Bottoms Up!

- or –

Get On Board!

Bottom-up fuel & emissions inventories and the role of on-board emission measurement

TRB 91st Annual Meeting
January 22, 2012

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We Know How Much Fuel Is Sold, What Else Do We Need to Know?

- Fuel tax data provides a good estimate of how much fuel is consumed in aggregate in U.S.
  - Also basis for national CO_2 inventories
  - But "top down" approach limited for policy evaluation
- "Bottom-up" approach is needed to estimate:
  - Where fuel is consumed (GHGs emitted)
  - Breakdowns by vehicle type, model year, modes of operation
  - Impacts of fuel economy / GHG policy
- Demand for regional and project level GHG emission estimation growing

"Simple" Bottom-Up Approach

- VMT ÷ Fuel Economy = Gallons
- Useful for evaluating macro-scale effects
  - e.g., VMT growth, car/truck shift, mpg standards
- Not very helpful for evaluating other factors that can influence fuel consumption
  - e.g., congestion, driving patterns, environmental conditions
- Why? Aggregate fuel economy data typically represents one of many possible…
  - Speed & acceleration profiles
  - Trip patterns
  - Environmental conditions
  - Road configurations (i.e., flat and straight)

MOVES
(Motor Vehicle Emission Simulator)

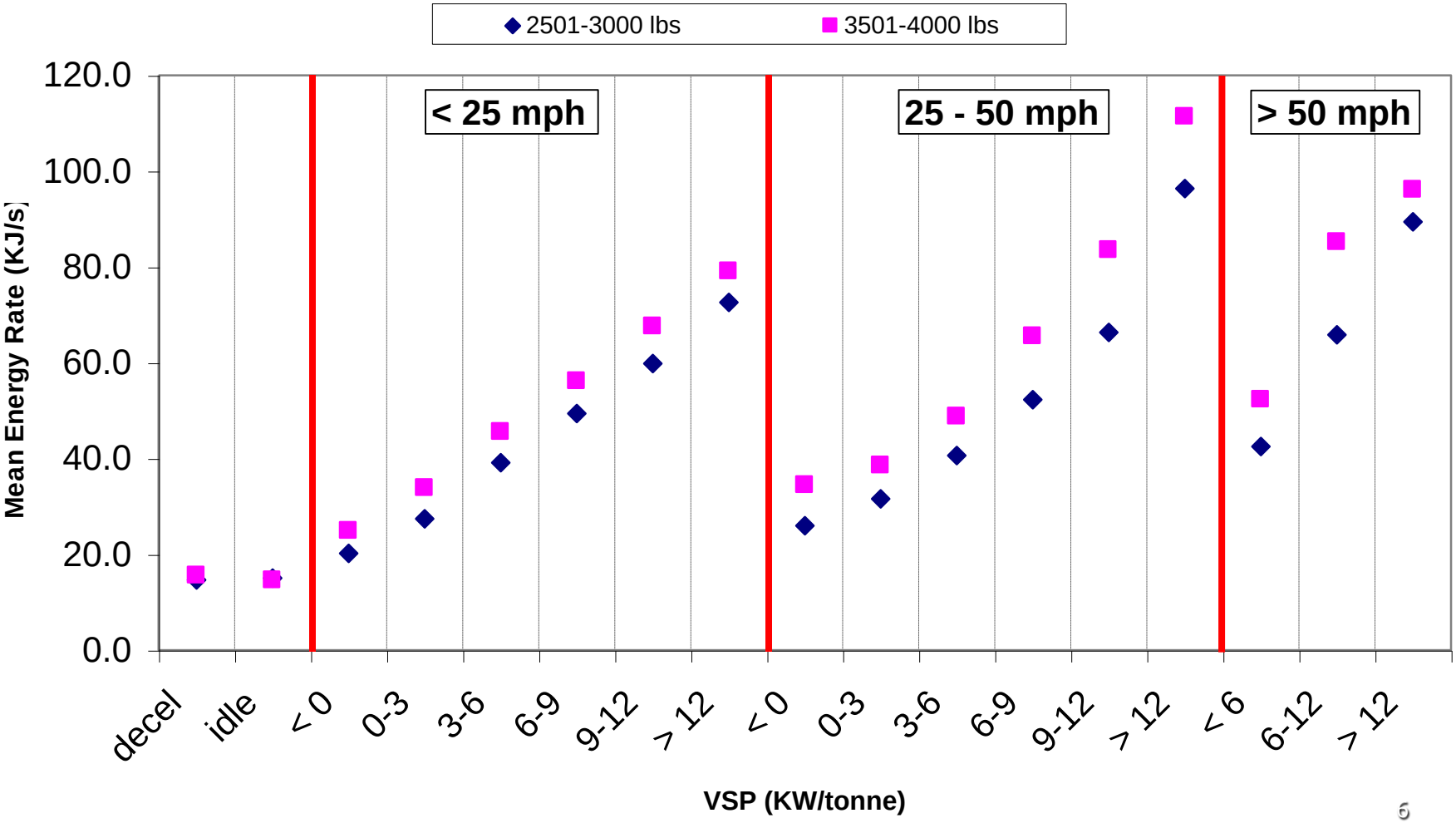
- EPA's official model for estimating motor vehicle emissions for SIP and transportation conformity analyses
- "MOVES2010a" is current version
- Also estimates energy consumption and GHGs
- www.epa.gov/otaq/models/moves/

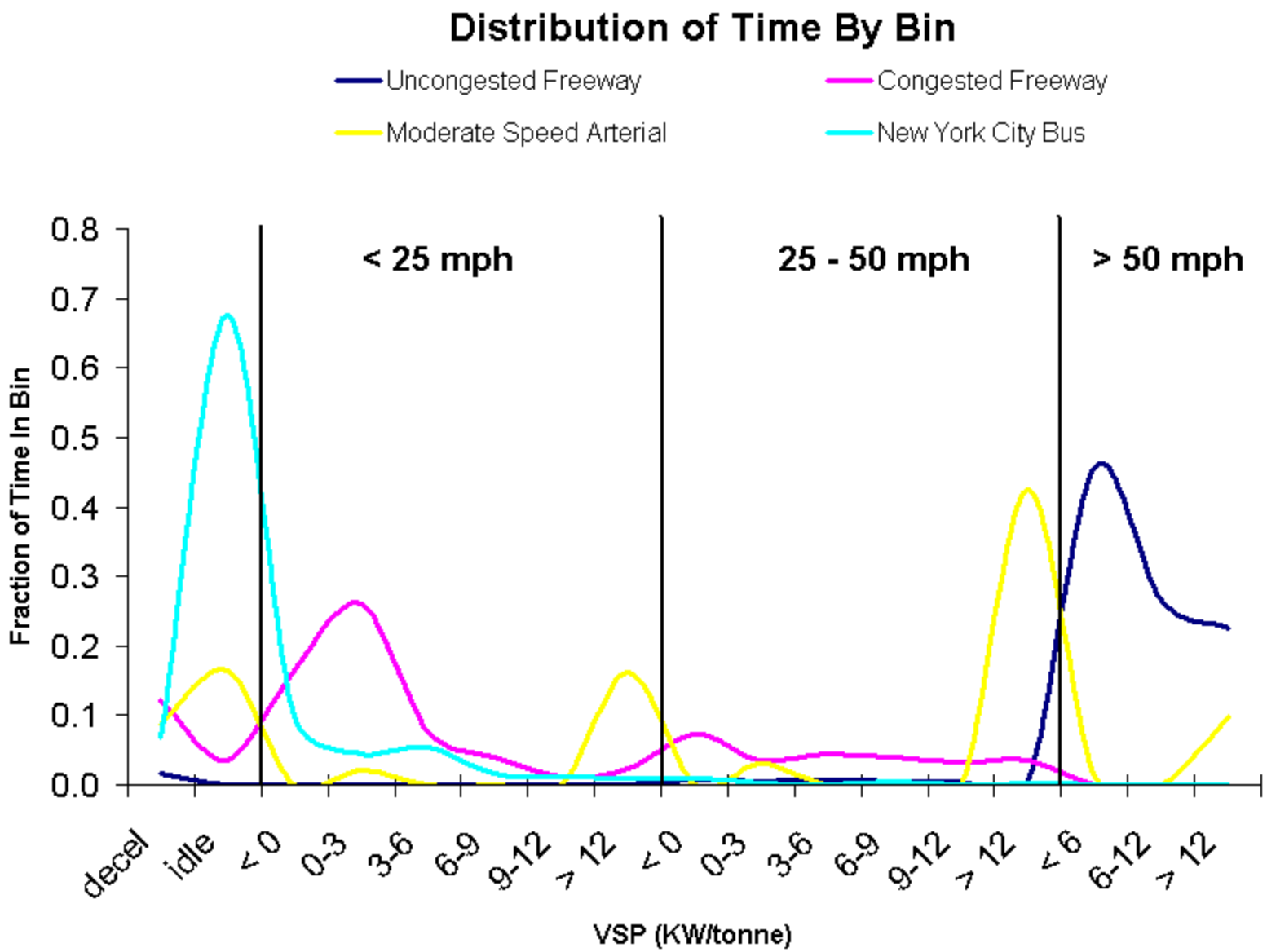
MOVES Bottom-Up Approach

- Developed for analysis at multiple scales
  - Project / Region (County) / Nation
  - Employs disaggregate approach to ensure consistency between scales
- Models energy consumption and emissions as series of "processes"
  - Running, starts, heavy-duty "hoteling", etc.
- Employs "modal" approach
  - Split emissions and activity into discrete "bins"
  - Re-aggregate to match specific condition

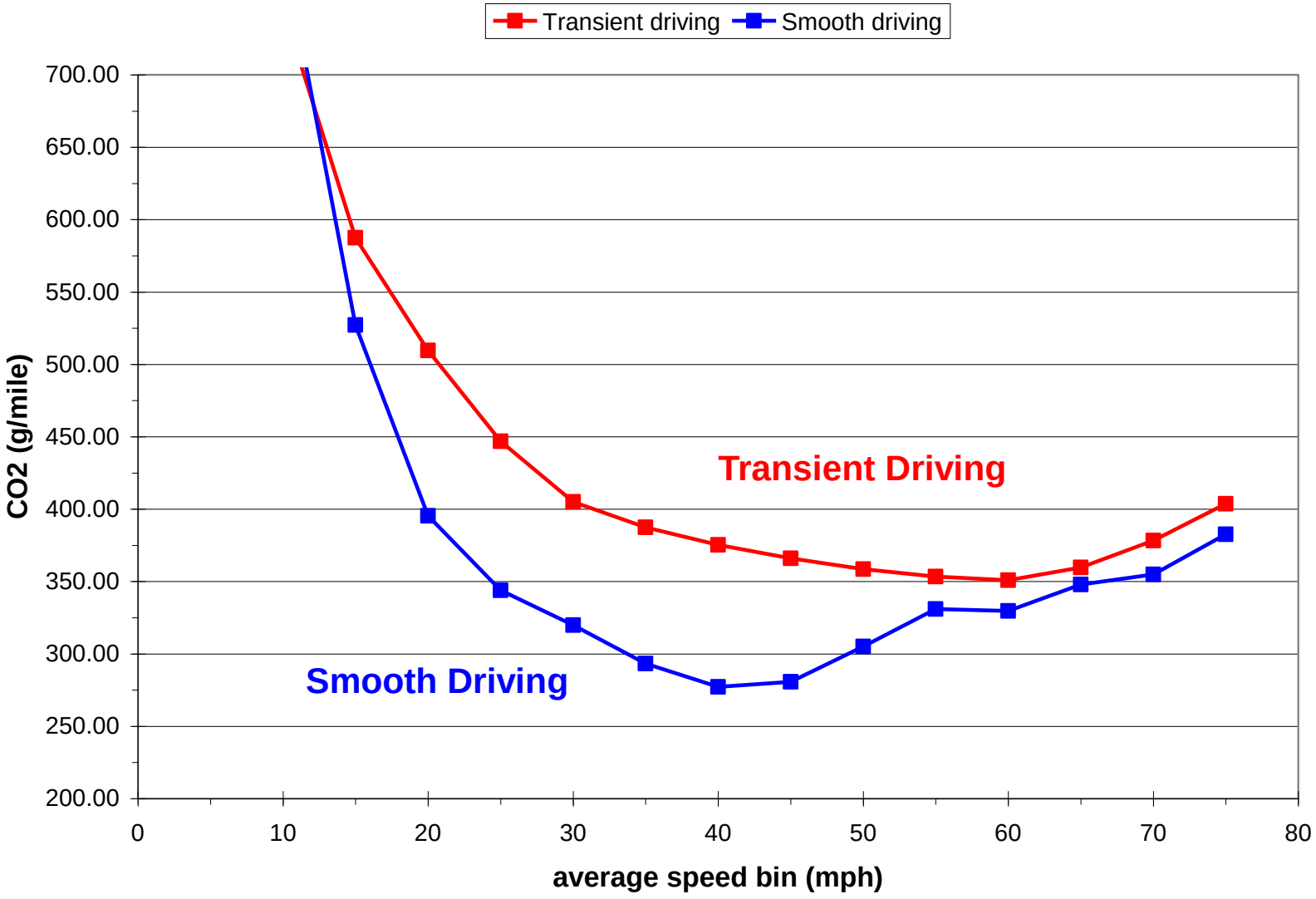
Energy Consumption Rates By Bin

Source Bin: Gasoline / 86-90 MY / 2.0-2.5 liter

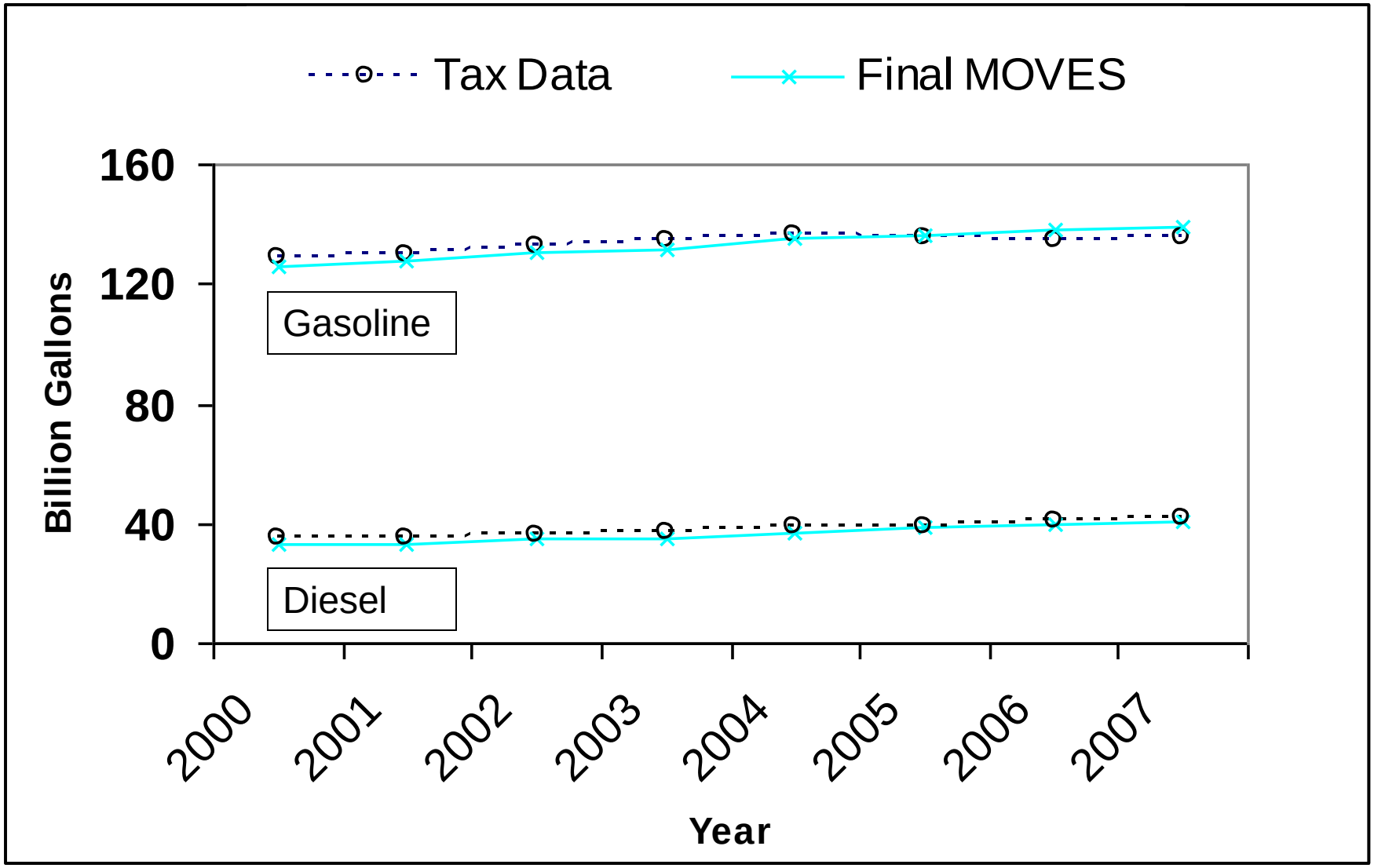



Distribution of Time By Bin
Uncongested Freeway
Congested Freeway
Moderate Speed Arterial
New York City Bus
< 25 mph
25 - 50 mph
> 50 mph
Fraction of Time In Bin
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
decel
idle
< 0
0-3
3-6
6-9
9-12
> 12
< 0
0-3
3-6
6-9
9-12
> 12
< 6
6-12
> 12
VSP (KW/tonne)

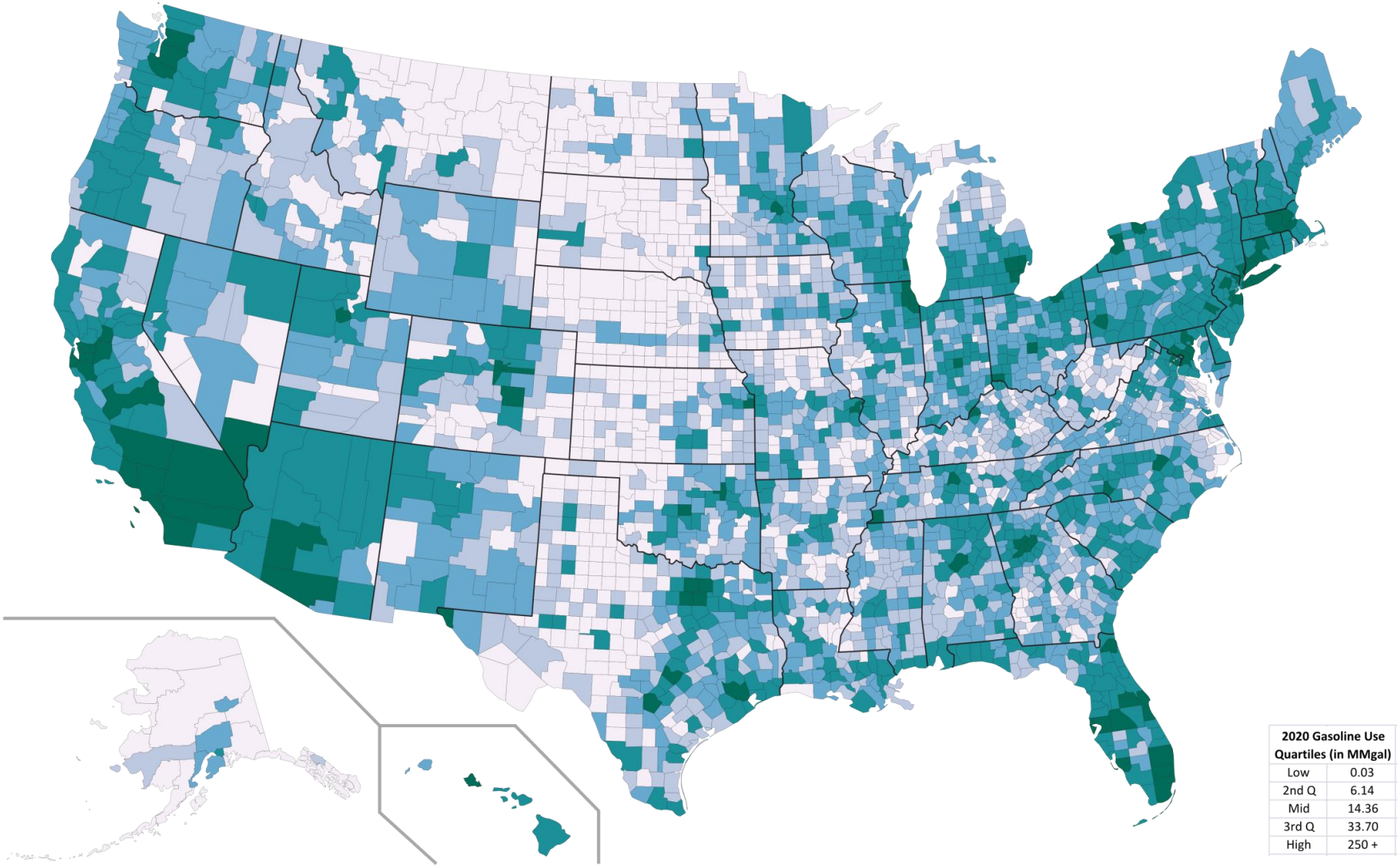
Example Result:
Evaluating Smooth vs. Transient Driving



Validating Bottom-Up Approach



Projected Fuel Consumption By County: 2020



2020 Gasoline Use Quartiles (in MMgal)	
Low	0.03
2nd Q	6.14
Mid	14.36
3rd Q	33.70
High	250 +

Activity Data Needed

- Required at vehicle type, roadway type, and month / day / hour level
  - Users can supply directly, or bring more aggregate data that is allocated using defaults
- Total activity (e.g., VMT)
  - Also by model year: requires sales and scrappage
- Trip patterns (e.g., # of starts, soak periods)
- Average Speed
  - Reflects congestion, urban vs. rural
- Driving patterns (e.g., drive schedules)
  - How much accel, cruise, idle, decel?

Fuel Economy Data Needed

- Don't expect users to provide - EPA focuses on compiling these data
- For modal emission rates: real time (e.g. second-by-second) emissions data
  - Sources of data:
    - Dynamometer studies
    - State I/M programs
    - Portable emissions measurement (PEMS)
- For start emissions: bag data
- Other data: extended idling, fuel & environmental effects, air conditioning…

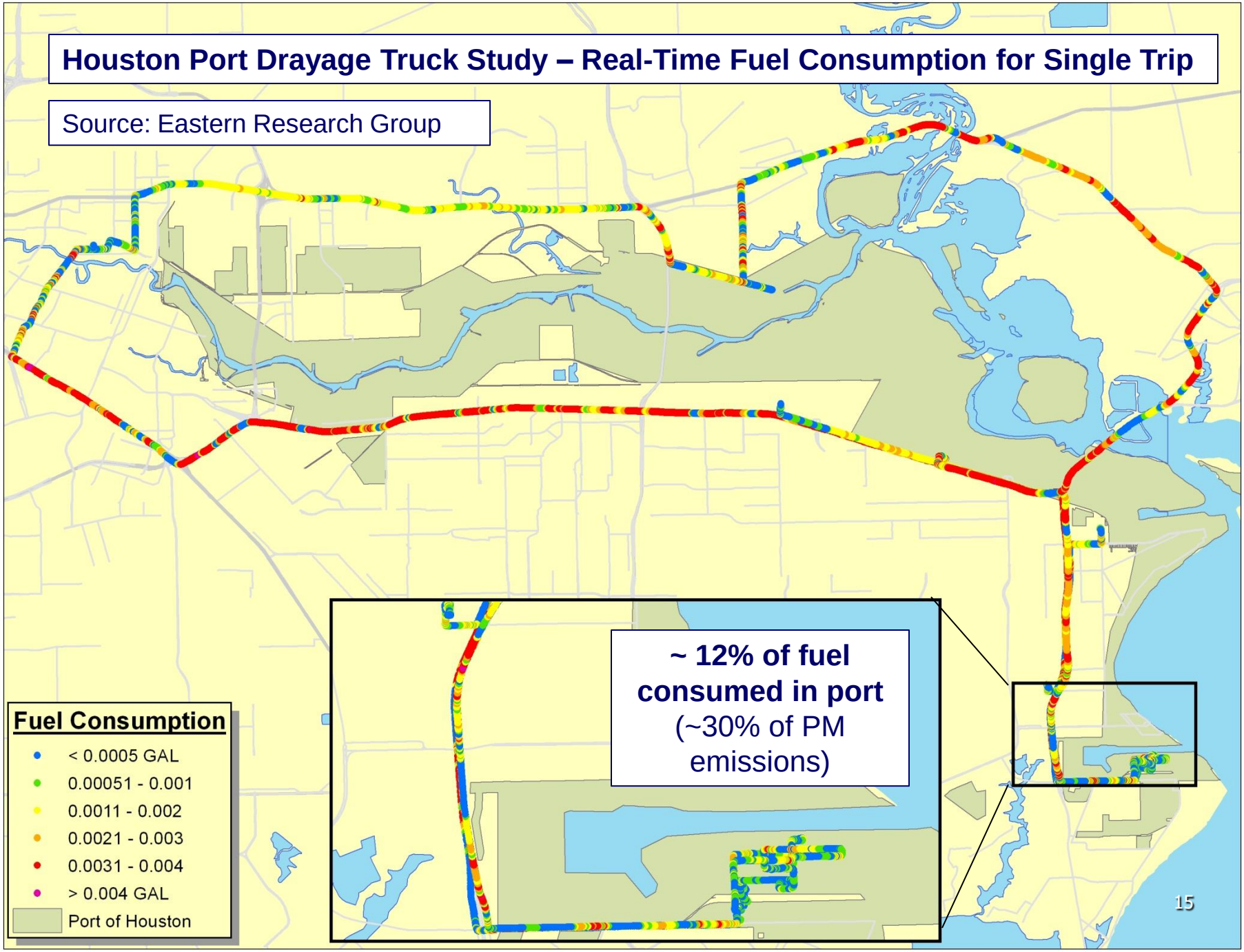
Portable Emission Measurement Systems (PEMS)

EPA PEMS Studies

- MOVES "Shootout" Study (2001)
  - 10 LDV, 15 transit buses in Ann Arbor area
- Kansas City Light-Duty PM Study (2004-05)
  - Partners: DOT, DOE, CRC, ERG
  - 51 cars and light truck "drive aways" with PEMS
- Nonroad "Pilot" Study (2008)
  - Partners: CRC (CRC E-70), ERG
  - 29 construction pieces in field with PEMS
- Houston Port Study (2009-10)
  - Partners: TCEQ, HGAC, ERG
  - 46 Heavy-Duty trucks in field with PEMS
- Light-Duty Tier 2 Study (2012)
  - ~100 "Tier 2" vehicles in Detroit area
  - Prescribed drive route + activity "drive aways"

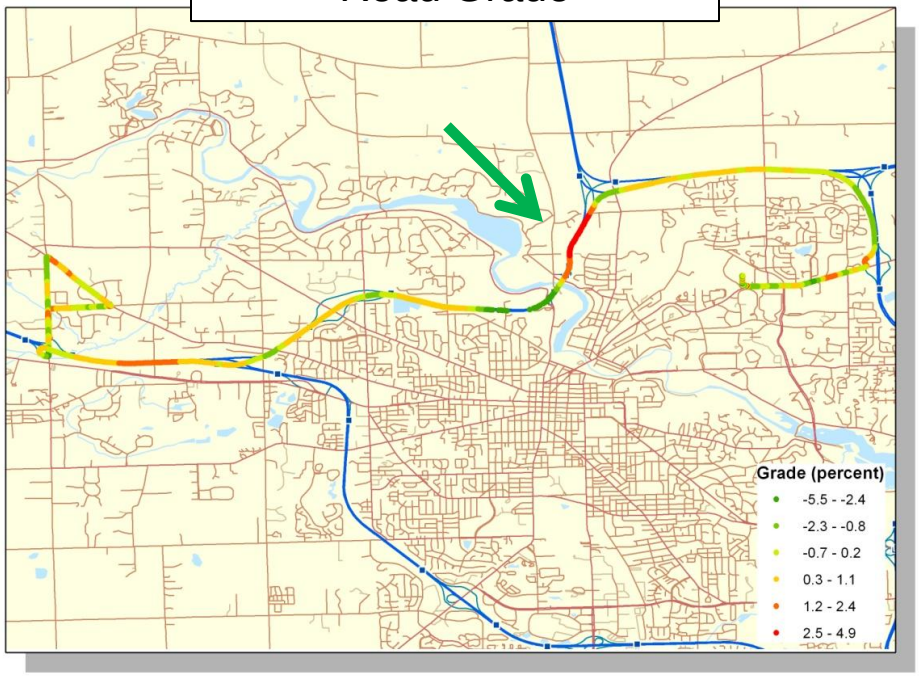
Houston Port Drayage Truck Study – Real-Time Fuel Consumption for Single Trip

Source: Eastern Research Group

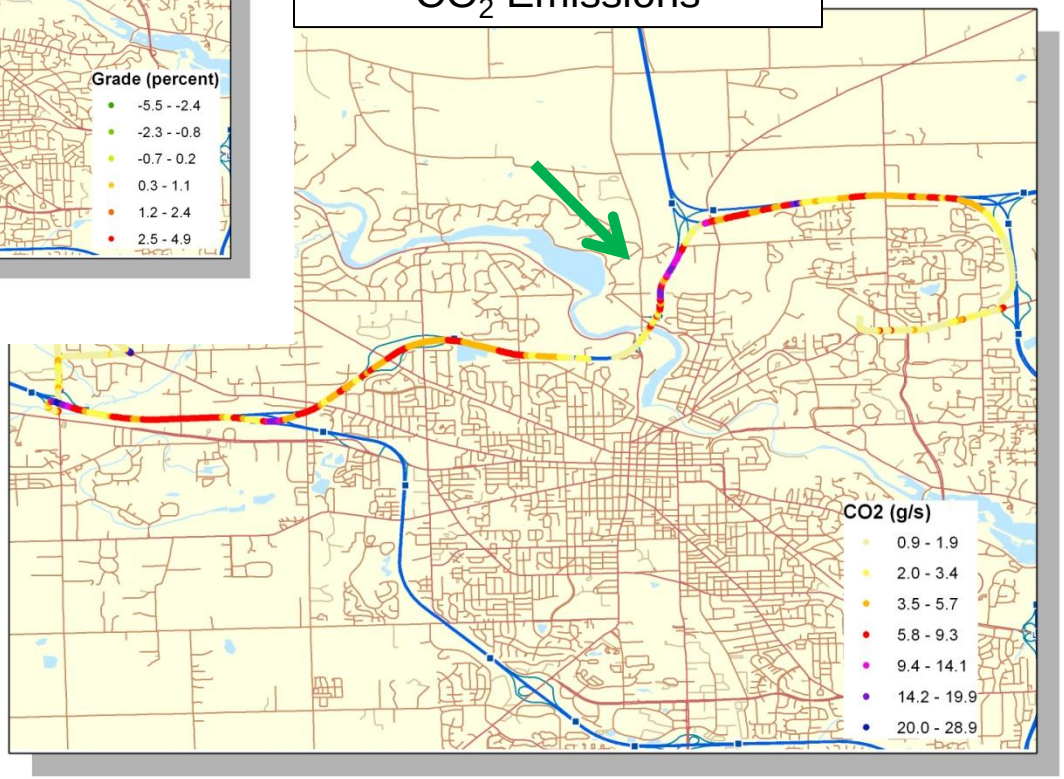


EPA Light Duty PEMS Study – Real-Time CO_2 Emissions for Single Trip

Road Grade



CO_2 Emissions



1 mile uphill climb @ 3-4% grade consumes ~ 20% of fuel on 8.5 mile freeway segment

Conclusions

- Although we already know how much fuel is consumed in the U.S., bottom up methods for calculating fuel consumption are necessary to understand **what, where and how**
- Range of bottom-up approaches possible depending on level of detail desired
- Portable emission measurement systems (PEMS) a promising tool for evaluating fuel consumption and emissions under real-world conditions that are not captured by test cycles
  - Examples: off-network (port), road grade

Acknowledgements

- Scott Fincher - Eastern Research Group
- Ari Kahan, Jarrod Brown, David Choi, Carl Fulper – U.S. EPA Office of Transportation and Air Quality