

An Introduction to Draft MOVES2009

MTAQS
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The word "MOVES" is displayed in a stylized, metallic, three-dimensional font with a glowing effect, set against a dark, gradient background.

Outline

- **MOVES overview**
 - What is Draft MOVES2009?
 - Comparison to MOBILE6.2
- **How does MOVES work?**
- **Making the transition to MOVES**
- **MOVES demonstration – Jeff Houk, FHWA**

MOVES

- **MO**tor **V**ehicle **E**mission **S**imulator
- State-of-the-art modeling framework
- Will replace current models (MOBILE & NONROAD) and expand capabilities
- Designed to allow easier incorporation of large amounts of in-use data from a variety of sources
 - MOBILE structure limited ability to incorporate new emissions data

Improvements in MOVES compared to MOBILE

- Graphical User Interface (GUI)
- Data elements easy to modify/update
- Both g/mi and total inventory output
- Output easy to customize
- Multiple scales – National, County, Project
- Emission rates calculated on modal basis
- Designed from the ground up as an energy consumption model for GHG estimation
- New data, new emission processes, updated vehicle and fuel standards

How Do Emissions Estimates of Draft MOVES2009 Compare to MOBILE6.2?

The logo for MOVES, featuring the word "MOVES" in a stylized, metallic, 3D font with a glowing effect, set against a dark, gradient background.

Early Draft MOVES Results

- **Data collected since MOBILE6 released drives differences between MOVES and MOBILE6**
- **National trends**
 - HC and CO emissions similar or lower than MOBILE6.2
 - Total NO_x emissions higher than MOBILE6.2
 - Total PM emissions substantially higher than MOBILE6.2
- **Local results may vary**
 - Local fleet mix, fuels, activity are important
 - Temperature drives PM emissions
- **For attainment analysis, relative change in emissions between base year and attainment year is more important than absolute emissions**



Why are emissions different?

- New car and light truck emissions data
- New heavy truck emissions data
- New emissions processes not included in MOBILE6
- Updated fuel and vehicle standards

Significant new data in MOVES

- **Updated emission rates**
 - Test results on millions of vehicles considered for MOVES
 - Passenger Cars & Trucks
 - Heavy Duty Trucks
- **New fleet & activity defaults**
 - National defaults:
 - Vehicle fleet from state registration data, VIUS
 - Vehicle Miles Traveled (VMT) from HPMS
 - Driving patterns from instrumented vehicle surveys
 - For local modeling, local data is likely to be most accurate & up-to-date

Extensive analysis of Car & Light Truck emissions

- **HC/CO/NOx rates based on ~ 70,000 vehicles randomly selected from Arizona IM program**
 - Able to tease out emissions from I/M and non I/M areas
- **Checked against data from multiple sources**
 - I/M data from Illinois, New York, Missouri and Colorado
 - Roadside remote sensing data from several cities
 - Kansas City Study
- **Extended to newest technology vehicles using compliance data**
 - In-use emissions data manufacturers required to collect
 - About 2,000 laboratory tests per year



Gasoline PM a major focus

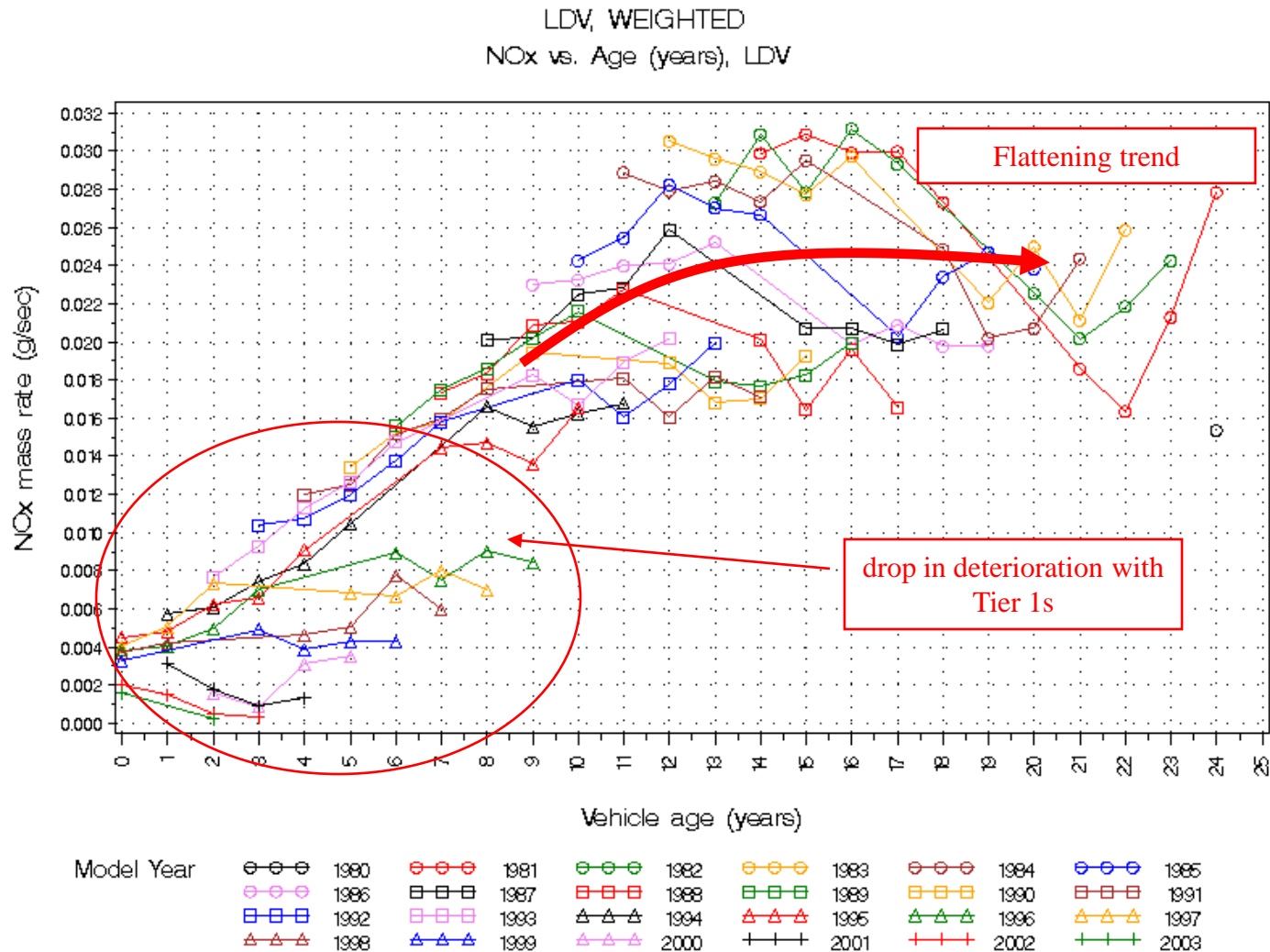
- **Landmark study conducted in Kansas City 2004-05 to address need for improved gas PM estimates**
 - Collaboration between EPA, DOE, DOT, States, Auto/Oils
- **496 gasoline light-duty cars and trucks tested**
 - Model Years 1968-2005
- **Summer and winter testing**
 - ~ half of the vehicles tested each season @ ambient temps
 - 43 vehicles tested in both winter and summer
- **More information at**
<http://www.epa.gov/otaq/emission-factors-research/>



What we've learned about Car & Light Truck emissions

- **New standards have been successful in reducing deterioration of HC/CO/NOx emissions**
- **On-Board Diagnostic (OBD) systems are a contributing factor to lower deterioration**
 - Owner response to repair identified malfunctions is better than MOBILE6 projected, particularly in non-I/M areas
- **Gas PM emissions are much higher than MOBILE6 projected**
 - Higher in-use deterioration
 - Significant increase at cold temperatures

Arizona I/M NOx data by Model Year and Age



Heavy Duty Diesel emissions updated based on real world data

- **MOBILE6 relied on certification data**
 - Engine tests only
- **Much research on in-use trucks since MOBILE6**
 - CRC E-55
 - 75 trucks on chassis dynamometer
 - Only real-time PM data of it's kind
 - On-Board Measurement: ~350 trucks on road
 - Provided most robust assessment of NOx emissions available
- **Extended idle, crankcase, starts, tampering & mal-maintenance factored in (not in MOBILE6)**

What we've learned about Heavy Duty Diesel emissions

- **NO_x**

- In-use emissions moderately higher than MOBILE6 projected
- Extended idle (hoteling) emissions are significant
 - And projected to grow as percent of NO_x inventory

- **PM**

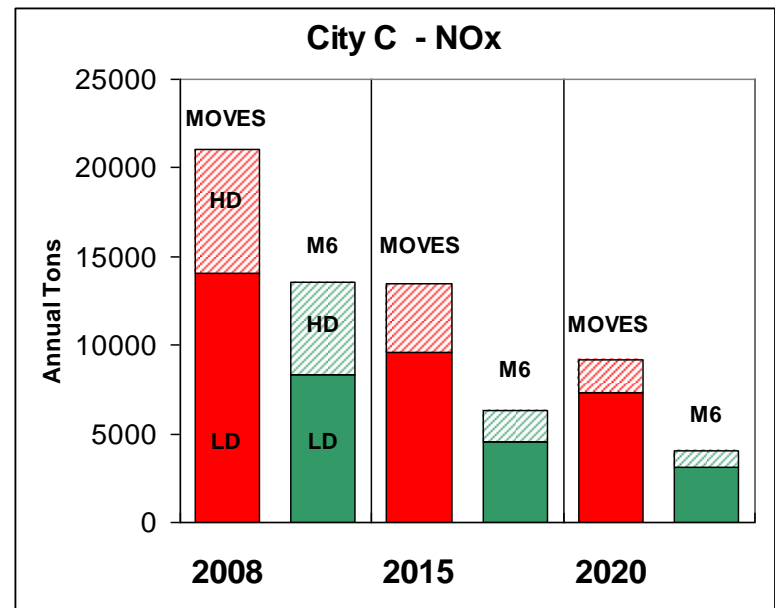
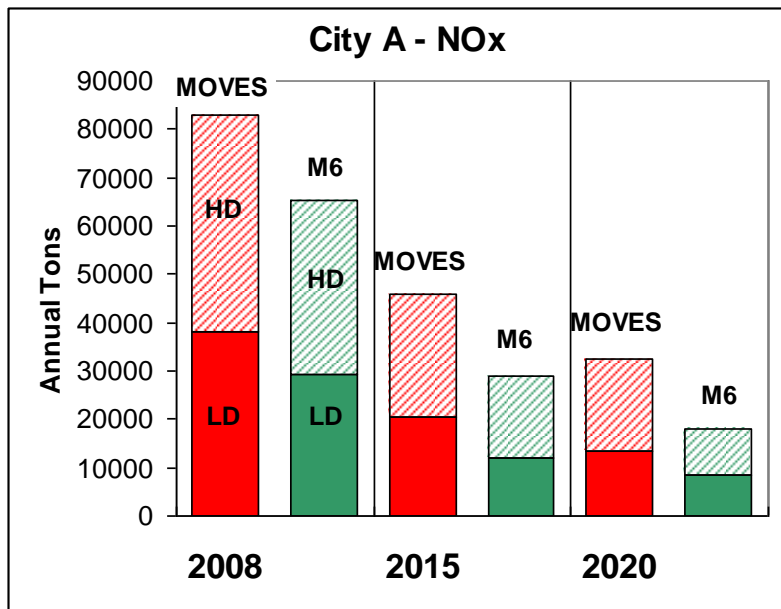
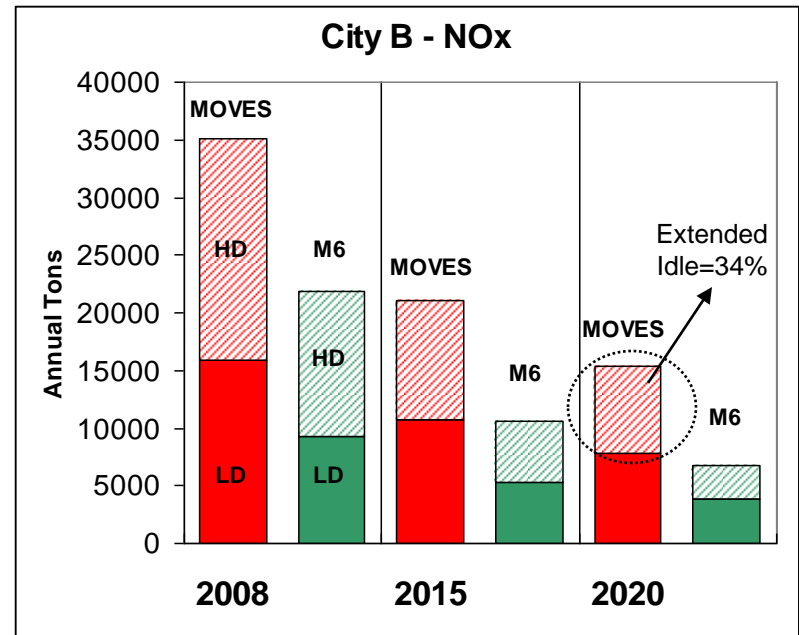
- Significant speed effect
 - MOBILE6 did not model any speed impacts
 - Large increase in emissions at lower speeds vs. MOBILE6
- Crankcase emissions significant

Analysis of Local Area Impacts

- **Did preliminary comparison of MOVES and MOBILE6 using surrogate local data to represent 3 different urban counties**
 - Local data very limited, may not be consistent with what states will actually use
- **Local data varied by:**
 - Fleet age distribution
 - Fraction of light and heavy duty VMT
 - Local fuel specifications
 - Meteorology
 - Other input factors

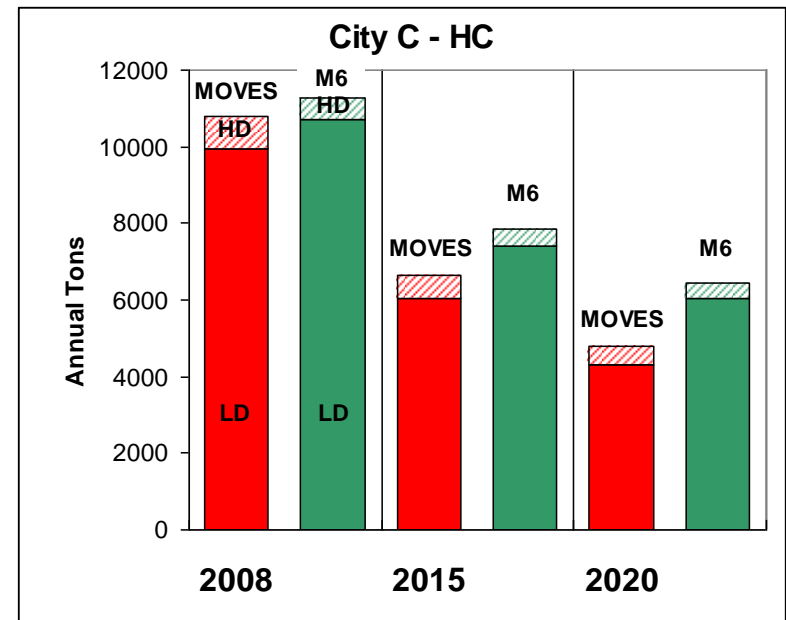
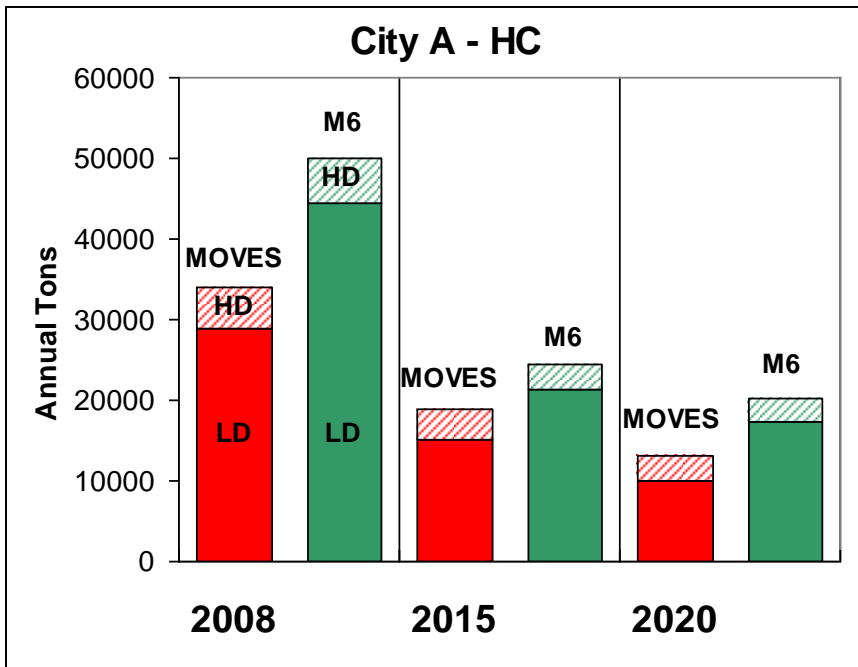
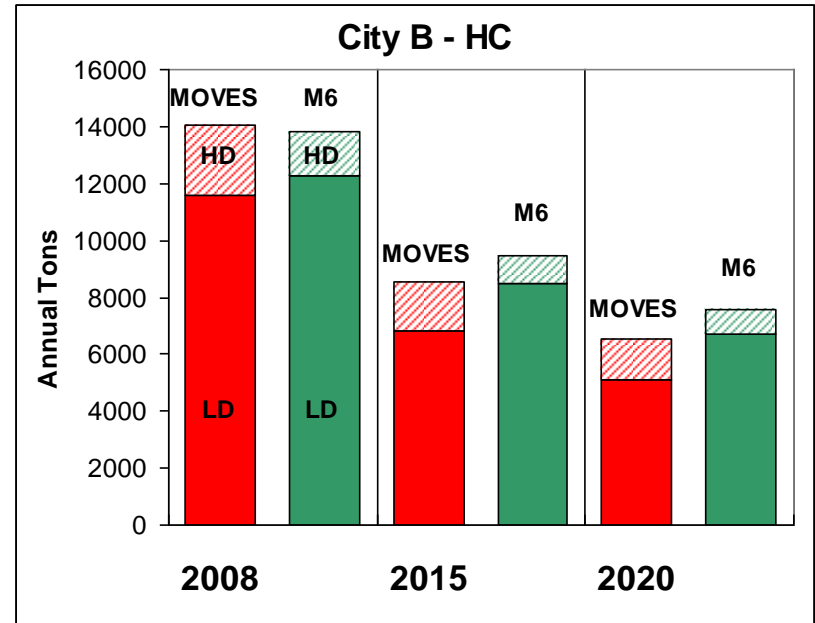
NO_x

- I/M program data shows MOBILE6 underestimated NO_x emissions from light trucks
- On-road data on heavy trucks shows higher emissions than MOBILE6 estimated from cert data
- Extended idle emissions become significant share of heavy-duty inventory in future



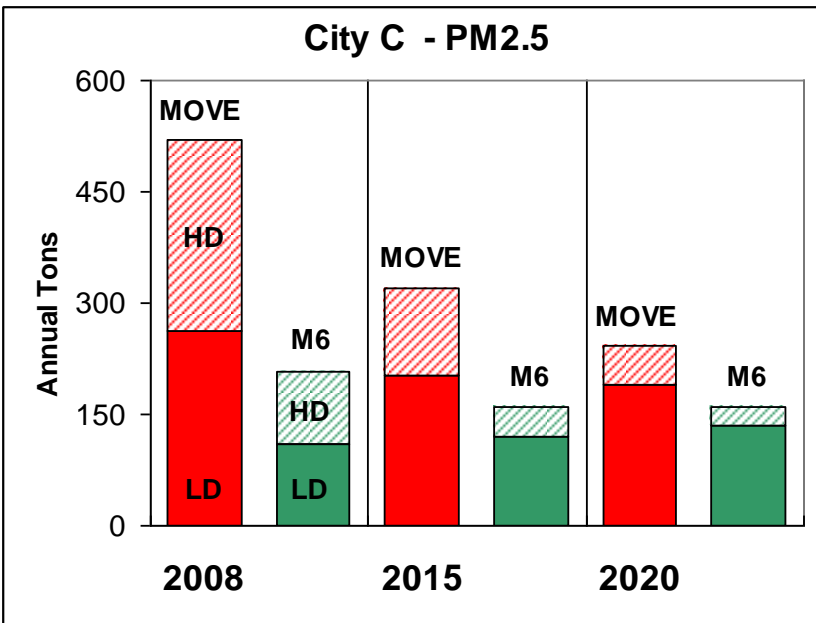
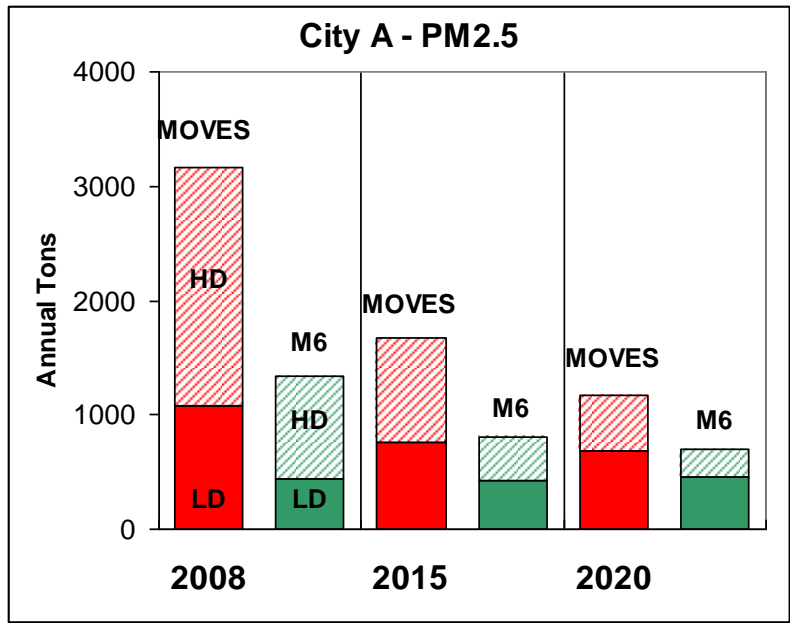
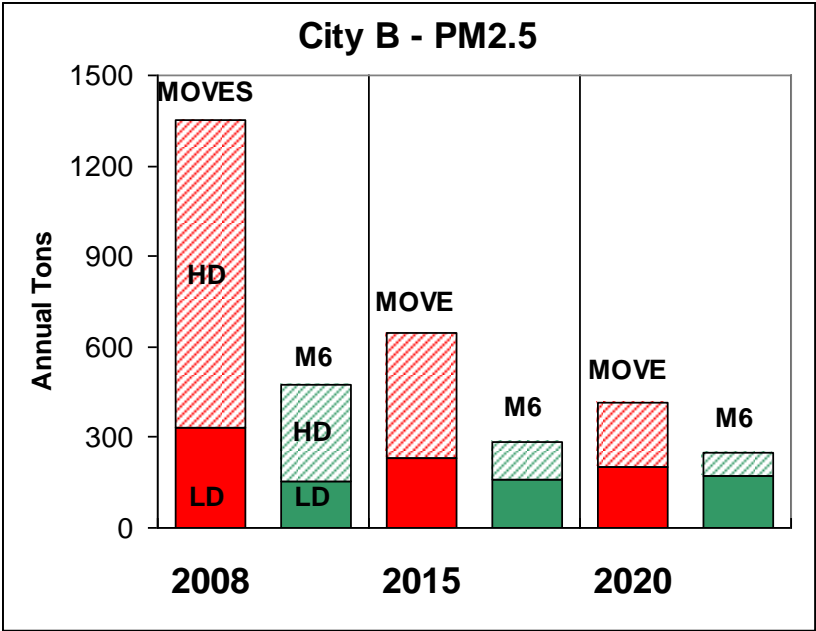
HC

- I/M program data shows MOBILE6 overestimated HC emissions from newer technology cars
- Evaporative emissions on newer technology vehicles very low; re-evaluating leak emissions for final model



PM_{2.5}

- Kansas City program found high gas PM emissions esp. at cold temps
- New data on heavy trucks shows higher deterioration than MOBILE6
- MOVES accounts for impact of vehicle speed – MOBILE did not



Percent Reduction in On-Road Emissions 2008 to 2015

| | City A | | City B | | City C | |
|--------------|---------------|----------------|---------------|----------------|---------------|----------------|
| | MOVES | MOBILE6 | MOVES | MOBILE6 | MOVES | MOBILE6 |
| HC | 50% | 50% | 39% | 32% | 38% | 31% |
| NOx | 54% | 56% | 40% | 52% | 36% | 53% |
| PM2.5 | 57% | 40% | 52% | 40% | 38% | 23% |

What It Means

- **Higher NOx and PM emissions mean mobile sources have bigger role in attainment**
- **Percent reduction from base year is key to attainment analysis**
 - PM2.5 shows higher overall emissions and higher % reductions
 - Effect on attainment demonstrations could be positive
 - NOx shows higher overall emissions but lower % reduction
 - Harder to show attainment
 - Future NOx control measures will have a bigger impact
- **States may need to redo some motor vehicle emissions budgets to meet conformity requirements with MOVES**

I/M Effects In MOVES

- **Benefits are comparable to MOBILE6 now, but will shrink over time.**
 - Conservative M6 OBD assumptions not supported by data
 - CRC did comprehensive survey of MIL response in non-I/M areas
 - Found high response even after warranty
 - Our analysis of I/M program data confirms that OBD works

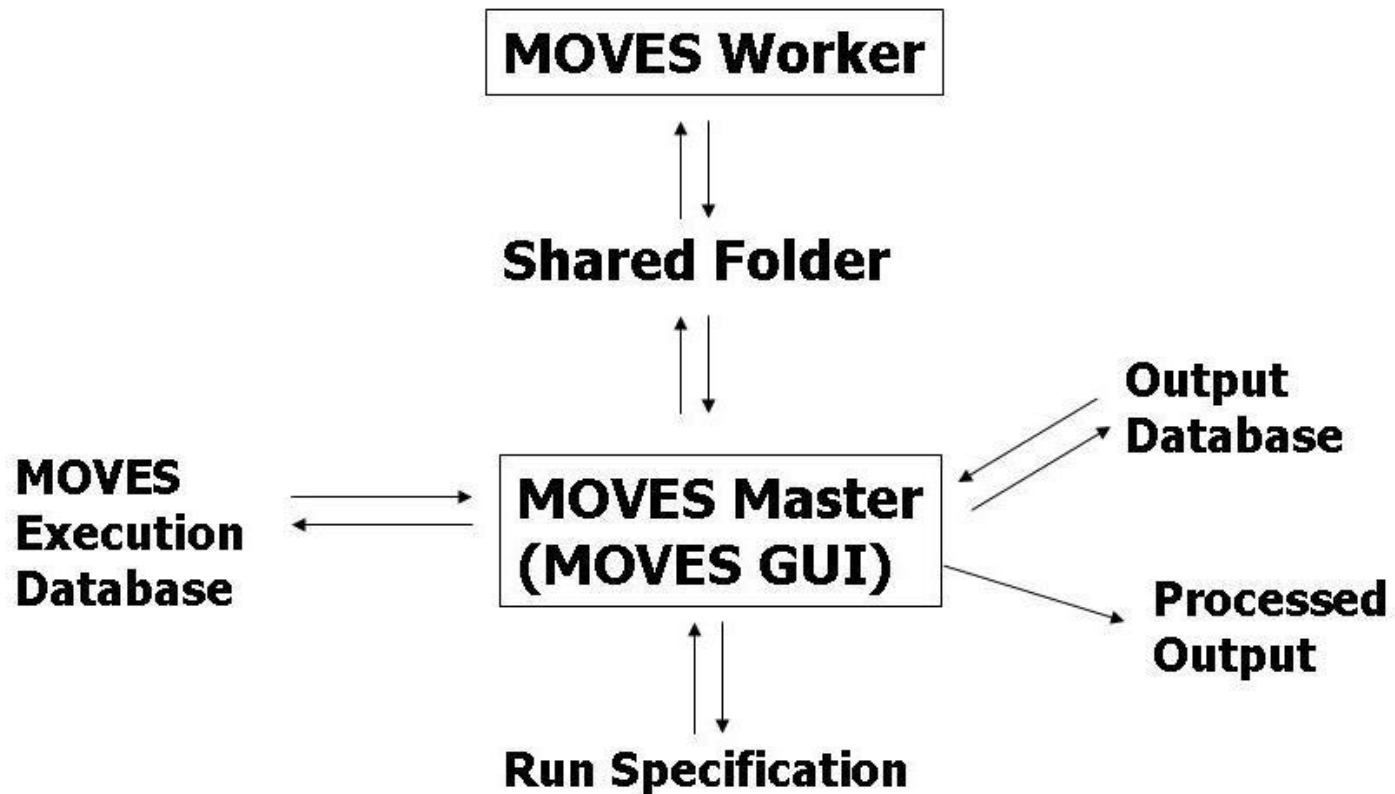
How Does MOVES Work?

The MOVES logo is displayed in a metallic, 3D-style font with a glowing effect, set against a dark rectangular background.

MOVES



Master – Worker Structure



Geography and Time in MOVES

- ✓ **Modeling domain is the entire U.S.**
 - 50 States plus (DC, Puerto Rico, & Virgin Islands)
 - 3222 Political subdivisions (counties as of CY 1999)
- ✓ **Calendar years (1990, 1999-2050)**
 - ✓ 12 months of the year
 - ✓ Week days and weekend days
 - ✓ 24 hours of the day

Emission Processes

- ✓ **Running Exhaust**
- ✓ **Start Exhaust**
- ✓ **Extended Idle**
- ✓ **Evaporative Processes**
 - Permeation, Vapor Venting, Leaks, Refueling Displacement, Refueling Spillage
- ✓ **Crankcase**
- ✓ **Tire Wear**
- ✓ **Brake Wear**
- ✓ **Well-To-Pump (energy only)**

MOVES Source Types (vs. HPMS Vehicle Types)

| HPMS Vehicle Type | MOVES2004 & HVI Demo SourceType |
|----------------------|--|
| Motorcycle | Motorcycle |
| Passenger Car | Passenger Car |
| Other 4-tire, 2 axle | Passenger Truck Light Commercial Truck |
| Bus | Intercity Bus Transit Bus School Bus |
| Single Unit Truck | Refuse Trucks Short-haul Single Unit Long-haul Single Unit Motorhomes |
| Combination Truck | Short-haul Combination Long-haul Combination |

Sub-categories (like refuse trucks and motorhomes) will be addressed in guidance; EPA does not expect areas to have local data for all subcategories.

Road Types

- ✓ **For running emissions, county-level VMT is distributed to four road types:**
 - Rural Restricted Access (freeways and Interstates),
 - Rural Unrestricted Access,
 - Urban Restricted Access (freeways and Interstates),
 - Urban Unrestricted Access
- **A fifth road type, “off-network”, is included to capture start, evaporative and extended idle emissions**
 - This is not the same as “off-network” vehicle activity in the travel modeling world.


Vehicle Ages

- ✓ Emission rates can vary by age as well as model year; activity also varies by age
- ✓ Vehicles 0-29 & 30+ years old modeled
- ✓ Age groups used for emissions calculations
 - 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

Emissions by Source, Age, Mode

✓ MOVES uses a different rate for each combination of:


- Source,


- 


Age group, and

- 

Operating mode


Gas-LDV-MY1998
Gas-LDT-MY2002


8-9 years
4-5 years


"low-speed" coast
"cruise/accel" (speed 25-50 mph, VSP 12-15 kW/tonne)

How MOVES handles vehicle activity - Definitions

- **Vehicle Specific Power (VSP)** – a measure of the energy the vehicle is using at a moment in time
 - Affected by acceleration, road grade, resistance, etc.
- **Operating Mode** – what the vehicle is doing, i.e., accelerating, braking, cruising, idling
 - Vehicles use different VSP in different operating modes
 - MOVES defines 23 operating mode bins – combinations of speed and VSP for different running conditions plus additional operating modes for starts and evaporative emissions
- **Drive Cycle** – a second-by-second description of vehicle activity over time, typically including multiple operating modes

MOVES: Operating Mode Bins

- ✓ Division of total activity into categories that differentiate emissions
- ✓ Defined by speed and **Vehicle Specific Power (VSP)** for running emissions
- ✓ There will be additional operating mode distributions for start and evaporative emissions in MOVES2009

Modal “Binning” Approach

- ✓ Any driving pattern can be modeled
 - Adds major flexibility compared to MOBILE
- ✓ Allows direct use of data from many sources
- ✓ Provides common emission rates for all scales
- ✓ Independent validation has shown good results even for macroscale application

Running Operating Modes in MOVES

- **MOVES uses second-by-second emissions data categorized in operating mode bins based on combination of speed and VSP**
- **MOVES includes default operating mode distributions based on typical driving cycles**
 - Different road types in MOVES have different default operating mode distributions
- **Users can create other operating mode distributions based on other driving cycles**
 - Unlike MOBILE, any driving pattern can be modeled in MOVES

Operating Mode Bins

| | | Speed Class (mph) | | |
|----------------------|-------|-------------------|-------|------|
| | | 1-25 | 25-50 | 50 + |
| VSP Class (kW/tonne) | 30 + | 16 | 30 | 40 |
| | 27-30 | | | |
| | 24-27 | | 29 | 39 |
| | 21-24 | | 28 | 38 |
| | 18-21 | | | |
| | 15-18 | | | 37 |
| | 12-15 | | 27 | |
| | 9-12 | 15 | 25 | |
| | 6-9 | 14 | 24 | 35 |
| | 3-6 | 13 | 23 | |
| | 0-3 | 12 | 22 | 33 |
| | < 0 | 11 | 21 | |

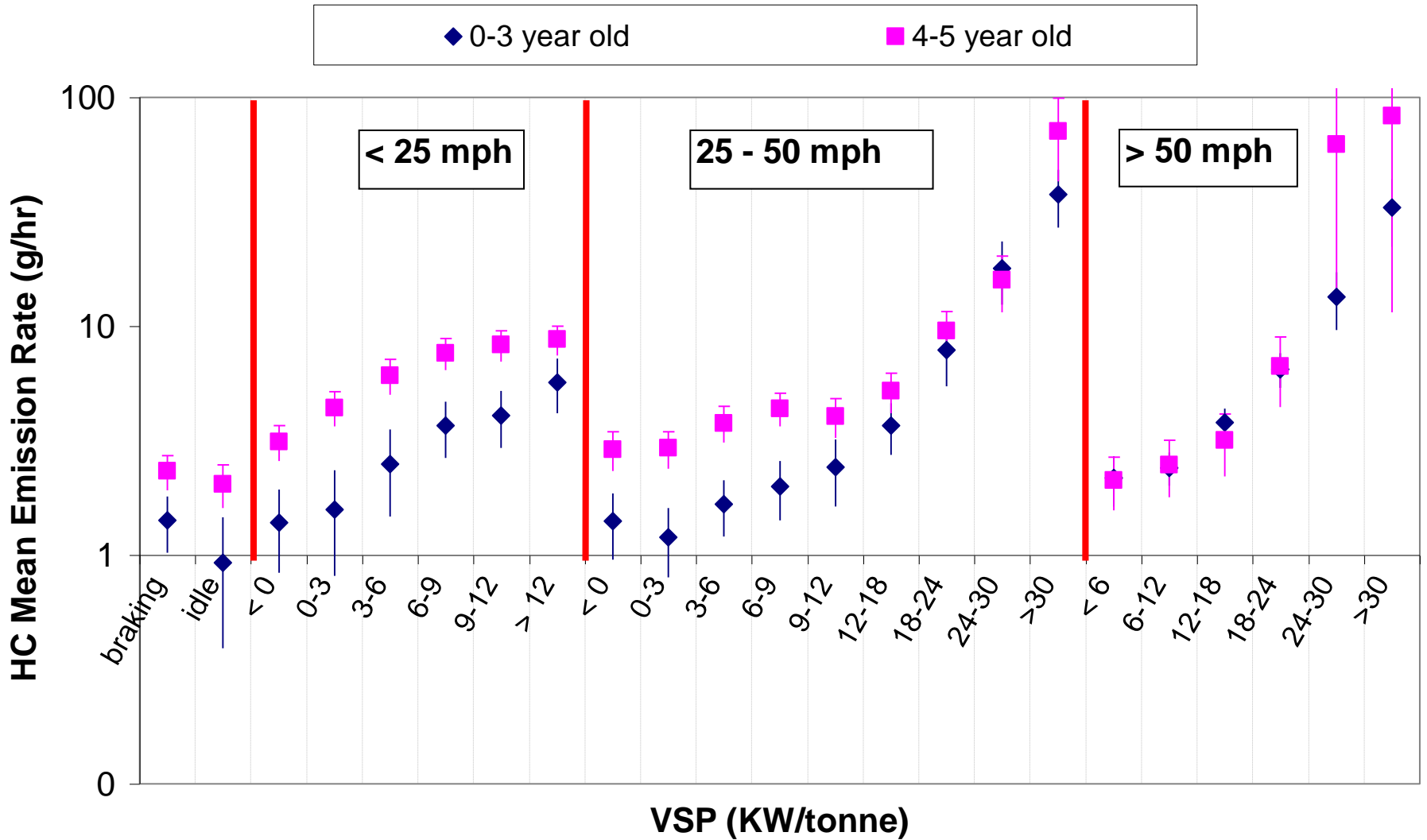
PLUS

One mode each for idle (Bin 0), and deceleration/braking (Bin 1)

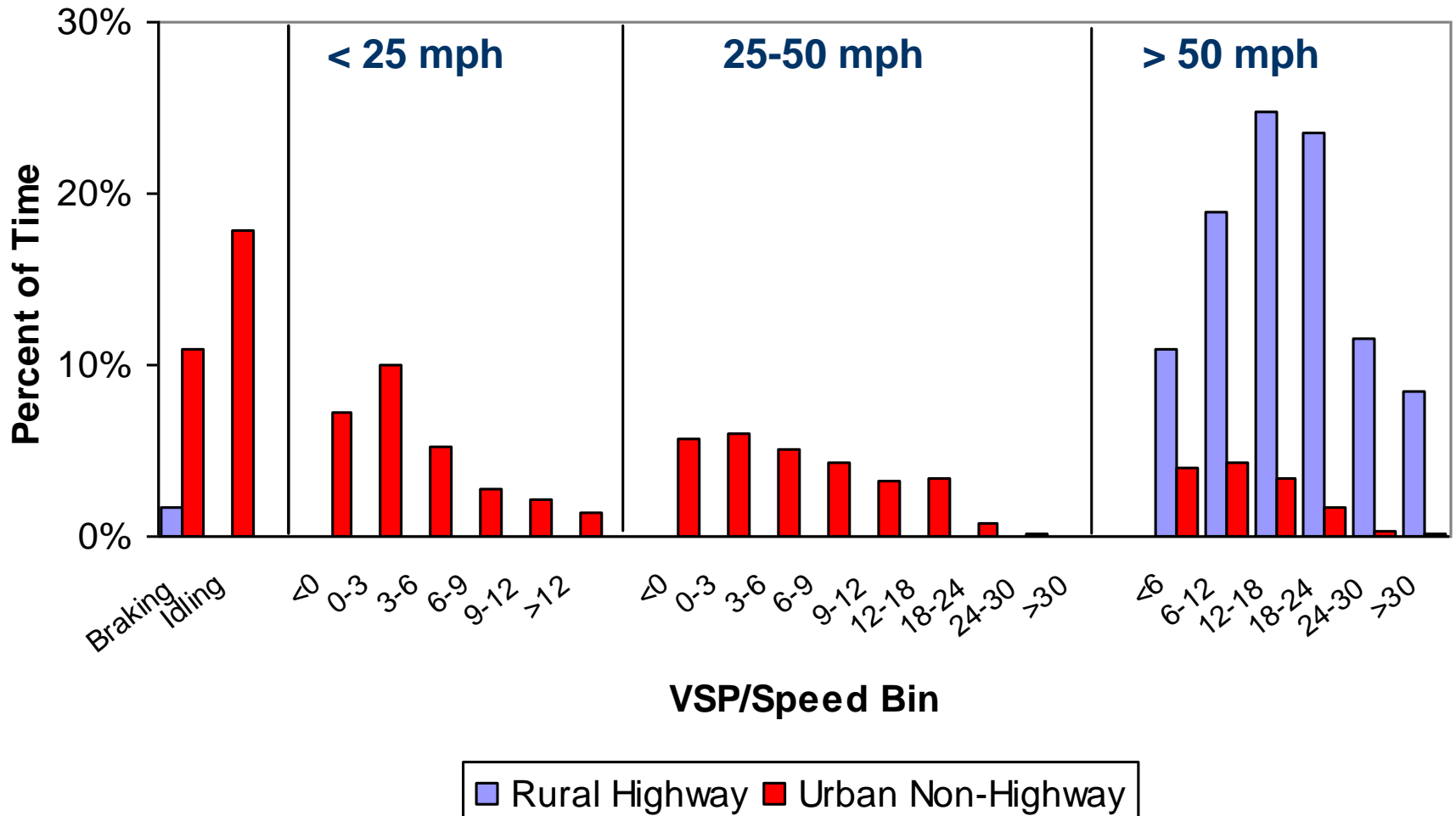
Gives a total of 23 opModes

HC Emission Rates By Bin

Source Bin: LDV Gasoline / 1996 MY



Distribution of Time by Mode



New Analysis Opportunities

- **Modal emission structure allows calculation of “Project-level” emission changes**
 - Changes in operating mode distribution → changes in emissions
- **Includes an “importer” to help users input project-specific information on driving activity**
 - Users can enter operating mode distribution or driving pattern by link
- **Areas will want tools to estimate how changing road design affects operating modes**
 - Adding lanes?
 - Synchronizing signals?
 - Replacing stop signs with rotaries?
- **Creates need to better characterize driving patterns** - MOVES defaults may not characterize local patterns, esp project level

MOVES Databases

- **MOVES stores information in MySQL databases**
- **Draft MOVES2009 default database has 119 different tables that store**
 - Lookup/reference information
 - Conversion/adjustment factors
 - Emissions data
 - Activity data
- **MOVES also uses databases to store intermediate results and final output**

MOVES Databases

- ✓ **Input Databases (default or user-created)**
 - Default Input Database
 - User Input Database(s) (optional-MOVES will run with just defaults for the National Scale)
- ✓ **Execution Database (created by MOVES)**
 - Resolves differences between the user input and default data
 - Contain information needed for a particular run
 - Temporary storage for intermediate results
 - Resources for new modeling applications
- ✓ **Output Database (created by user)**
 - ✓ Run results
 - ✓ Run diagnostics and documentation



Output

- **Post-processing scripts**
- **MOVES Summary Reports**
- **Exporting MOVES output to EXCEL**
- **MySQL can also be used to summarize output**

Making the Transition to MOVES

The MOVES logo is presented in a metallic, 3D style with a brushed metal texture and a slight glow. The letters are bold and blocky, set against a dark, gradient background that transitions from light at the top to dark at the bottom.

MOVES



MOVES Schedule

- **January 2005**
 - **MOVES2004 released**
 - Includes energy consumption, greenhouse gases
- **May 2007**
 - **MOVES Demo released**
 - Basic structure of MOVES without criteria pollutant emission factors
- **April 2009**
 - **Release of Draft MOVES2009**
 - Adds draft criteria pollutant emission factors
- **End of 2009**
 - **Planned release of official MOVES2009**
 - Final onroad criteria pollutant model
- **2010**
 - **Begin adding nonroad emissions to MOVES**

MOVES2009 Schedule

- **Official MOVES2009 planned for release at the end of 2009**
 - Will be official model for on-road vehicles outside of California
- **Use will be required for:**
 - State Implementation Plans (SIPs)
 - Transportation Conformity Analysis
 - After grace period of from 3 to 24 months: tbd
- **Nonroad work to begin in 2010**



Where Are We Now?

- **Training**

- Over 400 participants at 20 hands-on training sessions
- Working on web-based training on specialized topics
- Planning additional hands-on training after final release

- **Processing comments**

- Over 600 total comments from individuals or organizations
- Bug reports, feature requests, guidance issues, questions
- Cannot respond to each individual commenter, but we are reviewing every comment we receive

Where Are We Now?

- **Model improvements**

- Fixing bugs and adding some new features
- Addressing the most important ones suggested by users:
 - Adding daily VMT input to County Data Manager
 - Adding more activity input options to Project Data Manager
 - Adding additional lookup table output options
 - Developing post-processor for SMOKE
 - Creating more MOBILE to MOVES data converters

Where Are We Now?

- **Writing guidance**

- Developing three guidance documents
 - Technical Guidance
 - Default vs. local inputs
 - Similar to MOBILE6.2 Technical Guidance
 - Project Level Guidance
 - Using MOVES for quantitative PM hotspot analysis
 - Using air quality dispersion models for quantitative PM hotspot analysis
 - SIP and Conformity Policy Guidance
 - When will MOVES be required for SIPs?
 - What is the grace period for MOVES for transportation conformity?
- Will share drafts of all three for comment before we finalize them

What Should You Do Now?

- **Update computer hardware**
 - **Dual-core processor (faster is better)**
 - **At least 1 GB memory (more is better)**
 - **At least 40 GB storage (more is better, output files can be very large)**
 - **Consider setting up a distributive network (specs of “master” computer are key)**
 - **Windows XP or 32-bit Vista**
 - **Results of testing MOVES on 64-bit XP, Vista, and Windows 7 coming later this year**

What Should You Do Now?

- **Build staff expertise in relational databases and MYSQL**
 - Not needed for simple runs
 - Some basic knowledge gives users flexibility to customize outputs and view inputs
 - In-house expert would be helpful for more advanced analysis
- **Subscribe to MOBILENEWS email list for MOVES updates**
<http://www.epa.gov/otaq/models/mobilelist.htm>



Feedback

- **Still taking comments, but there are limits on what changes we can incorporate in final version at this late date**
- **For more information, go to the MOVES website:**
 - www.epa.gov/otaq/ngm.htm
- **Best way to provide comments:**
 - Send an email to: mobile@epa.gov