MOVES
Motor Vehicle Emission Simulator

Updates to "high-power" emission rates and start deterioration for light-duty vehicles

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MOVES Review Work Group

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Background

- As part of our ongoing efforts for MOVES validation, we have evaluated default model inputs using newer data or assumptions based on latest science.

- Here, we focus on the planned updates for light-duty emission rates at high-power (US06 rates) and the deterioration applied to light-duty start emissions.

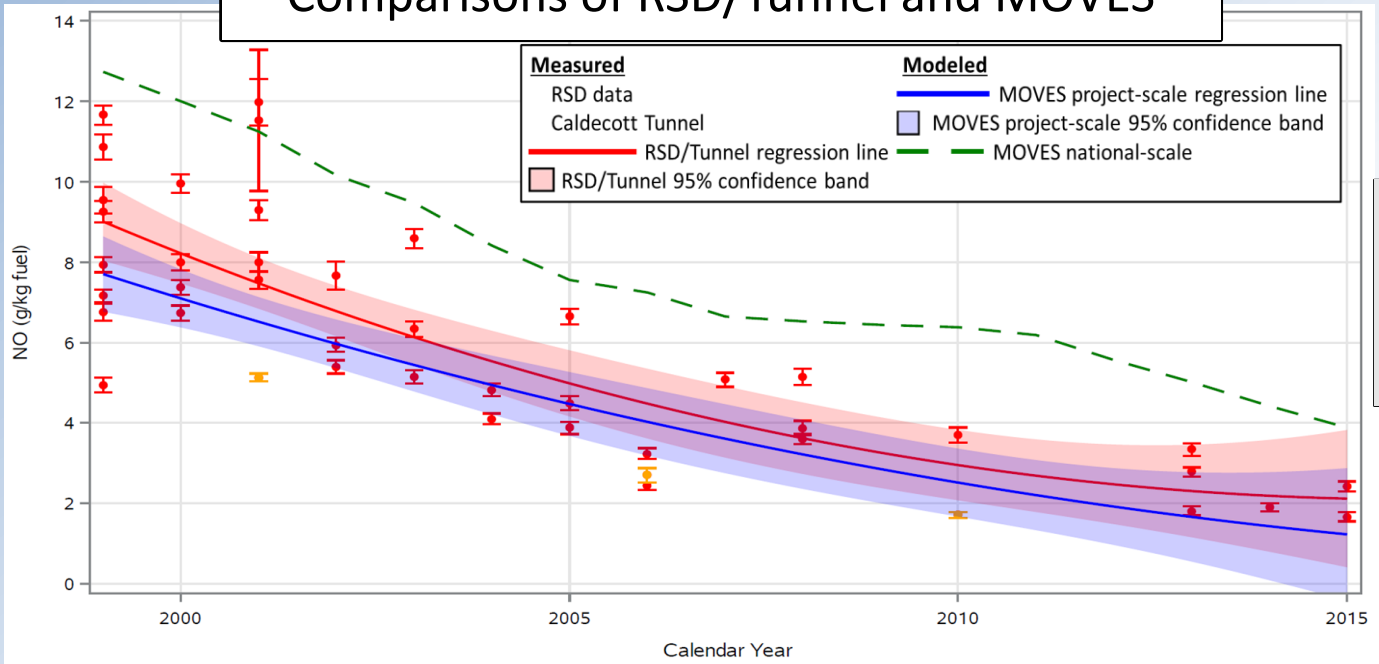
Part 1

UPDATES TO "HIGH-POWER" RUNNING EMISSION RATES

Motivation for updating "high-power" rates

- Previous NOx evaluation efforts showed that
  - MOVES compares well to Remote Sensing data (RSD) when modeled at the project scale using location-specific inputs
  - MOVES overestimates when modeled at the national scale using inputs from the National Emissions Inventory (NEI)

Comparisons of RSD/Tunnel and MOVES



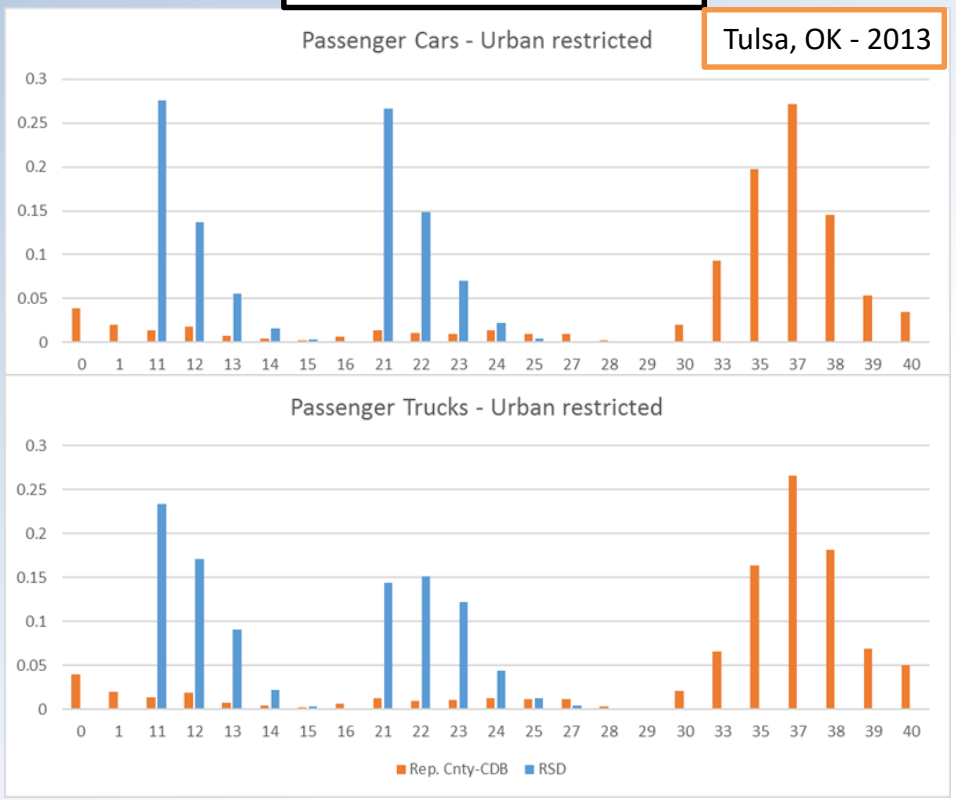
MOVES lower than RSD/tunnel regression and generally within the variability of the data

Sonntag et al., "*Update on MOVES Model Evaluation: NOx*", MOVES Review Workgroup, September 2017, Ann Arbor, MI
Choi et al., "*Comparisons of MOVES Light-duty Gasoline NOx Emission Rates with Real-world Measurements*", American Geophysical Union Fall Meeting, December 2017, New Orleans, LA

Motivation for updating "high-power" rates

- One of our key findings was that the operating mode distributions in the NEI include higher power operating modes compared to RSD sites modeled at the project-scale level with local data.
  - This was relevant as some literature (e.g. McDonald et al. 2018) argue that MOVES overestimates NOx based on site-specific RSD data modeled using county-average NEI estimates.
- Since a key difference between the modeling scales was the presence of high-power operating modes, we focused on evaluating these emission rates.

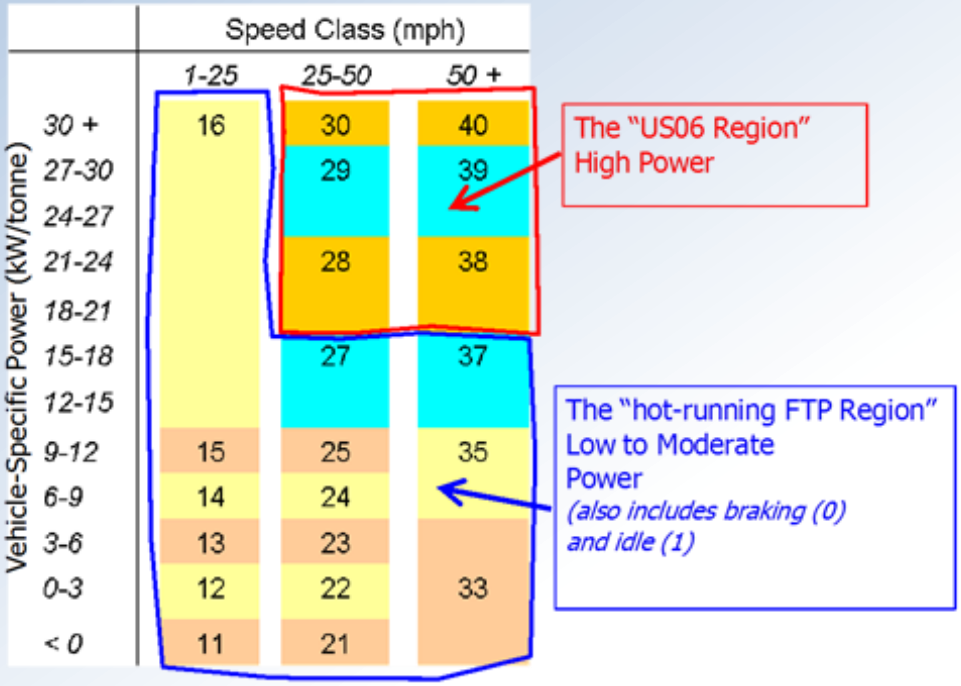
2014 NEI vs RSD site



Choi et al., "*Comparisons of MOVES Light-duty Gasoline NOx Emission Rates with Real-world Measurements*", 2017 American Geophysical Union Fall Meeting, New Orleans, LA

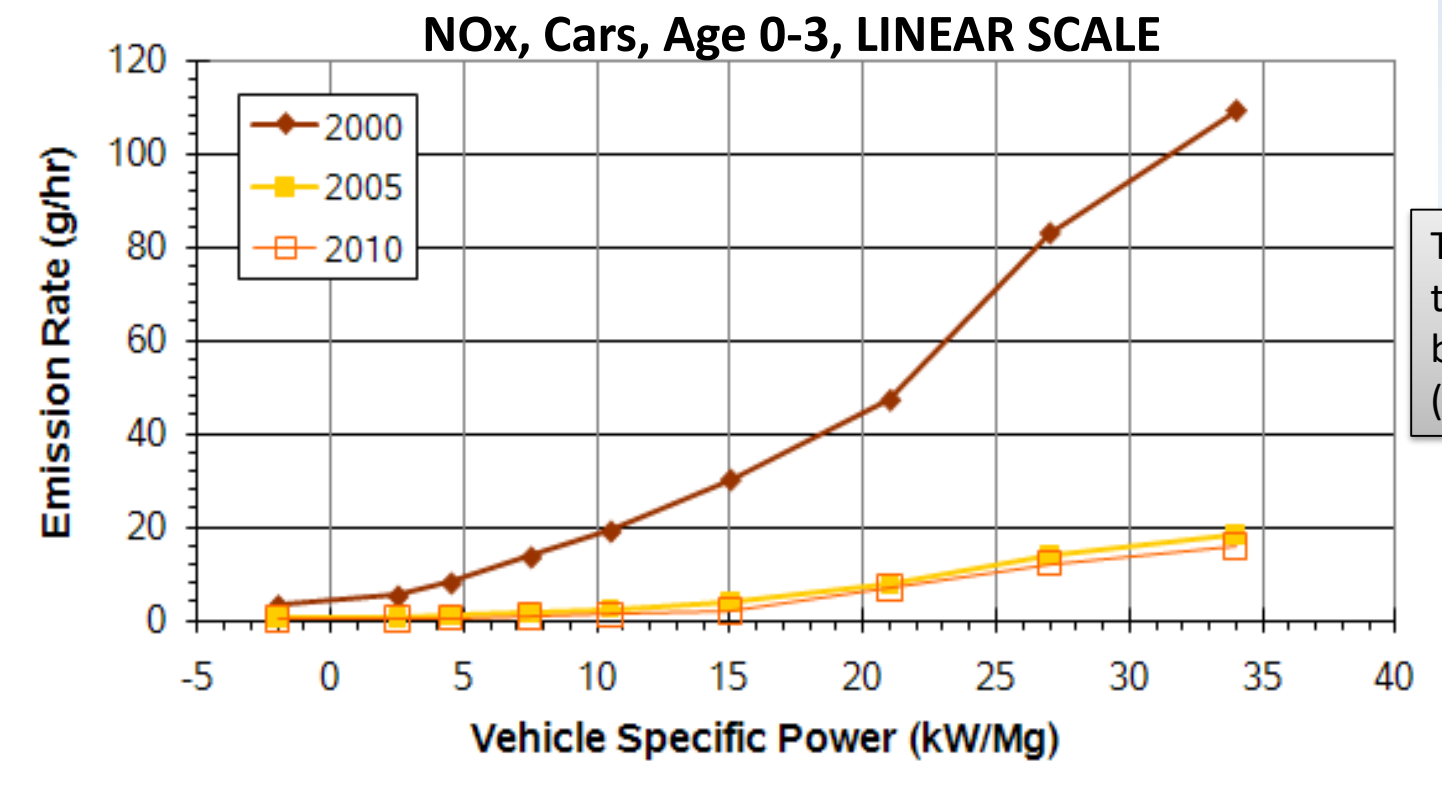
What are “high-power” rates?

- “High-power” refers to six MOVES operating modes, where:
  - The “Supplemental Federal Test Procedure Applies” (SFTP)
    - MY 2001 and later
  - Speed > 25 mph, AND
  - VSP > 18 kW/Mg
- Laboratory, I/M and RSD typically provide data more representative of the Low/Moderate region



MOVES2014 Running Emissions Rates for 3 model years

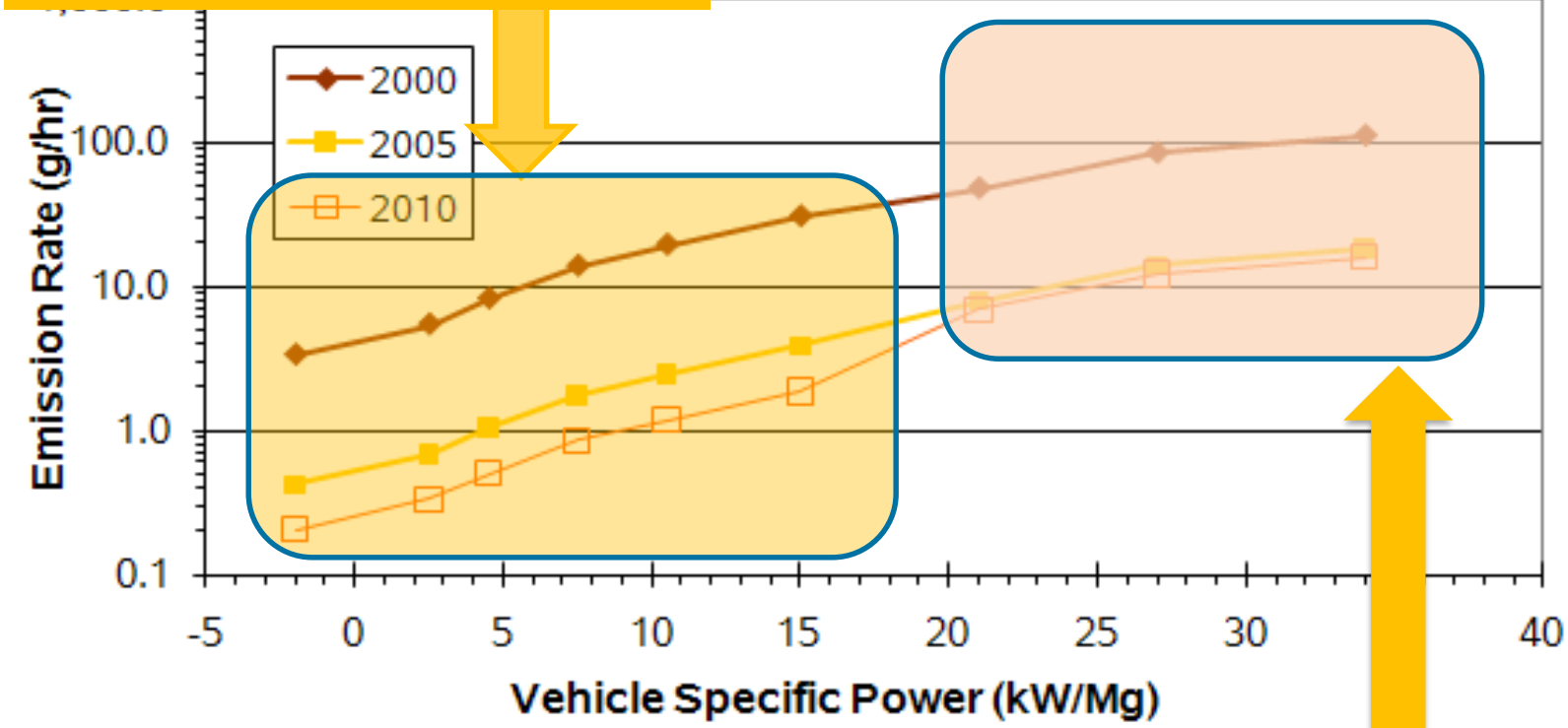
- The rates for MY2000 (representing Tier 1) were scaled down to represent the mix of standards in MY2005 (NLEV phasing out, Tier 2 phasing in) and MY2010 (Tier 2 phase-in complete)



These rates represent the operating modes between 25-50 mph (opmodes 21-30)

MOVES2014 Running Emissions Rates for 3 model years

At lower power, reduction was greater (~1 order magnitude), representing new standards on FTP



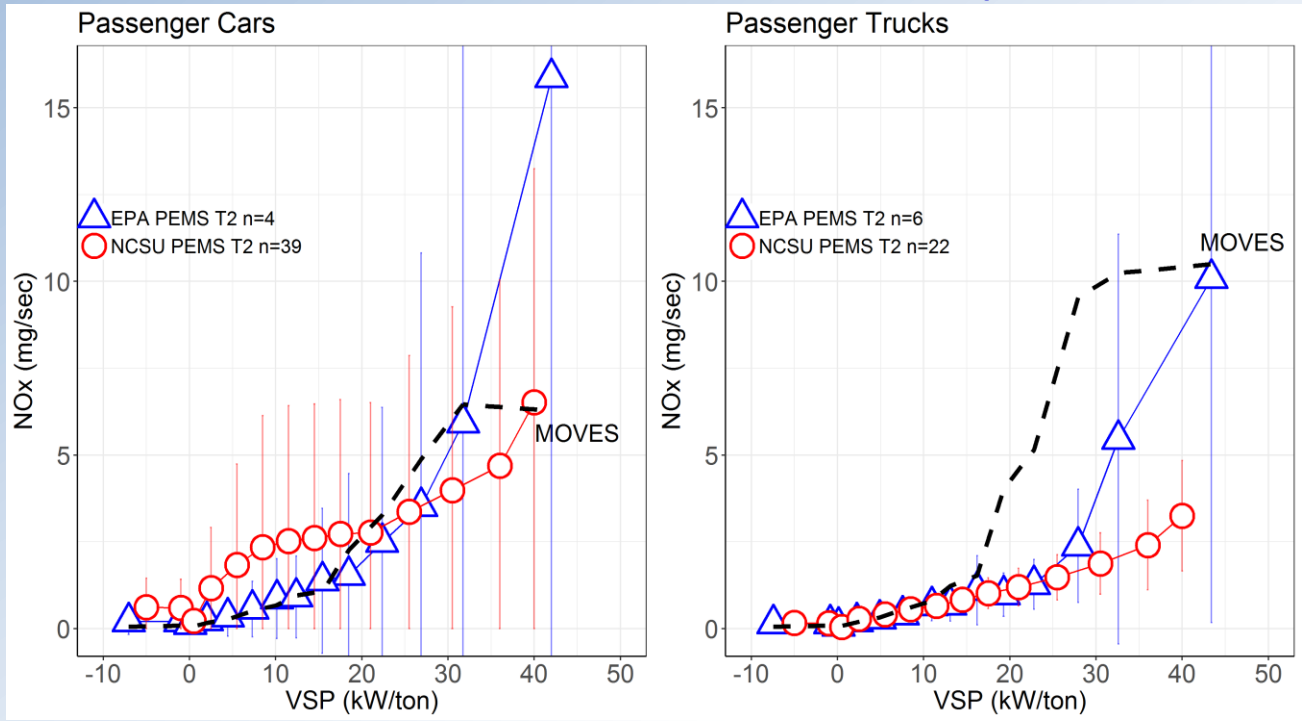
At higher power, reduction was less because regulations were less stringent on the SFTP (US06)

Reevaluating Power Trends

- We used continuous real-world data to evaluate the power trends
  - Collected in two studies using portable instruments (PEMS)
  - Data from 134 “Tier-2”vehicles
    - measured by North Carolina State University
      - Liu & Frey, 2015; Khan & Frey, 2018
    - Using Clean-Air Technologies (CATI) instruments
  - Data for 10 Tier 2 Vehicles
    - Measured by EPA in Ann Arbor
    - Using Sensors instruments
- Due to small sample sizes, the goal was not to estimate fleet-average emission rates but to reassess shapes of VSP trends from low to high power.

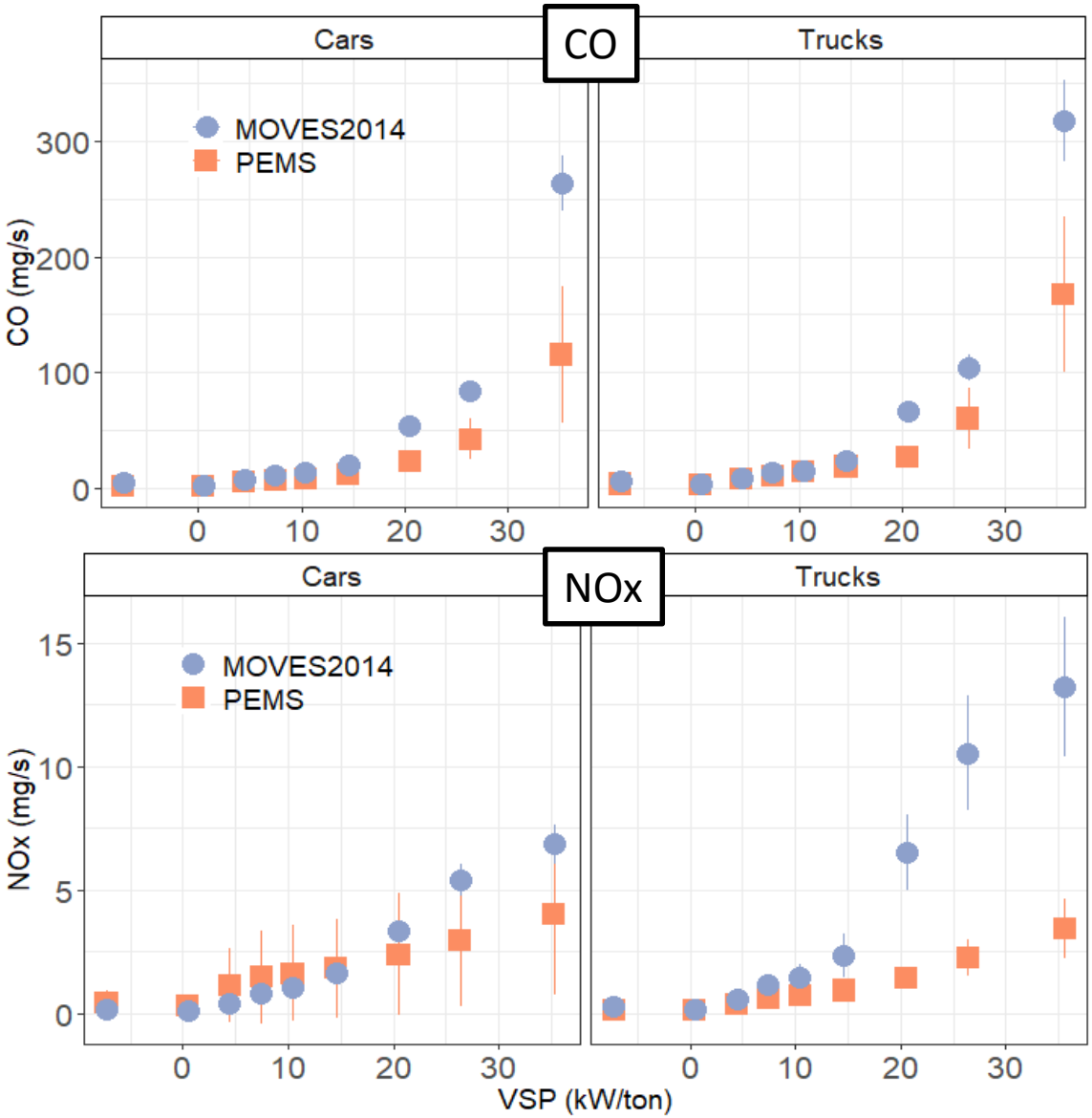
Comparing PEMS to MOVES

- We performed an initial comparison with subsets of data
  - from NCSU and EPA test programs
  - "MOVES" trend selected to match data by model year (2004-2017) and age
- MOVES NOx-VSP trends are steeper than PEMS data for both cars and trucks. However, the difference is more pronounced for trucks.



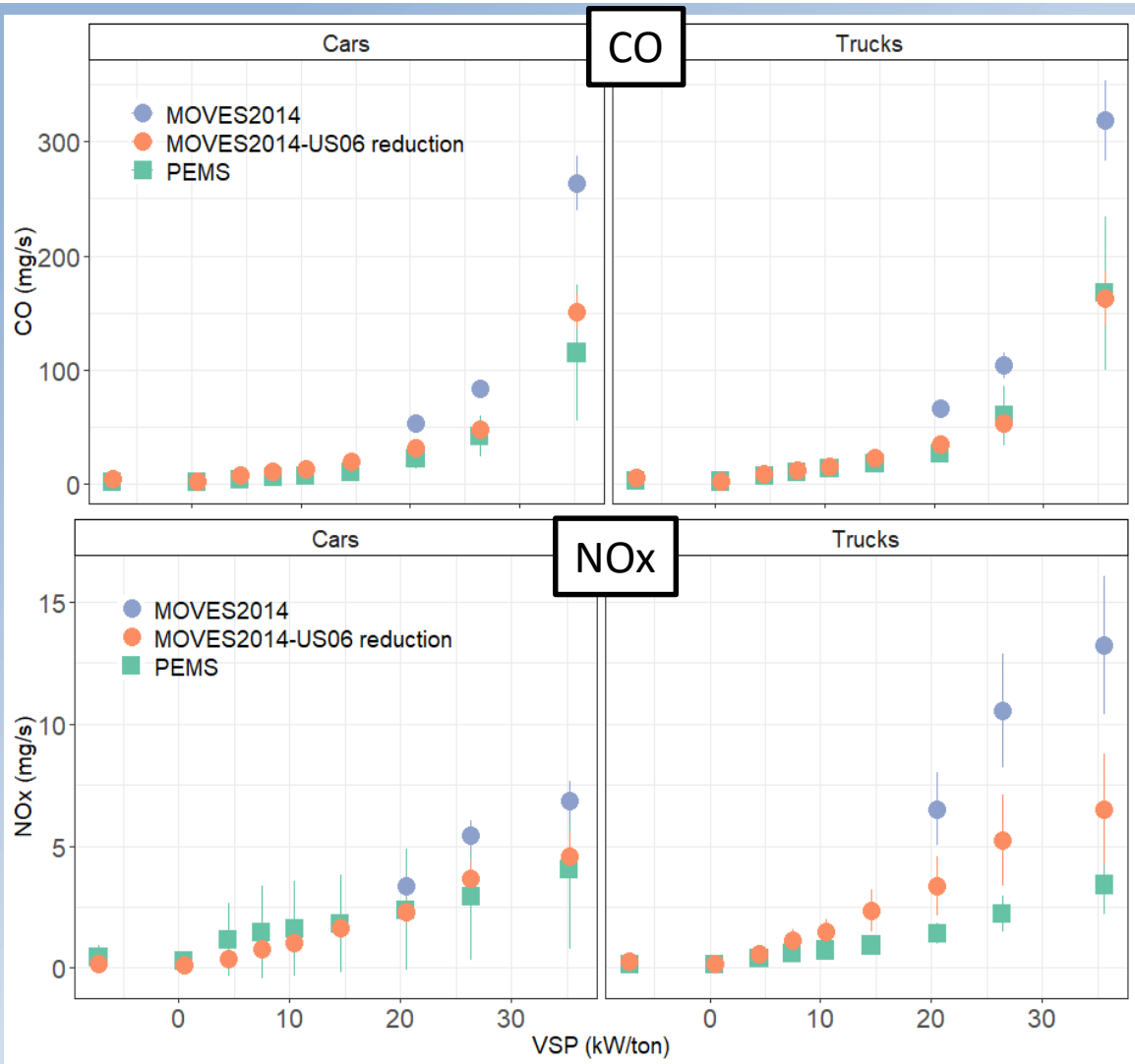
Sonntag et al., "*Updated Evaluation of MOVES Light-duty Gasoline NOx Emission Rates with Real World Measurements*", 28th CRC Real World Emissions Workshop, March 2018, Garden Grove, CA

Comparing PEMS to MOVES



- Later comparison to the full NCSU dataset confirmed initial findings for NOx and other gaseous pollutants.

Comparing PEMS to MOVES



- We decided to scale the rates uniformly across the VSP trend, as opposed to having a more aggressive scaling in the SFTP region.
- Orange circles represent the revised rates ("US06 reduction")
  - For NOx, the reduction is not enough to close the gap between model and measurements in trucks

Updated "high power" rates - Summary

- Our analysis indicates that the power trends in MOVES2014 are more aggressive than the observed power trends in the NCSU data.
- Planned Revision:
  - Treat all rates uniformly (e.g., same reductions across power trend)
- Scope:
  - This update affects all gaseous pollutants (NOx, HC and CO) for NLEV, Tier 2 and Tier 3 vehicles

Part 2

UPDATES TO DETERIORATION TRENDS FOR START EMISSION RATES

Reexamining Deterioration for NOx Start Emissions

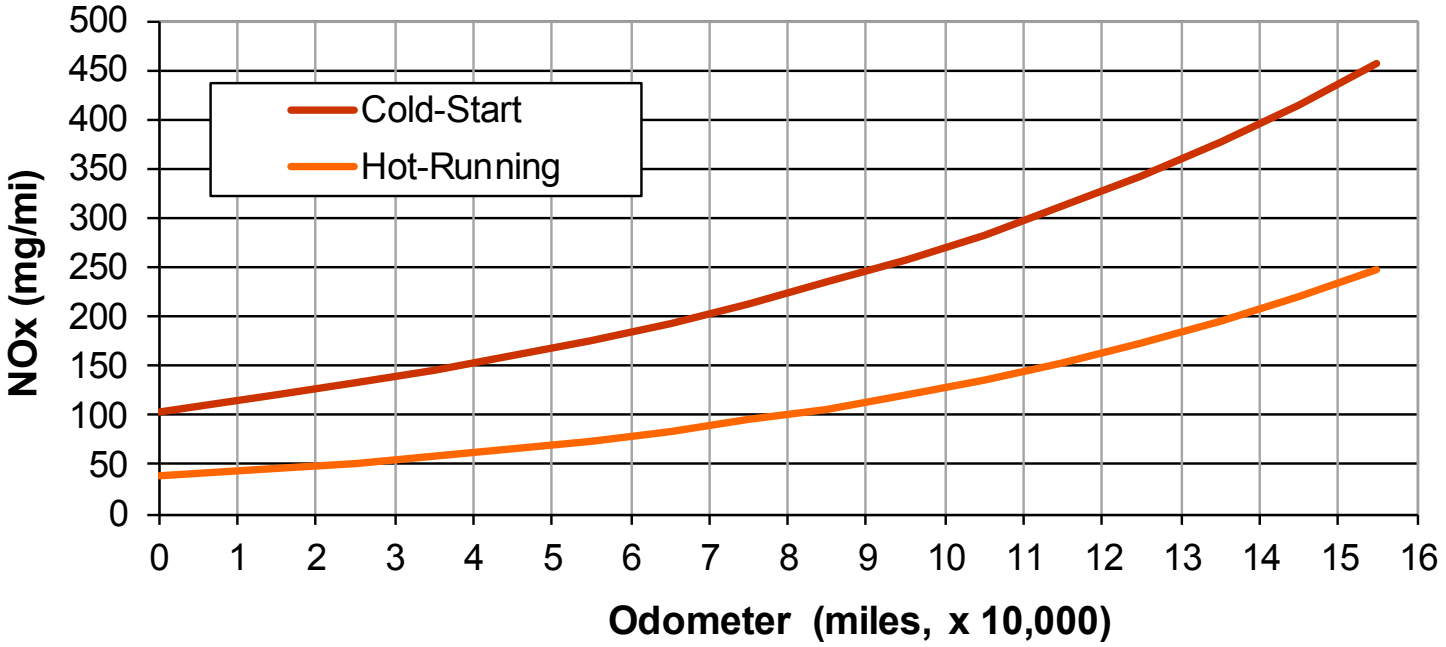
- Starts in MOVES
  - Incremental mass emitted (g/start)
    - During several minutes after engine start
  - Defined by Federal Test Procedure (FTP)
    - "Cold-start" = Phase 1 – Phase 3
    - "Hot-running" = Phase 2
  - Do starts deteriorate?
    - Data are sparse

Estimating NOx Start Deterioration

- "In-use Verification Program" (IUVP)
  - run by manufacturers
- Goal: verify that onroad vehicles meet standards
- Vehicles
  - recruited from public
  - measured at
    - 0-50,000 mi (certification standards apply)
    - 50,000-120,000 mi (useful-life standards apply)
- Measured on certification cycles (including FTP)
  - Results available by test phase
- Can be used to estimate deterioration
  - For starts as well as running
  - On absolute basis
  - On relative basis

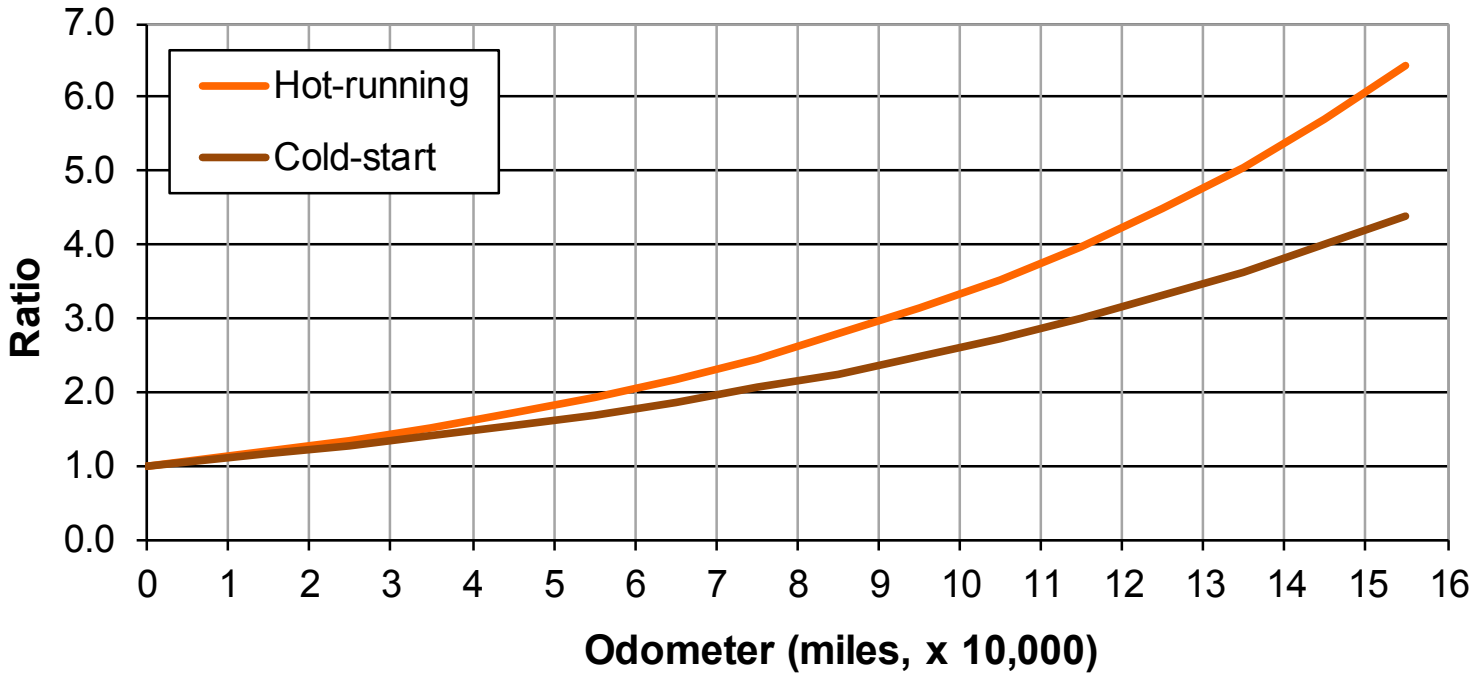
Absolute NOx Deterioration
for Cars

- Deterioration evident for starts as well as running
  - Based on log-linear regressions
  - Trend for starts is steeper



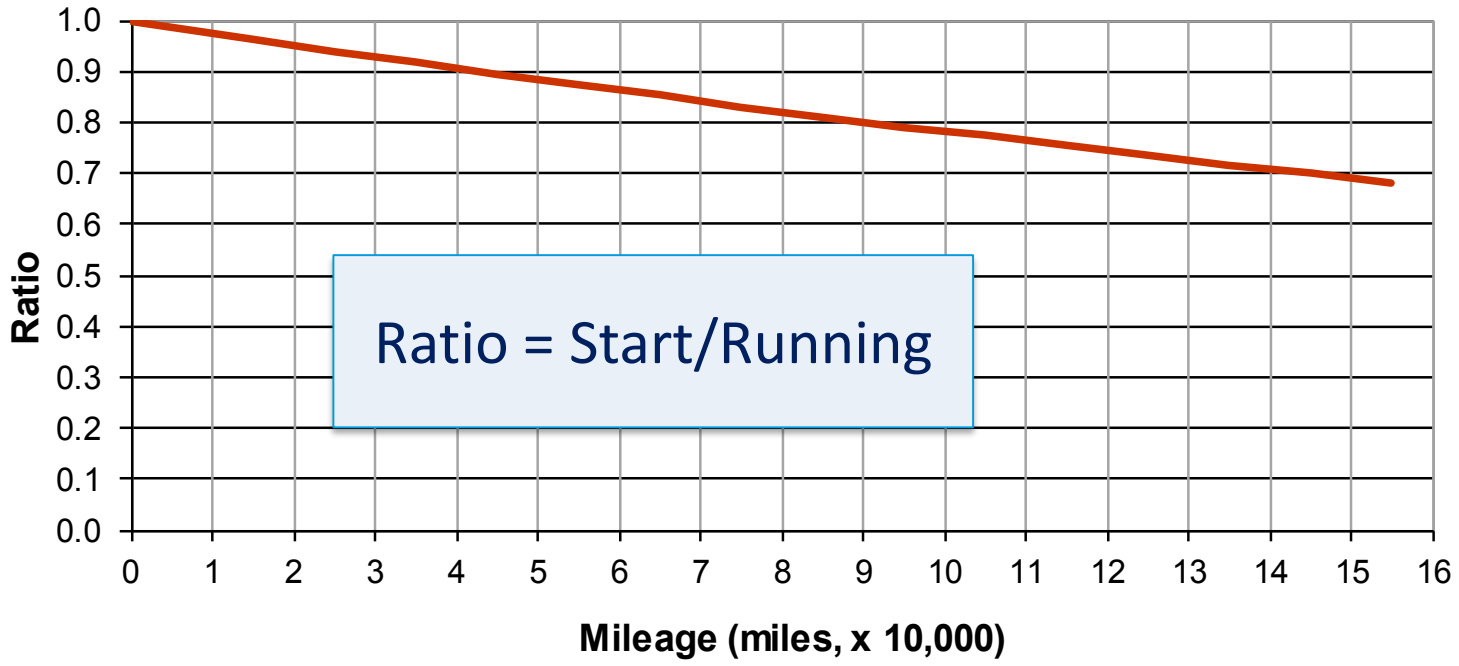
Relative NOx Deterioration
for Cars

- Normalize emissions to zero-mile level
  - Trend for running is steeper
  - Starts deteriorate, but at lower relative rate



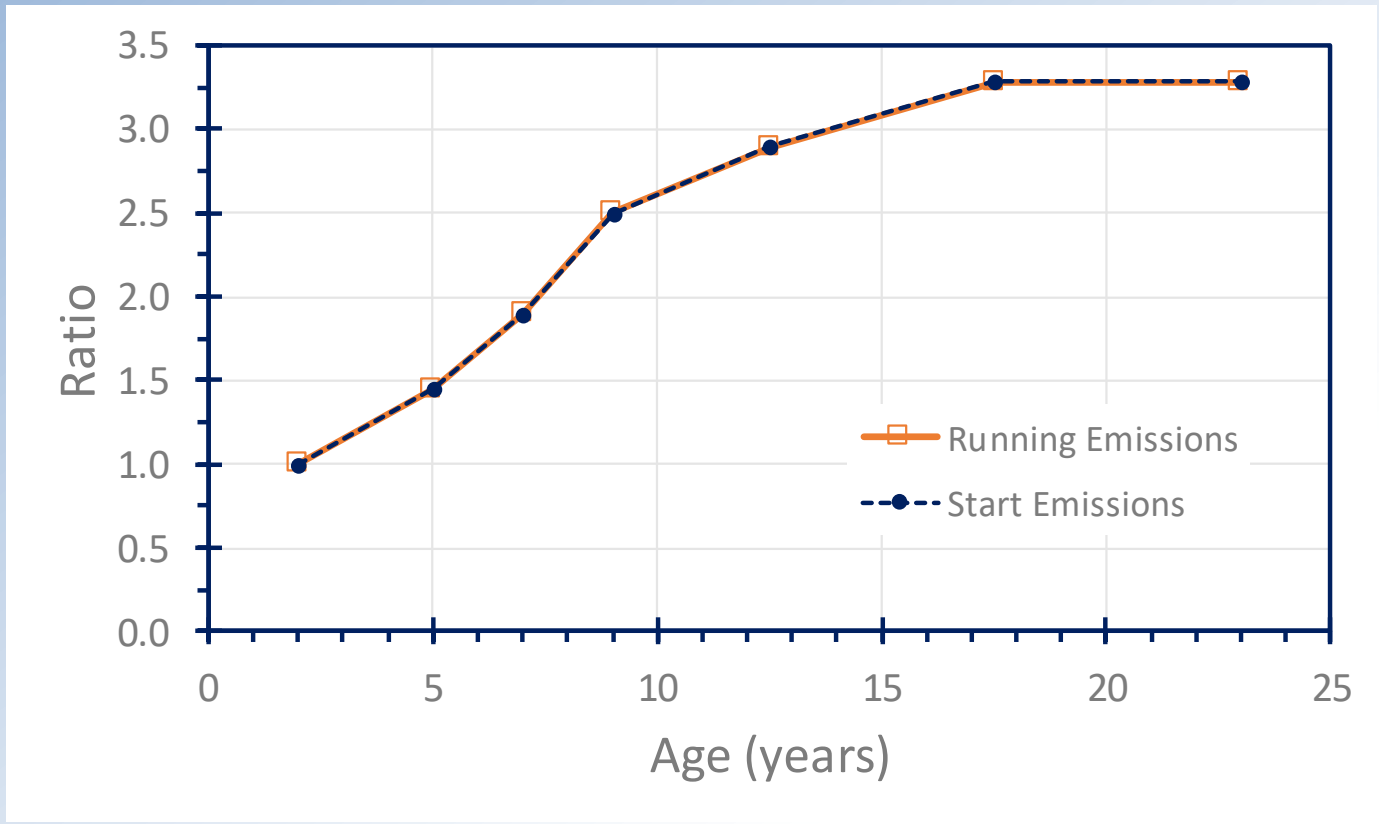
Relative NOx Deterioration Adjustment
for Cars and Trucks

- Relate start to running deterioration
  - At any mileage level, as a ratio



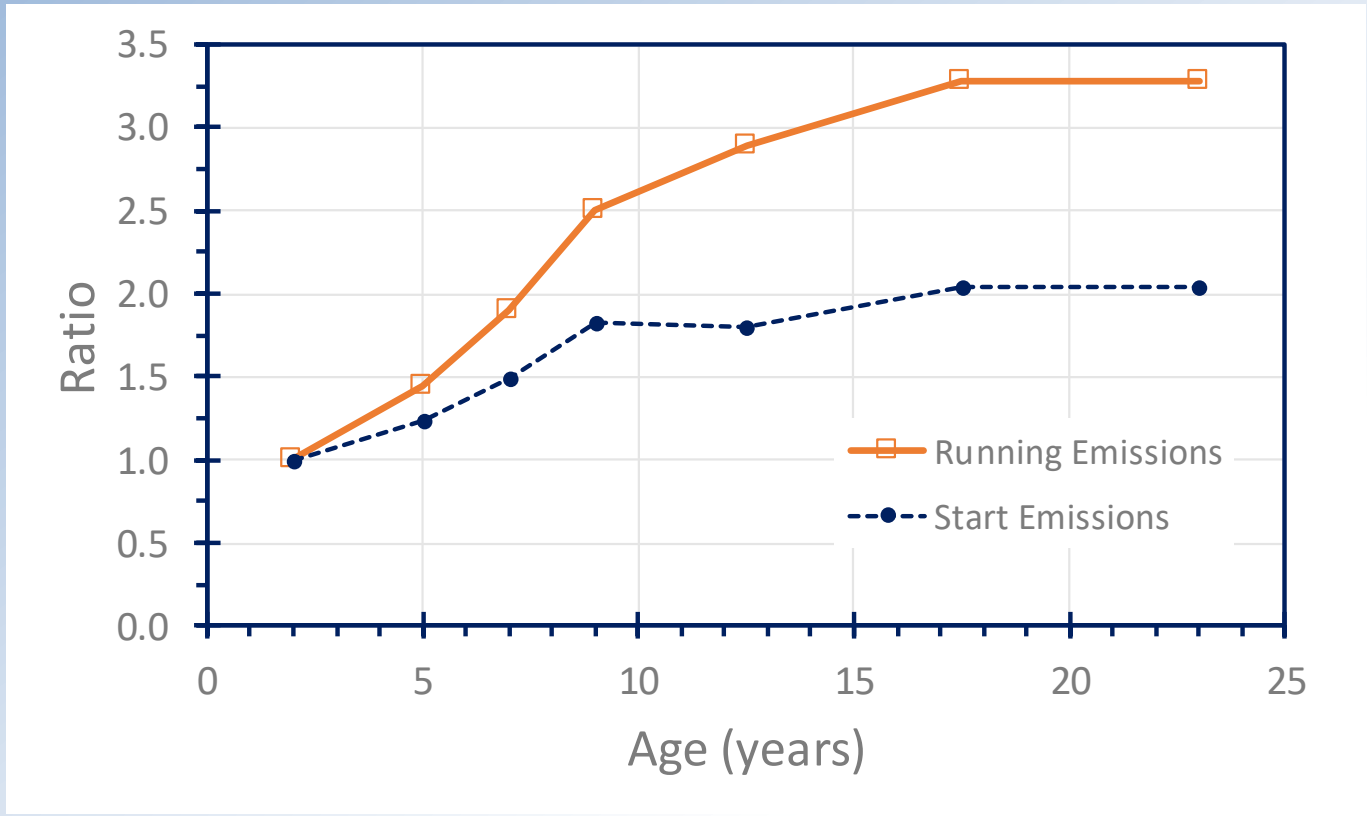
What we do now

- In MOVES2014, the deterioration for NOx starts is calculated in relation to that for running
  - applying the same relative deterioration trend



Planned Update For NOx Start Deterioration

- Apply reduced relative deterioration trend
  - After translating from mileage to age basis
  - And renormalizing to MOVES ageGroups



Scope of Application

- Pollutant: Oxides of nitrogen (NOx)
  - pollutantID = 3
  - NOTE: since MOVES2010, have used reduced relative starts deterioration for HC and CO
    - After this update, NOx, HC and CO will be treated similarly
- Process: start exhaust (processID = 2)
- Fuels:
  - Gasoline (fuelTypeID = 1)
  - E85 (fuelTypeID = 5)
  - Diesel (fuelTypeID = 2)
- regulatoryClass
  - Passenger Cars (LDV, regClassID = 20)
  - Light-duty trucks (LDT, regClassID = 30)
- modelYearGroups
  - All modelYearGroups for exhaust process

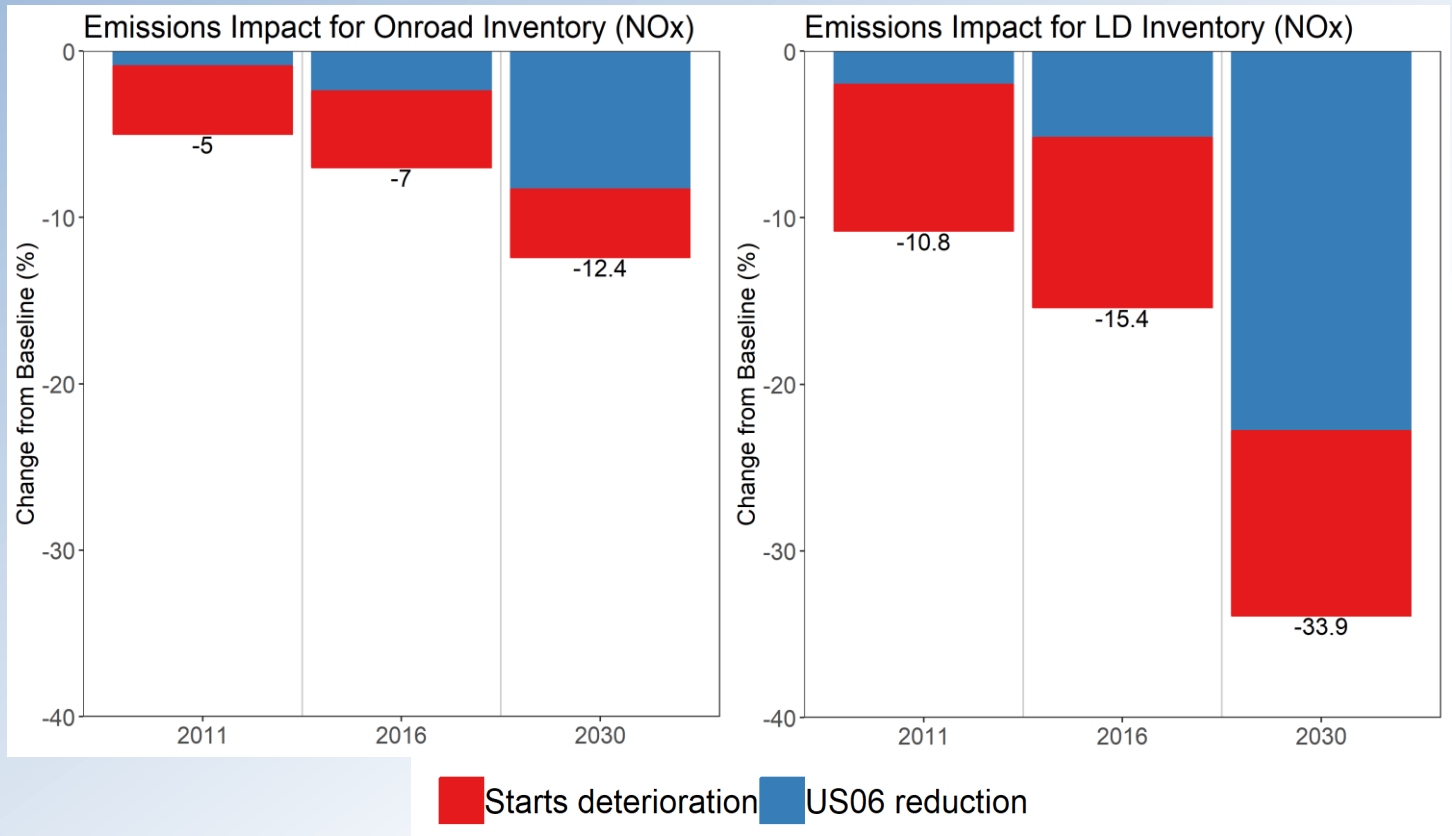
Note: In MOVES2014, the start deterioration for heavy-duty gasoline vehicles is the same as light-duty gasoline vehicles. We are also updating the start deterioration for heavy-duty gasoline, but it is not included in the emissions impacts quantified in this presentation.

Part 3

EMISSIONS IMPACT

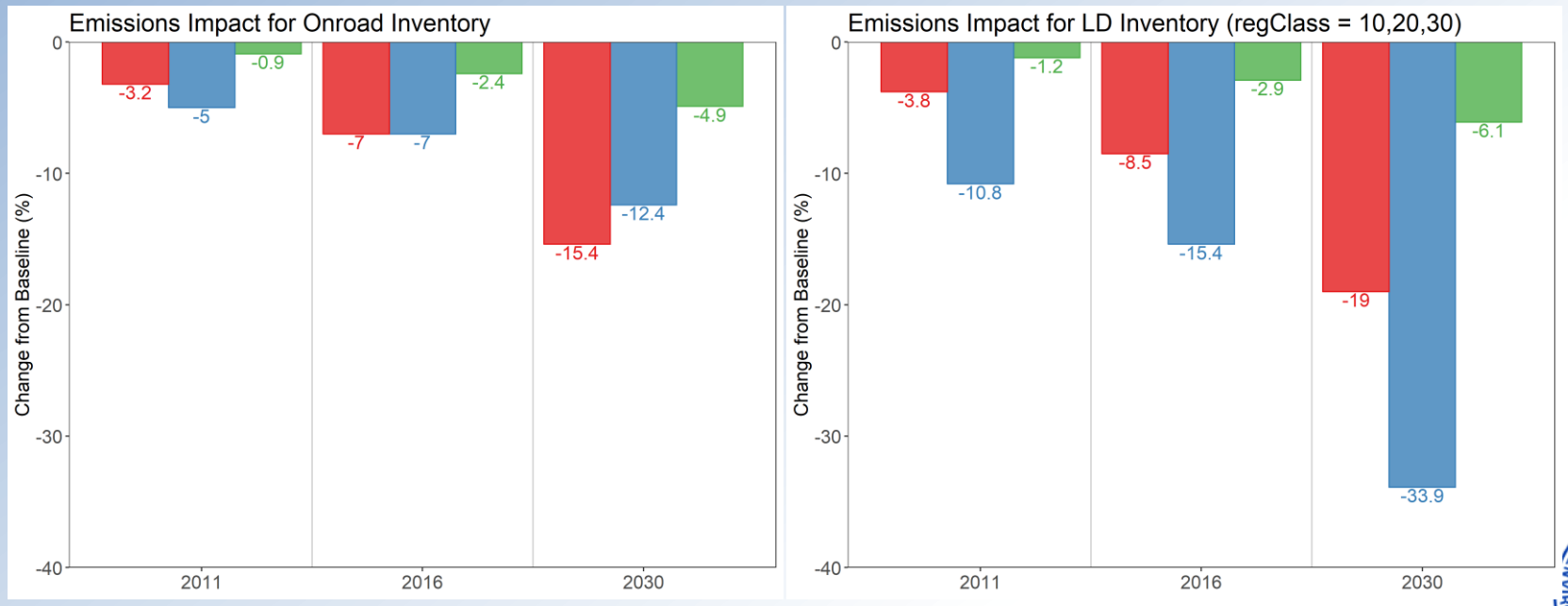
Cumulative Emissions Impact – breakdown for NOx

- Updated start deterioration effect expected to have similar magnitude of impact across all calendar years
- However, updated "high power" rates expected to result in more reductions in future years because "high power" emissions were a larger fraction of NOx emissions for future vehicles.



Cumulative Emissions Impact – THC and CO

- THC and CO results reflect updates to “high power” running rates only; no changes were made to start deterioration
- Resulting changes to THC and CO inventories are larger for future years due to larger contribution from the US06 region in future vehicles (similar to NOx).



(*) Figure does not include evaporative emissions

Summary and Next Steps

- Based on analysis of the latest data (EPA/NCSU PEMS and IUVP), we recommend updating both "high power" rates and start deterioration effect for NLEV, Tier 2 and later light-duty vehicles in the next version of MOVES
  - "high power" rates: apply uniform scaling factors across all VSP ranges
  - Start deterioration: apply a reduced effect to starts relative to running (only for NOx)
- The updates are expected to result in lower emission inventories for criteria pollutants across all years
- We are continuing our efforts to evaluate MOVES LD rates as more data become available
  - A/C assumptions
  - Deterioration trends for running exhaust
  - Relative Mileage Accumulation