

APPENDIX C

INVENTORY AND EMISSIONS MODELING

I. Methodology

The emissions inventory model EMFAC2002, which is used by the Air Resource Board (ARB) to estimate on-road motor vehicle emissions inventories, also calculates an inventory for urban buses. However, for a number of reasons staff believes that, without modification, the EMFAC model may not be suitable for developing regulations that address only urban transit buses. First, the population of the urban bus vehicle class in EMFAC is derived from the Department of Motor Vehicles (DMV) registration database and contains urban buses as well as other categories of buses (examples are Greyhound and tour buses). The urban bus population reported by transit agencies is much smaller than the urban bus population in EMFAC. Second, the urban bus fleet in EMFAC contains 45 model years of vehicles and buses of all ages are assumed to accrue 37,700 miles per year on average. Data reported for the years 2000-2002 by transit agency show that the transit bus fleet consists of only 23 model years and that mileage accrual rate is a function of vehicle age. Finally, the EMFAC model does not include alternative-fueled vehicles, but alternative-fueled buses have increasingly become an important part of every transit fleet.

In support of the ARB's amendments to the Fleet Rule for Transit Agencies, staff has constructed an inventory model specifically for diesel and alternative-fueled urban buses. The model uses the population and activity data reported by transit agencies, diesel bus emission rates from the EMFAC model, and alternative-fueled bus emission rates estimated from recent test data. The following sections discuss the urban bus activity and emission rate estimates and present an urban bus specific inventory.

II. Urban Bus Activity Data

The Fleet Rule for Transit Agencies, adopted in 2000, has required that transit agencies provide an annual report of their urban buses since 2001. The population data were, therefore, based on reported data.

The following urban transit bus activity data were obtained and analyzed:

- Annual mileage accrual rate;
- Population (POP) and age distribution;
- Total vehicle miles traveled (VMT).

The annual mileage accrual rate for urban buses was estimated from the annual mileage data provided by transit agencies. The average annual mileage data by model year was statistically fit to obtain a relationship between annual mileage accrual rate and vehicle age. Alternative-fueled urban buses were assumed to accrue the same annual miles as diesel urban buses at the same age.

A. Statewide

The statewide population of urban buses, based on the 2002 reports from transit agencies, was 10,142, or 6,476 diesel buses and 3,666 alternative-fuel buses. Staff calculated the age distributions (number of vehicles by age) for diesel and alternative-fueled urban buses using these data. For the statewide alignment analysis, only the diesel population was analyzed. Alternative fuel urban buses are assumed not to be affected by engine availability as described below.

Staff projected the population for future years for the statewide baseline emissions, alignment scenario emissions, and statewide alternative fuel scenario based on the following assumptions:

- For the baseline scenario, no growth between 2004 and 2009 and growth resuming starting 2010 at a 1.6 percent growth rate. As stated, in the Staff Report, no engine manufacturer plans to certify a diesel engine for urban buses during this time frame. Therefore, staff assumes that transit agencies on the diesel path will maintain their current fleets through repowering until 2010 when diesel engines become available. The slow down in turnover is reflected in the reported data.
- For the alignment scenario, no growth between 2004 and 2006 and growth resuming starting in 2007 at a 1.6 percent growth rate. Diesel engines will be available at 1.2 g/bhp-hr NO_x for 2007 through 2009. Fleets will start buying diesel buses again at their usual rate in 2007, however, once the 2010 diesel buses are available at 0.2 g/bhp-hr NO_x, it is expected there will be larger purchases made in 2010 and 2011 to catch up to their needed fleet sizes.
- For the statewide alternative fuel mandate, staff assumed the emissions would follow the same declining rate as was projected in the original rule since it followed the same engine standards path, i.e., 0.2 g/bhp-hr engines starting in 2007. However, the emissions starting points were adjusted to the 2006 emission values of 10.6 tons per day NO_x and 420 pounds per day PM consistent with the baseline values. All purchases will be alternative fuel buses beginning in 2007 and continuing through 2015 when the alternative fuel path mandate expires, but all engines whether diesel or alternative fuel will meet the 0.2 g/bhp-hr NO_x standard from 2010 on.

Staff estimated the populations of diesel urban buses for 2003 and later model years using reported 2002 populations as the base year. The projected populations for future years were adjusted using the survival rates (the fraction of the new vehicles that remains in the fleet after certain years) for urban diesel buses in EMFAC2002 and modified to reflect the reported urban bus population survival rate.

The urban bus daily vehicle miles traveled (VMT) for any given year was estimated from the population (POP) and accrual rate using the following equation:

$$\text{VMT} = \sum (\text{POP}_{\text{age}} \times \text{Accrual Rate}_i), \text{ where } \text{age} = 0 \text{ to } 22. \quad (1)$$

The urban bus mileage accrual rate, survival rate, and population distribution for years 2002 and 2020 are found in Table 1.

Table 1. Statewide Urban Bus Accrual Rate, Survival Rate and Population Distribution

Age	Accrual Rate (mi/year)	Survival Rate	2002 Diesel Population ¹	2020 Diesel Population ²
0	30,868	1.00000	501	647
1	31,679	1.00000	675	658
2	32,332	1.00000	796	670
3	32,824	0.99301	364	657
4	33,158	0.99301	438	637
5	33,332	0.99301	558	615
6	33,346	0.98943	237	588
7	33,201	0.98774	215	556
8	32,897	0.98399	154	496
9	32,434	0.97909	165	466
10	31,811	0.93291	610	461
11	31,028	0.93291	360	444
12	30,087	0.84530	355	392
13	28,986	0.71960	398	344
14	27,725	0.60220	336	287
15	26,305	0.49520	7	250
16	24,726	0.37055	59	182
17	22,987	0.24590	41	120
18	21,089	0.13950	161	70
19	19,032	0.07180	20	48
20	16,815	0.02960	25	24
21	14,439	0.00070	0	0
22	11,904	0.00070	1	0

1 Reported by transit agencies.

2 Projected from year 2002 original rule population.

B. South Coast Air Quality Management District (SCAQMD)

The SCAQMD urban bus population of 4,632 urban buses is based on data reported for 2004 by the 17 transit agencies located within the jurisdiction of SCAQMD, which reported populations of 1,865 diesel fuel and 2,767 alternative-fuel buses. Staff calculated the age distributions (number of vehicles by age) for diesel and alternative-fueled urban buses using the survival rates (the fraction of the new vehicles that remains in the fleet after certain years) based urban diesel buses in EMFAC2002. A 95

percent fleet turnover rate of the oldest diesel buses to be replaced with alternative-fuel buses was used, except for years 2005 to 2009.

For model years 2005 to 2009, staff conducted a telephone survey of the six diesel path transit agencies to obtain specific plans for purchasing, including replacement and growth vehicles (Table 2). All other assumptions regarding growth rate and VMT remain the same as in the statewide model. The population distribution for years 2005 and 2020 are given in Table 3.

Table 2. Reported Plans for Bus Purchases, SCAQMD Diesel Path Agencies

Year	GHEB ¹	CNG Bus ²
2005	71	14
2006	23	
2007	55	9
2008	64	
2009	51	

¹Gasoline Hybrid Electric Bus

²Compressed Natural Gas Bus

Table 3. SCAQMD Transit Bus Population Distribution

Age	2005 Diesel Population ¹	2020 Diesel Population ²	2005 Alt Fuel Population ¹	2020 Alt Fuel Population ²
0	2	394	63	402
1	90	63	122	72
2	135	103	210	87
3	112	105	1054	134
4	233	138	322	75
5	24	42	321	68
6	42	78	266	70
7	255	92	359	70
8	99	106	1	72
9	127	75	17	52
10	48	76	32	247
11	25	2		6
12	387	88		6
13	19	131		7
14	59	110		7
15	68	228		7
16	101	22		59
17	0	39		114
18	9	238		197
19	0	92		982
20	0	116		296
21	0	44		294
22	30	22		242

1 Reported by transit bus agencies.

2 Projected from year 2005 population.

III. Emission Rates of Diesel and Alternative-Fueled Urban Buses

The diesel urban bus emission rates used for this analysis are the same as those used in EMFAC2002 version 2.2 (Table 4). The emission rates are based on the currently adopted exhaust emission standards for urban bus engines and were adjusted for the modeled scenarios. Changes to the emission factors for the scenarios were calculated using a ratio between the adopted emission standard and the "projected" emission standard to determine the emission rate for that year.

Table 4. EMFAC2002 Diesel Urban Bus Emission Rates (g/mi)¹

Model Year Group	HC	NOx	PM
Pre 1987	2.06	46.18	1.29
1987-1990	2.05	40.20	1.22
1991-93	2.02	25.49	1.16
1994-95	1.99	29.84	1.41
1996-98	1.98	39.17	1.69
1999-02	1.98	20.39	0.58
2003	0.84	10.20	0.12
2004-06	0.84	2.55	0.12
2007	0.84	1.02 ^{2,3}	0.12
2008+	0.75	0.90 ^{2,3}	0.10

¹ Values assumed for baseline, if all engines were available.

² The difference in the emission factors for 2007 and 2008+ is based on the implementation Zero Emission Bus purchasing requirements.

³ To model the alignment scenario, staff used emission factors of 6.14 for 2007 and 0.90 for 2010, to reflect certification values of 1.2 g/bhp-hr in 2007 and 0.2 g/bhp-hr (+ZEB) in 2010.

Emission rates for alternative-fueled transit buses were estimated from emission data collected by West Virginia University (WVU) (Table 5). The WVU data include emission data for 71 1991-1998 model year CNG-powered urban buses. The emission data were first divided into model year groups corresponding to the model year groups of diesel transit buses and the data in each group were then averaged. Emission rates for model years after 1998 were estimated using the ratio of the standards. As with the statewide analysis, changes to the emission factors for the scenarios were calculated using a ratio between the adopted emission standard and the "projected" emission standard to determine the emission rate for that year.

Table 5. Alternative-Fuel Urban Buses Emission Rates (g/mi)

Model Year Group	HC	NOx	PM
1991-93	14.6	25.4	0.02
1994-95	15.5	11.2	0.02
1996-98	20.7	20.0	0.02
1999-02	20.7	20.0	0.02
2003	7.96	10.0	0.004
2004-06	0.80	7.5 ¹	0.004
2007	0.80	1.0	0.004
2008+	0.80	1.0	0.004

¹The range of the certification values for alternative-fuel buses is 0.6 to 2.5 g NOx+NMHC/bhp-hr. For the Baseline calculation, staff used the average value of 1.5 g NOx/bhp-hr certification level to determine the emission factor of 7.5 g/mi. For the scenarios, staff used the emission factor of 2.5g/mi (0.5 g/bhp-hr) because the predominant urban bus purchased in these years is the gasoline hybrid certified at the 0.6 g NOx+NMHC level.

For comparison, Table 6 shows the currently adopted emission standards for urban buses.

Table 6. Urban Bus Standards (g/bhp-hr)

Model Year	HC	CO	NOX	PM	HC+NOx
1973-74	---	40.0	---	---	16.0
1975-76	---	30.0	---	---	10.0
1977-79	1.00	25.0	7.5	---	---
1980-83	1.00	25.0	---	---	6.0
1984-86	1.30	15.5	5.1	---	---
1987-90	1.30	15.5	6.0	0.60	---
1991-93	1.30	15.5	5.0	0.10	---
1994-95	1.30	15.5	5.0	0.07	---
1996-98	1.30	15.5	4.0	0.05	---
1999-02	1.30	15.5	4.0	0.05	---
10/2002-03	---	15.5	2.5 (NOx+NMHC)	0.01	---
2004-06		15.5	Diesel: 0.5 Alt Fuel:2.5 (NOx+NMHC)	0.01	---
2007		15.5	0.2	0.01	---
2008+			15% of new purchases are ZEBs for large fleets		

IV. Urban Bus Emission Inventory

Using the data presented above, staff calculated baseline inventories for the statewide and SCAQMD urban buses. Tables 7 and 8 show the diesel urban bus baseline inventories for selected calendar years for the statewide and SCAQMD inventories and Tables 9 presents the alternative-fueled urban buses for the SCAQMD inventories.

Table 7. Statewide Diesel Urban Bus Baseline Emissions (tons/day)

Pollutant	2000	2005	2010	2015	2020
HC	0.56	0.52	0.41	0.25	0.09
NOx	13.5	10.6	7.93	3.72	1.37
PM (lbs/day)	540	420	320	142	100

Table 8. Statewide Alignment Scenario Emissions (tons/day)

Pollutant	2000	2005	2010	2015	2020
HC	0.56	0.52	0.39	0.26	0.10
NOx	13.5	10.6	7.79	4.91	1.86
PM (lbs/day)	540	420	300	142	100

Table 9. Statewide Alternative Fuel Path Mandate Scenario Emissions (tons/day)

Pollutant	2000	2005	2010	2015	2020
HC	0.56	0.52	0.55	0.56	0.56
NOx	13.5	10.6	7.18	3.72	1.37
PM (lbs/day)	540	420	300	142	100

Table 10. SCAQMD Diesel Urban Bus Baseline Emissions (tons/day)

Pollutant	2000	2005	2010	2015	2020
HC	0.23	0.15	0.13	0.11	0.062
NOx	5.72	3.03	2.64	2.11	1.19
PM (lbs/day)	239	125	107	85.3	48.8

**Table 11. SCAQMD Alternative-Fuel Urban Bus Baseline Emissions
(tons/day)**

Pollutant	2000	2005	2010	2015	2020
HC	2.61	5.42	5.19	4.17	2.38
NOx	2.50	5.27	5.06	4.09	2.38
PM (lbs/day)	5.1	10.5	10.3	8.6	5.6