International Vehicle
Emissions Model

Attachment A
Development of the Base Emission Rates for Use in the IVE Model
Version 1.2

April 2008

Notice

This section of the User's Guide describes the assumptions, options, and limitations of the base emission rates developed for the IVE model. It is recommended that the user read and understand this section of the manual before using results of the model for any purpose. Any questions about the user's guide or model may be directed to: ive_feedback@issrc.org. This user's guide and model may be downloaded at www.issrc.org/ive.

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1. Base Emission Rate Description

The basis of the emission prediction process of the IVE model is to apply a base emission rate with a series of correction factors to estimate the amount of pollution from a variety of vehicle types (Eq. 1-2, Table 1). Equation 1 estimates the adjusted emission rate by multiplying the basic emission rate by each correction factor. Equation 2 weights the adjusted emission rate by the travel fraction for each technology and the amount of each driving type for each technology. The final step in equation 2 is to multiply these results by the ratio of the average velocity of the LA4 driving cycle and the average velocity of the modeled cycle and multiply by the distance traveled (for running emissions only). The result is the overall fleet running emissions for the allocated distance (in grams). There are two types of base emission rates, one for running emissions and one for start emissions. The definition and data for both types of base emission rate is described below.

$$Q_{[t]} = B_{[t]} * K_{(Base)[t]} * K_{(Tmp)[t]} * K_{(Hmd)[t]} * K_{(IM)[t]} * K_{(Fuel)[t]} * K_{(Alt)[t]} * K_{(Cntry)[t]} \quad \text{(Eq. 1)}$$

$$Q_{running} = \bar{U}_{FTP} * D / \bar{U}_{C} * \Sigma_t \{f_{[t]} * Q_{[t]} * \Sigma_d [f_{[dt]} * K_{[dt]}]\} \quad \text{(Eq. 2)}$$

$$Q_{start} = \Sigma_t \{f_{[t]} * Q_{[t]} * \Sigma_d [f_{[dt]} * K_{[dt]}]\} \quad \text{(Eq. 2)}$$

Table 1. Description of Variables found in the IVE Emission Rate Equation

Variable	Description
$B_{[t]}$	Base emission rate in for each technology (start (g) or running (g/km))
$Q_{[t]}$	Adjusted emission rate for each technology (start (g) or running (g))
Q	Average emission rate for the entire fleet (start (g) or running (g))
$f_{[t]}$	Fraction of travel by a specific technology
$f_{[dt]}$	Fraction of each type of driving or soak by a specific technology
$\bar{U}_{FTP}$	average velocity of the LA4 driving cycle (a constant (g/km))
D	Distance traveled as input by user in Location File (km)
$\bar{U}_{C}$	Average velocity from the specific driving cycle, as input by user in Location File (kph)
$K_{(Base)[t]}$	Adjustment to the Base Emission Rate (described in detail in the next section)
$K_{(Tmp)[t]}$	Temperature Correction Factor
$K_{(Hmd)[t]}$	Humidity Correction Factor
$K_{(IM)[t]}$	Inspection/Maintenance Correction Factor
$K_{(Fuel)[t]}$	Fuel Quality Correction Factor
$K_{(Alt)[t]}$	Altitude Correction Factor
$K_{(Cntry)[t]}$	Country Correction Factor
$K_{[dt]}$	Driving or Soak Style Correction Factor (Also accounts for other load effects from air conditioning usage and road grade)

The basic running emission rates ($Brun_{[t]}$) are defined in the IVE model as emissions accrued during the running LA4 cycle (g/km) (Eq. 3). This is the same definition the US EPA uses to define the base running emissions rates used in the MOBILE6 model (EPA

2001 (20), EPA 2002 (25)). The running LA4 emissions are a composite of the hot running 505 (HR505) and Bag 2 of the FTP. The HR505 is equivalent to Bags 1 or 3 of the FTP without a start. The EPA has developed a methodology of deriving the hot running bag (HR505) from Bags 1-3 of the FTP (EPA2001 (19)). Therefore, it is possible to estimate running emissions for a specific technology wherever FTP bag data is available. Where HR505 data is not available and cannot be estimated, Bag 3 is used in place of the HR505.

Running LA4 Emissions ($Brun_{[t]}$)(g/mi) = (HR505*(.206+.273))+ (Bag2*.521) (Eq. 3)

The basic start emission Rates ($Bstart_{[t]}$) are defined in the IVE model as the emissions accrued from a cold start in grams (Eq. 4) (EPA 2001 *). These emissions are in excess of any driving that occurs. For example, if a vehicle is started and then drives 5 kilometers, the running emissions would represent the emissions from all five miles if the vehicle had not been started, and the start emissions would represent the start emissions from the single start. Running and start emissions may overlap in time. Equation 4 shows the formula for calculating start emissions. Where HR505 data is not available and cannot be estimated, Bag 3 is used in place of the HR505.

Start Emissions ($Bstart_{[t]}$)(grams) = (Bag1 - HR505)*3.6 (Eq. 4)

Default values for the basic running and start emission rates for each technology are provided in the IVE model. The basic emission rates for each technology are developed from a variety of sources, but many of the data for gasoline and diesel vehicles was taken from the MOBILE6 model and documentation (EPA, 2001, 16,20). Development of emission factors for vehicles following the European Standards was found using the COPERT 4 model and documentation (EEA 2000). As more information becomes available, it can easily be incorporated for timely improvements of the IVE model. More detail on the estimate of individual emission factors are included later in this report.

The basic emissions rates ($Brun_{[t]}$, $Bstart_{[t]}$) are designed to be representative of the average emissions of a specific technology and mileage group. Therefore it is necessary to take into consideration the emissions from both normal emitting vehicles and high emitting vehicles in the proper proportions. While the percentage of high emitters in a given fleet, age and technology is difficult to predict and will vary by location and time, these differences can be applied to the model using country adjustment factors. For the model, the EPA's estimate of the percentage of high emitters and the appropriate emission rates was used. The methodology for estimating the average basic emission rate may vary from technology to technology, but is typically estimated from an equation similar to Eq. 5.

$$B_{[t]} = (B_{ODO=0} + DR*ODO)*(1-\%HE) + (\%HE)*B_{HE} \quad \text{(Eq. 5)}$$

where

ODO = average odometer reading (assumed to be 20k, 75k, and 150k for the three age categories in the IVE technology distributions)
%HE = percentage of the fleet that are high emitters
$B_{ODO=0}$ = Basic emission rate for a normal emitter with zero miles accumulated
B_{HE} = Basic emission rate for a high emitter

The EPA and the ARB has available a comprehensive set of emissions data from dynamometer tests over the FTP, LA4 and other cycles for a wide variety of technologies and conditions, (EPA 2002 (25)). In addition, the EPA has performed analysis and refined approaches to estimating the emissions from each of these technologies, including the effect of vehicle aging on emissions (EPA 2001 (20&22), EPA 2002 (26)). Therefore, it is advantageous to use this as the basis for developing base emission rates as a function of technology. There is, however, one complication with using the available US data. The EPA typically develops emission rates as a function of model year of the vehicle, not technology. Since there can be multiple technologies in each model year, along with changes in emission standards with no changes in control strategy, careful mapping from the model year specific emission rates documented in the EPA documents to the individual technology category in the IVE model is necessary. This conversion was also used in changing the fleet registration and travel fraction as defined by EPA from model year to technology type. The disadvantage of this approach is that it requires a significant number of assumptions. An alternate approach would be to derive technology-specific emission rates directly from provided individual dynamometer data. However, this would require a significant effort of re-analyzing the data, development of new deterioration rates and high emitter fractions. This may be done in the future and compared with current estimates.

MOBILE6 predicts emission rates of CO, NOx, VOC, SOx, Lead, Aldehydes, NH3, and CH4, although current documentation is extremely limited on some of these pollutants. Based on the documentation available for each pollutant and technology group, various methods of developing the base emission rate were used. In many instances, the EPA's documentation or MOBILE model was used to develop the base emission rates. For motorcycles and pollutants not predicted by EPA, alternative data sources were used. Described below are the process and data sources for development of the base emission rates.

2. NOx, VOC, and CO Base Emission Rates

Light Duty Vehicles and Trucks

The basic emission rates from light duty vehicles and trucks were obtained from three EPA documents (EPA 2001 (16, 19, 20)). For open loop vehicles, EPA estimated the exhaust and start emission rates for the fleet average as a function of model year. For all other gasoline light duty vehicles, the methodology described in EPA report EPA-420-R-01-002 is used to estimate running emissions (Eq. 6). This equation uses a piecewise linear deterioration for the normal emitters and a fraction of constant high emitters. The model year to technology mapping described in the report "Creating US Fleet Files" was used to determine which model year emission rates to apply to the appropriate technology (IVE, 2003 (30)).

$$B_{[t]} = (B_{ODO=0} + DR1*ODO1 + DR2*ODO2)*(1-\%HE) + (\%HE)*B_{HE} \quad \text{(Eq. 6)}$$

Heavy Duty Gasoline and Diesel Vehicles

The basic emission rates for heavy duty gasoline and diesel vehicles was obtained from two EPA documents (EPA 2001 (16), EPA 2002 (27)). The emission rates for heavy duty vehicles do not include a separate portion for starts. The emissions for these vehicles are from test data from new engine certification due to the lack of in-use data. These emission rates are given for only one category of gasoline vehicles, and three weight categories for diesel vehicles for a variety of model years. A conversion factor, given for each weight class of gasoline and diesel vehicles, is used to convert the measured engine emissions in g/bhp-hr to g/mi (Eq. 7). The model year to technology mapping described in the report "Creating US Fleet Files for the IVE Model" was used to determine which model year emission rates to apply to the appropriate technology (IVE, 2003 (30)).

$$B_{[t]} = CF *(B_{ODO=0} + DR*ODO) \quad \text{(Eq. 7)}$$

where

$B_{ODO=0}$ = zero mile emission rate (g/bhp-hr)

DR = deterioration rate (g/bhp-hr/10,000 mi)

CF (Bhp-hr/mi) =

Fuel Density (lb/gal)/(Brake specific fuel economy (lb/bhp-hr) * fuel economy (mi/gal)

Where there is overlap of the technologies for a given model year, some values had to be interpolated from the MOBILE6 results. For example, model year 1975 vehicles are comprised of 20% carbureted, non-catalyst vehicles and 80% carbureted, 2 way catalyst vehicles. By using the technology distribution for multiple model years and the emission rate for each model year, the best emission rate for each technology was found.

Emissions from Motorcycles (Small Engine Vehicles)

Emissions in the Small Engine Vehicle Category include emissions from 2 wheeled motorcycles and scooters and 3 wheeled vehicles. Because of the miniscule contribution of motorcycles to the US mobile source inventory, the EPA has collected very limited emissions data from these technologies. However, in many other countries, the quantities of small engine vehicles are significant and can play an important role in characterizing the mobile source inventory. There have been many emissions tests on these types of vehicles throughout the world. Several major studies were used as the source of information on motorcycle emissions: "Measurement of Mass Emissions from In-use Two-Stroke Engine Three-Wheelers in South Asia", "Improving Urban Air Quality in South Asia by Reducing emissions from Two-Stroke Engine Vehicles" and "Report of the Expert Committee on Auto Fuel Policy" by the Government of India (GIA 2002, Kojima, 2002, Kojima 2000). In addition, these emissions were compared with MOBILE6 motorcycle emissions (EPA 2002).

Emissions from Alternative Fueled Vehicles

Several sources were used to develop base emission rates for alternative fueled vehicles (Andress 2000, NREL 31-38, DOE 1-10). Because of the limited number and wide range of design parameters for these vehicles, in many instances, the emissions from these vehicles can range from well below to above their gasoline counterpart. Therefore, an effort to select a conservative average of the values presented in the literature was made for the emission rates for these alternative fueled vehicles. Table 2 presents the emission ratio relative to an equivalent gasoline vehicle for the various alternative fueled technologies. The ratios of VOC to THC and CH4 was obtained from the "Conversion Factors for Hydrocarbon Emission Components" (EPA 1997). These values should not be used as a blanket value for what is expected if an alternative fuel is used. Instead, these values should be viewed as the effect alternative fueled vehicles *could* have on emissions, given appropriate technology, implementation, and maintenance.

Table 2. Ratio of Emissions from Alternative Fueled Vehicles to Gasoline Vehicles used in the IVE model

Applies To	VOC Ratio	CO Ratio	NOx Ratio
Ethanol	0.85	1	1
Ethanol retrofit	0.9	1	1
Natural Gas	0.06	0.7	0.8
Natural Gas Retrofit	0.06	1	1
Propane	0.5	0.7	0.95
Propane Retrofit	0.6	2	2.6

Emissions from Vehicles with European Standards

There are several categories in the IVE model dedicated to gasoline and diesel vehicles complying with European standards. For a crude estimate of the base emission rates for these vehicles, the ratio of the standards was used and applied as a correction to the comparison vehicle (Table 3) (EEA2000). For example, a European vehicle with emissions standard 50% greater than a US vehicle would have an emission ratio of 1.5 x US vehicle emissions.

Table 3. Ratio of Emissions from European Vehicles to a Reference Vehicle used in the IVE model

Applies To	Reference Technology	VOCrun	COrun	NOxrun
EuroI Light duty Gasoline	Tier 0 Light duty Gasoline	3.3	1.4	1.5
EuroII Light duty Gasoline	EuroI Light duty Gasoline	0.4	0.4	0.6
EuroIII Light duty Gasoline	EuroI Light duty Gasoline	0.2	0.7	0.5
EuroIV Light duty Gasoline	EuroIII Light duty Gasoline	0.7	0.4	0.8
EuroI Light duty Diesel	Tier 0 Light duty Diesel	0.1	0.4	0.7
EuroII Light duty Diesel	EuroI Light duty Diesel	0.7	0.9	1.1
EuroIII Light duty Diesel	EuroI Light duty Diesel	0.5	0.3	1.0
EuroIV Light duty Diesel	EuroI Light duty Diesel	0.7	0.9	0.8
EuroI Heavy Duty Gasoline	1988-90 HDGV (837)	1.0	1.0	1.0
EuroII Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	1.0	0.9	0.9
EuroIII Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7	0.7	0.7
EuroIV Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7	0.7	0.7
EuroV Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7	0.7	0.7
EuroI Heavy Duty Diesel	1988-90 HDDV (1073)	0.3	0.1	0.4
EuroII Heavy Duty Diesel	EuroI Heavy Duty Diesel	0.6	0.8	1.1
EuroIII Heavy Duty Diesel	EuroI Heavy Duty Diesel	0.9	1.2	0.8
EuroIV Heavy Duty Diesel	EuroI Heavy Duty Diesel	0.1	0.1	0.6
EuroV Heavy Duty Diesel	EuroI Heavy Duty Diesel	1.0	1.0	0.6

Emissions Effect of Various Control Technologies

Where data was not explicitly available, assumptions were made as to the effect of various control technologies to the base emission rates. The control technologies used in the IVE model include Exhaust Gas Recirculation (EGR), two and three way catalysts, hybrid technology, and for diesel vehicles a particulate trap and NOx control. The effect on VOC, CO, and NOx emissions applied in the model is shown in Table 4.

Table 4. Effect of Control Technology on Emissions to a Reference Vehicle used in the IVE model

Applies To	Reference Technology	VOC Ratio	CO Ratio	NOx Ratio
EGR	Gasoline	1	1	0.85
Diesel Particulate Trap	Diesel Uncontrolled	1	1	1
Diesel Particulate Trap/NOx Control	Diesel Uncontrolled	1	1	0.3
3 way Catalyst	no Catalyst	0.1	0.1	0.1
2 way	no Catalyst	0.1	0.1	1
Hybrid	SULEV	1	1	1

3. CO2 Base Emission Rates

Running CO2 emissions were calculated from the fuel economy and VOC, CO, and PM emissions using equation 8. Fuel economy estimates for gasoline and diesel vehicles were taken from EPA's newest documentation (EPA 2002 (28)). For small engines (motorcycles), fuel economy estimates were taken from Asian literature where small engines are more widespread and more recent data is available (GIA 2002, Kojima, 2002, Kojima 2000). For a first cut estimate for alternative fueled vehicles, CO2 estimates were assumed to be 95% of an equivalent gasoline vehicle. Hybrid vehicles were assumed to have a 20% reduction in fuel economy and CO2 emissions.

$$CO2=((1/(FE*1.6)*3.785*740*0.82)-CO*12/28-VOC*12/14-0.9*PM)*44/12 \quad \text{(Eq. 8)}$$

Where CO2, CO, VOC and PM are base emission rates in g/km
FE is the gasoline equivalent fuel economy in miles/gallon

There were no fuel estimates available for start emission rates, and CO2 emissions are not yet available in MOBILE6, therefore bag emission rates from CARB were used as the basis for estimating start emissions (ARB 2002). A CO2 start ratio was estimated from this data by subtracting the grams emitted in Bag 3 of the FTP from Bag 1 and then dividing by the running emissions in g/km. Running emissions were assumed to be Bag 2 of the FTP or the UC cycle, which ever was available. (There was not a significant difference in the start ratio using Bag 2 of the UC or the FTP.) A start ratio for gasoline vehicles of 0.74 and 0.23 for diesel vehicles was applied to the running CO2 emissions calculated for the IVE model. There was not a consistent variation between sizes or technologies within the same fuel type vehicles from the ARB dataset available, therefore the same value was used for different size and technologies.

4. Pb and SOx Base Emission Rates

Both lead and sulfur emissions are simply proportional to the quantity present in the fuel. The calculation for estimating lead emissions from lead content in the fuel is presented in Equation 9. The calculation for estimating sulfur emissions from lead content in gasoline fuel is presented in Equation 10. For other fuels, the fuel converted to gasoline equivalent fuel usage and these equations are applied. For the base emission rates, it is assumed that there is no lead present in the fuel, and therefore there are no lead emissions. For sulfur, it is assumed there is 300 ppm present in gasoline fuel and 500 ppm in diesel fuel. For alternative fueled vehicles, it was assumed that there is no lead and 5 ppm sulfur.

$$Pb=\text{g lead content/L fuel}*(CO2*12/44+CO*12/28)/(740*0.82) \quad \text{(Eq. 9)}$$

$$SO2=\text{sulfur content (ppm)}/10^6*(CO2*12/44+CO*12/28)/(0.82) \quad \text{(Eq. 10)}$$

5. PM, NH3, 1-3 butadiene, acetaldehyde, formaldehyde, and evaporative VOC Base Emission Rates

Particulate matter, ammonia, 1-3 butadiene, acetaldehyde, formaldehyde, and evaporative emissions are based on MOBILE6 results for the twenty eight vehicle types modeled in MOBILE. Emissions from these technologies were mapped to all of the IVE technologies. PM, ammonia, and evaporative emissions from ethanol, propane, and methanol vehicles were assumed to have the same emissions as an equivalent gasoline vehicle. Other emission effects for alternative fueled vehicles were obtained from the Department of Energy (DOE 1996) (Table 5). In general, the emissions have a wide variation and so some assumptions were necessary in determining emission rates.

Particulate trap technology applied to diesel vehicles were assumed to have a 88% reduction in particulate emissions only. For Euro standard vehicles, the same approach as the criteria pollutants was used to estimate ammonia, 1,3 butadiene, acetaldehyde, formaldehyde, and evaporative emissions (Table 5).

COPERT IV provides enough information in PM emissions for gasoline and diesel vehicles, (Table 6). As more documentation and data becomes available, it will be possible to estimate these emissions directly.

Table 5. Ratio of Emissions from Alternative Fueled Vehicles to Gasoline Vehicle used in the IVE model

Pollutant	Ethanol	Ethanol retrofit	Natural Gas	Natural Gas Retrofit	Propane	Propane Retrofit
PM	1	1	.05	0.9	1	1
NH3	1	1	1	1	1	1
1,3 butadiene	0.3	0.3	0.01	0.01	0.01	0.01
Formaldehyde	1.7	1.7	1.16	1.16	1.16	1.16
Acetaldehyde	33	33	0.35	0.35	0.35	0.35
Benzene	0.4	0.4	0.03	0.03	0.03	0.03
EVAP	1	1	1	1	1	1

Table 6. Ratio of Emissions from European Vehicles to Gasoline Vehicle used in the IVE model

Applies To	Reference Technology	PM Ratio
EuroI Light duty Gasoline	Tier 0	1.2
EuroII Light duty Gasoline	EuroI Light duty Gasoline	1.0
EuroIII Light duty Gasoline	EuroI Light duty Gasoline	0.4
EuroIV Light duty Gasoline	EuroIII Light duty Gasoline	1.0
EuroI Light duty Diesel	Tier 0 LDDV	1.0
EuroII Light duty Diesel	EuroI Light duty Diesel	0.8
EuroIII Light duty Diesel	EuroI Light duty Diesel	0.6
EuroIV Light duty Diesel	EuroI Light duty Diesel	1.0
EuroI Heavy Duty Gasoline	1988-90 HDGV (837)	1.0
EuroII Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.6
EuroIII Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7
EuroIV Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7
EuroV Heavy Duty Gasoline	EuroI Heavy Duty Gasoline	0.7
EuroI Heavy Duty Diesel	1988-90 HDDV (1073)	0.4
EuroII Heavy Duty Diesel	EuroI Heavy Duty Diesel	0.4
EuroIII Heavy Duty Diesel	EuroI Heavy Duty Diesel	1.1
EuroIV Heavy Duty Diesel	EuroI Heavy Duty Diesel	0.2
EuroV Heavy Duty Diesel	EuroI Heavy Duty Diesel	1.0

6. N20 Base Emission Rates

Very limited data exists on nitrous oxide emissions from vehicles. Two studies by the EPA and CE-CERT were used as the basis of the emission factors for nitrous oxides (CE-CERT 2001, CE-CERT 2002, Michaels 1998). The rates for each technology can be seen in the excel Base Emission Rate document.

7. Benzene and Methane Base Emission Rates

Standard Gasoline and Diesel Vehicles

Benzene and methane emissions were assumed to be proportional to the VOC emissions, and the values vary only by fuel type and weight class. Benzene emissions were assumed to be 5.27% of the VOC emissions for light duty gasoline vehicles, 2.1% for light duty diesel vehicles, 5.21% for heavy duty gasoline vehicles, and 1.05% for heavy duty diesel vehicles (DOE (1-10),CE-CERT 2001).

Emissions from Alternative Fueled and European Vehicles

Emissions data from some alternative fueled vehicles were used to develop emission rates as a function of a comparable gasoline vehicle. The main source of information used to develop emissions data for alternative fueled vehicle was the Department of Energy (Andress 2000, NREL 31-38, DOE 1-10). In general, the emissions have a wide variation and so some assumptions were necessary in determining emission rates. The emission ratio for alternative fueled vehicles to a comparable gasoline vehicle is shown in Table 6. Ethanol, methanol, and propane vehicles were assumed to have zero benzene emissions. Methane emissions were assumed to be 20% of VOC emissions for all gasoline vehicles, 900% for natural gas and propane vehicles, 40% for ethanol vehicles, and 0% for diesel vehicles.

Table 6. Ratio of Emissions from Alternative Fueled Vehicles to Gasoline Vehicle used in the IVE model

Pollutant	Ethanol	Ethanol retrofit	Natural Gas	Natural Gas Retrofit	Propane	Propane Retrofit
Benzene	0.4	0.4	0.03	0.03	0.03	0.03
CH4	2	2	13	13	1	1

Effect of Standards and Control Technology

There was assumed to be no effect of the various control technologies on benzene and methane emissions. In addition, the European standard vehicles were assumed to have emissions equivalent to the comparable vehicles.

8. Comparison of Predicted Emissions with Other Data Sources

It is useful to compare emissions predictions from the IVE model to other existing models. It is expected that the IVE and MOBILE6 emissions predictions should be similar since much of the data used in the IVE development is from MOBILE. However, it is not a direct comparison. The emission prediction process in these models do not predict only the base emission rate, there are inherent "corrections" applied in the model, although where possible these corrections have been minimized. Nevertheless, it is still valuable to see how other models compare both in terms of absolute values of emissions.

In addition to MOBILE, two other models were used in this comparison: ARB's EMFAC2002 model, and the University of California's Comphrensive Model Emissions Model (CMEM) (CE-CERT 1998, ARB 2002). EMFAC2002 is the California Air Resources Boards most recent mobile source emissions inventory model. The CMEM model is designed primarily to compare emissions differences on microscale level of driving behavior, and at this stage, is limited to modeling only light duty gasoline vehicles.

Figures 1 through 6 show a comparison of the base emission rates used in the IVE model with MOBILE6 output average emission rates (EPA 2002 (23)). The results are presented as a ratio of the emissions from the model listed divided by the emissions from an equivalent vehicle scenario in MOBILE6 (shown in the IVE rows). Table 7 lists the emissions predicted from a moderately aged vehicle of a specific technology. Table 8 lists the emissions predicted from a calendar year 2001 fleet (with and without light duty vehicle emissions). The most compatible options in the MOBILE6 file were selected for this comparison, including no inspection maintenance, average minimum and maximum temperature of 75 degrees Fahrenheit, average speed of the LA4 cycle, and low altitude. However, these values can not be compared exactly to the IVE's base emission rates because many additional parameters are applied in the MOBILE6 model, including some corrections inherent in the model, and additional differences related to US specific programs, such as the variation of emissions with specific (non-technology related) standards. The purpose of these tables is for a rough comparison of order of magnitude and relative variation between vehicle types.

From these results, these vehicle classes show consistent trends with the MOBILE output. In general, IVE emissions range from about 90 to 110% of MOBILE emissions for individual vehicle technologies. Comparisons with the other two models are not as close to the MOBILE emissions for both start and running. Start emission rates from heavy duty vehicles do not exist in the MOBILE model so these columns are blank. Additionally, start and heavy duty emissions in CMEM do not exist. For the entire fleet comparison, IVE predictions are within 10% of the MOBILE prediction.

Table 7. Individual Vehicle Type Emissions Comparison: Ratio Of Emissions to M6 Comparable Emissions

Vehicle Type and Model Used in Comparison		Running Emission Ratio			Start Emission Ratio		
		CO	HC	NOx	CO	HC	NOx
Carbureted Non Catalyst Light Duty Vehicle	IVE	1.0	1.0	1.1	1.0	1.0	1.0
	CMEM	1.7	3.0	0.4			
	EMFAC	2.3	1.8	1.1	0.1	0.2	0.2
Carbureted 2 way Catalyst Light Duty Vehicle	IVE	1.0	1.3	1.0	1.0	1.0	1.0
	EMFAC	1.6	0.7	0.7	0.2	0.2	0.2
Single Point Fuel Injected 3 way Catalyst Light Duty Vehicle	IVE	1.0	1.1	1.0	1.4	0.9	0.8
	EMFAC	1.4	2.3	1.3	0.3	0.4	0.8
Multipoint Fuel Injected 3 Way Catalyst Light Duty Vehicle	IVE	1.0	1.0	1.1	0.8	0.9	0.5
	EMFAC	0.8	1.3	0.9	0.3	0.4	0.2
Tier 0 Light Duty Vehicle	IVE	1.0	1.0	1.0			
	CMEM	0.3	0.4	0.2			
	EMFAC	0.5	0.9	0.7			
Tier 1 Light Duty Vehicle	IVE	1.1	1.0	1.0	1.0	1.0	1.0
	EMFAC	0.4	0.4	0.4	0.2	0.2	0.6
No Control Heavy Duty Diesel Vehicle	IVE	0.9	1.0	1.1			
	EMFAC	1.8	1.2	1.2			
Moderate Controlled Heavy Duty Diesel Vehicle	IVE	0.9	1.0	1.0			
	EMFAC	2.2	2.3	0.8			

Table 8. Calendar Year 2001 Fleet-wide Emissions Comparison: Ratio Of Emissions to M6 Comparable Emissions

Vehicle Fleet and Model Used in Comparison		Running Emission Ratio		
		CO	HC	NOx
CY 2001 US Fleet	IVE	1.1	1.0	0.9
	EMFAC	1.2	1.4	0.5
CY 2001 US HD Fleet	IVE	0.8	1.0	0.9
	EMFAC	3.9	2.6	1.2

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Appendix A. Base Emission Rates Used in the IVE model

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