auxiliary Boiler	Cruise	-	-	-	-	-	-	-	-	-	-	-	-	-
		RSZ	-	-	-	-	-	-	-	-	-	-	-	-	-
		Manoeuvre	255	1.74	6.70×10^{-2}	3.35×10^{-4}	11	1.04	0.96	8.37×10^{-2}	1.67×10^{-3}	0.17	809	3.37×10^{-3}	7.22×10^{-11}
		Anchorage	6,682	46	1.76	8.78×10^{-3}	310	28	26	2.20	4.39×10^{-2}	4.39	21,224	9.05×10^{-2}	1.97×10^{-9}
		Berth	35,033	240	9.21	4.61×10^{-2}	1,628	150	138	12	0.23	23	111,268	0.48	1.03×10^{-8}
	Auxiliary Boiler Total		41,970	288	11	5.52×10^{-2}	1,950	179	165	14	0.28	28	133,300	0.57	1.24×10^{-8}
	All Engine	Cruise	76,115	6,606	12	1.15	3,693	505	464	112	2.16	231	241,738	1.62	3.59×10^{-8}
		RSZ	3,087	240	0.47	4.43×10^{-2}	148	23	21	9.01	0.16	16	9,791	6.21×10^{-2}	1.37×10^{-9}
		Manoeuvre	1,785	117	0.30	2.21×10^{-2}	84	12	11	4.19	7.01×10^{-2}	7.80	5,664	3.36×10^{-2}	7.36×10^{-10}
		Anchorage	15,462	563	2.96	0.13	736	80	74	18	0.20	47	49,106	0.25	5.60×10^{-9}
		Berth	63,217	1,900	13	0.42	2,896	303	279	62	0.73	161	200,787	0.98	2.12×10^{-8}
	All Engine Total		159,665	9,426	29	1.76	7,557	923	849	204	3.32	463	507,087	2.95	6.48×10^{-8}

3.7.8 Emission Projection Methodology

Table 3-185 summarises the data used to estimate the emission projection factors for OGVs, while Figure 3-117 shows the emission projection factors for calendar years 2009 to 2036.

Table 3-185: Ocean going vessel emission projection factors

Emission source	Projection factor surrogate	Projection factor source
Exhaust emissions from main engine, auxiliary engine and auxiliary boilers and evaporative emissions from refuelling OGVs with RO, IFO, MDO and MGO	Final energy consumption for international water transport using petroleum	- *Australian Energy, National and State Projections to 2029-30, ABARE Research Report 06.26* (ABARE, 2006)

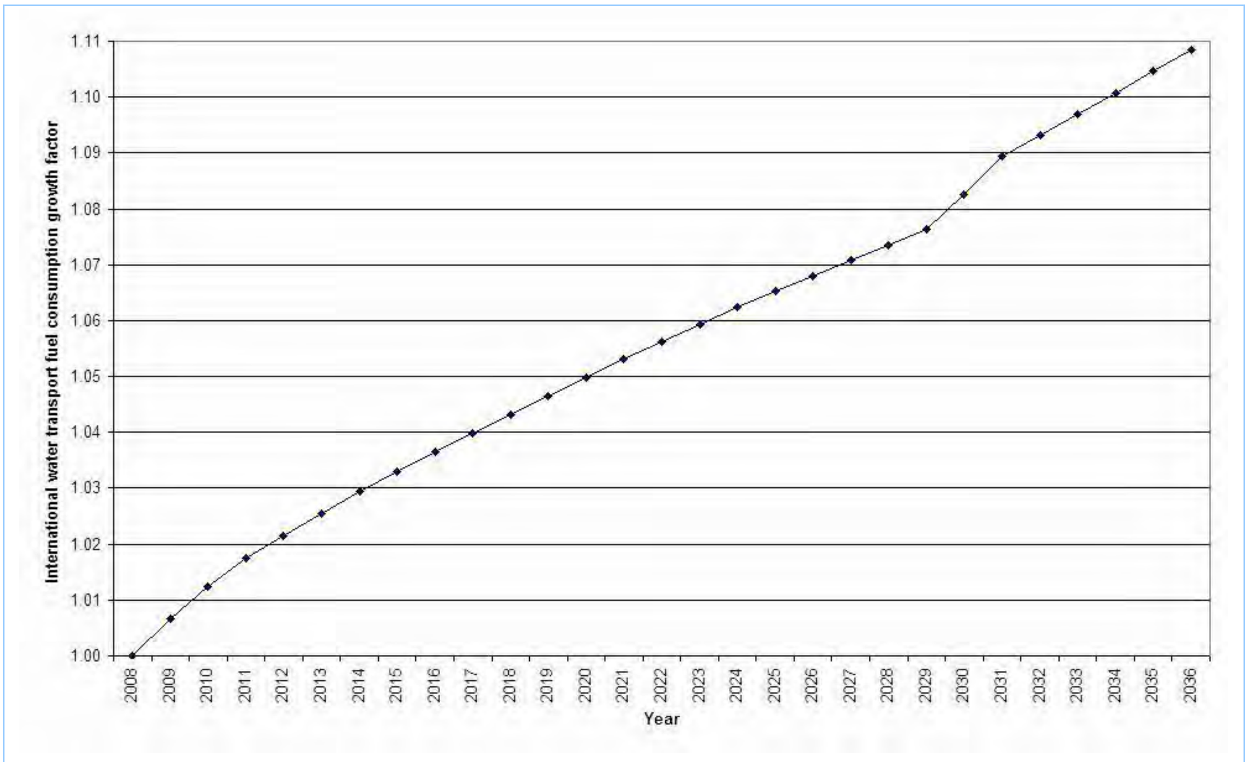

Figure 3-117: Ocean going vessel emission projection factors

4 EMISSIONS SUMMARY

The off-road mobile 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 off-road mobile air emissions inventory includes emissions from the following sources:

- Aircraft (flight operations);
- Aircraft (ground operations);
- Commercial boats;
- Commercial off-road vehicles and equipment;
- Industrial off-road vehicles and equipment;
- Locomotives;
- Recreational boats; and
- Ships.

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 off-road mobile 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 off-road mobile sources in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions.

Table 4-1: Total estimated annual emissions from off-road mobile sources in each region

Substance	Emissions (tonne/year)				
	Newcastle	Non Urban	Sydney	Wollongong	GMR
1,3-BUTADIENE	2.78	18	18	1.16	40
ACETALDEHYDE	9.97	151	47	4.26	212
BENZENE	31	196	164	13	404
CARBON MONOXIDE	3,343	27,975	20,801	1,698	53,817
FORMALDEHYDE	22	333	113	11	478
ISOMERS OF XYLENE	112	596	602	45	1,356
LEAD & COMPOUNDS	5.85×10^{-2}	0.85	1.28	3.0×10^{-2}	2.22
OXIDES OF NITROGEN	3,548	31,826	16,238	1,598	53,210
PARTICULATE MATTER ≤ 10 µm	284	2,185	1,019	119	3,607
PARTICULATE MATTER ≤ 2.5 µm	266	2,104	952	112	3,433
PERCHLOROETHYLENE	1.77×10^{-5}	6.80×10^{-5}	5.80×10^{-4}	1.24×10^{-4}	7.89×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	0.73	3.18	5.02	0.31	9.24
SULFUR DIOXIDE	1,300	1,246	4,725	553	7,824
TOLUENE	105	566	563	43	1,276
TOTAL SUSPENDED PARTICULATE	294	2,276	1,056	123	3,749
TOTAL VOLATILE ORGANIC COMPOUNDS	1,303	8,715	7,341	591	17,950

Figure 4-1: Proportions of total estimated annual emissions from off-road mobile 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 off-road mobile 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 off-road mobile source type in the whole GMR and the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Table 4-2: Total estimated annual emissions by off-road mobile source type in the GMR

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	3.86	0.13	12	9.42×10^{-2}	6.48	0.95	16	4.71×10^{-2}	40
ACETALDEHYDE	9.88	3.68	17	1.01	160	6.93	12	1.82	212
BENZENE	3.91	1.60	134	0.65	65	0.80	193	4.60	404
CARBON MONOXIDE	3,128	1,895	12,153	256	20,431	906	14,585	463	53,817
FORMALDEHYDE	29	8.20	33	2.99	366	15	20	3.84	478
ISOMERS OF XYLENE	1.03	0.76	542	0.60	38	1.72	770	2.35	1,356
LEAD & COMPOUNDS	1.71	4.58×10^{-4}	0.17	6.15×10^{-4}	7.32×10^{-2}	2.01×10^{-2}	0.23	2.39×10^{-2}	2.22
OXIDES OF NITROGEN	1,850	265	4,404	162	30,716	6,087	301	9,425	53,210
PARTICULATE MATTER ≤ 10 µm	58	15	193	11	2,094	171	143	922	3,607
PARTICULATE MATTER ≤ 2.5 µm	49	14	182	10	2,031	166	132	849	3,433
PERCHLOROETHYLENE	-	-	-	4.96×10^{-5}	7.39×10^{-4}	-	-	-	7.89×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	2.80	1.52×10^{-2}	0.37	1.73×10^{-2}	2.28	0.45	0.34	2.95	9.24
SULFUR DIOXIDE	167	1.97	15	0.41	64	11	7.46	7,557	7,824
TOLUENE	1.44	1.20	496	0.69	51	1.14	720	4.45	1,276
TOTAL SUSPENDED PARTICULATE	60	15	200	11	2,181	183	148	951	3,749
TOTAL VOLATILE ORGANIC COMPOUNDS	274	113	5,299	32	3,195	358	8,476	204	17,950

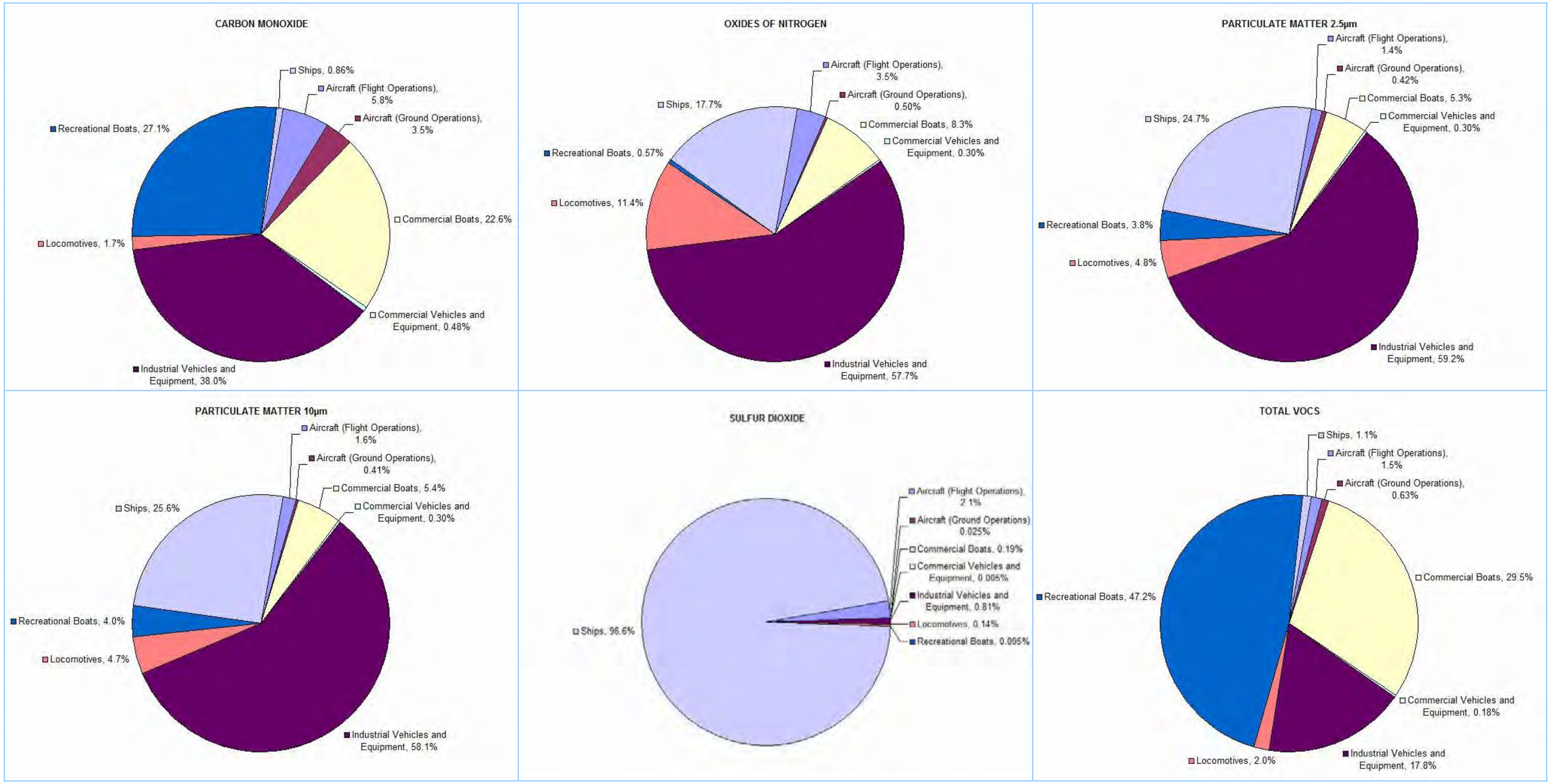

Figure 4-2: Proportions of total estimated annual emissions by off-road mobile source type in the GMR

Table 4-3: Total estimated annual emissions by off-road mobile source type in the Sydney region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	3.54	0.12	5.14	2.93×10^{-2}	0.95	0.46	7.64	2.83×10^{-2}	18
ACETALDEHYDE	9.02	3.54	10	0.51	13	3.33	5.83	1.09	47
BENZENE	3.56	1.47	58	0.23	7.13	0.38	91	2.63	164
CARBON MONOXIDE	2,407	1,823	5,332	136	3,484	436	6,912	271	20,801
FORMALDEHYDE	26	7.89	21	1.57	37	7.02	9.51	2.30	113
ISOMERS OF XYLENE	0.94	0.72	227	0.17	5.84	0.83	365	1.34	602
LEAD & COMPOUNDS	1.07	4.41×10^{-4}	7.03×10^{-2}	2.19×10^{-4}	1.03×10^{-2}	9.65×10^{-3}	0.11	1.44×10^{-2}	1.28
OXIDES OF NITROGEN	1,771	255	3,319	84	2,600	2,927	143	5,138	16,238
PARTICULATE MATTER ≤ 10 µm	46	14	114	5.34	150	82	68	539	1,019
PARTICULATE MATTER ≤ 2.5 µm	41	14	108	5.18	146	80	62	496	952
PERCHLOROETHYLENE	-	-	-	3.0×10^{-5}	5.50×10^{-4}	-	-	-	5.80×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	2.46	1.46×10^{-2}	0.19	8.76×10^{-3}	0.23	0.22	0.16	1.73	5.02
SULFUR DIOXIDE	160	1.89	9.89	0.21	6.10	5.10	3.54	4,538	4,725
TOLUENE	1.33	1.09	209	0.21	7.02	0.55	341	2.55	563
TOTAL SUSPENDED PARTICULATE	47	15	118	5.55	156	88	70	556	1,056
TOTAL VOLATILE ORGANIC COMPOUNDS	253	99	2,296	15	372	172	4,016	117	7,341

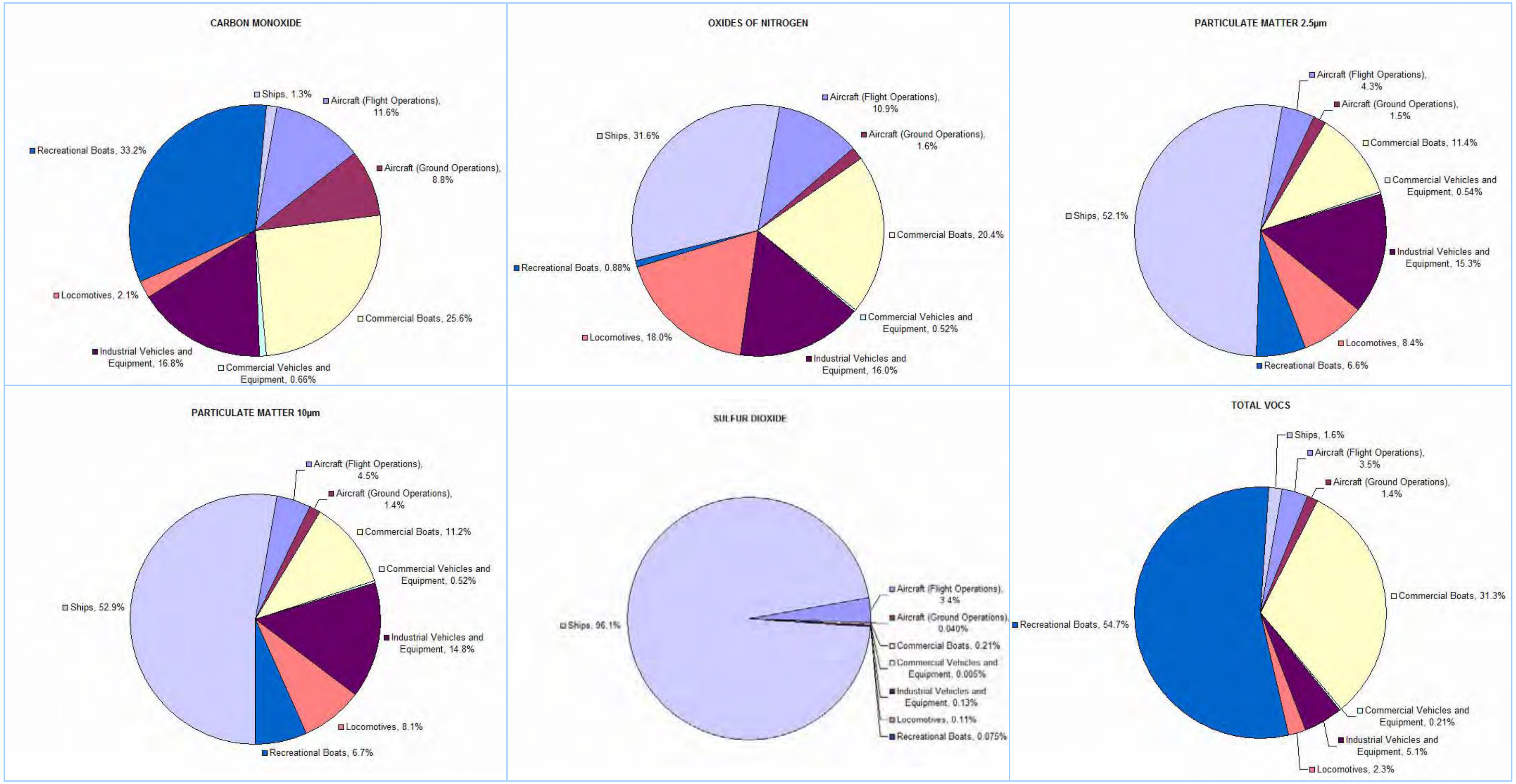

Figure 4-3: Proportions of total estimated annual emissions by off-road mobile source type in the Sydney region

Table 4-4: Total estimated annual emissions by off-road mobile source type in the Newcastle region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	6.34×10^{-2}	4.10×10^{-3}	1.59	2.60×10^{-3}	0.27	4.77×10^{-2}	0.79	8.04×10^{-3}	2.78
ACETALDEHYDE	0.16	0.12	1.56	7.38×10^{-2}	6.79	0.35	0.61	0.31	9.97
BENZENE	6.37×10^{-2}	4.74×10^{-2}	18	2.42×10^{-2}	2.77	4.01×10^{-2}	9.49	0.79	31
CARBON MONOXIDE	41	60	1,566	18	816	46	717	79	3,343
FORMALDEHYDE	0.47	0.26	2.84	0.22	15	0.73	0.99	0.66	22
ISOMERS OF XYLENE	1.69×10^{-2}	2.37×10^{-2}	72	1.28×10^{-2}	1.59	8.63×10^{-2}	38	0.40	112
LEAD & COMPOUNDS	1.70×10^{-2}	1.45×10^{-5}	2.19×10^{-2}	2.45×10^{-5}	3.09×10^{-3}	1.01×10^{-3}	1.14×10^{-2}	4.09×10^{-3}	5.85×10^{-2}
OXIDES OF NITROGEN	32	8.42	227	12	1,305	306	15	1,643	3,548
PARTICULATE MATTER ≤ 10 µm	0.80	0.47	18	0.79	90	8.59	7.04	159	284
PARTICULATE MATTER ≤ 2.5 µm	0.71	0.46	17	0.77	87	8.33	6.48	146	266
PERCHLOROETHYLENE	-	-	-	3.88×10^{-6}	1.38×10^{-5}	-	-	-	1.77×10^{-5}
POLYCYCLIC AROMATIC HYDROCARBONS	4.36×10^{-2}	4.82×10^{-4}	4.17×10^{-2}	1.21×10^{-3}	9.60×10^{-2}	2.28×10^{-2}	1.68×10^{-2}	0.51	0.73
SULFUR DIOXIDE	2.88	6.25×10^{-2}	1.16	2.99×10^{-2}	2.68	0.53	0.37	1,292	1,300
TOLUENE	2.38×10^{-2}	3.52×10^{-2}	66	1.82×10^{-2}	2.16	5.75×10^{-2}	35	0.77	105
TOTAL SUSPENDED PARTICULATE	0.82	0.48	18	0.82	94	9.21	7.26	164	294
TOTAL VOLATILE ORGANIC COMPOUNDS	4.55	3.05	690	1.97	133	18	417	35	1,303

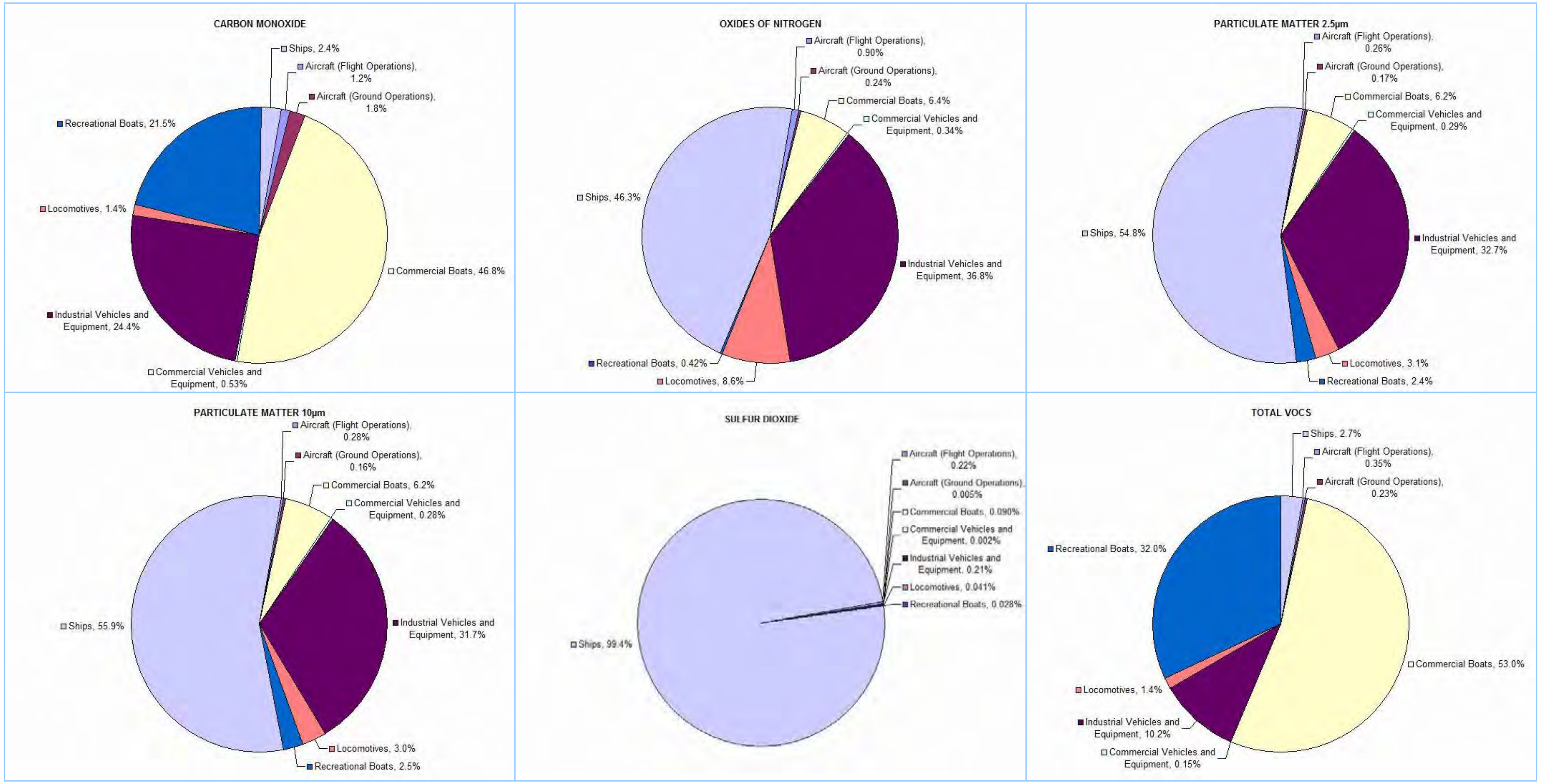

Figure 4-4: Proportions of total estimated annual emissions by off-road mobile source type in the Newcastle region

Table 4-5: Total estimated annual emissions by off-road mobile source type in the Wollongong region

Substance	Emissions (tonne/year)							
	Aircraft (flight operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	4.53×10^{-3}	7.77×10^{-2}	4.33×10^{-4}	0.19	3.92×10^{-2}	0.84	3.77×10^{-3}	1.16
ACETALDEHYDE	1.22×10^{-2}	8.64×10^{-2}	1.23×10^{-2}	3.07	0.29	0.64	0.15	4.26
BENZENE	5.02×10^{-3}	0.87	4.65×10^{-3}	1.50	3.30×10^{-2}	10	0.35	13
CARBON MONOXIDE	13	77	1.38	770	37	762	37	1,698
FORMALDEHYDE	3.90×10^{-2}	0.16	2.83×10^{-2}	8.62	0.60	1.05	0.31	11
ISOMERS OF XYLENE	1.25×10^{-3}	3.53	2.43×10^{-3}	1.15	7.10×10^{-2}	40	0.18	45
LEAD & COMPOUNDS	1.22×10^{-2}	1.07×10^{-3}	4.84×10^{-6}	2.05×10^{-3}	8.30×10^{-4}	1.21×10^{-2}	1.75×10^{-3}	3.0×10^{-2}
OXIDES OF NITROGEN	0.57	16	1.85	607	252	16	706	1,598
PARTICULATE MATTER ≤ 10 µm	0.22	0.98	0.15	35	7.06	7.48	68	119
PARTICULATE MATTER ≤ 2.5 µm	0.15	0.91	0.15	34	6.85	6.89	62	112
PERCHLOROETHYLENE	-	-	6.91×10^{-8}	1.24×10^{-4}	-	-	-	1.24×10^{-4}
POLYCYCLIC AROMATIC HYDROCARBONS	5.43×10^{-3}	2.15×10^{-3}	1.67×10^{-4}	5.33×10^{-2}	1.87×10^{-2}	1.79×10^{-2}	0.22	0.31
SULFUR DIOXIDE	6.15×10^{-2}	6.87×10^{-2}	3.99×10^{-3}	1.41	0.44	0.39	551	553
TOLUENE	1.48×10^{-3}	3.23	3.43×10^{-3}	1.41	4.73×10^{-2}	38	0.34	43
TOTAL SUSPENDED PARTICULATE	0.22	1.01	0.16	37	7.58	7.72	70	123
TOTAL VOLATILE ORGANIC COMPOUNDS	0.26	34	0.24	83	15	443	16	591

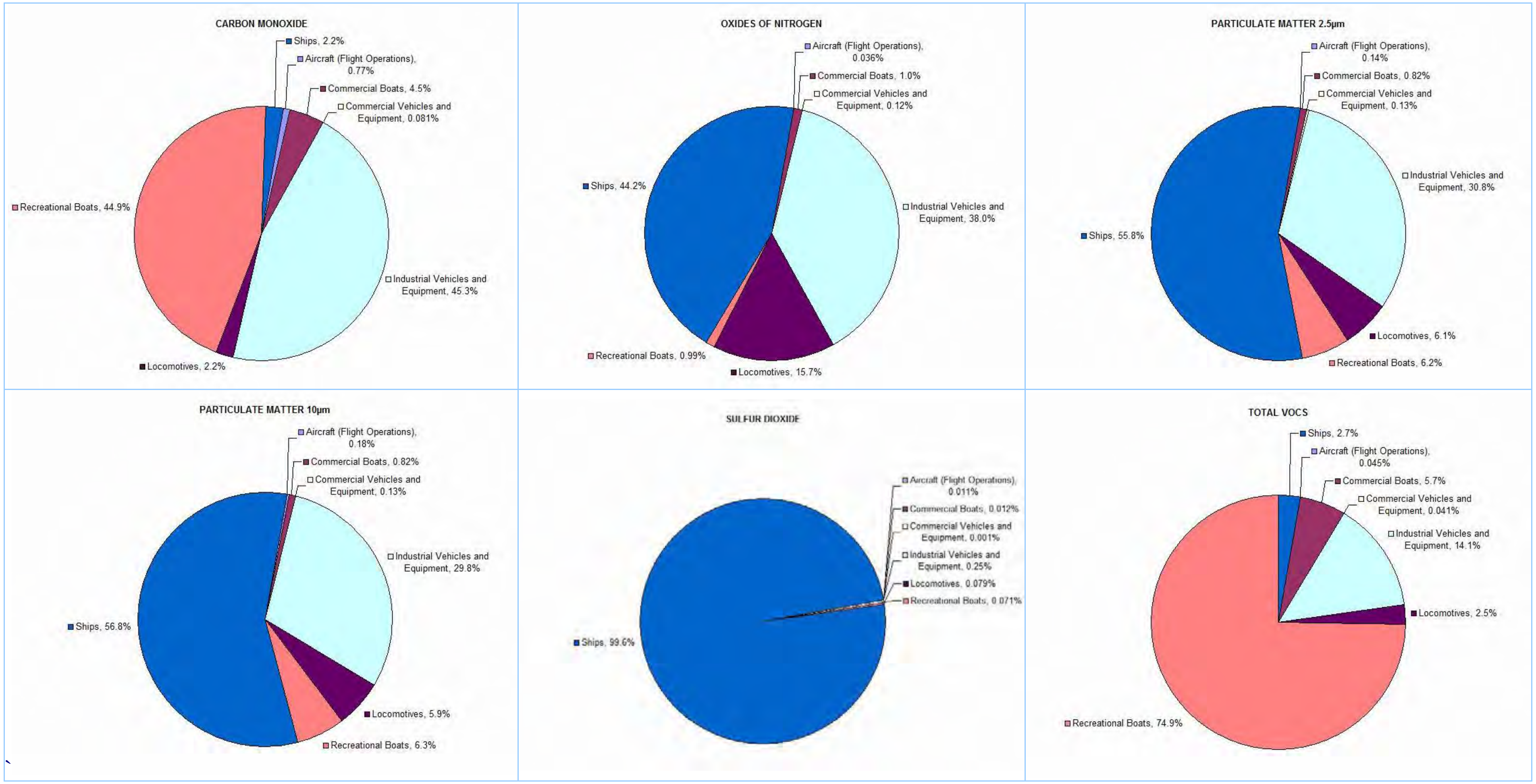

Figure 4-5: Proportions of total estimated annual emissions by off-road mobile source type in the Wollongong region

Table 4-6: Total estimated annual emissions by off-road mobile source type in the Non Urban region

Substance	Emissions (tonne/year)								
	Aircraft (flight operations)	Aircraft (ground operations)	Commercial boats	Commercial off-road vehicles and equipment	Industrial off-road vehicles and equipment	Locomotives	Recreational boats	Ships	Off-Road Mobile Total
1,3-BUTADIENE	0.26	7.79×10^{-4}	5.24	6.19×10^{-2}	5.06	0.41	6.84	7.05×10^{-3}	18
ACETALDEHYDE	0.69	2.22×10^{-2}	5.35	0.41	137	2.96	5.23	0.27	151
BENZENE	0.28	8.32×10^{-2}	58	0.40	54	0.34	82	0.82	196
CARBON MONOXIDE	667	11	5,178	100	15,361	387	6,194	76	27,975
FORMALDEHYDE	2.18	4.94×10^{-2}	9.79	1.18	305	6.24	8.52	0.58	333
ISOMERS OF XYLENE	7.09×10^{-2}	1.48×10^{-2}	239	0.41	29	0.73	327	0.42	596
LEAD & COMPOUNDS	0.61	2.76×10^{-6}	7.24×10^{-2}	3.66×10^{-4}	5.78×10^{-2}	8.58×10^{-3}	9.80×10^{-2}	3.67×10^{-3}	0.85
OXIDES OF NITROGEN	46	1.60	843	64	26,204	2,602	128	1,938	31,826
PARTICULATE MATTER ≤ 10 μm	11	8.84×10^{-2}	61	4.42	1,818	73	61	157	2,185
PARTICULATE MATTER ≤ 2.5 μm	7.87	8.68×10^{-2}	57	4.29	1,764	71	56	145	2,104
PERCHLOROETHYLENE	-	-	-	1.56×10^{-5}	5.23×10^{-5}	-	-	-	6.80×10^{-5}
POLYCYCLIC AROMATIC HYDROCARBONS	0.29	9.15×10^{-5}	0.14	7.19×10^{-3}	1.90	0.19	0.15	0.50	3.18
SULFUR DIOXIDE	4.62	1.19×10^{-2}	4.07	0.16	53	4.54	3.17	1,176	1,246
TOLUENE	8.61×10^{-2}	7.05×10^{-2}	218	0.46	41	0.49	306	0.79	566
TOTAL SUSPENDED PARTICULATE	11	9.21×10^{-2}	63	4.60	1,894	78	63	162	2,276
TOTAL VOLATILE ORGANIC COMPOUNDS	16	11	2,279	15	2,607	153	3,599	36	8,715

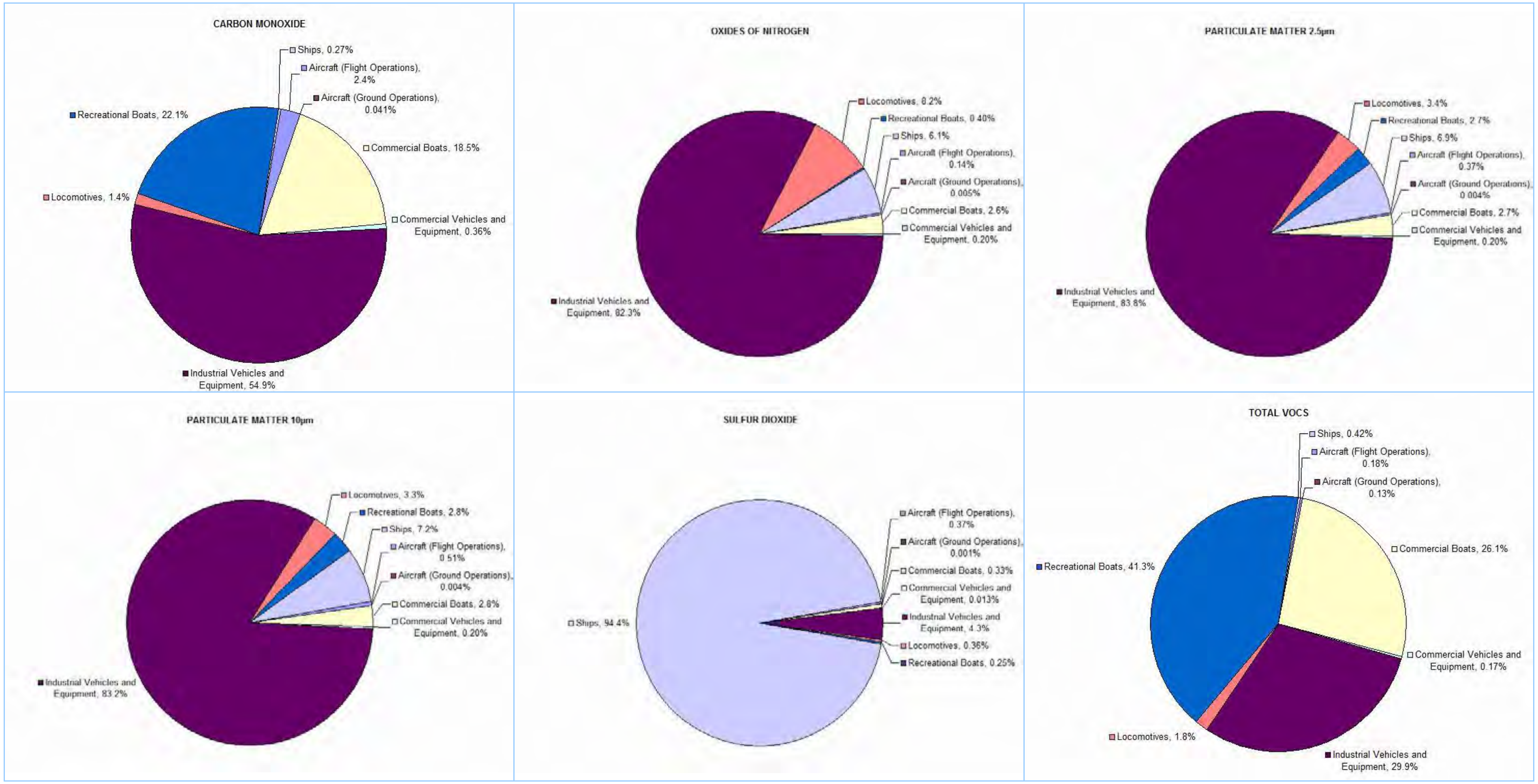

Figure 4-6: Proportions of total estimated annual emissions by off-road mobile source type in the Non Urban region

Table 4-7 presents total estimated fuel consumption from all off-road mobile sources in the GMR by volume and energy content.

Table 4-7: Total estimated annual fuel consumption from off-road mobile sources by volume and energy content in the GMR

Fuel	Annual fuel consumption	
	Volume (kL/year)	Energy content (TJ/year)
2-Stroke petrol	63,776	2,181
4-Stroke petrol	17,090	584
Avgas	2,009	66
Avtur	178,129	6,555
Diesel	1,014,171	39,147
LPG	21,780	555
Marine diesel oil	18,589	706
Marine gas oil	3,053	111
Residual oil	145,424	5,748
Grand Total	1,464,021	55,655

Figure 4-7 and Figure 4-8 show total estimated fuel consumption from all off-road mobile sources in the GMR by volume and energy content, respectively.

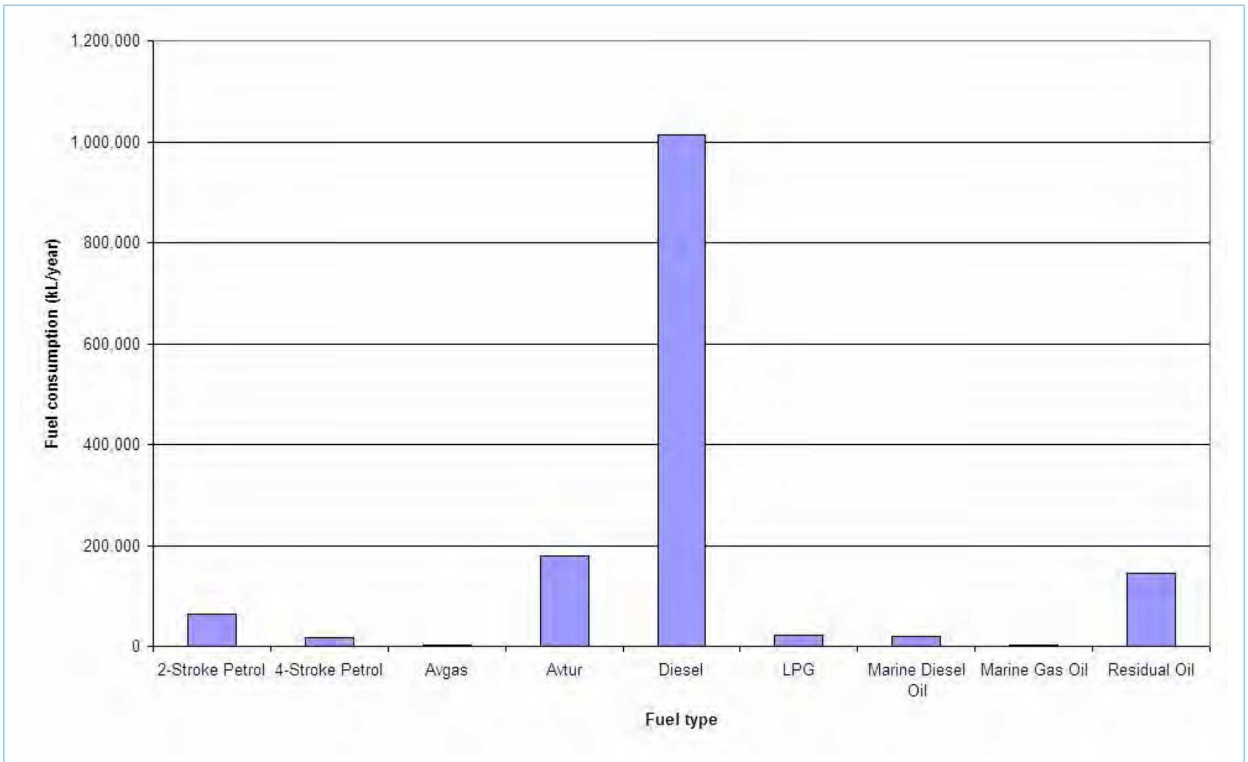

Figure 4-7: Total estimated annual fuel consumption from off-road mobile sources by volume in the GMR

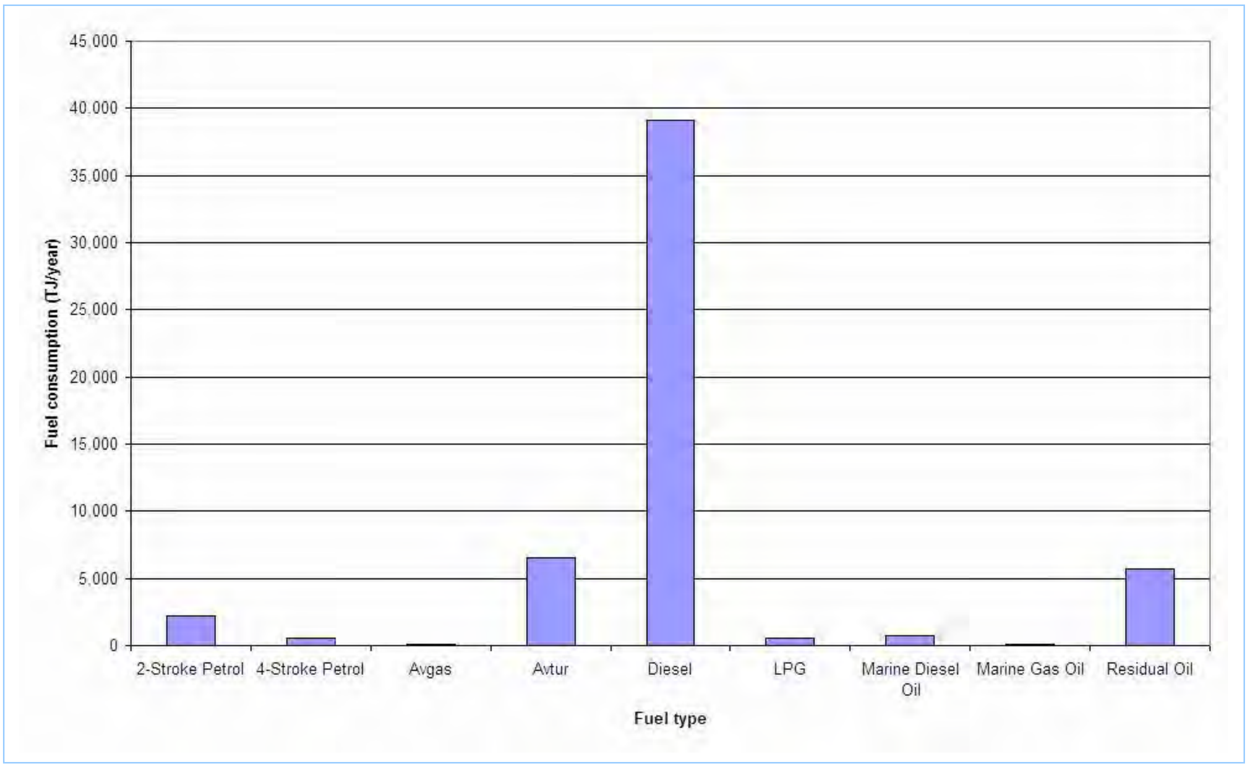

Figure 4-8: Total estimated annual fuel consumption from off-road mobile sources by energy content in the GMR

Table 4-8 and Table 4-9 present estimated fuel consumption by off-road mobile source type in the GMR by volume and energy content, respectively.

Figure 4-9 and Figure 4-10 show total estimated fuel consumption by off-road mobile source type in the GMR by volume and energy content, respectively.

Table 4-8: Total estimated annual fuel consumption by off-road mobile source type and volume in the GMR

Source type	Volume (kL/year)									
	2-Stroke petrol	4-Stroke petrol	Avgas	Avtur	Diesel	LPG	Marine diesel oil	Marine gas oil	Residual oil	Grand Total
Aircraft ground operations – diesel	-	-	-	-	23,858	-	-	-	-	23,858
Aircraft flight operations – avgas	-	-	2,009	-	-	-	-	-	-	2,009
Aircraft flight operations – avtur	-	-	-	178,129	-	-	-	-	-	178,129
Commercial boats – diesel	-	-	-	-	120,180	-	-	-	-	120,180
Commercial boats - petrol 2 stroke	25,501	-	-	-	-	-	-	-	-	25,501
Commercial boats - petrol 4 stroke	-	7,070	-	-	-	-	-	-	-	7,070
Commercial vehicles and equipment – diesel	-	-	-	-	3,128	-	-	-	-	3,128
Commercial vehicles and equipment – gas	-	-	-	-	-	1,332	-	-	-	1,332
Commercial vehicles and equipment – petrol	-	57	-	-	-	-	-	-	-	57
Industrial vehicles and equipment – diesel	-	-	-	-	737,337	-	-	-	-	737,337
Industrial vehicles and equipment – gas	-	-	-	-	-	20,448	-	-	-	20,448
Industrial vehicles and equipment – petrol	-	2,092	-	-	-	-	-	-	-	2,092
Locomotives – line haul	-	-	-	-	114,170	-	-	-	-	114,170
Locomotives – passenger	-	-	-	-	14,666	-	-	-	-	14,666
Recreational boats – diesel	-	-	-	-	831	-	-	-	-	831
Recreational boats – petrol 2 stroke	38,275	-	-	-	-	-	-	-	-	38,275
Recreational boats – petrol 4 stroke	-	7,871	-	-	-	-	-	-	-	7,871
Ships auxiliary boiler – diesel oil	-	-	-	-	-	-	5,881	-	-	5,881
Ships auxiliary boiler – gas oil	-	-	-	-	-	-	-	843	-	843
Ships auxiliary boiler – residual oil	-	-	-	-	-	-	-	-	37,264	37,264
Ships auxiliary engine – diesel oil	-	-	-	-	-	-	6,396	-	-	6,396
Ships auxiliary engine – gas oil	-	-	-	-	-	-	-	845	-	845
Ships auxiliary engine – residual oil	-	-	-	-	-	-	-	-	37,921	37,921
Ships main engine – diesel oil	-	-	-	-	-	-	6,313	-	-	6,313
Ships main engine – gas oil	-	-	-	-	-	-	-	1,365	-	1,365
Ships main engine – residual oil	-	-	-	-	-	-	-	-	70,239	70,239
Grand Total	63,776	17,090	2,009	178,129	1,014,171	21,780	18,589	3,053	145,424	1,464,021

Table 4-9: Total estimated annual fuel consumption by off-road mobile source type and energy content in the GMR

Source type	Energy content (TJ/year)									
	2-Stroke petrol	4-Stroke petrol	Avgas	Avtur	Diesel	LPG	Marine diesel oil	Marine gas oil	Residual oil	Grand Total
Aircraft ground operations – diesel	-	-	-	-	921	-	-	-	-	921
Aircraft flight operations – avgas	-	-	66	-	-	-	-	-	-	66
Aircraft flight operations – avtur	-	-	-	6,555	-	-	-	-	-	6,555
Commercial boats – diesel	-	-	-	-	4,639	-	-	-	-	4,639
Commercial boats – petrol 2 stroke	872	-	-	-	-	-	-	-	-	872
Commercial boats – petrol 4 stroke	-	242	-	-	-	-	-	-	-	242
Commercial vehicles and equipment – diesel	-	-	-	-	121	-	-	-	-	121
Commercial vehicles and equipment – gas	-	-	-	-	-	34	-	-	-	34
Commercial vehicles and equipment – petrol	-	2	-	-	-	-	-	-	-	2
Industrial vehicles and equipment – diesel	-	-	-	-	28,461	-	-	-	-	28,461
Industrial vehicles and equipment – gas	-	-	-	-	-	521	-	-	-	521
Industrial vehicles and equipment – petrol	-	72	-	-	-	-	-	-	-	72
Locomotives – line haul	-	-	-	-	4,407	-	-	-	-	4,407
Locomotives – passenger	-	-	-	-	566	-	-	-	-	566
Recreational boats – diesel	-	-	-	-	32	-	-	-	-	32
Recreational boats – petrol 2 stroke	1,309	-	-	-	-	-	-	-	-	1,309
Recreational boats – petrol 4 stroke	-	269	-	-	-	-	-	-	-	269
Ships auxiliary boiler – diesel oil	-	-	-	-	-	-	223	-	-	223
Ships auxiliary boiler – gas oil	-	-	-	-	-	-	-	31	-	31
Ships auxiliary boiler – residual oil	-	-	-	-	-	-	-	-	1,473	1,473
Ships auxiliary engine – diesel oil	-	-	-	-	-	-	243	-	-	243
Ships auxiliary engine – gas oil	-	-	-	-	-	-	-	31	-	31
Ships auxiliary engine – residual oil	-	-	-	-	-	-	-	-	1,499	1,499
Ships main engine – diesel oil	-	-	-	-	-	-	240	-	-	240
Ships main engine – gas oil	-	-	-	-	-	-	-	50	-	50
Ships main engine – residual oil	-	-	-	-	-	-	-	-	2,776	2,776
Grand Total	2,181	584	66	6,555	39,147	555	706	111	5,748	55,655

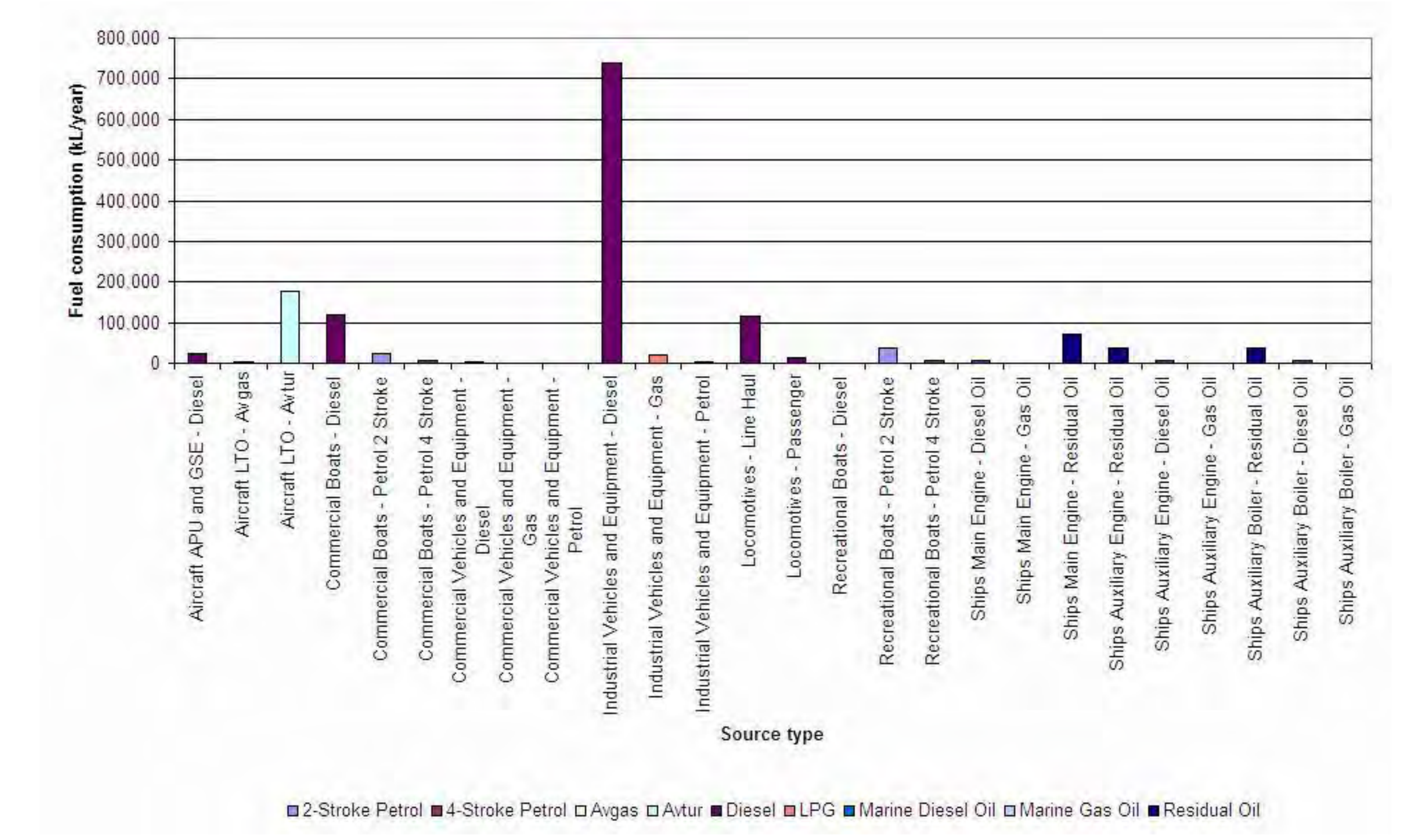

Figure 4-9: Total estimated annual fuel consumption by off-road mobile source type and volume in the GMR

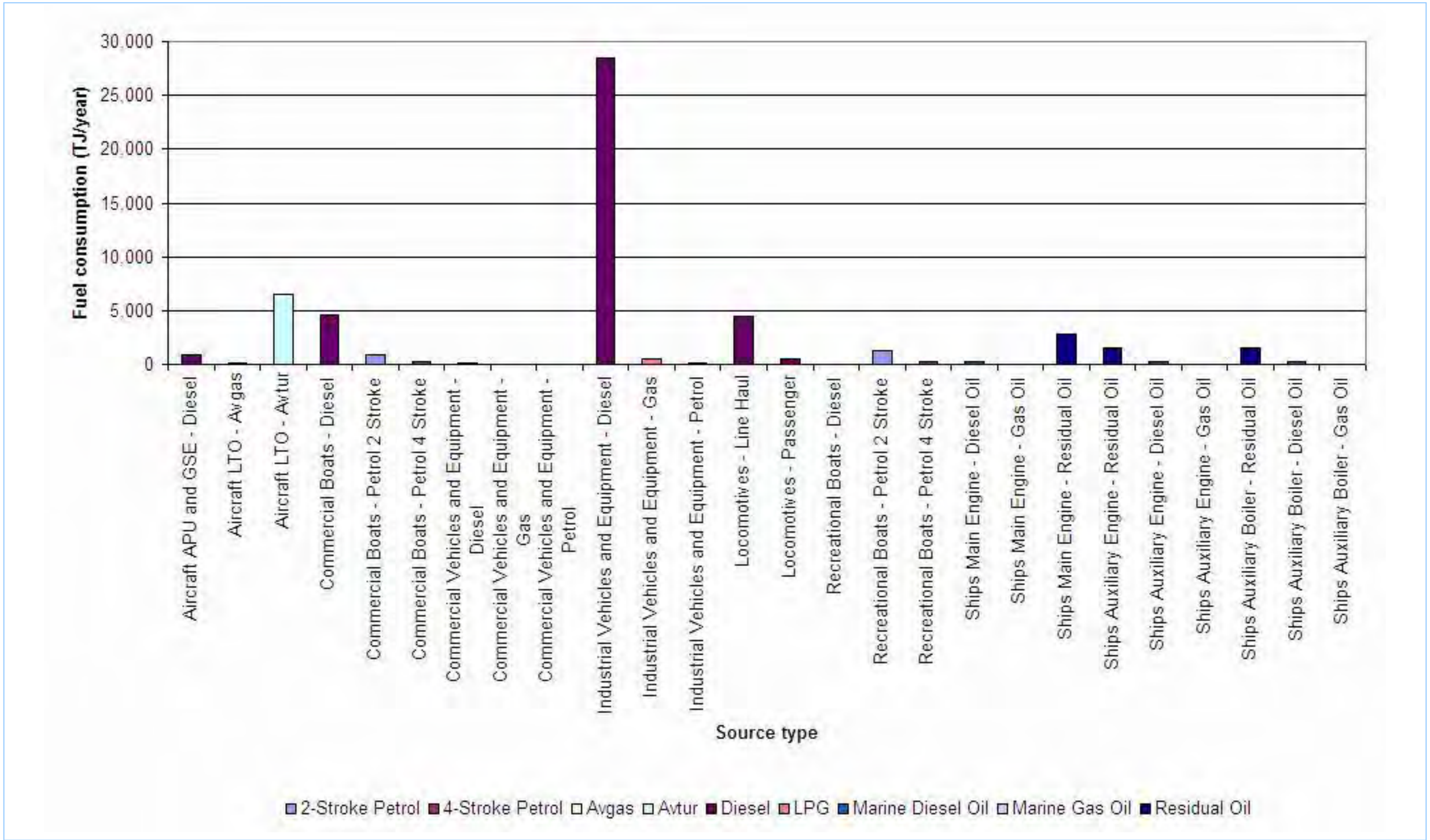

Figure 4-10: Total estimated annual fuel consumption by off-road mobile source type and energy content in the GMR

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