MOVES
Status and Overview

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FACA Modeling Workgroup Meeting
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MOVES

- **MOtor Vehicle Emission Simulator**
- **State-of-the-art modeling framework**
- **Will replace current models (MOBILE & NONROAD) and expand capabilities**
- **Designed to allow easier incorporation or large amounts of in-use data from a variety of sources**
  - MOBILE structure limited agility in incorporating new data
- **New software framework**
  - MOBILE code has been built on since 1978

MOVES

On-Road Development Team

Team Leaders

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Team

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Design & Coding Support

Cimulus Software, Inc.

ECO

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MOVES

Planned MOVES Versions

- ✓ **MOVES2004 released**
  - On-road Energy Consumption, GHGs, Life Cycle Analysis
- **MOVES2006**
  - Adds on-road HC, CO, NOx and PM
- **MOVES2007**
  - Adds on-road Toxics, NH_3, SO_2
  - Final MOBILE6.2 replacement
- **MOVES2008 and beyond**
  - Off-road implementation
    - Will include aircraft, commercial marine, locomotive
  - Updates to on-road model with new data

MOVES2006 Status

- Initial draft complete; internal testing underway
- Stated goal has been to release as draft at end of the year…

Change in Plan

- **Now that we have a draft model it is clear more time is needed to resolve key technical issues**
  - Light duty HC/CO/NOx: how to get representative sample
  - Gasoline PM:
    - how to integrate and project Kansas City results
    - How to develop modal rates
  - Heavy-Duty: how to treat potentially unrepresentative datasets
  - I/M: how to determine I/M benefits under “simplified” approach
- **We would like to engage stakeholders on these issues before putting out a model**

MOVES

Current Thinking on MOVES Rollout Process

- Instead of releasing a draft model all at once, publish technical reports on specific issues for stakeholder comment / formal peer review over the next 6 months (schedule TBD)
- By the end of the year put out a “demonstration” version without data tables that are planned for separate publication
- As reports are published provide the data tables to make that area of the model “work”

Purpose of Today's Meeting

- EPA present details on data, analyses current and planned, and issues
- Looking for technical feedback on data and methodologies
- Give a "preview" for review period
- Results are in flux and not ready for prime time

MOVES

MOVES – what's different?

- **Inventory estimation**
  - MOBILE estimates emission factors (grams/mile)
- **Designed for analysis at multiple scales**
- **Emission rates on modal basis**
  - MOBILE rates based on aggregate driving cycles
- **Software framework**
  - Relational database structure allows easier updates
  - Graphical User Interface (GUI) allows easier use
  - Allows multiple-computer processing if desired
- **New data and methodologies**

MOVES Software Framework

- **Language: Java™**
- **Fleet, activity, emission rate data stored in relational database**
  - Open-source relational database system (MySQL™)
  - Enables modularity, easy updates with new data
- **Graphical user interface or batch mode**
- **Designed for single or multiple-computer processing**
- **Output reporting and visualization**

MOVES will be largely shaped by data collected since release of MOBILE6

- **Activity**
  - In-use vehicle trip patterns
  - VIUS2002
- **Light-duty vehicles**
  - Thousands of in-use vehicles from I/M programs
  - Kansas City gasoline PM study
  - Remote Sensing Data
- **Heavy-duty vehicles**
  - 100 in-use vehicles from WVU (E-55 plus)
    - MOBILE6 based on engine certification data

Quality Measures

- **Model Validation**
  - MOVES2004: compare with fuel sales (< 5% nationally)
  - MOVES2006 and later: compare with independent datasets, tunnel studies, ambient ratios
- **Uncertainty Estimation**
  - MOVES2006 will include Monte Carlo simulation
  - Uncertainties of emission rates populated initially; placeholders for fleet and activity uncertainties as well
- **Peer Review**
  - Paid review via EPA guidelines
  - FACA Modeling Workgroup
  - Stakeholder and public review
  - Technical articles and conference presentations

National Results

U.S. Annual Highway Fuel Consumption Estimates from FHWA and MOVES2004 (billion gallons)

Year	Gasoline			Special Fuel		
	FHWA	MOVES	% Diff	FHWA	MOVES	% Diff
1999	128.7	126.6	-2%	31.9	30.8	-3%
2000	128.9	127.9	-1%	33.4	32.0	-4%
2001	129.7	129.0	-1%	33.4	32.7	-2%
2002	133.0	131.5	-1%	34.8	33.8	-3%

Criteria Pollutant Validation

- More challenging than fuel consumption
- CRC E-64 project performed validation of MOBILE6 against independent datasets, tunnel studies and ambient ratios
- Will follow the same path for MOVES

Understanding MOVES Design

On-Road Emission Processes

- **Running**
- **Start**
- **Extended Idle (“hoteling”)**
- **Evaporative Processes**
  - Permeation, Vapor Venting, Leaks, Non-Fuel Evap, Refueling
- **Crankcase**
- **Tire Wear**
- **Brake Wear**
- **Life Cycle Processes**
  - Well-To-Pump, Manufacture and Disposal (placeholder)

A process is defined by unique definitions of:

- **Activity Basis: total activity for that process**
  - Running: hours operating
  - Start: number of starts
  - Evaporative Processes: hours existing
- **Operating Modes: modes of activity**
  - Running: Vehicle Specific Power (VSP) & Speed
  - Start: soak time bin
  - Evaporative Processes: hot soak, cold soak, operation
- **Source Bins: vehicle categories important for distinguishing emissions**
  - Model year groups
  - Regulatory classes

Mobile Source Classification

- **Source Use Type (or just Source Type)**
  - Top Level Classification
  - Reflects major differences in usage pattern
- **Source Bins**
  - Classify sources in terms of characteristics which affect emissions
  - Based on permanent characteristics of vehicles
  - Distribution of these characteristics currently may not vary by location
  - Not reported in output, except for Fuel Type

Source Use Types – For Activity

HPMS Vehicle Type	MOVES Use Type
Passenger car	Passenger car
Other 4-tire / 2-axle	Passenger truck Light commercial truck
Single Unit Trucks	Refuse truck Short Haul truck (< 200 miles) Long Haul truck (> 200 miles) Motorhomes
Combination Trucks	Short Haul truck Long Haul truck
Buses	Transit buses School buses Intercity buses
Motorcycles	Motorcycles

Source Bins – For Emissions

- **Vehicle characteristics important for distinguishing emissions**
- **Bin definitions can vary by process & pollutant**
  - Energy
    - Fuel Type, Engine Technology, Model Year Group, Loaded Weight, Engine Size
  - CH_4 and N_20
    - Fuel Type, Engine Technology, Model Year Group, Regulatory Class
  - HC, CO, NOx & PM
    - Fuel Type, Engine Technology, Model Year Group, Regulatory Class

Emission Rates in MOVES

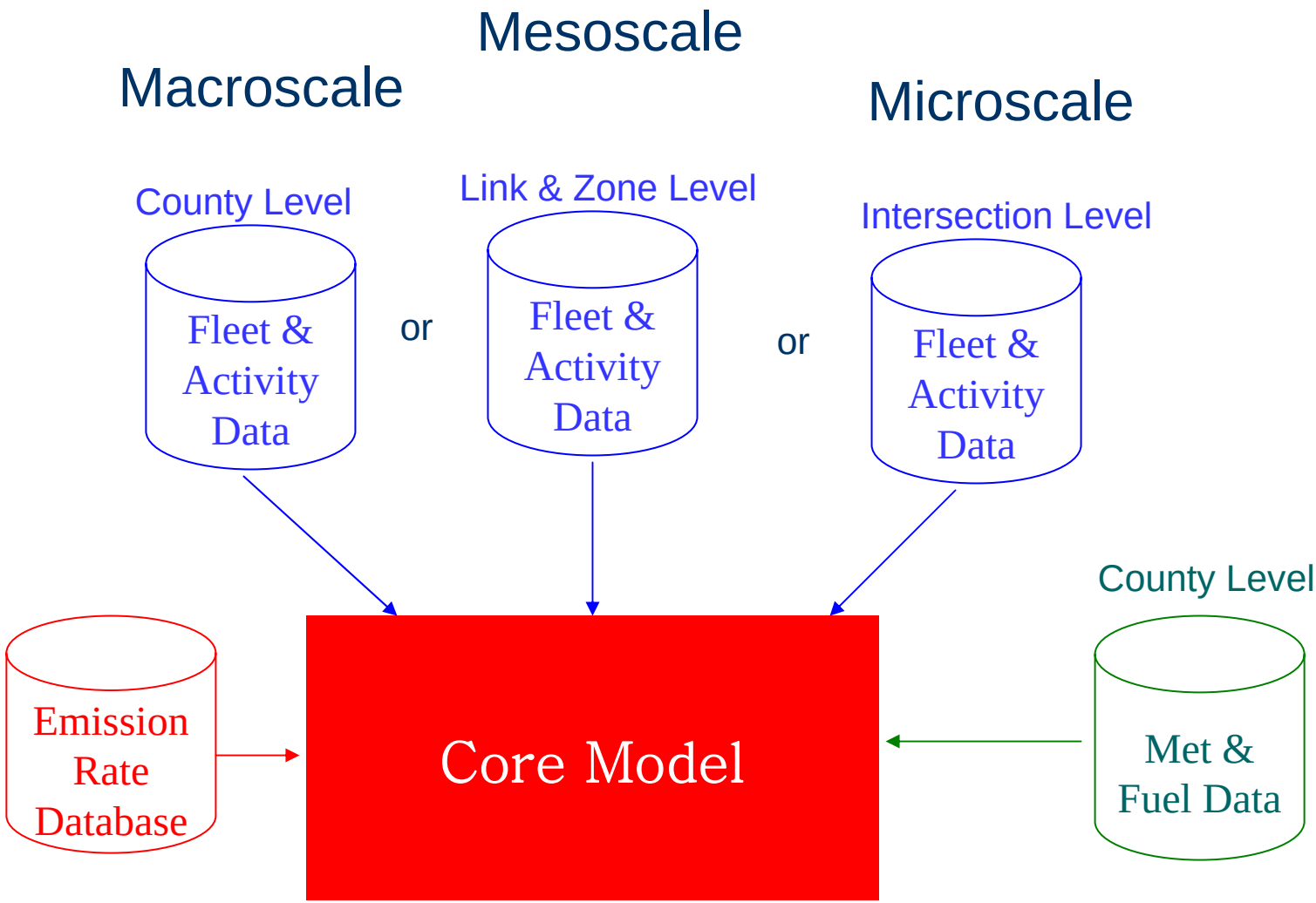
- **Two database tables: EmissionRate and EmissionRateByAge**
- **EmissionRate**
  - Rates (mass per activity basis) by pollutant/process, source bin, operating mode for which we are not modeling deterioration
    - Start & extended idle all pollutants
    - All processes for energy consumption
    - Brake and tire wear
- **EmissionRateByAge**
  - Adds age group distinctions for pollutant/process for which we are modeling deterioration
    - Running all pollutants
    - Permeation HC
- **In some cases emissions are handled with other tables**
  - Fuel vapor venting, well-to-pump, sulfate emissions

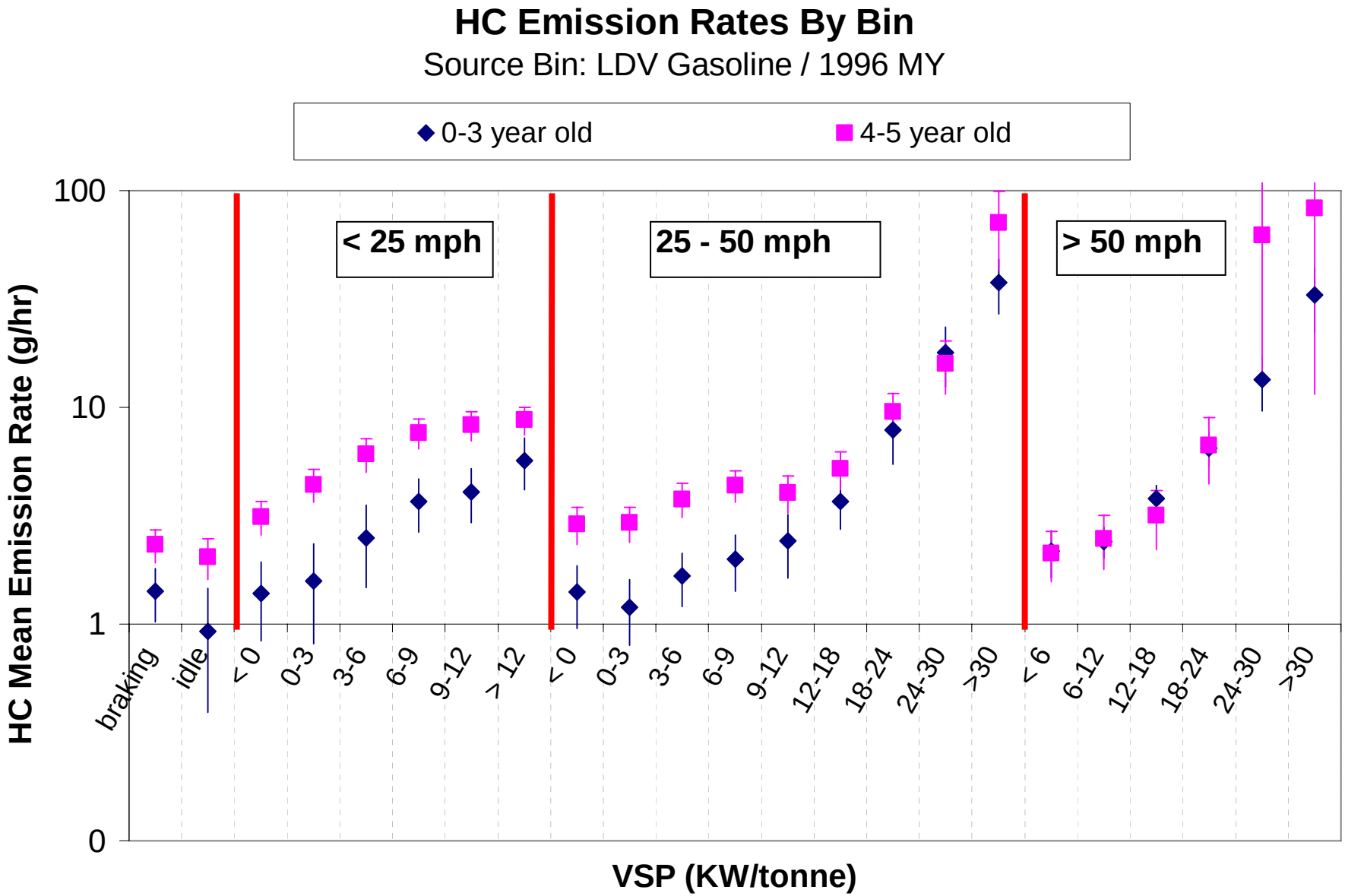
Age in MOVES2006

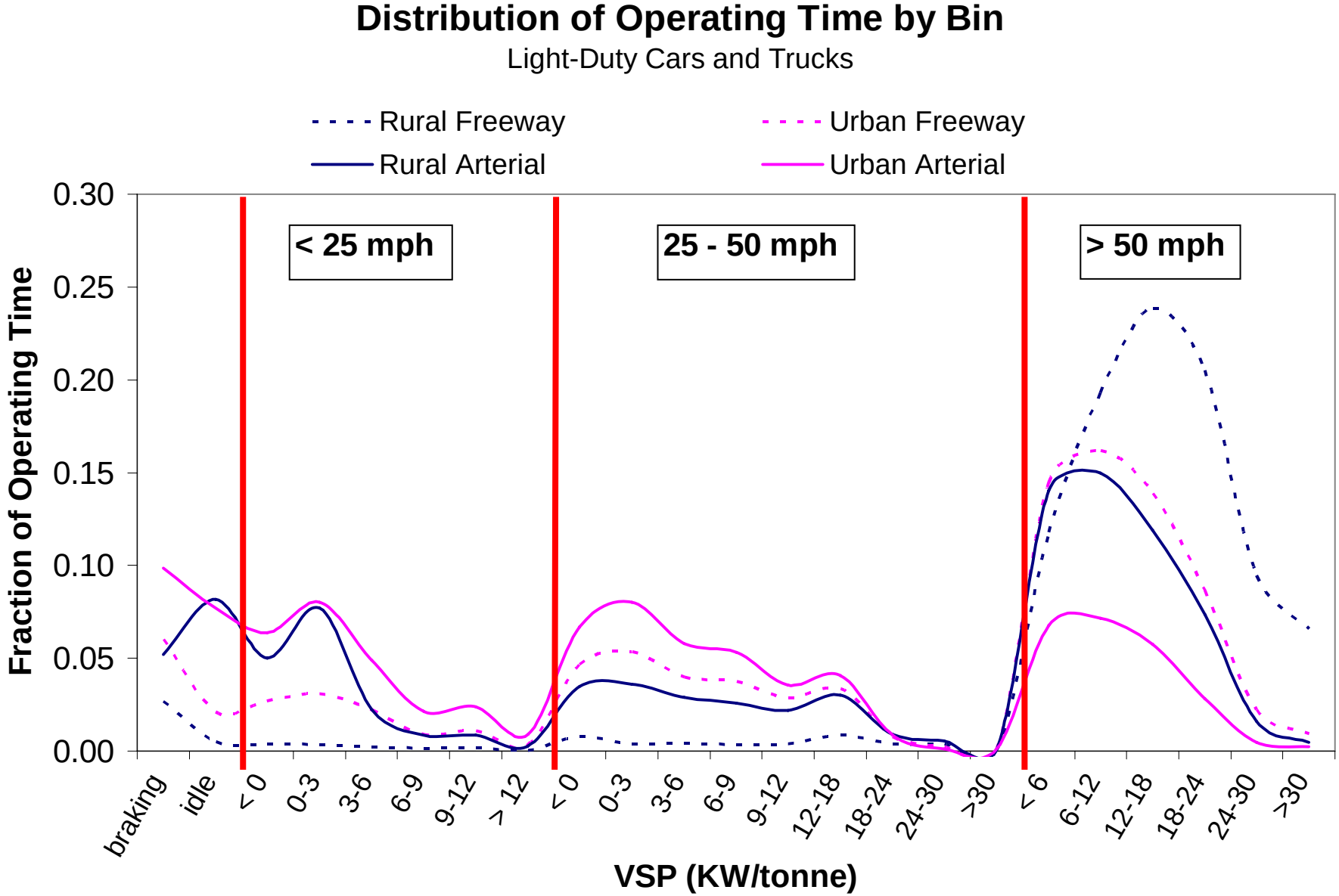
- **Emission rates in MOVES2006 can vary by age as well as model year**
- **Age bins**
  - 0 to 3 years old
  - 4 or 5 years old
  - 6 or 7 years old
  - 8 or 9 years old
  - 10 to 14 years old
  - 15 to 19 years old
  - 20 or more years old

Modal "Binning" Approach

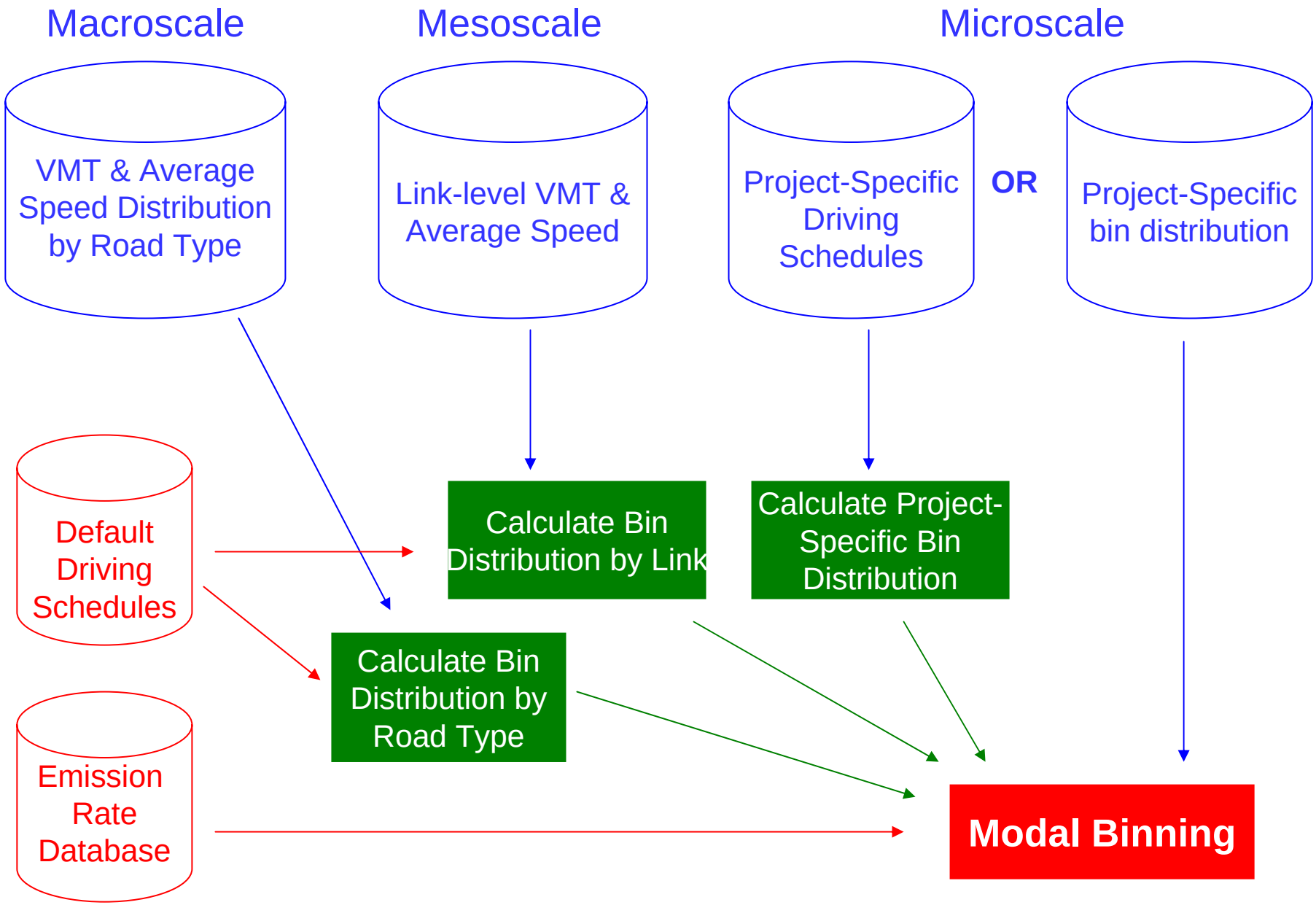
- **Applies to running process only**
- **Group activity and emissions into "bins"**
  - Vehicle Specific Power (VSP) & Speed
    - Accounts for speed, acceleration, grade, road load
- **Any driving pattern can be modeled**
  - Adds major flexibility compared to MOBILE
- **Allows direct use of data from many sources**
  - Laboratory, I/M programs, RSD
- **Provides common emission rates for all scales**
- **Independent validation has shown good results even for macroscale application**


Mesoscale
Macroscale
Microscale
County Level
Fleet & Activity Data
or
Link & Zone Level
Fleet & Activity Data
or
Intersection Level
Fleet & Activity Data
County Level
Emission Rate Database
Core Model
Met & Fuel Data


HC Emission Rates By Bin
Source Bin: LDV Gasoline / 1996 MY
0-3 year old
4-5 year old
< 25 mph
25 - 50 mph
> 50 mph
HC Mean Emission Rate (g/hr)
100
10
1
0
braking
idle
< 0
0-3
3-6
6-9
9-12
> 12
< 0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
< 6
6-12
12-18
18-24
24-30
>30
VSP (KW/tonne)


Distribution of Operating Time by Bin
Light-Duty Cars and Trucks
Rural Freeway
Urban Freeway
Rural Arterial
Urban Arterial
< 25 mph
25 - 50 mph
> 50 mph
Fraction of Operating Time
0.30
0.25
0.20
0.15
0.10
0.05
0.00
braking
idle
< 0
0-3
3-6
6-9
9-12
> 12
< 0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
< 6
6-12
12-18
18-24
24-30
>30
VSP (KW/tonne)

Applying Modal Binning at Different Scales



Start Design

- **More aggregate approach**
  - Current data doesn't support modal approach for starts
- **Start rates = "incremental emissions per start"**
  - Activity is the number of starts by time and place; mesoscale and microscale provide finer resolution of this
- **Soak time bins defined as operating modes**
  - < 6 min, 6-30, 30-60, 60-90, 90-120, 120-360, 360-720, >720
- **Soak distribution calculated within model from instrumented vehicle data (SampleVehicleTrip)**
- **Adjustments**
  - Temperature (will vary by soak bin), fuel

Evaporative Emissions

- **Redefined evaporative processes**
  - Permeation, Vapor Venting, Leaks, Non-Fuel Evap, Refueling
    - Operating modes: cold soak, hot soak, operating
  - Allows more direct estimation of EtOH and RVP effects
- **Design allows better allocation of evaporative emissions by space and time**
  - Evaporative emissions no longer coupled to miles traveled
- **Real-world fuel temperature patterns estimated within model based on instrumented vehicle data**
- **Will use data from CRC and compliance programs**
  - New testing: Defining shape of EtOH curve, CRC E-77 (aged enhanced vehicles, “off-cycle” diurnal)

Inspection/Maintenance

- **Simplifying considerably from MOBILE**
- **Single set of "With IM" emission rates**
  - Both sets of rates in EmissionRatebyAge and EmissionRate
  - Model Year ≥ 1996
    - OBD-based program
    - Gas Cap Check MY 96-99
  - Model Year ≤ 1995
    - Enhanced IM240
    - Gas Cap Check and/or Pressure Test
- **IM adjustment fraction**
  - accounts for program effectiveness, etc
- **Limited program options**

Uncertainty in MOVES

- **National Research Council and EPA quality guidelines recommend assessment of model uncertainties**
- **MOVES includes Monte Carlo simulation**
- **Input database is constructed so that each data input includes a Coefficient of Variation (CV) field**
  - For MOVES2006, CV will only be populated for emission rates
- **Main purpose is for understanding the source of uncertainty in model results, and guiding data collection**
  - "Official" results would likely use point estimates; guidance will be needed to clarify