APPENDIX B

ETS Emissions Calculation Methodology

As Approved
by the Scientific Review Panel
on June 24, 2005

Overview

ETS is a complex mixture of compounds and it would be difficult and impractical to quantify emissions based on individual compounds. We are unaware of any studies that quantify ETS emissions based on the sum of all individual compounds. Adequate analytical methods do not exist for some suspected compounds in ETS, and the cost of sampling and analysis would be high. Therefore, staff selected three compounds to characterize ETS emissions: nicotine, respirable suspended particulate (RSP), and carbon monoxide (CO). These compounds all have specific health effects associated with their exposures and have been used as markers for ETS exposure.

Nicotine emissions are unique to tobacco products and have been linked to health effects (Benowitz, 2002). Particulate matter emissions from tobacco products have been linked to respiratory problems, such as asthma, and the development or exacerbation of cardiovascular disease (Smith and Fischer, 2001). Likewise, CO has also been linked to cardiovascular and birth weight effects (Horner, 2000).

Methodology

In general, our estimate of ETS emissions is based on data from emission rate studies and tobacco product sales tax data compiled by the California State Board of Equalization (CBOE). For purposes of this estimate, we assumed that cigarette consumption among the smoking population was uniform.

Limited data exists on pipe tobacco emissions and consumption information indicates that pipe tobacco consumption is far less than for cigarettes and cigars (USDA, 2003a). Therefore, staff based the ETS emission estimate predominantly on cigarette and cigar consumption. The estimate of ETS emissions is based on the following equation:

$$\text{Emissions (tons/yr)} = [EF \times N \times CF \times 90\%] \qquad \text{(Equation 1)}$$

Where: EF = Average cigarette or cigar emission factor (mg/cig)
N = Number of cigarettes or cigars per year (cig/yr)
CF = Unit conversion factor (tons/mg)

We adjusted the number of cigarettes and cigars by 90% to account for the finding that smokers do not typically consume one hundred percent of a cigarette. In a study measuring mass emission rates from cigarettes, Hildemann, *et al.,* 1991, found that smokers consumed approximately 90% of cigarettes and cigars.

Assumptions Used to Estimate Outdoor ETS Emissions

As previously mentioned in Chapter IV, there is limited information pertaining to direct measurements of indoor vs. outdoor cigarette consumption in California -- making it difficult to accurately determine. However, other germane information can assist staff in estimating outdoor ETS emissions. Outdoor ETS emissions include direct emissions from outdoor smoking, plus ETS emissions generated indoors, which eventually ventilate outside. Since 1998, under Assembly Bill 13, all workplaces (including bars and restaurants) are smoke-free in California. In addition, smoking behavior has changed as well. Based on the 2002 California Adult Tobacco Survey (CATS), over 80% of all California homes with children are smoke-free. For California smokers, 50% have reported smoking bans in their homes. Therefore, with no indoor smoking in workplaces and other public venues, and indoor smoking bans in half of all California residences with a smoker, we assume that most physical smoking occurs outdoors. Furthermore, for ETS generated indoors, building ventilation studies show that 50 - 80% of indoor air gets exchanged with outdoor air (Rogge *et al.*, 1994).

Next, we made assumptions as to what a typical smoking adult lifestyle entails. For instance, an adult might work 60% of the day and spend 40% of the day at home (not including sleeping hours). According to the 2002 CATS, the average smoker in California consumes 15-cigarettes per day and either has a home smoking ban or no home smoking ban (50% of California smokers have reported a home smoking ban). From this information, we developed two smoking adult lifestyle scenarios to provide insight on the relative amounts of indoor vs. outdoor ETS emissions (Table B-1).

Table B-1

Cigarette Consumption Based on Adult Lifestyles
(15 cigarettes per day)

Adult Lifestyle 1 (Home Smoking Ban)				Adult Lifestyle 2 (No Home Smoking Ban)			
* % of Time at Work	Cigarettes Consumed at Work	* % of Time at Home	Cigarettes Consumed at Home (Outside/Inside)	* % of Time at Work	Cigarettes Consumed at Work	* % of Time at Home	Cigarettes Consumed at Home (Outside/Inside)
60	9	40	6 / 0	60	9	40	** 3 / 3

* Percent of non-sleeping hours.
** Based on 50% ventilation.

For Adult Lifestyle 1 (home smoking ban), all 15-cigarettes are smoked outdoors, since no smoking is allowed in the workplace or in the home. This amounts to 100% outdoor ETS emissions. However, for Adult Lifestyle 2 (no home smoking ban), emissions from 12 of 15 cigarettes (80%) consumed are estimated outdoor ETS emissions. This assumes a 50% ventilation rate from indoors to outdoors. In the time spent at home, we assume six cigarettes per day are smoked indoors (15 cigarettes x 0.4 = 6), although, smoking rates may vary throughout the day. All six cigarettes are assumed to be

smoked inside the home, however, 50% of the emissions, or essentially the emissions from three cigarettes, are assumed to ventilate outdoors. Therefore, staff estimates at least 80 - 90% of cigarette emissions are outdoor emissions.

Cigarette Emission Factors

Staff conducted a literature search to review the research on cigarette emission factors for nicotine, RSP, and CO. The search found five-studies on nicotine emission rates, six on RSP, and three on CO. The most pertinent studies are shown in the following tables. While the studies evaluated emissions from major national cigarette and cigar brands, the results are applicable to California since many of the same brands are also marketed in the state.

Table B-2 shows the results found for nicotine emission factors from three studies, where the average nicotine emission rate was 1.44 milligrams per cigarette (mg/cig). Martin *et al*. (1997) chose the top fifty U.S. market brand styles (determined by market share) and a national average cigarette (Kentucky Research-K1R4F). Nicotine emissions were reported in relation to the mainstream (MS) tar content of the cigarette. The fifty top selling cigarettes represented over 65% of the U.S. cigarette market and included full flavor (FF) ($\geq$ 13.5 mg/cig MS tar), full flavor low tar (FFLT) (7.5 - 13.4 mg/cig MS tar), and ultra low tar (ULT) ($\leq$ 7.4 mg/cig MS tar) cigarettes. Their results showed a 0.1 mg mean difference among all cigarette types.

Table B-2

Nicotine Emission Factor Studies

Study #	Authors	Emission Factor
1	Martin *et al*. (1997)	1.59 mg/cig
2	Daisey *et al*. (1998)	0.92 mg/cig
3	Nelson (1994)	1.8 mg/cig
Avg.		**1.44 mg/cig**

Daisey *et al*. (1998) determined the emission factors of six major cigarette brands smoked in California and a national average cigarette (Kentucky Research-K1R4F). The six major brands represented a market share of over 63% in 1990, and included five filtered and one unfiltered brand; two were mentholated and one brand was low tar. The nicotine emission factors for all six brands showed a coefficient of variability of over 26% (0.92 ± 0.24 mg/cig). In Nelson (1994), the top 50 brands of cigarettes were analyzed for emissions generated by a person in an unventilated room.

Table B-3 is a summary of the pertinent studies on RSP emissions. From five studies, the average RSP emission rate was 13.3 mg/cig. Repace (2001) based his RSP

emission factors (i.e., 14 and 10.9 mg/cig) on a habitual smoker model that utilizes different numbers of smokers per unit volume.

Table B-3

RSP Emission Factor Studies

Study #	Authors	Emission Factors
1	Repace (2001)	14 mg/cig
2	Nelson *et al.* (1997)	14 mg/cig
3	Martin *et al*. (1997)	13.7 mg/cig
4	Nelson (1994)	13.8 mg/cig
5	Repace (2001)	10.9 mg/cig
Avg.		**13.3 mg/cig**

Nelson *et al*. (1997) generated ETS in an environmental chamber in which five replicate runs were performed, while six smokers each smoked one popular "light" cigarette. RSP yields were determined using the method in Martin et al. (1997), which draws in air at 2 liters/min with a personal sampling pump through a 1.0-µm pore membrane filter.

Martin *et al*. (1997) found a range in RSP emission rate from 10.5 mg/cig for ULT to 14.9 mg/cig for FF, with an average of 13.7 mg/cig among the three MS tar cigarette categories. Nelson (1994) reported an average RSP emission factor of 13.8 mg/cig.

Table B-4 is a summary of the two studies on CO. Nelson *et al*. (1997) determined a CO emission factor of 61.9 mg/cig by non-dispersive infrared gas analysis (cf. Martin *et al*., 1997). Martin *et al*. (1997) reported CO emission rates of 47.8 mg/cig for ULT to 57.5 mg/cig for CO for FF, with an average of 55.1 mg/cig among the three MS tar categories. The average CO emission factor from the two studies is 58.5 mg/cig**.**

Table B-4

CO Emission Factor Studies

Study #	Authors	Emission Factors
1	Nelson *et al.* (1997)	61.9 mg/cig
2	Martin *et al.*, 1997	55.1 mg/cig
Avg.		**58.5 mg/cig**

Cigar Emission Factors

Staff conducted a literature search on cigar emission factor studies for nicotine, RSP, and CO. Three studies were found: one for nicotine, one for RSP, and two for CO.

For nicotine, premium (i.e., large) cigars were smoked under test conditions established by the International Committee for Cigar Smoke Study (ICCSS) (Hoffmann and Hoffmann, 1997). The ICCSS specifies that one 20-milliliter (mL) volume puff be taken within a 1.5-second interval every 40 seconds, using a standardized smoking machine. An average emission factor was determined after three runs. For small cigars, the cigarette-smoking parameters of the Federal Trade Commission were followed, in which one 35-mL puff is taken within a 2-second duration every minute, using a standardized smoking machine. The nicotine emission factors for small and large cigars are 3.8 and 13.3 mg/cigar, respectively.

For RSP, data from Repace *et al*. (1998) were evaluated in which three experiments were conducted. In the first experiment, one Santona cigar was smoked by a person in a 97 m^3 parlor for 1.3 hours. The number of air changes per hour (ach) was 2.5. For this cigar, the RSP emission factor was 78 mg/cigar. In the second experiment, a Paul Garmirian cigar was smoked by a person in a 97 m^3 parlor for 1.5 hours with an ach of 1.2. For this cigar, the RSP emission factor was 86 mg/cigar. In the third experiment, a Marsh Wheeling Stogie was smoked by a person in a 51 m^3 office for 20 minutes with an ach of 3.8. The emission factor for this cigar was 53 mg/cigar. The average RSP emission factor from these three experiments was 72 mg/cigar.

For CO, an emission factor was derived from two studies: Repace *et al*., (1998), and Klepeis *et al*., (1999). Over 13 different experiments were conducted in the two studies. A summary of the experimental parameters are in Table B-5. The overall average CO emission rate was 1,025 mg/cigar.

Table B-5

Experimental Parameters for Cigar CO Emission Factors
(Source: Repace *et al*. (1998) and Klepeis *et al.* (1999))

Cigar Brand	Machine or Person	Cigar Duration (min)	Air Exchange Per Hour	Volume of Testing Area (m^3)	Emission Factor (mg/cigar)
Santona	Person	76	2.5	97	1,100
Marsh Wheeling Stogie	Person	20	3.8	51	1,140
N/A	Machine	11	7.2	521	1,200
N/A	Machine	11	7.2	521	1,300
Sante Fe Fairmount	Machine	20	2.1	49.6	1,200
Imported Ashton	Machine	28	1.8	49.6	1,200
Swisher Sweets	Machine	42	0.96	49.6	980
Dutch Masters El Presidente	Machine	9	0.06	49.6	750
Antonio y Cleopatra Grenadiers	Machine	17	3.0	49.6	630
Sante Fe Fairmont	Machine	7.8	4.5	49.6	1,100
Sante Fe Fairmont	Machine	24	0.12	49.6	1,100
Antonio y Cleopatra Grenadiers	Machine	10	0.12	49.6	860
Antonio y Cleopatra Grenadiers	Machine	12	4.5	49.6	780

Number of Cigarettes and Cigars

To calculate the number of cigarettes smoked in California, data from CBOE, which maintains a statewide inventory of annual cigarette pack distributions, were used. The CBOE collects taxes at the point of distribution from certified vendors, who may conduct business in multiple counties. Distribution is defined as: “the sale or use or the placing of cigarettes in retail stock for the purpose of selling the cigarettes to consumers” (Revenue & Taxation Code sections 3001-30018). Thus, taxes are incurred at the wholesale level. To estimate statewide emissions, we assumed that distribution represented actual consumption, as consumers generally do not maintain large inventories. In fiscal year 2001-02, the CBOE reported that over 1.27 billion packs of

cigarettes were distributed in California. Since the average cigarette pack contains 20 cigarettes, the total number of cigarettes distributed in California was calculated to be 25.4 billion (i.e., total cigarettes = (20 cigarettes/pack x 1.27 billion packs)).

In 2002, the U.S. Department of Agriculture (USDA) estimated that smokers in the U.S. consumed 4.1 billion large cigars (10% increase vs. 1998), and 2.2 billion small cigars (28% increase vs. 1998) (USDA, 2003b). While the USDA, does not compile California-specific cigar inventories, California accounts for 6% of nationwide cigarette sales. On this basis, staff estimated that the number of large and small cigars smoked in California to be 247-million (6% of 4.1 billion) and 135-million (6% of 2.2 billion), respectively.

Statewide ETS Emissions Inventory

Using the methodology described above, staff estimated total statewide ETS emissions for nicotine, RSP, and CO. Table B-6 shows our estimates of statewide emissions.

Table B-6

2002 California Statewide ETS Emissions (Tons/Year)

	Cigarettes	Cigars	[a] Total
Nicotine	36	4	40
RSP	335	30	365
CO	1475	432	1907

[a] Staff estimates 80-90% of total emissions reside outdoors.

Countywide emissions were also calculated using Equation 1 (see p. B-1) adjusted for the total number of cigarettes smoked per county (i.e., percent of total California smokers per county multiplied by the total number of cigarettes). Attachment A presents our estimated emission results by county.

Emissions by Age

We also estimated ETS emissions amongst two age groups: adults (18 years and older) and adolescents (12-17 years of age). These two age groups comprise virtually all smokers, with adults accounting for about 95% of all California smokers.

For this analysis, we used data from the Tobacco Control Section of the California Department of Health Services (CDHS). Under Proposition 99 (The Tobacco Initiative), CDHS routinely conducts surveys to determine the prevalence of smoking in California. Specifically, we used smoking prevalence data from the 2002 Adult California Tobacco Survey (CTS) and the 2001 Adolescent California Student Tobacco Survey (CSTS) in Attachment B. The number of smokers (adult or adolescent) per county was calculated

using 2002 population data for each county, multiplied by the established smoking prevalence for the county or region, as follows:

No. Smokers per County = [County Population x County Smoking Prevalence]

In 2002, we estimate the number of adult and adolescent smokers in California to be over 4.2 million and 400,000, respectively.

The number of cigarettes smoked per county was calculated by taking the number of smokers (adults and adolescents) in each county as a statewide percentage, then multiplying by the total number of cigarettes smoked statewide, as follows:

No. Cigarettes per County = [Smokers per County (%) x Total Cigarettes Statewide]

A complete summary of estimated total smokers and cigarettes in each county or region is in Attachment C.

In Table B-7, the total adult and adolescent cigarette emissions of nicotine, RSP, and CO in California were estimated to be 36.4, 335, and 1,476 tons/yr, respectively.

Table B-7

Estimated Adult and Adolescent Cigarette Emissions of Nicotine, RSP, and CO (Tons/Year)

	Adult (18+)	Adolescent (12-17)	[a] Total
Nicotine	32.9	3.5	36.4
RSP	303	32	335
CO	1,335	141	1,476

[a] Staff estimates 80-90% of total emissions reside outdoors.

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Attachment A

2002 Estimated Adult and Adolescent Cigarette ETS Emissions Per California County or County Region (lbs/year)

Region	[a] Combined Adult & Adolescent		
	Nicotine	RSP	CO
Los Angeles	19,724	182,173	801,286
San Diego	5,677	52,433	230,628
Orange	5,394	49,817	219,119
San Bernardino	4,124	38,120	167,672
Riverside	4,116	38,012	167,194
Fresno, Madera, Merced, Stanislaus	3,978	36,204	159,246
Imperial, Inyo, Kern, Kings, Mono, Tulare	3,345	30,897	135,899
Alpine, Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, San Joaquin, Sierra, Sutter, Tuolumne, Yuba	3,299	30,454	133,959
Alameda	2,947	27,215	119,704
Sacramento	2,871	26,519	116,645
Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity, Yolo	2,784	25,726	113,155
Santa Clara	2,676	24,712	108,696
San Luis Obispo, Santa Barbara, Ventura	2,605	24,064	105,845
San Mateo, Solano	2,164	19,985	87,904
San Francisco	1,923	17,757	78,103
Contra Costa	1,825	16,858	74,152
Marin, Napa, Sonoma	1,739	16,061	70,645
Monterey, San Benito, Santa Cruz	1,495	13,809	60,737

[a] Staff estimates 80-90% of total emissions reside outdoors.

Attachment B

The following table illustrates the adult and adolescent smoking prevalence within California regions in 2002. The data for these tables can be found from the County and Statewide Archive of Tobacco Statistics at http://webtecc.etr.org/cstats/ .

2002 Adult and Adolescent Smoking Prevalence by Region Within California

Region	Adult (%)
Los Angeles	16.0 (±0.8)
San Diego	15.1 (±1.2)
Orange	14.3 (±1.3)
Santa Clara	12.3 (±1.3)
San Bernardino	19.3 (±1.4)
Alameda	15.8 (±1.5)
Riverside	20.3 (±1.4)
Sacramento	17.6 (±1.4)
Contra Costa	13.7 (±1.4)
San Francisco	17.9 (±1.6)
San Mateo, Solano	14.8 (±1.4)
Marin, Napa, Sonoma	15.3 (±1.5)
Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity, Yolo	19.5 (±1.5)
San Luis Obispo, Santa Barbara, Ventura	13.7 (±1.3)
Alpine, Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, San Joaquin, Sierra, Sutter, Tuolumne, Yuba	17.7 (±1.4)
Monterey, San Benito, Santa Cruz	15.9 (±1.5)
Fresno, Madera, Merced, Stanislaus	19.3 (±1.4)
Imperial, Inyo, Kern, Kings, Mono, Tulare	19.9 (±1.5)

Region	Adolescent (%)
Los Angeles	14.4 (±3.9)
San Diego	18.3 (±2.9)
Orange	15.0 (±2.7)
Santa Clara	13.7 (±2.0)
San Bernardino	14.5 (±3.8)
Alameda	11.4 (±4.3)
Riverside	13.7 (±3.5)
Sacramento, San Joaquin, Stanislaus, Yolo, Yuba	16.6 (±4.3)
Contra Costa, Marin, San Francisco, San Mateo, Solano	18.9 (±4.4)
Fresno, Imperial, Kern, Kings, Madera, Mariposa, Merced, Tulare	16.8 (±3.1)
Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz, Ventura.	19.2 (±4.0)
Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, El Dorado, Glenn, Humboldt, Inyo, Lake, Lassen, Mendocino, Modoc, Mono, Napa, Nevada, Placer, Plumas, Shasta, Sierra, Siskiyou, Sutter, Sonoma, Tehama, Trinity, and Tuolumne.	18.6 (±5.9)

Attachment C

2002 Estimated California County Information Regarding Population, Smokers, and Cigarettes

County	Population (age 12+)	Smokers	Smoker %	Cigarettes	County	Population (age 12+)	Smokers	Smoker %	Cigarettes
Alameda	1,220,022	187,823	4.06	1,031,274,433	Orange	2,392,579	343,813	7.43	1,887,764,881
Alpine	1,054	187	0.004	1,028,072	Placer	233,056	41,468	0.90	227,685,517
Amador	32,483	5,775	0.12	31,710,818	Plumas	18,237	3,540	0.08	19,438,077
Butte	177,815	34,521	0.75	189,541,487	Riverside	1,335,738	262,339	5.67	1,440,418,884
Calaveras	37,394	6,652	0.14	36,526,234	Sacramento	1,045,404	183,024	3.95	1,004,922,459
Colusa	15,494	3,003	0.06	16,489,793	San Benito	43,083	7,006	0.15	38,467,153
Contra Costa	816,686	116,349	2.51	638,833,408	San Bernardino	1,401,270	263,089	5.68	1,444,534,034
Del Norte	23,358	4,533	0.10	24,889,929	San Diego	2,354,432	361,871	7.82	1,986,916,617
El Dorado	139,742	24,869	0.54	136,548,878	San Francisco	682,900	122,549	2.65	672,878,091
Fresno	658,381	124,995	2.70	686,304,253	San Joaquin	480,685	84,516	1.83	464,050,153
Glenn	21,489	4,166	0.09	22,871,408	San Luis Obispo	216,343	30,504	0.66	167,487,083
Humboldt	108,782	21,121	0.46	115,967,477	San Mateo	583,632	88,148	1.90	483,990,274
Imperial	117,340	22,885	0.49	125,655,482	Santa Barbara	330,086	46,684	1.01	256,328,483
Inyo	15,598	3,083	0.07	16,929,654	Santa Clara	1,374,113	170,552	3.68	936,442,457
Kern	547,837	106,898	2.31	586,941,956	Santa Cruz	211,008	34,112	0.74	187,299,820
Kings	108,712	21,263	0.46	116,747,380	Shasta	142,217	27,613	0.60	151,615,865
Lake	52,691	10,226	0.22	56,147,122	Sierra	3,040	540	0.01	2,966,634
Lassen	29,534	5,736	0.12	31,495,866	Siskiyou	37,437	7,271	0.16	39,920,666
Los Angeles	7,941,811	1,257,271	27.16	6,903,261,516	Solano	327,497	49,781	1.08	273,330,417
Madera	105,238	20,002	0.43	109,823,664	Sonoma	388,079	60,444	1.31	331,875,994
Marin	213,100	33,194	0.72	182,258,636	Stanislaus	377,308	71,734	1.55	393,868,942
Mariposa	15,054	2,652	0.06	14,561,781	Sutter	66,116	11,762	0.25	64,579,930
Mendocino	73,687	14,297	0.31	78,502,053	Tehama	46,893	9,103	0.20	49,981,545
Merced	174,831	33,136	0.72	181,936,600	Trinity	11,286	2,193	0.05	12,038,575
Modoc	7,965	1,545	0.03	8,484,977	Tulare	291,303	56,909	1.23	312,470,195
Mono	11,107	2,197	0.05	12,065,267	Tuolumne	48,386	8,596	0.19	47,195,933
Monterey	333,276	54,181	1.17	297,488,537	Ventura	625,002	88,890	1.92	488,063,220
Napa	110,232	17,209	0.37	94,488,444	Yolo	148,886	28,677	0.62	157,457,005
Nevada	82,396	14,656	0.32	80,472,160	Yuba	48,446	8,516	0.18	46,761,128