

Emission Rate Approach for Evaluating the Differences in Emissions Between CNG and Diesel Buses

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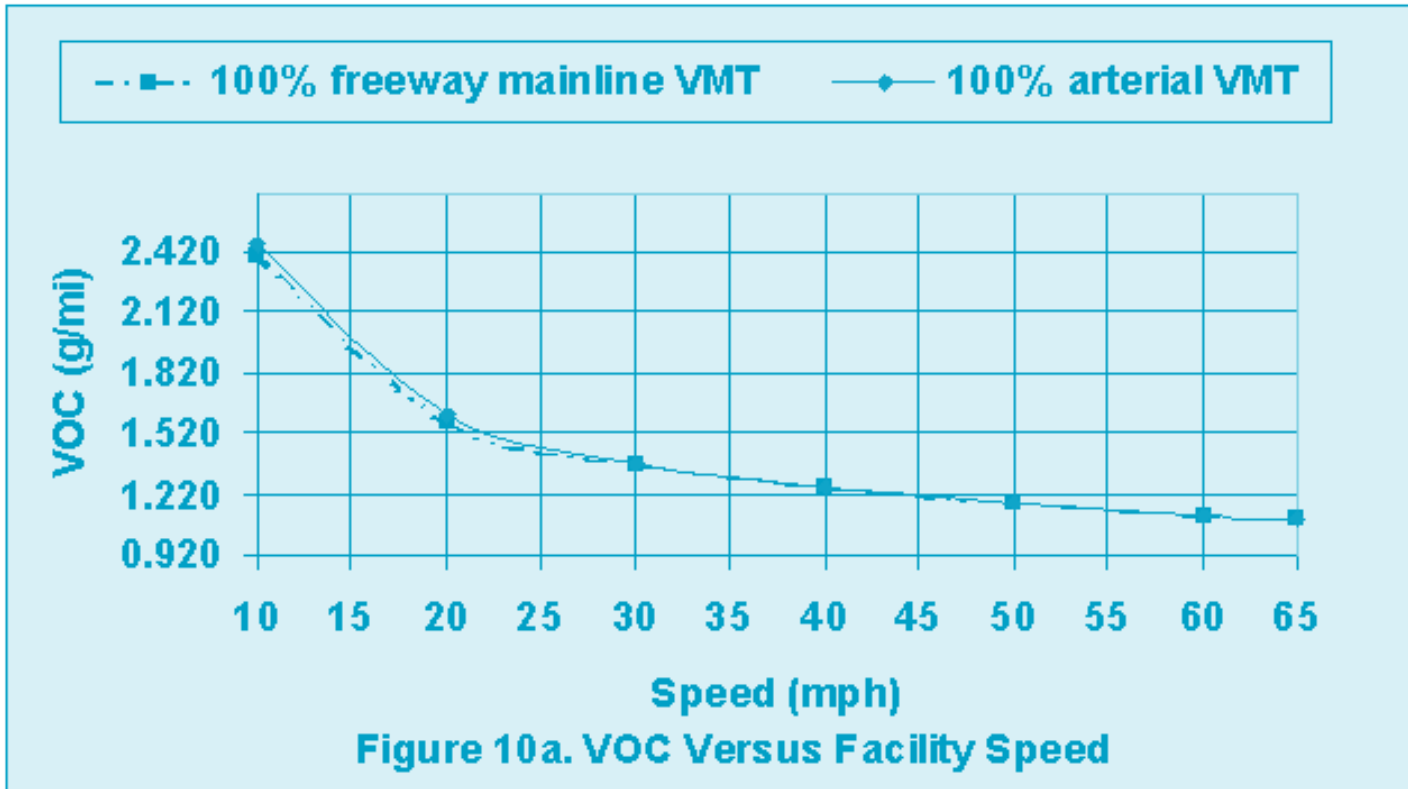
Federal Highway Administration

Background Information

(MOBILE vs. MOVES)

MOBILE6.2 Modeling Approaches

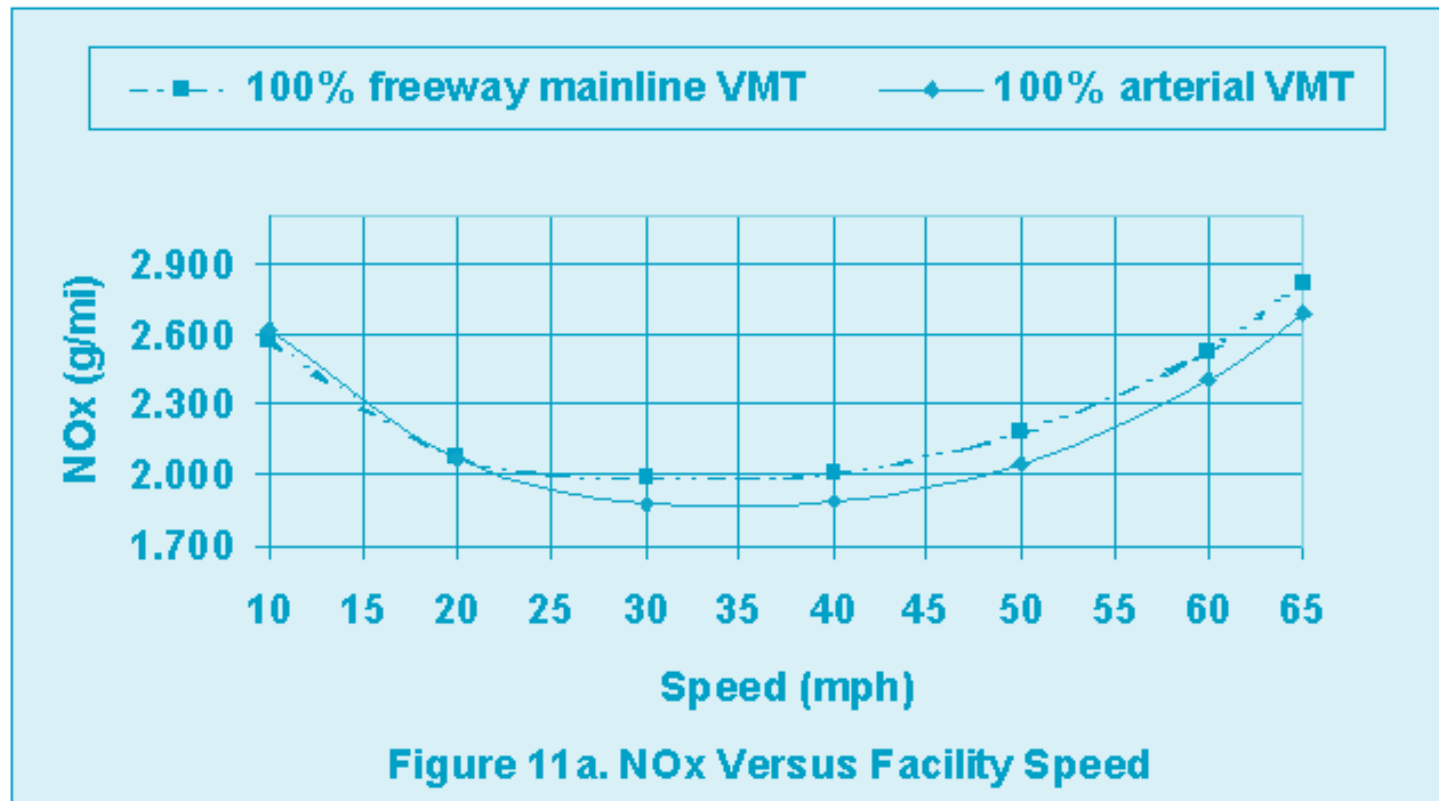
HC Curve



Source: Tianjia Tang, Ph.D., FHWA

MOBILE6.2 Modeling Approaches

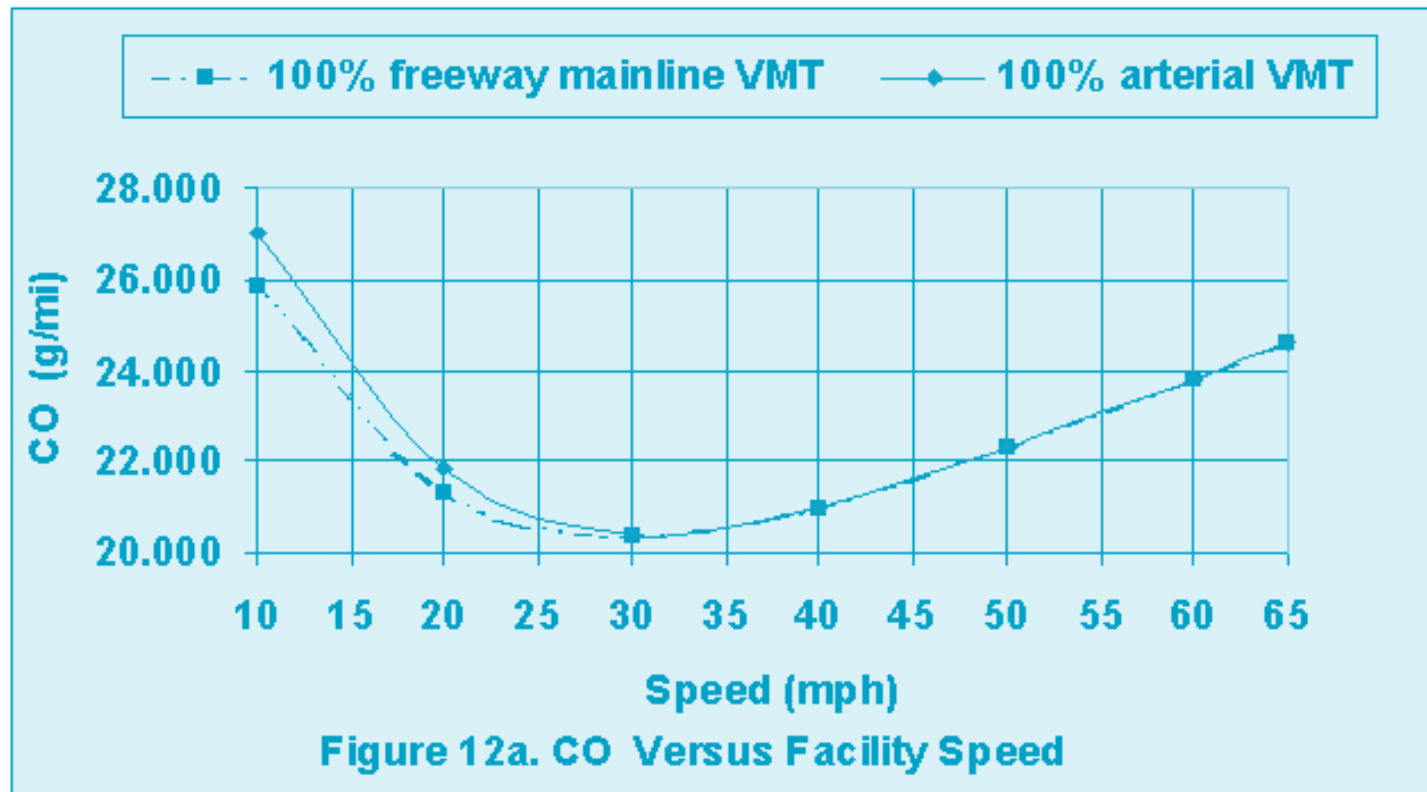
NOx Curve



Source: Tianjia Tang, Ph.D., FHWA

MOBILE6.2 Modeling Approaches

CO Curve



Source: Tianjia Tang, Ph.D., FHWA

How About Start & Evaporative Emissions?

- Grams per VMT (Vehicle Miles Traveled)
- Grams per engine starts
- Default: combination of both (g/mile)
- Higher the VMT, higher the start & evaporative emissions

MOVES Modeling Approaches

(Emission Processes)

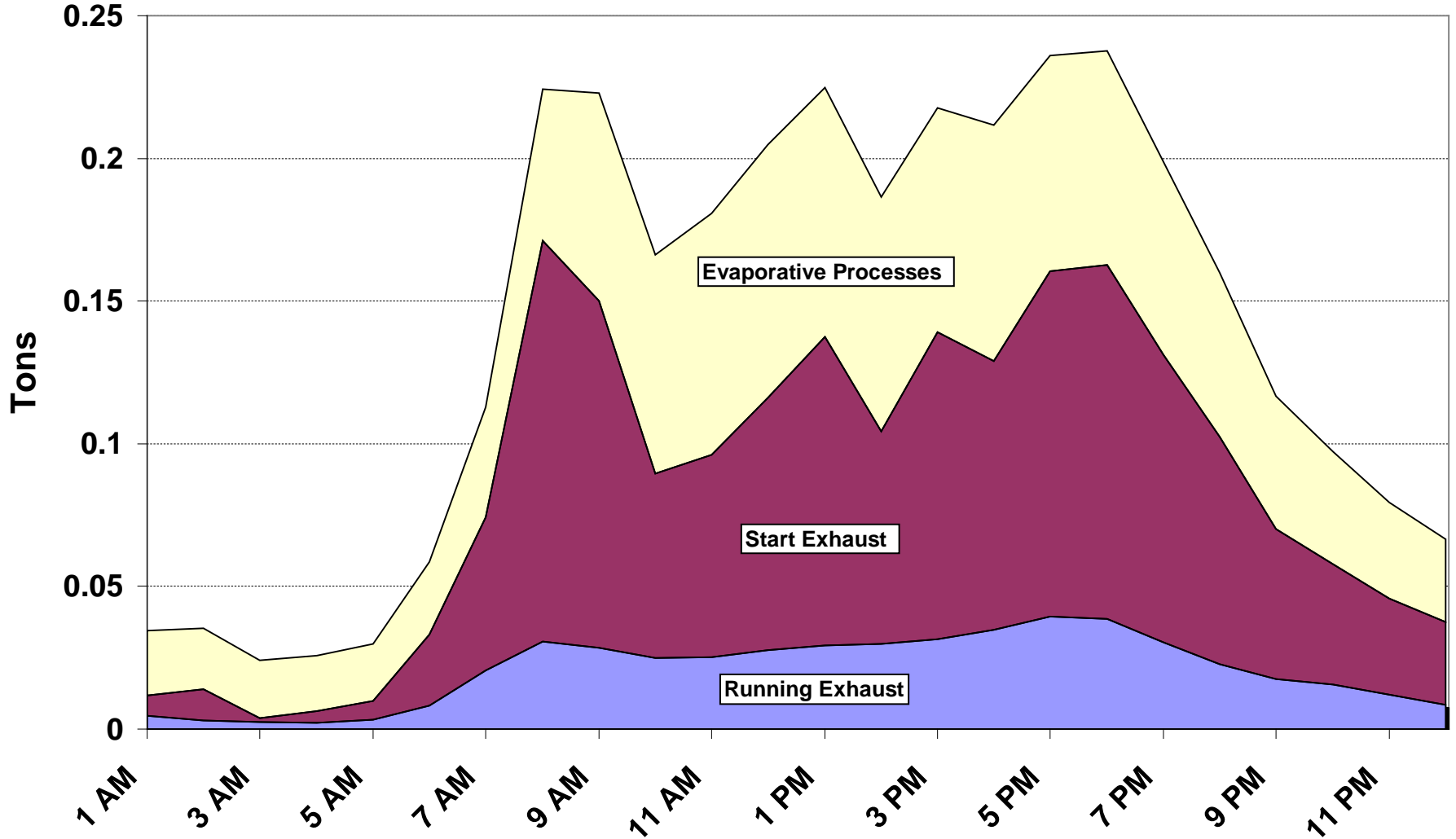
Running

Start

Evaporative Processes

- Crankcase
- Tire Wear
- Brake Wear
- Extended Idle
- Life Cycle Processes

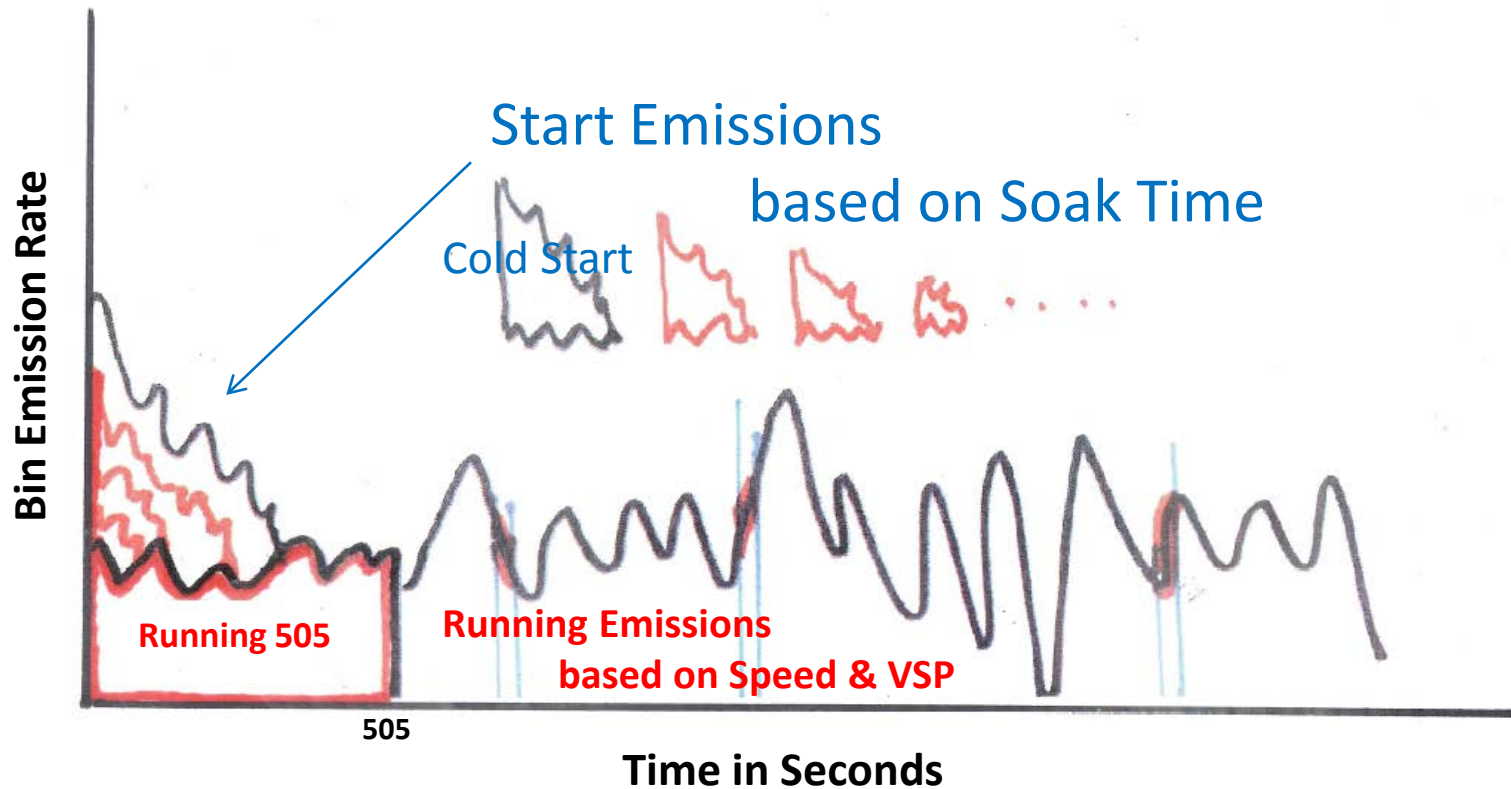
Weekday Passenger Car HC Emissions MOVES Projection - Salt Lake County, July 2020



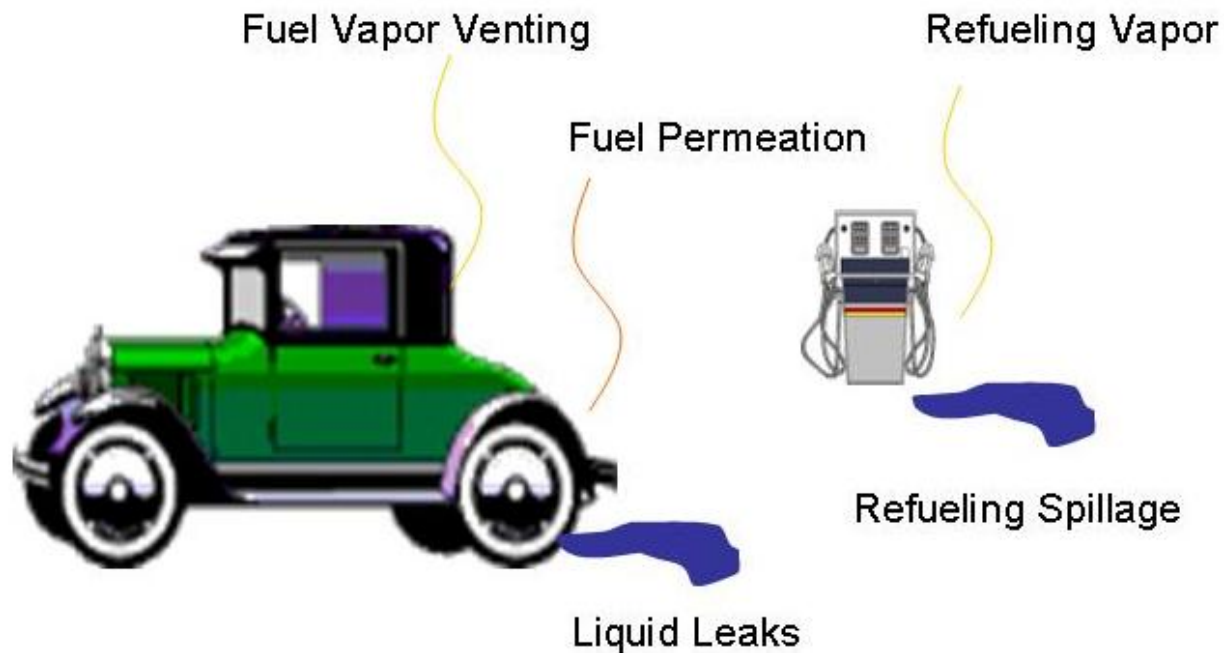
Source: John Koupal, EPA

MOVES Modeling Approaches

(Start and Running Emissions)



MOVES Modeling Approaches (Evaporative Emissions)



Source: US EPA

Emission Processes and Mobile Source Activities

Emission Process	Activity Basis
Running Exhaust, Brake Wear, Tire Wear, Running Loss, Crankcase, Extended Idle	Source Hours Operating (SHO)
Start Exhaust	Number of Starts
Diurnal, Hot Soak	Source Hours Parked (SHP)
Resting Loss, Manufacture/Disposal	Source Hours (SH)
Refueling, Well-To-Pump	Energy (Fuel) Used

Emission Processes vs. Rates (MOVES vs. MOBILE6)

Emission Processes	MOVES			MOBILE6
	Rates/Distance	Rates/Vehicle	Rates/Profile	Rates/Distance
Running Exhaust	Grams/Mile			Grams/Mile
Start Exhaust		Grams/Vehicle		Grams/Mile
Evap Permeation	Grams/Mile	Grams/Vehicle		Grams/Mile
Evap Fuel Vapor Venting	Grams/Mile		Grams/Vehicle	Grams/Mile
Evap Fuel Leaks	Grams/Mile	Grams/Vehicle		Grams/Mile
Crankcase Running Exhaust	Grams/Mile			Grams/Mile
Crankcase Start Exhaust		Grams/Vehicle		NA
Crankcase Extended Idle Exhaust				NA
Refueling Displacement Vapor Loss				Grams/Mile
Extended Idle Exhaust		Grams/Vehicle		Included in the HDDV8b Class

Running Emissions

Grams/Mile by Temperature

Running Emissions

(County Data Manager)

- Facility based drive schedules (cycles)
 - Urban Freeway, Urban Non-freeway, Rural Freeway, Rural Non-freeway
- Emission rates option
 - grams/mile by temp
- Reason to believe that the drive schedules of your projects are significantly different from the MOVES default schedules, **Project Level Analyses are required**

MOVES Drive Schedules

Drive Schedule Set	DriveScheduleName(ID)	AverageSpeed (mph)
Light-Duty Non-Freeway	Low Speed 1 (101)	2.5
	New York City (102)	7.1
	Non-Freeway LOS EF (103)	11.6
	Non-Freeway LOS CD (104)	19.2
	Non-Freeway LOS AB (105)	24.8
Light-Duty Freeway	Freeway LOS G (151)	13.1
	Freeway LOS F (152)	18.6
	Freeway LOS E (153)	30.5
	Freeway LOS D (154)	52.9
	Freeway LOS AC (155)	59.7
	Freeway High Speed 1 (156)	63.2
	Freeway High Speed 2 (157)	68.2
	Freeway High Speed 3 (158)	76
Medium Heavy-Duty Non-Freeway	Freeway Ramp (199)	34.6
	5 mph (201)	4.6
	10 mph (202)	10.7
	15 mph (203)	15.6
	20 mph (204)	20.8
	25 mph (205)	24.5
	30 mph (206)	31.5
Medium Heavy-Duty Freeway	30 mph (251)	34.4
	40 mph (252)	44.5
	50 mph (253)	55.4
	60 mph (254)	60.4
	Ramp (299)	31
Heavy Heavy-Duty Non-Freeway	5 mph (301)	5.8
	10 mph (302)	11.2
	15 mph (303)	15.6
	20 mph (304)	19.4
	25 mph (305)	25.6
	30 mph (306)	32.5
Heavy Heavy-Duty Freeway	30 mph (351)	34.3
	40 mph (352)	47.1
	50 mph (353)	54.2
	60 mph (354)	59.4
	Ramp (399)	25.3
Bus Non-Freeway	Low Speed Urban (401)	15*
	30 mph flow (402)	30*
	45 mph flow (403)	45*
Refuse Truck	Refuse Truck Urban (501)	2.2

* Speed represents average of traffic the bus is traveling in, not the average speed of the bus, which is lower due to stops.

Modeling Area

MOVES - ID 4574748199528094994

File Edit Pre Processing Action Post Processing Tools Settings Help

Geographic Bounds (highlighted in red)

Region:

- Nation
- State
- County
- Zone & Link
- Custom Domain

States:

- IDAHO
- ILLINOIS
- INDIANA
- IOWA
- KANSAS
- KENTUCKY
- LOUISIANA
- MAINE
- MARYLAND

Counties:

- INDIANA - La Porte County
- INDIANA - Lagrange County
- INDIANA - Lake County
- INDIANA - Lawrence County
- INDIANA - Madison County
- INDIANA - Marion County
- INDIANA - Marshall County
- INDIANA - Martin County

Selections:

- INDIANA - Lake County

Buttons: Select All, Add, Delete

Domain Input Database

The County domain scale requires a database of detailed data.

Server: localhost

Database: [Dropdown]

Buttons: Enter/Edit Data, Refresh

Geographic Bounds Requirements

Please select a domain database.

Create new RunSpec

Start Emissions

Grams/Vehicle by Hours

Start Emissions

□ Engine Starts per day per vehicle (autos & trucks)

– MOBILE6

- Baltimore, Spokane & Atlanta

– MOVES

- Baltimore, Spokane, Atlanta, Minneapolis, Knoxville & Las Vegas

□ Engine Temperatures

– Soak Distribution

- Differs by hour

Start per Day by Vehicle Types

(MOVES vs. MOBILE6)

Source Type	Draft MOVES2009 Weekday	Draft MOVES2009 Weekend	MOBILE6*
Motorcycles	0.78	0.79	1.35
Passenger Cars	5.89	5.30	6.75
Passenger Trucks	5.80	5.06	7.38
Light Commercial Trucks	6.05	5.47	7.38
Intercity Buses	2.77	0.88	6.88
Transit Buses	4.58	3.46	6.88
School Buses	5.75	1.26	6.88
Refuse Trucks	3.75	0.92	6.88
Single-unit short-haul trucks	6.99	1.28	6.88
Single-unit long-haul trucks	4.29	1.29	6.88
Motor homes	0.57	0.57	6.88
Combination short-haul trucks	5.93	1.16	6.88
Combination long-haul trucks	4.29	1.29	6.88

* Note, MOBILE6 distinguished "starts" and "trips." MOVES does not, but MOVES does include some very short "trips."

Operating-Mode Definitions for Start Exhaust Emissions

opModeID	Description	Soak Period (min)¹
101	“hot start”	≤ 6
102		6 - 30
103		30 – 60
104		60 – 90
105		90 – 120
106		120 – 360
107		360 - 720
108	“cold start”	≥ 720

¹ Defined in terms of *lower-bound* \leq soak period $<$ *upper-bound*.

Number of Vehicle Starts

- No seasonal variations
- Default number of starts per vehicle
 - Check with local data
 - Alternative source of data

Number of Engine Starts per Day

(Local Sources of Data)

- TDF model O/D trip table
 - Provides approximate number of “engine starts”
 - Seasonal variation
 - Reflective to: annual growth, transportation projects/policies etc.
 - Number of auto trips per day < number of engine starts per day
 - Provides good information where starts are located
- O/D trip table approach may provide better local number of engine starts than the MOVES model defaults
- Regionally non-significant projects can not be modeled through TDF model. Use project level analysis methodologies

On Road Vehicle Equipment

The screenshot shows the MOVES software interface with the following components:

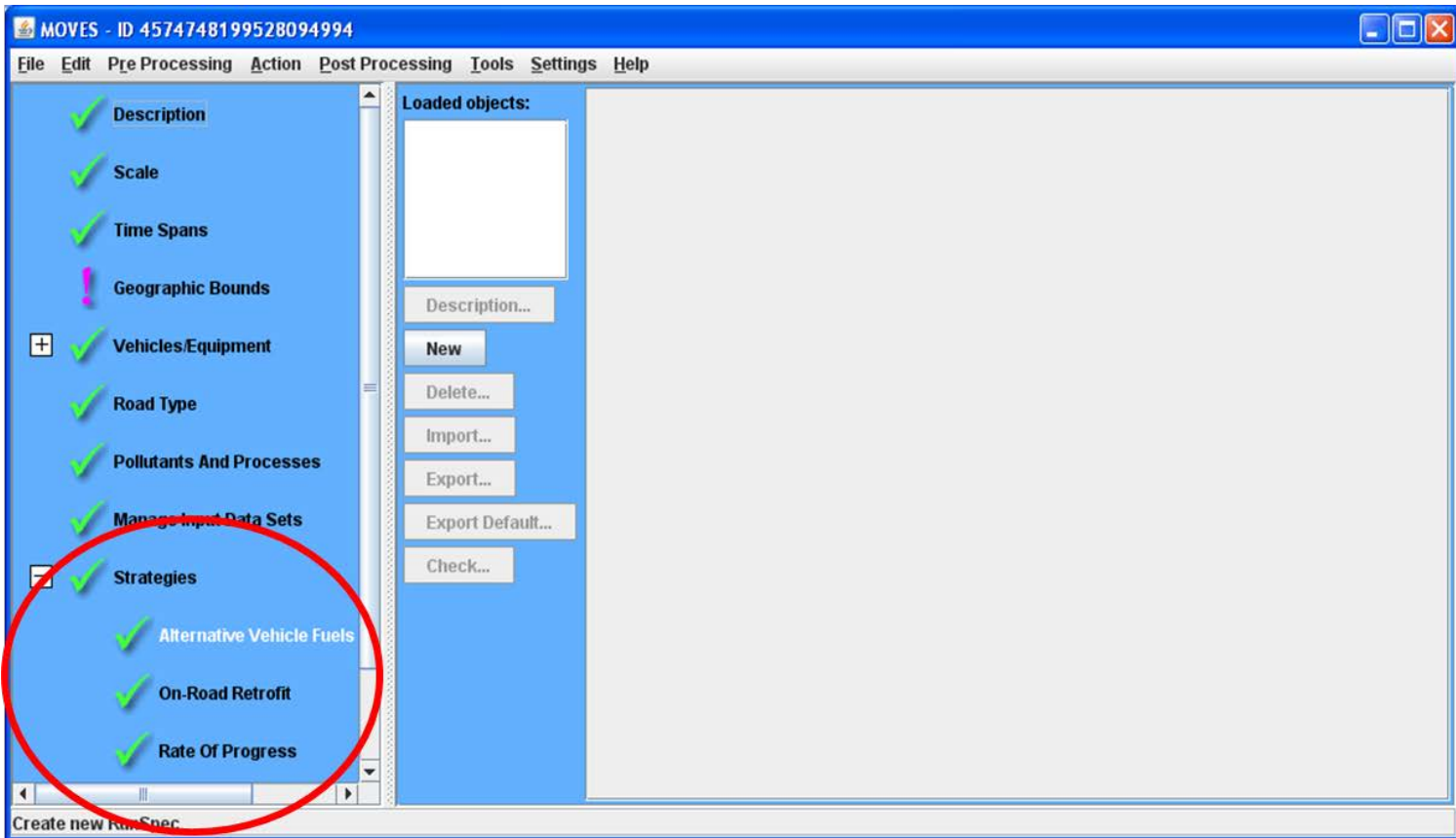
- Window Title:** MOVES - ID 4574748199528094994
- Menu Bar:** File, Edit, Pre Processing, Action, Post Processing, Tools, Settings, Help
- Left Sidebar (Navigation):**
 - Description (checked)
 - Scale (checked)
 - Time Spans (checked)
 - Geographic Bounds (warning icon)
 - Vehicles/Equipment (minus icon, checked)
 - On Road Vehicle Equipment (checked, circled in red)**
 - Road Type (warning icon)
 - Pollutants And Processes (warning icon)
 - Manage Input Data Sets (wavy icon)
 - Strategies (plus icon, checked)
 - Output (plus icon, warning icon)
 - Advanced Performance Features (checked)
- Main Content Area:**

Fuels:	Source Use Types:	Selections:
Compressed Natural Gas (CNG)	Combination Long-haul Truck	Diesel Fuel - Light Commercial Truck
Diesel Fuel	Combination Short-haul Truck	Diesel Fuel - Passenger Car
Electricity	Intercity Bus	Diesel Fuel - Passenger Truck
Gasoline	Light Commercial Truck	Gasoline - Light Commercial Truck
Placeholder Fuel Type	Motor Home	Gasoline - Passenger Car
	Motorcycle	Gasoline - Passenger Truck
	Passenger Car	
	Passenger Truck	
	Refuse Truck	
	School Bus	
	Single Unit Long-haul Truck	
	Single Unit Short-haul Truck	
	Transit Bus	
- Buttons:** Select All (under Fuels), Select All (under Source Use Types), Delete (under Selections), Add Fuel/Type Combinations
- Status Bar:** Create new RunSpec

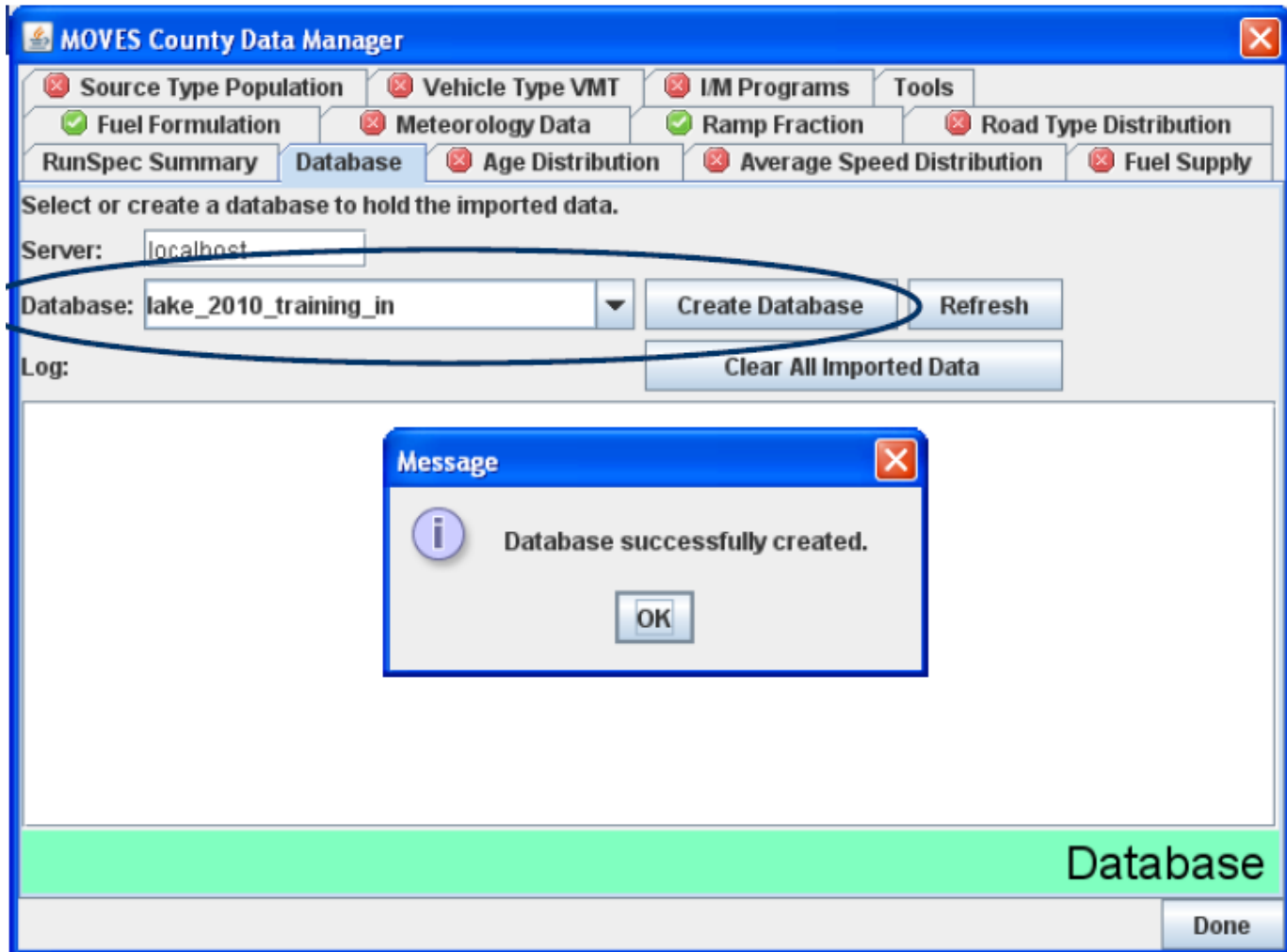
Caution

- When transit buses are selected, default database allocates some VMT to Compressed Natural Gas (CNG) transit buses
 - Therefore, users should either select the CNG transit bus combination; or
 - Edit the AVFT input (covered in later session) so that no VMT is allocated to CNG buses.
 - If one of these approaches is not used, some VMT assigned to buses (HPMS class 40) will be “lost”

MOVES Strategies Option (AVFT, Retrofit, ROP)



County Data Manager

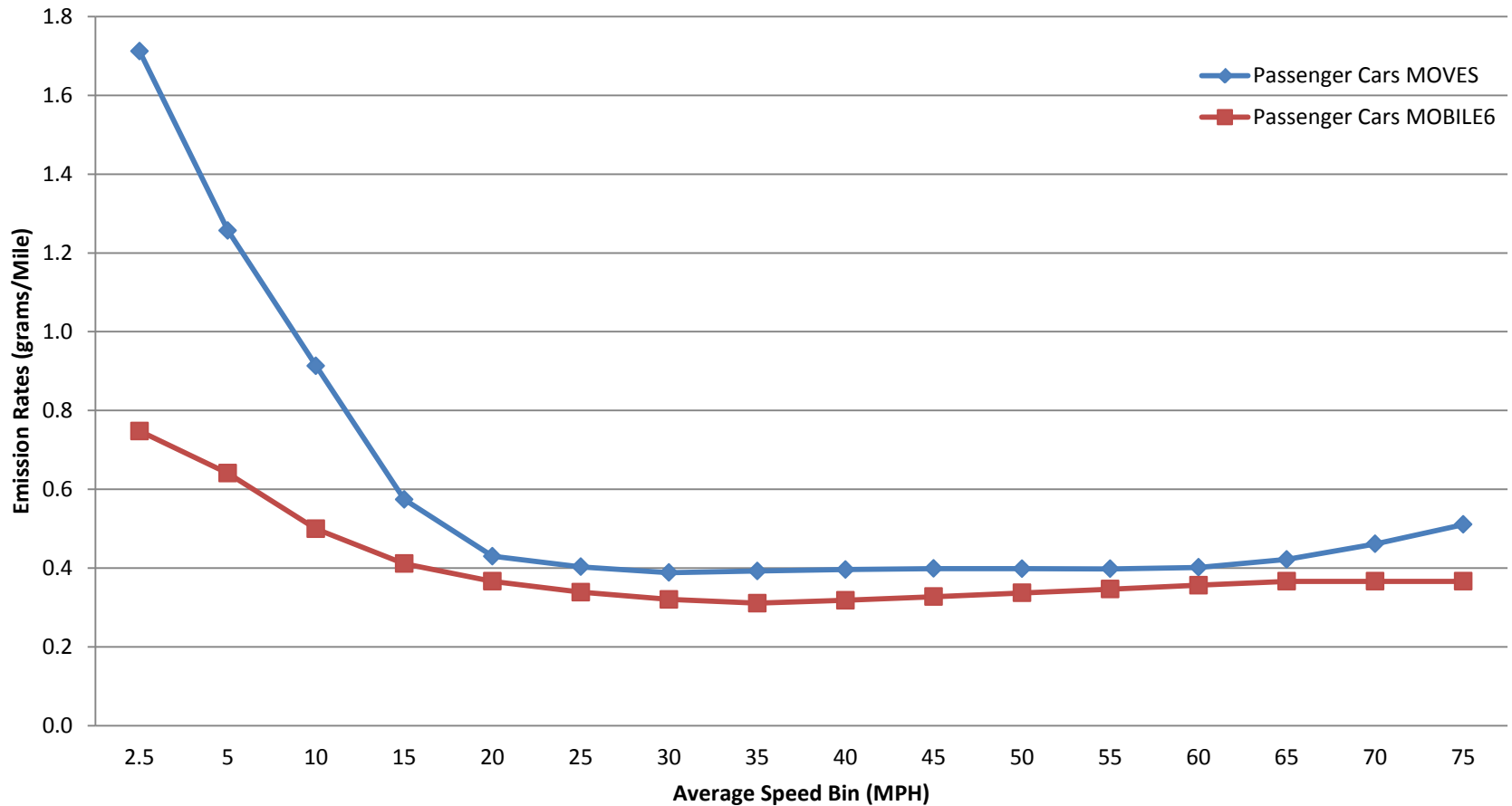


National Trend on Vehicle Age

(BTS Data)

- In 2007 the median age for automobiles was 9.2 years, a significant increase over 1990 (6.5 years)
- As SUVs are part of a relatively new consumer trend originating mostly in the 1990s, SUVs had the lowest mean age of any body style (6.1 years in 2007).
- Between 2007 to 2008 alone, the median age of passenger cars increased to 9.4 years, and that the median age for light trucks increased from 7.1 years in 2007 to 7.5 years in 2008 (RL Polk, March 2009)

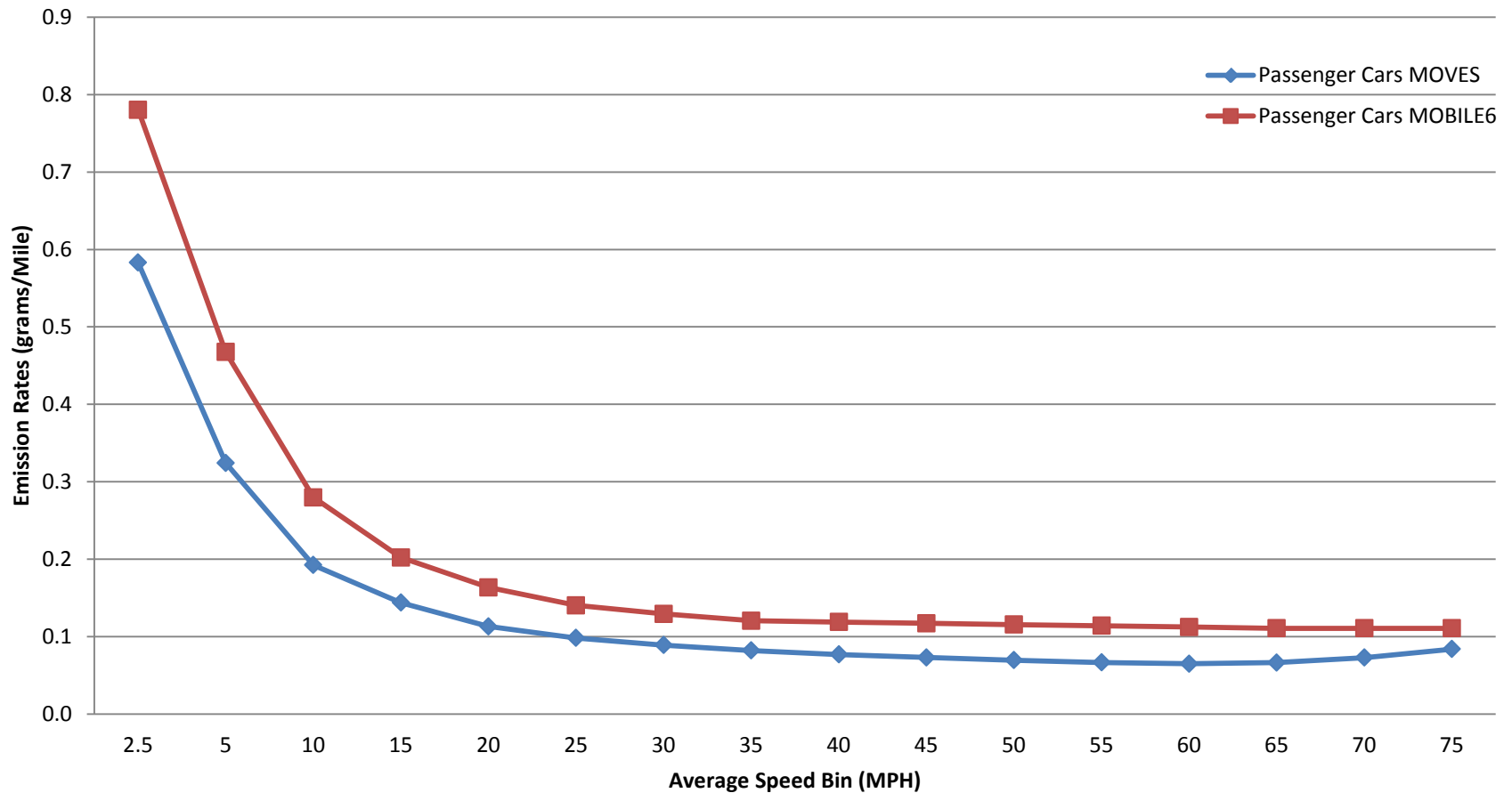
NOx Emission Rates for Passenger Vehicles (MOVES vs. MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

VOC Emission Rates for Passenger Vehicles

(MOVES Vs MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

Evaporate Emissions Only for HC

Grams/Profile

Modeling Emissions CNG vs. Diesel Buses

Replace old technology vehicles with new technology vehicles:

Often this is a replacement of urban diesel buses with cleaner fuel vehicles such as CNG buses.

Add new CNG Vehicles

- 1) Determine the daily bus service frequency (F: one-way) and route length (L)
- 2) Run MOVES by using Alternative Fuel Option initiating with base (before) conditions: no CNG Buses
- 3) Run MOVES by using Alternative Fuel Option initiating with after conditions: with CNG Buses

Conventional bus emission factor = CBEF in grams/mile

CNG bus emission factor = CNGBEF

Emission benefits = $F \times L \times (CBEF - CNGBEF)$

Add new CNG Vehicles

- 1) Determine the daily bus service frequency (F: one-way) and route length (L)
- 2) Allocate F into hourly bases: f
- 3) Allocate L into hourly bases: l
- 4) Run MOVES by using Alternative Fuel Option initiating with base (before) conditions: no CNG Buses
- 5) Run MOVES by using Alternative Fuel Option initiating with after conditions: with CNG Buses

Conventional Bus Emission factor = CBEF in grams/mile

CNG bus emission factor = CNGBEF

Daily Running Emission benefits = $\sum f \times l \times (CBEF - CNGBEF)$

How about start emissions?