Appendix E: Calculations for Federal Motor Vehicle Controls and St. Louis Heavy Duty Diesel Idle Reduction Program

Calculation of Emission Reductions from Federal Motor Vehicle Controls

The emission reductions from federal motor vehicle controls were calculated consistent with EPA's *Guidance for Creating Annual On-Road Mobile Source Emission Inventories for PM2.5 Nonattainment Areas for Use in SIPs and Conformity*. In addition, the calculations incorporate the latest planning assumptions established by the Inter Agency Consultation Group coordinated by the East West Gateway Council of Governments.

Consistent with the Inter Agency Consultation Group's planning assumptions, a two-season approach was used to estimate annual motor vehicle emissions. This approach uses winter and summer input conditions to develop inventories based on two sets of MOBILE6.2 runs. Each set of input conditions is assumed to represent six months of the year, and annual VMT is apportioned to the winter and summer seasons. The total annual inventory is the sum of the winter and summer inventories.

2002 average weekday VMT was projected to 2012 and 2014 by applying a growth rate of 1.5% per year. The growth rate of 1.5% per year is consistent with the average region-wide growth rate for the St. Louis nonattainment area counties used in the attainment demonstration modeling. The VMT projection calculations were applied by speed and road type (freeway and arterial). The calculations were done separately for Franklin County and the rest of the nonattainment area (Jefferson, St. Charles, St. Louis Counties and the City of St. Louis) as was done in the preparation of the 2002 base year inventory.

Daily VMT estimates for 2012 and 2014 were converted to annual VMT estimates by applying a multiplier of 365. Seasonal VMT estimates for winter and summer were derived by dividing the annual totals by 2. The annual and seasonal adjustment factors were based on discussions with East West Gateway and are consistent with their practices in conformity determinations. Table 1 summarizes the 2012 and 2014 projected annual VMT by county.

Table 1. 2012 and 2014 Annual VMT by County

County	2012 Annual VMT	2014 Annual VMT
Franklin	1,595,395,454	1,637,014,466
Jefferson	2,061,873,284	2,115,661,282
St. Charles	2,805,854,554	2,879,050,760
St. Louis	11,965,568,956	12,277,714,233
St. Louis City	3,425,543,232	3,514,905,229
St. Louis NAA Totals	**21,854,235,479**	**22,424,345,970**

Winter and summer emission factors for 2012 and 2014 were generated using the EPA's MOBILE6.2 model. East West Gateway provided the winter and summer minimum and maximum temperature inputs and absolute humidity values. The local program specifications for the 2012 and 2014 runs included reformulated gasoline and the Gateway Vehicle Inspection Program that began October 1, 2007. A diesel sulfur content of 11.0 ppm was used for both 2012 and 2014 based on the EPA's NMIM National County Database. In addition, the MOBILE6.2 model accounts for the impacts of the federal rules, such as the Tier 2 motor vehicle emission standards and the 2007 heavy-duty diesel standards. Although the local program, temperature, and humidity specifications were identical, separate sets of inputs were created for Franklin County and the rest of the nonattainment area (Jefferson, St. Charles, and St. Louis Counties and City of St. Louis) in order to utilize the separate speed by VMT (SVMT) inputs for Franklin versus the rest of the nonattainment area and to be consistent with the way the 2002 VMT was prepared.

The winter and summer MOBILE6.2 runs produced emission factors by pollutant (NOx, ECARBON, OCARBON, SO4, GASPM, BRAKE, TIRE), roadway type (freeway and arterial), and average speed (2.5 mph and 10 - 65 mph in 5 mph increments). The 2012 and 2014 onroad mobile emissions were calculated by multiplying the projected VMT for a given speed, road type, and nonattainment area subregion (Franklin County versus the rest of the nonattainment area) by the corresponding composite emission factor representing all vehicle types. Directly emitted $PM_{2.5}$ was calculated by summing diesel carbon emissions (ECARBON and OCARBON), gasoline carbon emissions (GASPM), sulfate particulate (SO4), and brake and tire wear. The results for each pollutant were summed across all speeds, road types, and nonattainment area counties. The emissions totals for winter and summer were summed to generate annual estimates.

The annual emission reduction benefits of federal motor vehicle controls were calculated using the following equation:

$$BENEFIT = EMISS_{2012} – EMISS_{2014}$$

Where:

BENEFIT = emission reductions due to federal motor vehicle programs from 2012-2014 (tons/yr)
$EMISS_{2012}$ = 2012 onroad mobile emissions (tons/year)
$EMISS_{2014}$ = 2014 onroad mobile emissions (tons/year)

The emission benefit calculations for contingency measure purposes are below.

NOx BENEFIT = 28,743.4 tons/year – 23,201.7 tons/year
NOx BENEFIT = 5,541.7 tons/year

$PM_{2.5}$ BENEFIT = 531.2 tons/year – 463.5 tons/year
$PM_{2.5}$ BENEFIT = 67.7 tons/year

St. Louis Heavy Duty Diesel Idle Rule

The idle reduction rule addresses idling during loading or unloading of goods or passengers. The vehicle types affected are commercial, institutional, and public vehicles in Classes 3 through 8, known as heavy-duty diesel vehicles (HDDVs), and include the following [2](see for references):

Class 3 – pick up trucks, the largest of compact vans (such as passenger vans), and the smallest of walk-in delivery trucks
Class 4 – larger walk-in delivery trucks and smaller moving vans
Class 5 – rack trucks (such as to transport gas cylinders), trucks with tree chippers and tree specialist equipment, and the largest of walk-in delivery vans
Class 6 – school buses, single axle vans, and the largest of furniture/moving vans
Class 7 – home fuel trucks, transit buses, garbage trucks, and smaller tractor-trailers.
Class 8 – dump trucks, cement trucks, and most tractor-trailers

Currently there is little to no conclusive data to quantify the expected emissions reduction due to a number of anti-idling laws. While the extent of overnight idling is relatively well defined, workday idling is far more difficult to parameterize in terms of both idling practices, magnitudes of vehicles idling in the affected counties, and emission rates. The methodology for estimating emissions reductions from the St. Louis idle rule was primarily based on studies conducted by the Pennsylvania Department of Environmental Protection and the Texas Commission on Environmental Quality [1], [4], [6].

Emission Factors

A U.S. EPA report [5] provides guidance on using MOBILE 6.2 to determine idling emission factors, but, for NO_x emissions from Class 8 HDDVs, these rates have been reported to be two to several hundred times higher in the literature [1], [15]. The recommended value of 135 g/h NO_x for any calendar year from 2002-2030 was therefore used.

The recommended value for PM2.5 for Class 8 trucks in 2012 of 1.75 g/h was used.

No guidance could be found on SO_2 so MOBILE 6.2 output was used. (Table 2)

As for school buses, MOBILE6.2 rates were used per guidance in [1].

The following table shows the emission factors used.

Table 2. Summary of emission factors used to estimate benefits of St. Louis HDDV idle rule

	Vehicle Type	Emission Factor (g/h)	Source of Emission Factor	Varies by Year?
NOx	Class 8 Trucks	135	EPA Guidance	No
	School Buses	34.9	MOBILE 6.2	Yes
SO2	Class 8 Trucks	0.027	MOBILE 6.2	Yes
	School Buses	0.028	MOBILE 6.2	Yes
PM2.5	Class 8 Trucks	1.75	EPA Guidance	Yes
	School Buses	1.0	MOBILE 6.2	Yes

The MOBILE6.2 runs were done for January to represent the winter months and July to represent summer months. The following inputs were used: a calendar year of 2012, minimum and maximum temperatures and relative humidity values of 18 and 55ºF and 20 grains/lb for January and 74 and 97ºF and 60 grains/lb for July. The winter and summer temperature and relative humidity values were obtained from East West Gateway. Since no seasonal distribution of *workday* idling was found, and since there is no reason to believe a significant temporal variation exists, equal seasonal distribution was assumed.

Methodology of Expected Reduction in Emissions

The reduction in emissions due to the rule was defined as the difference between idling emissions during loading or unloading *that would be affected by the rule* and idling emissions during loading and unloading after the rule takes affect. Since only the idling activities potentially affected by the proposed rule were included in the estimates of idling emissions before and after the rule, no idling activities that were expected to always be about five minutes or less, or were exempt for other reasons, were included in the estimations. In other words, if a certain type of HDDV loading or unloading activity was expected to never exceed about five minutes, these emissions are not included in the estimation. However, if a certain activity (such as school bus loading or unloading) had an idle time distribution that included idle times less than five minutes, these activities were accounted for in the estimate.

Since the reduction due to idling while waiting to load or unload is expected to be much smaller than that while loading or unloading, the restriction of idling while waiting to load or unload was not accounted for in this study. Additionally, the existing idling law in St. Louis city restricting idling to ten minutes was not accounted for in this study [14].

Classes 3 through 5

Classes 3 through 5 have not been included in workday idling estimations for several reasons:

- There are fewer vehicles.

- The vehicles have substantially lower emission rates, about one half of the higher classes.
- The workday idling of Classes 3 through 5 is even more uncertain than that of the higher classes.
- There is much less idling in excess of five (or so) minutes with these vehicles [1], [4], [6].

Some of the most extensive idling reported for Classes 3 to 5 are newspaper delivery and municipal utility trucks [9], as well as highway maintenance trucks [11]. This idling may be especially prevalent in poor weather or when the majority of the population feels the need for heat or air conditioning. Since idling to "prevent a health or safety emergency" is exempt, this type of idling can be argued to occur for the majority of the days of the year.

For estimation purposes, the workday idling of Classes 3 through 5 should not be included due to the high degree of uncertainty and probability of being insignificant.

Class 6

The vehicles in this class which transport goods, such as retail and furniture delivery vans and trucks, are not expected to idle for more than about five consecutive minutes. Additionally, idling at homes and retail establishments may be more difficult to regulate than at the pick up and drop off points of the tractor trailers in Class 8. School buses, however, are expected to be significantly affected by the proposed rule. The total idling time and idle time distribution applied to metropolitan counties in Pennsylvania [1], [12] was used, assuming a maximum idle time of one hour per day, and was scaled by total population of the counties with the closest population *density* to the potentially affected counties in Missouri. This was assumed to most closely represent similar counties with similar business characteristics.

Average daily idle time distributions per school bus were obtained from [12] assuming the bus is at school two times per day. The number of school days (184 days including summer school) was obtained from the St. Louis Public School District calendar. The number of buses was estimated by using data from counties in Pennsylvania in or around the major metropolitan areas [1] and roughly scaling these values by the total population of the county.

The average idle time was found to be 13 minutes per trip, with two trips per day. If you assume that this idling is while waiting to load or unload and therefore restricted to 30 minutes, then there would be negligible emissions reductions. Even if this idling time is assumed to occur while loading and unloading students as a worst case scenario (with the idle reduction rule in St. Louis not accounted for) then the reductions are around four tons per year of NO_x and around zero tons per year of SO_2 and $PM_{2.5}$, and are therefore not included in the results section.

Class 7

This class includes home fuel delivery trucks, transit buses, garbage trucks, and smaller tractor-trailers.

Although garbage trucks emit large amounts of pollution from idling [8], [9], nearly all of this idling is expected to be exempt from the proposed rule.

Transit buses are not expected to be affected since the idling that does occur can be argued to be exempt.

Home fuel delivery trucks are not included because they are not relatively numerous nor do they idle without reason [9].

The few tractor-trailers that do fall in this class can be assumed to operate at Class 8 emission rates since these rates are extremely uncertain and what little is published is published for Class 8. All potential emissions reduction in Class 7 can therefore be assumed to be included in Class 8.

Class 8

This class includes cement trucks, dump trucks, and tractor trailers. Since cement and dump trucks must idle in order to load or unload, the potentially affected class 8 HDDVs consist solely of tractor trailers. They idle at a variety of locations, or sectors:

- public rest areas
- truck stops
- interchanges
- industries with loading/unloading points (mainly warehouses, wholesalers, and manufacturing facilities); and
- ports and other intermodal facilities [1], [4], [6].

The public rest area, truck stop, interchange, and port sectors were well defined, and the estimated idling emission reductions were found to be insignificant in these sectors. Estimating emissions reduction for the remaining sectors: warehouses, wholesalers, manufacturing facilities, and intermodal facilities required a study of their NAICS sectors in order to avoid double counting of Missouri facilities and to ensure accurate allocation of Missouri business data to the methods derived from each study.

It was determined that the Pennsylvania method [1] of estimating emissions at warehouses and intermodal facilities did not include any manufacturing facilities, and it was therefore concluded that this estimation represented only those wholesaling facilities that do not have manufacturing activities at them. The Texas method [4] used electronic yellow page searches to find the number of “manufacturing and wholesaling” establishments. This study used Census Bureau data [3] to find the number of “manufacturing and wholesaling” (lumped together) establishments. An electronic yellow pages search on the St. Louis area revealed that the vast majority, about 99%, of all "wholesaling" facilities also have manufacturing activities, and therefore the Texas [4] method used here represents only "manufacturing" (and not any significant wholesaling only facilities) and the Pennsylvania method [1] used here represents all warehousing/wholesaling and intermodal facilities.

Based on these sector definitions and the literature, we can assume that potentially significant idle reductions may occur in the following categories: truck stops, manufacturing facilities/industries, ports, intermodal facilities, and warehouses/wholesalers.

A. Truck Stops

Significant idling is reported to occur during loading activities at these facilities [9]. As one driver reported, "for the most part it (the unnecessary idling) is the large trucks and tractor trailers making deliveries to the diner." However, since there are only a few truck stops in Missouri, these idling emissions were assumed to be negligible.

B. Manufacturing Facilities/Industries

This sector is the most uncertain in terms of idling, and possibly the highest source of emissions [1].

The number of "manufacturers and wholesalers" was assumed to include non-merchant wholesalers. Since the non-merchant wholesalers do not have the merchandise at their establishments, no truck activity is present. This is valid provided the Texas study [4] also included all establishments in this sector when assigning a value for the number of trucks per establishment (i.e., they included non-merchant establishments with zero trucks when averaging the "number of trucks per establishment" factor).

The following assumptions of [6] were used to determine total idling time which, when multiplied by the emissions rates, yielded total idling emissions and reduction:

- 118 employees per establishment
- 8.75 daily truck trips per 100 employees
- 50 minutes average idle time per truck
- All idle times are above 5 minutes (assumed for this study)
- 60% of establishments allow idling (in excess of five minutes, which was assumed for this study)

C. Ports

It was estimated that no significant idle reductions should occur at ports in Missouri.

D. Intermodal Facilities

The methods used to estimate idling emission reduction at warehouses is assumed to include that from idling at intermodal facilities, which is reported to be a significant source of workday idling [4], [6].

E. Warehouses and Intermodal Facilities

The expected annual emissions reduction was estimated by using the following overall equation

$$A \text{ (trip/ft}^2\text{/d)} \times B \text{ (ft}^2\text{)} \times (C_2 - C_1) \text{ (min/trip)} \times D_i \text{ (lb/min)} \times E \text{ (d/yr)} = F_i \text{ (lb/yr)} \quad (1)$$

where

A = daily trips per vehicle per total warehouse square footage in a county (trip/ft^2·d)
B = total square footage of warehouse space used by all applicable vehicles (ft^2)
C_2 = idle duration of an average trip without idling restrictions (min/trip)
C_1 = idle duration of an average trip with idling restrictions (min/trip)
D_i = emission rate of pollutant *i* from MOBILE6.2 (converted to lb/min)
E = annual days of operation (d/yr)
F_i = expected annual emission reduction of pollutant *i* due to idling restrictions (lb/yr)
i = pollutants NO_x, SO_2, and $PM_{2.5}$

The following methodologies were used to estimate the values of these variables.

Daily Number of Trips per Warehouse Space: *A*

The value of *A* of 0.21 daily Class 8 truck trips per 1,000 square feet of warehouse space was used [1].

Warehouse Space: *B*

This information was not available without a costly subscription, so, after examining a large amount of census and other data [3] to which warehouse space may be related, no relationships were found, even when suspected outliers were discarded. The averages of data sets were also examined, and the one with the smallest standard deviation per average value still had a tenfold difference between the smallest and largest values in the range.

Some of the data examined from the U.S. Census Bureau for the counties of interest in Pennsylvania included the total number of employees and number of establishments in "warehousing and transportation", population, population density, number of establishments in warehousing, number of establishments in transportation, and the ratio of various combinations of these data.

Finally, a simple assumption that total square footage of warehouse should be related to population density was reexamined. With population density as the independent variable, no relationships were found even after discarding suspected outliers. When these data were plotted with population density as the dependent variable, however, the curve seemed to resemble a third order polynomial, as shown below.

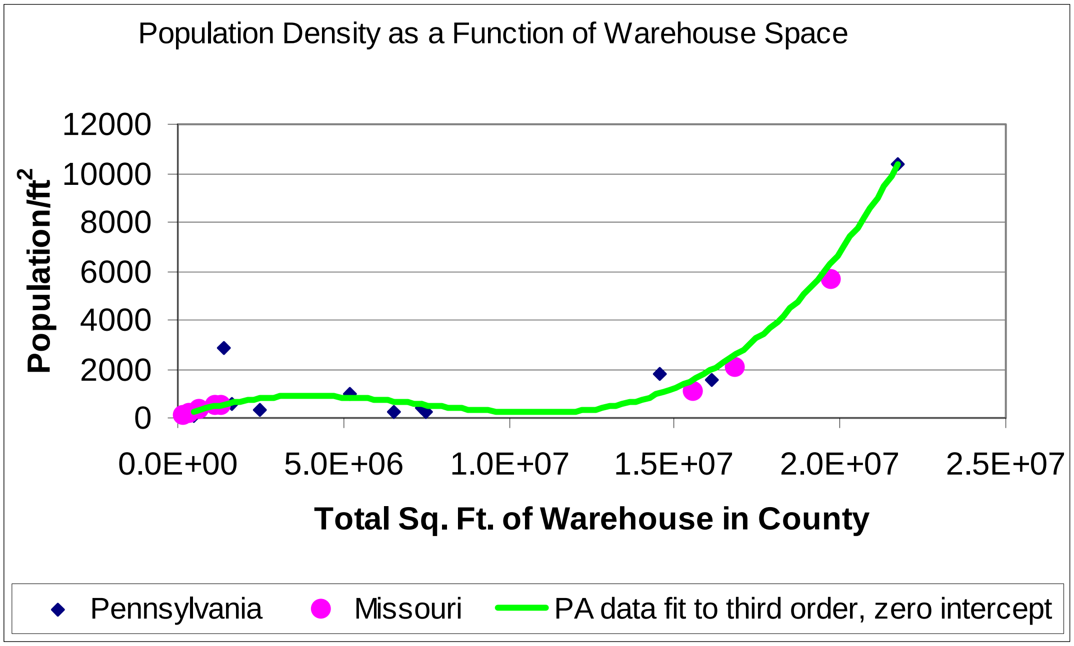

Figure 1. Relationship between population density in a county and warehouse space.

Since St. Louis City has a population density of approximately 5000, it was decided not to exclude Philadelphia County with its population density of 10,000. The second data point was not discarded as an outlier because this same variation could very well exist in the Missouri metropolitan areas. A third order polynomial fit the data with the results of a least squares regression analysis yielding $R^2 = 0.94$. Since all other relationships tested yielded an R^2 below 0.8, this relationship was by far the best. However, it had to be corrected for counties with lower population densities by forcing the intercept to pass through the origin. The resulting $R^2 = 0.92$, so this relationship was used in the estimation by solving the polynomial for each county in Missouri.

The following values were found for total warehouse space (ft^2) in a county:

County	Population Density	Warehouse Space (ft^2)
St. Louis City	5600	20 million
St. Louis	2000	17 million
St. Charles	500	1.3 million
Jefferson	300	690,000
Franklin	100	210,000
St. Louis Area Total		**39 million**

One problem with this relationship is that it is relatively weak. The value of the dependent variable (population density) does not increase appreciably with that of the dependent variable (warehouse space). Additionally, the third order shape of the data gives solutions around a million or less as well as around the 10 million range, which results in a ten fold uncertainty. The lower solutions were used.

Idling Time: C_1, C_2, and E

Currently no data establish the annual idle time by the affected vehicle types, so a number of assumptions were used. The Pennsylvania study used idle time distributions from the Texas study [4] for the warehouse and intermodal sector, but the Texas data consisted of only three observations of intermodal facility idling, and no warehouse idling. Therefore, it was decided to use the Texas study average idle time for intermodal facilities of 25 minutes. Since the Texas study lumped wholesalers with manufacturers with that average idle time of 50 minutes, our usage of 25 minutes is on the conservative side, as desired. (Note, as for the manufacturing and wholesale sectors, it was assumed that all trips had an idle time of 25 minutes, therefore it was assumed that no trucks idled for five minutes or less.) Additionally, the annual idle time estimates only include idling restrictions during loading and unloading, and not while waiting to load or unload.

A value of E of 250 annual days of operation were obtained directly from the Pennsylvania study [1].

Emission Rates: D

Refer to Section 9.2.5 – *Emission Rates*.

In summary, the following values were used:

- A = 0.21 trips/d/1000 ft^2 warehouse space
- B = 39 million ft^2
- C_1 = 5 minutes
- C_2 = 25 minutes
- D = 135 g/h NO_x, 0.027 g/h SO_2, 1.75 g/h $PM_{2.5}$
- E = 250 operating days per year
- In the St. Louis area, F_{NOx} = 100 tons per year NO_x, F_{SO2} = 0.008 tons per year SO_2, $F_{PM2.5}$ = 6 tons per year $PM_{2.5}$. (The equation gives lb/yr / 2000lb/ton = ton/yr.)

The reductions in idling emissions (F_i) are tabulated in the following section under the "Warehouse, Intermodal" sector.

Results and Recommendations

The expected emissions reductions in the affected counties are 450 tons per year NO_x, 0.04 tons per year SO_2 and 6 tons per year $PM_{2.5}$. The following table (Table 3) shows the estimated expected emissions due to idling activities over five minutes during loading and unloading under the "before rule" condition, these emissions "after rule", and the difference of the two, or "reduction".

Table 3. Estimated HDDV idling emissions affected by rulemaking (tpy)

Condition	NOx			SO2			PM2.5		
	Manufacturing	Warehouse, Intermodal	**Total**	Manufacturing	Warehouse, Intermodal	**Total**	Manufacturing	Warehouse, Intermodal	**Total**
before rule	386	112	498	N/A	N/A	N/A	N/A	N/A	N/A
after rule	39	11	50	N/A	N/A	N/A	N/A	N/A	N/A
reduction	347	101	**448**	0.028	0.008	**0.037**	4.5	1.3	**5.8**

* This study [4] used 144 g/h NOx, whereas this study used 135 g/h.

Quantification of the benefits due to idling laws in the U.S. still requires more research and disaggregation of current idling data. A better breakdown of emissions due to the various types of idling with respect to vehicle type, reason for idling, and locations of idling is needed. Also especially critical are idle time distributions, emission rates, and quantification of number of HDDVs idling at the various scenarios. While a better picture is clearly needed at this time, the estimates provided are roughly consistent with those from the literature [1], [4], [6], and can therefore serve as an estimate for this plan.

References

[1] Baker, M. (2007). *Quantification of Pennsylvania Heavy-Duty Diesel Vehicle Idling and Emissions, Final Report*, prepared for the Pennsylvania Department of Environmental Protection. March, 2007.

[2] Gaines, L., A. Vyas, and J. Anderson (2006). *Estimation of Fuel Use by Idling Commercial Trucks*, Prepared for the Center for Transportation Research, Argonne National Laboratory, Argonne, IL.

[3] www.census.gov Maps, Thematic Maps, 2006 County Business Patterns, and NAICS information.

[4] TCEQ (2004) *Heavy-Duty Vehicle Idle Activity and Emissions Characterization Study*, prepared for the Texas Commission on Environmental Quality. August, 2004.

[5] EPA (2004) *Technical Guidance on the Use of MOBILE6.2 for Emission Inventory Preparation,* prepared for the United States Environmental Protection Agency. August, 2004.

[6] TCEQ (2003) *Heavy-Duty Diesel Vehicle (HDDV) Idling Activity and Emissions Study: Phase 1 – Study Design and Estimation of Magnitude of the Problem*. Texas Commission on Environmental Quality. August 2003.

[7] Lutsey, N., C. Brodrick, D. Sperling, and C. Oglesby (2004) *Heavy-Duty Truck Idling Characteristics*. Transportation Research Record: Journal of the Transportation Research Board, No. 1880, TRB, National Research Council, Washington, D. C. pp.29-83.

[8] Siuru, B. (2003) *New Study Makes Strong Case for Natural Gas Garbage Trucks*. Diesel Progress North American Edition.

[9] Winsor, J. (2004) *Idle Thoughts on Engine Idling*. Heavy Duty Trucking: Delivering the World of Trucks.
[10] U.S. EPA (2002) *Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idle-Reducing Devices*. Prepared for the United States Environmental Protection Agency, October, 2002.
[11] Personal communication with the authors of the proposed rule.
[12] Environmental Bulletin, A Maine EEP Informational Bulletin for Maine Citizens & School Officials, Fall 2002.
http://www.maine.gov/dep/air/school/docs/Newsletter%20Fall_02.pdf
[13] Idling Myths. http://www.epa.gov/OMS/schoolbus/antiidling.htm
[14] Idling Laws in Missouri.
http://www.afdc.energy.gov/afdc/progs/ind_state_laws.php/MO/IR
[15] U.S. EPA. Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and transportation Conformity. January 2004.