Approaches for Using Portable Emissions Measurement System (PEMS) Data for On-Road Heavy-Duty Vehicle Inventory Development

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Next steps
(from 2023 CRC RWEW)

- Keep using chassis dyno data to develop HD base emission rates, with continuing efforts of comparing emission rates derived from PEMS and dyno.

- Acquire more PEMS data through CARB internal testing programs and extramural contracts for further analysis.

- Evaluate and apply the two new methods to develop SCFs for EMFAC202Y.

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How Do They Compare?

Chassis Dyno

PEMS

vs.

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HDV Running Exhaust Emission Rates Modeling in EMFAC2021

$$\text{Emission Rate}\left(\frac{g}{mile}\right) = BER \times SCF$$

- Base Emission Rate (BER) is developed for each Model Year group and weight class group (MHD/HDD).

- Speed correction factors (SCFs) account for variation of emissions under different vehicle speed.

Typical SCFs of SCR*-equipped HD Vehicles
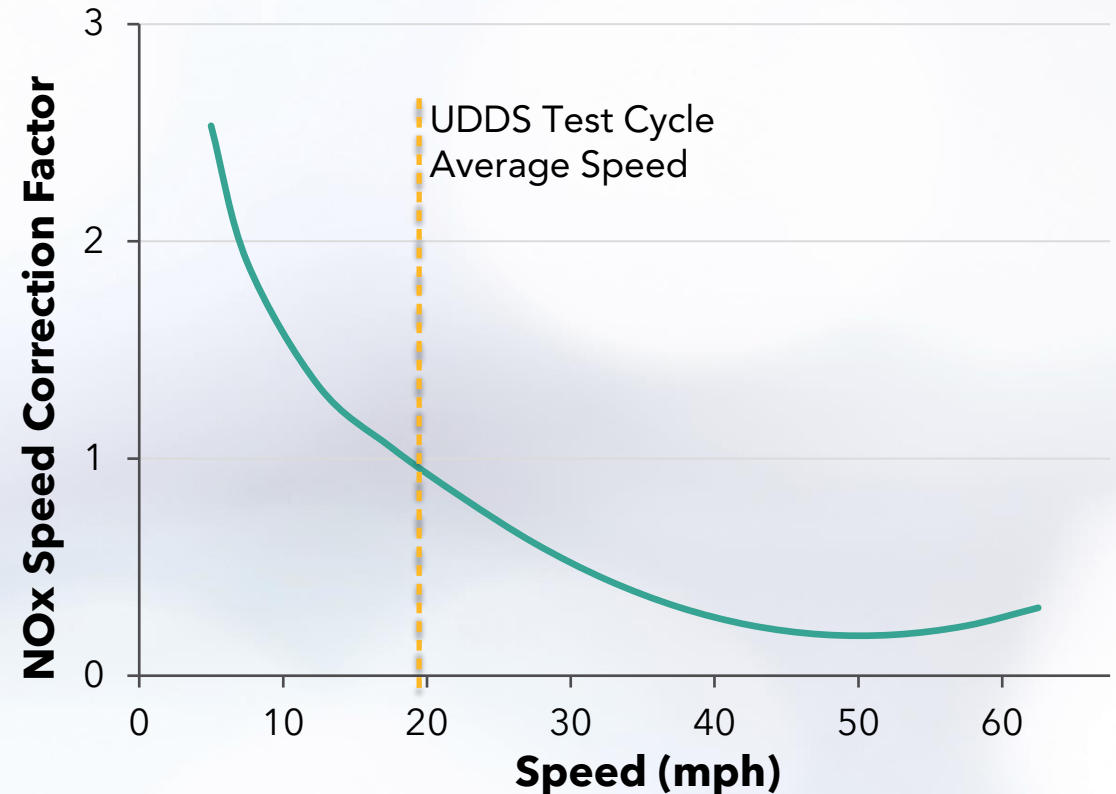
* SCR=Selective catalytic reduction

Updates to NOx Base Emission Rates

MHD/HHD New PEMS Analysis Method

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Base Emission Rate Data Sources for EMFAC202Y

Data from EMFAC2021 after recalled vehicles taken out

Data from existing vehicles in EMFAC2021 that were not analyzed

Test Program	Fuel Type	Weight Class	Engine MY Range	Test Type and Sample Size	
CARB TBSP*	Diesel	Class 8	2013-2019	Chassis Dyno 15	PEMS 10
		Class 6-7	2013-2017	Chassis Dyno 8	PEMS 1
200-Vehicle Study	Diesel	Class 7-8	2010-2018	Chassis Dyno 11	PEMS 15

New vehicles that are not included in EMFAC2021 (excluding recalled vehicles)

TBSP: Truck and Bus Surveillance Program

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PEMS Data Analysis Method

- Exclude start emissions from the PEMS data
- Running exhaust emissions were analyzed for each vehicle
- Steps
  1. Aggregate second-by-second PEMS data points into micro-trips
  2. Aggregate micro-trip level data into speed bins of 5 mph
  3. Develop a function of emission rate based on speed
  4. Determine the base emission rate at 18.8 mph
- Compare NO_x emission rates (g/mile) of PEMS vs Chassis dyno

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Step 1: Identifying Micro Trips in PEMS Data

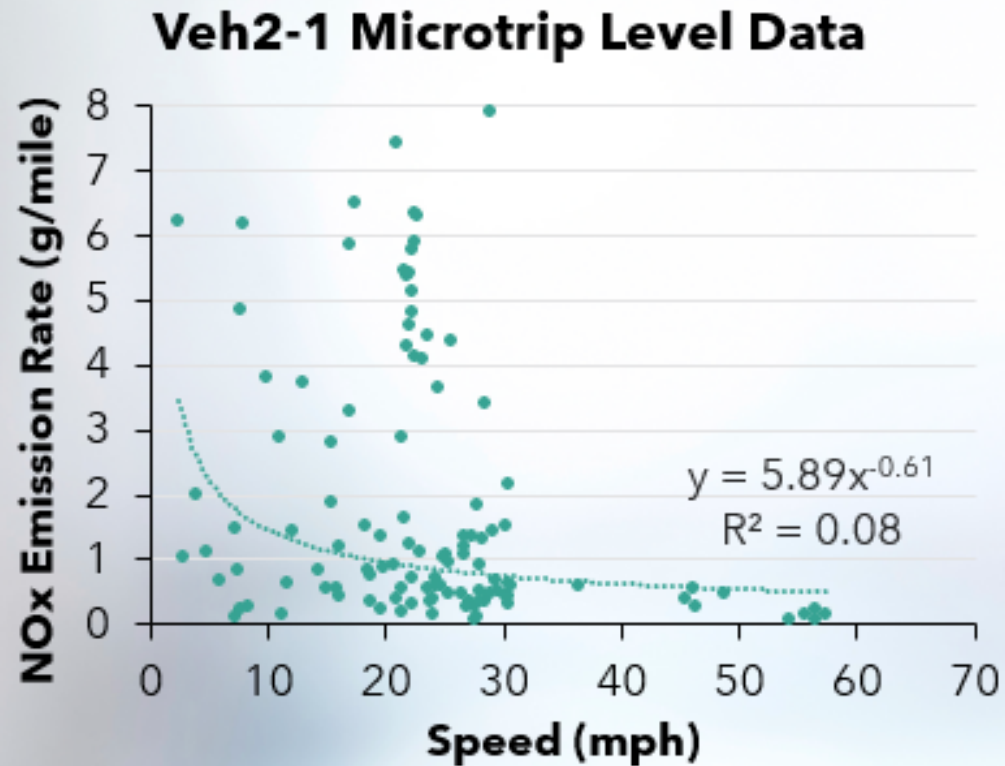**Micro-trips are defined as "from start to stop"**
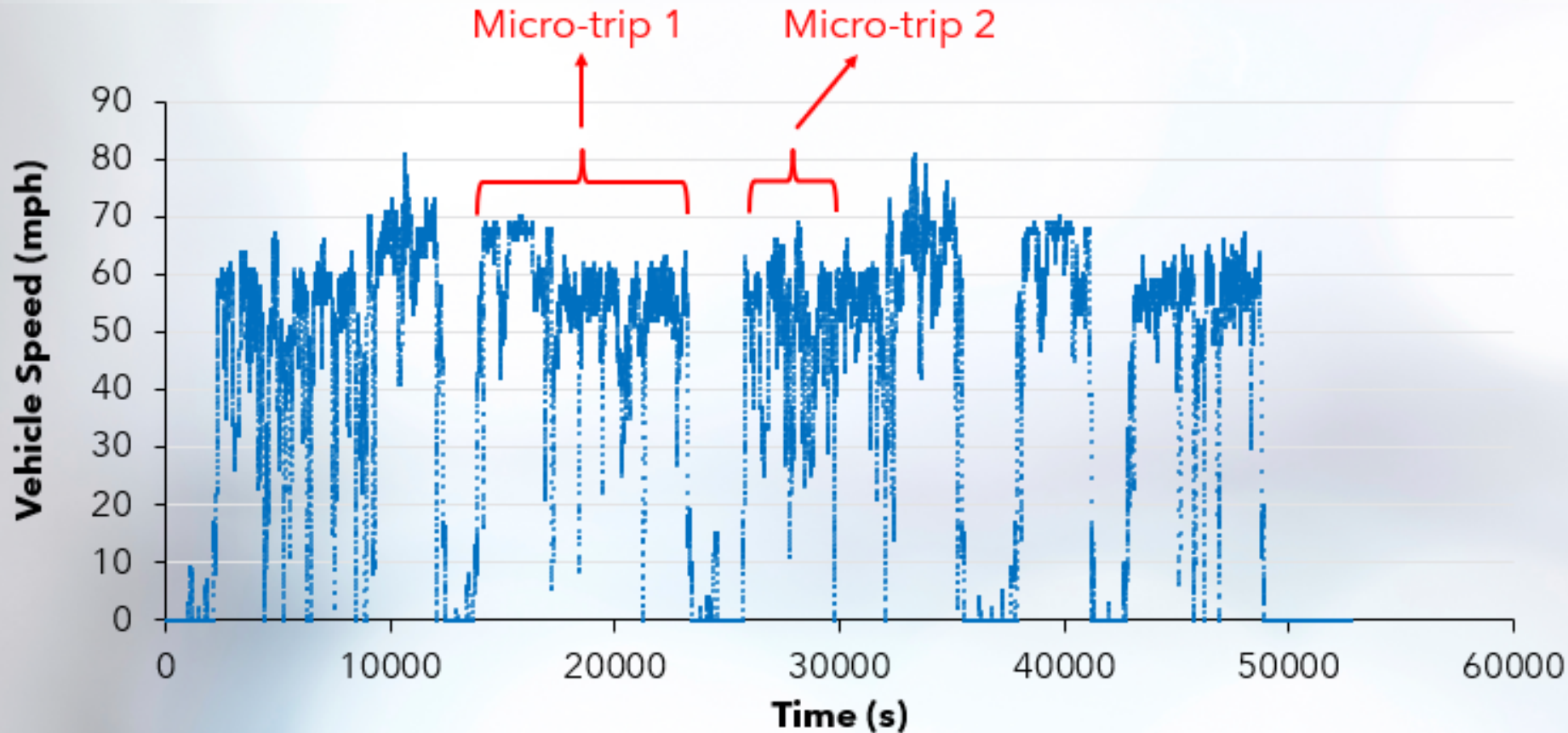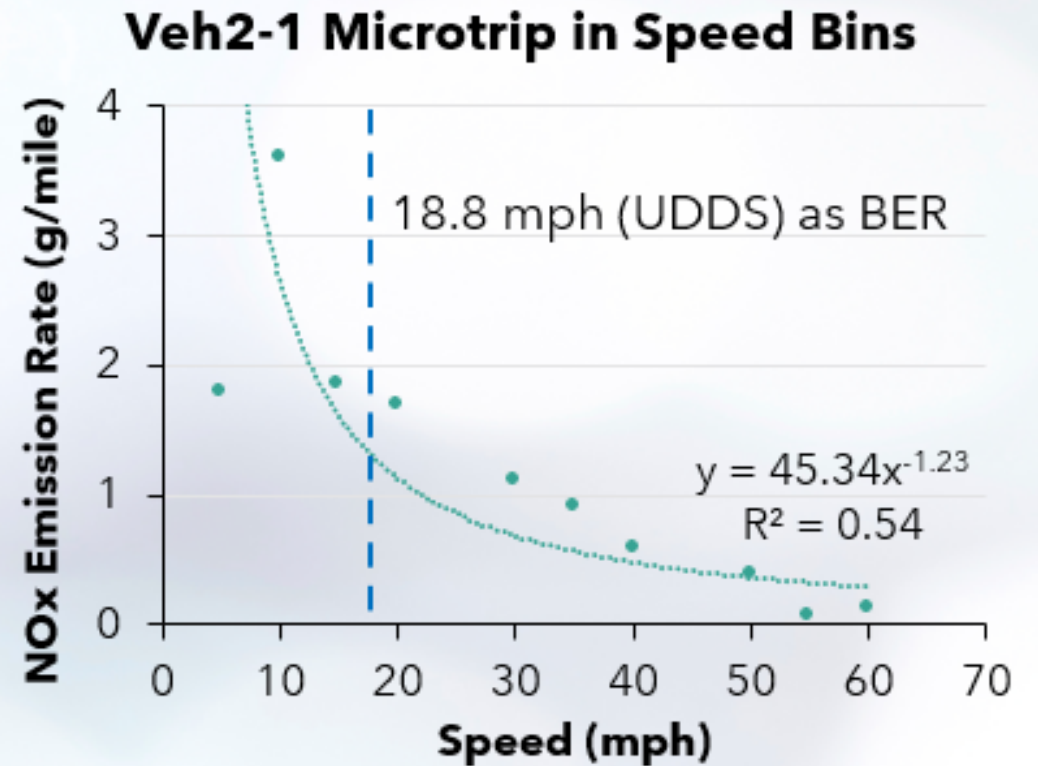

Processing micro trips:

1. Exclude extended idling events
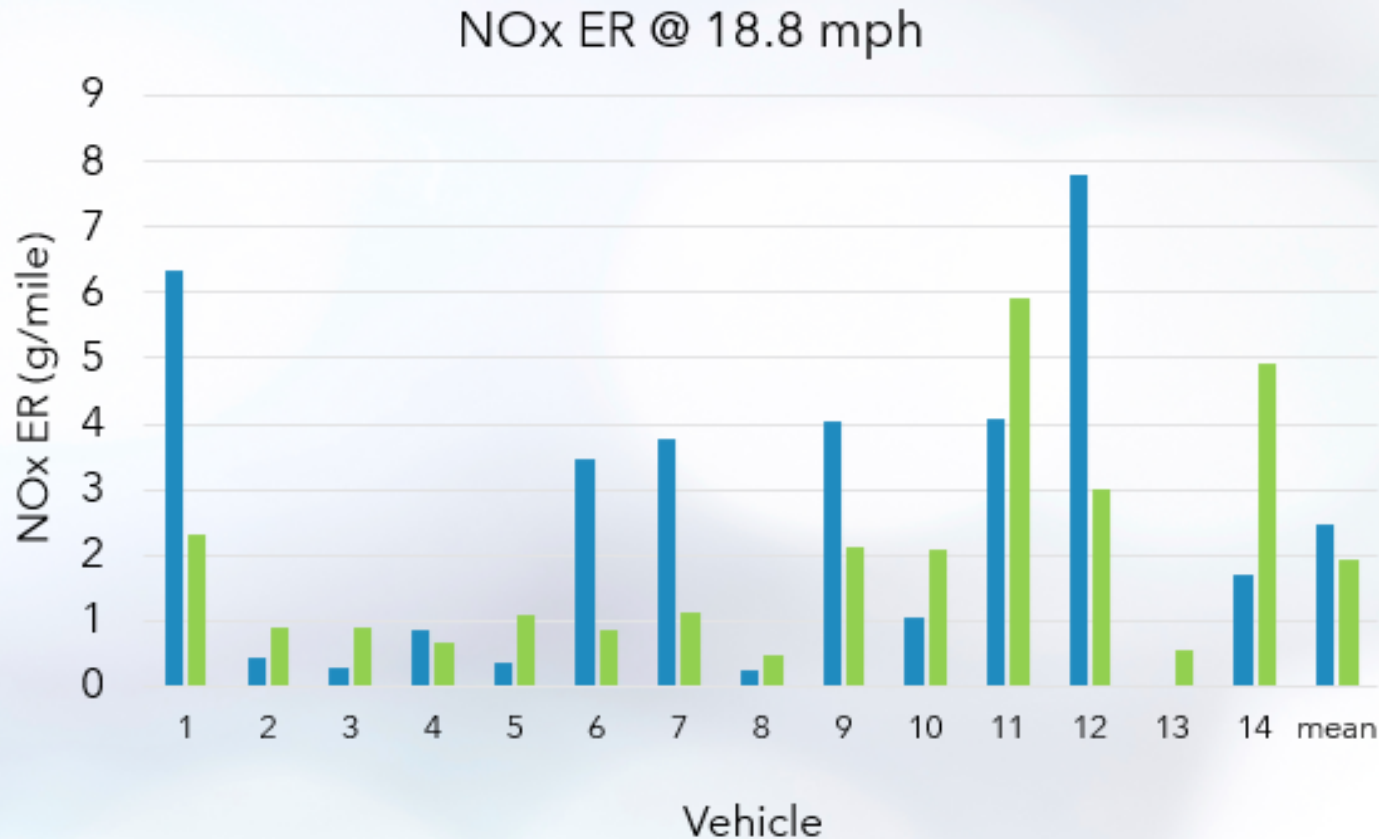2. Merge trips <0.25 mile
3. Split trips >3 miles

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Step 2/3/4: Use Average Emissions Rates for 5-mph Speed Bins

Veh2-1 Microtrip Level Data

NOx Emission Rate (g/mile) vs Speed (mph)

$y = 5.89x^{-0.61}$
$R^2 = 0.08$

Summarize into 5 mph speed bins

Veh2-1 Microtrip in Speed Bins

NOx Emission Rate (g/mile) vs Speed (mph)

18.8 mph (UDDS) as BER

$y = 45.34x^{-1.23}$
$R^2 = 0.54$

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NOx Emission Rates Comparison PEMS vs Chassis Dyno

Micro-trip in Speed Bins

Fitted Power Function
$y = 60.40 * x^{-0.82}, r2 = 0.7$
● Micro-trip Data in Speed Bins

18.8 mph

NOx ER @ 18.8mph	PEMS	Chassis dyno
Fleet average	2.1	1.9
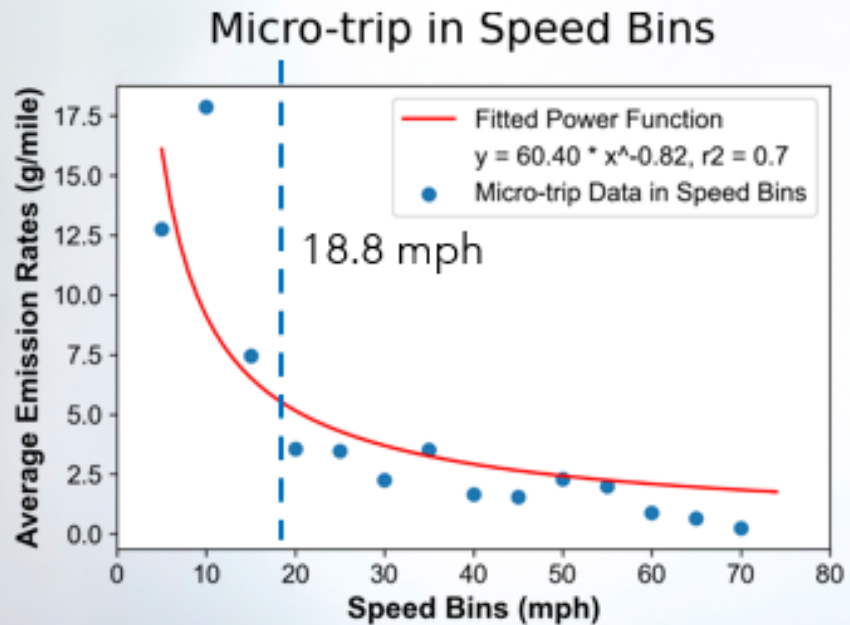
NOx ER @ 18.8 mph

■ Chassis Dyno UDDS   ■ PEMS @ 18.8 mph

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Zero-Mile Rate and Deterioration Rate Update for HHD 2013+

Legend:
- EMFAC2021 v1.0.2
- EMFAC202Y (proposed)
- EMFAC2021 - Remove Recalls

Y-axis: Emission Rates (g/mi)
X-axis: Odometer
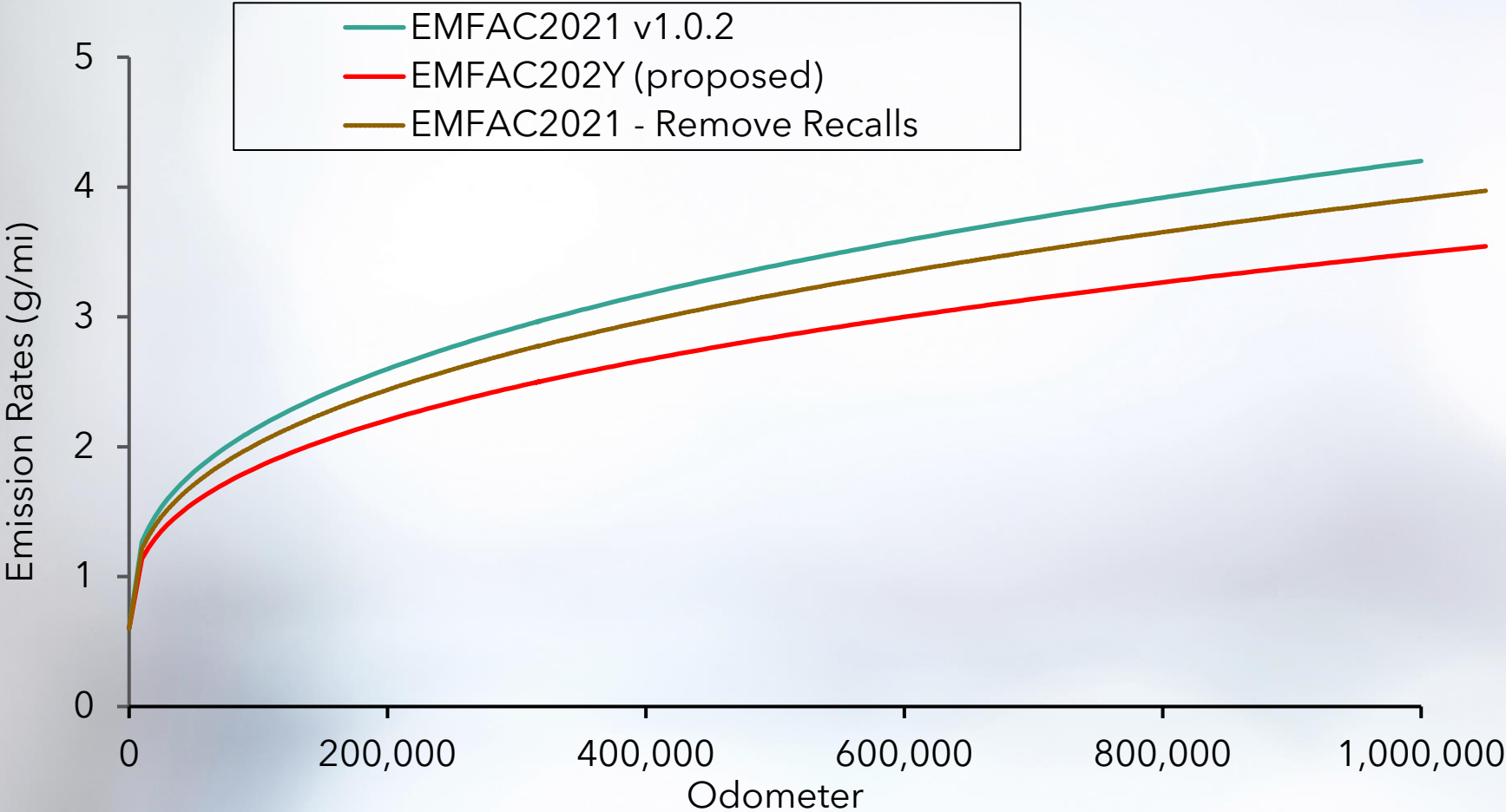
- EMFAC202Y emission rate is a 50% Chassis Dyno and 50% PEMS weighted average.

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Updates to NOx Speed Correction Factors

MHD/HHD

HDV Speed Correction Factors in EMFAC2021

- Speed correction factors (SCF): account for variation of emissions under different vehicle speed

- EMFAC2021
  - Used lab dynameter testing data for HD emission rates
  - Two SCFs, one for all T6, another for all T7 vehicles

- Potential EMFAC202Y Improvements
  - Use PEMS data for closer-to-real-world SCFs
  - Increase sample size for more detailed SCFs by vocation and MY group
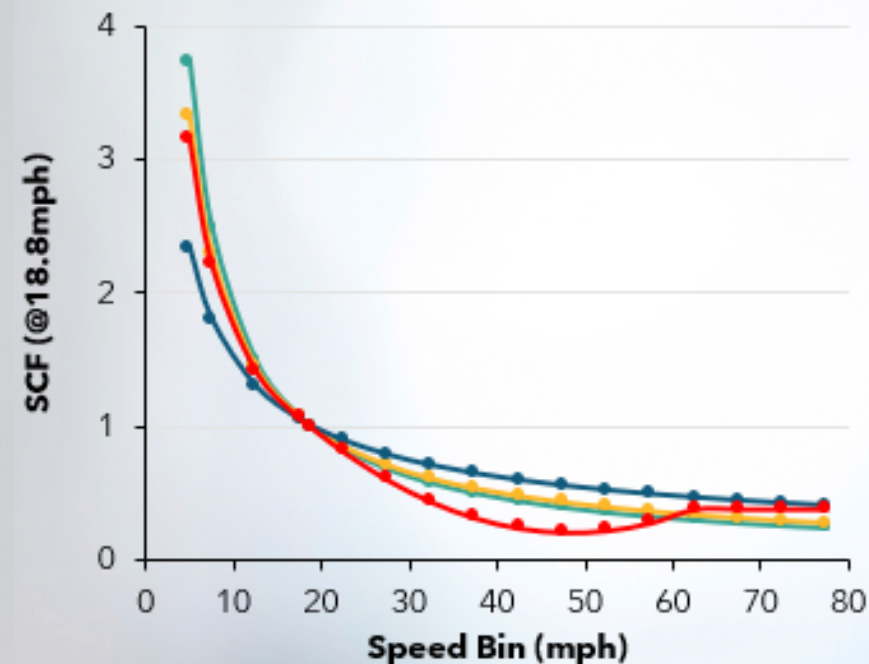
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Speed Correction Factor Data Sources

Test Program	Fuel Type	Weight Class	Engine MY Range	Test Type and Sample Size
Heavy-Duty In-Use Testing (HDIUT)	Diesel	Class 4-8	2003-2017	PEMS: 566
CARB TBSP	Diesel	Class 6-8	2013-2018	PEMS: 10
200-Vehicle Study	Diesel	Class 7-8	2010-2018	PEMS: 20

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SCFs for Heavy HDV (Class 8)
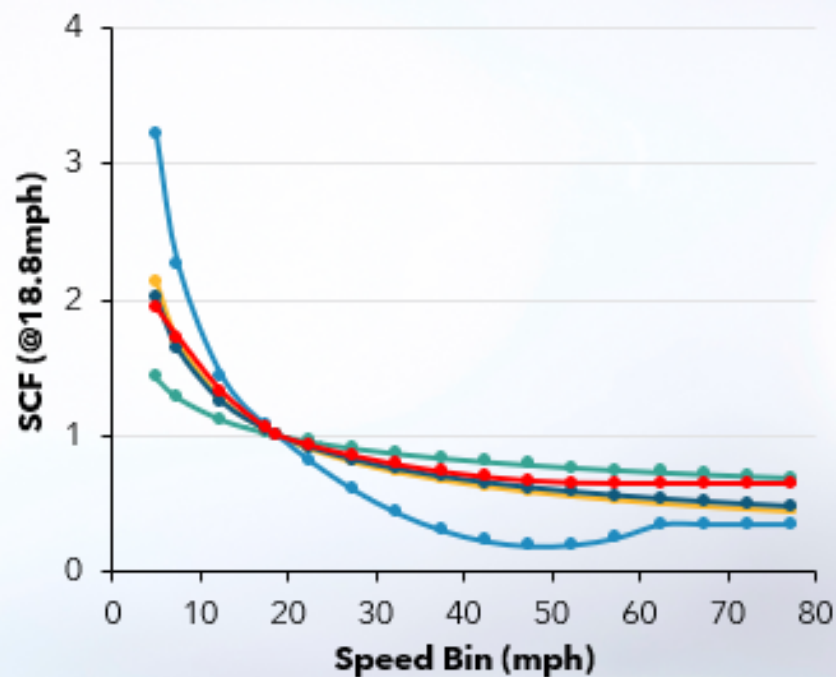

Engine Model Year 2013+

SCF (@18.8mph) vs Speed Bin (mph)

Legend:
- Concrete/Transit Mix
- Delivery
- Line haul
- EMFAC2021

Sample size:
- Concrete/Transit Mix: 1
- Delivery: 7
- Line haul: 63

Engine Model Year 2010-2012

SCF (@18.8mph) vs Speed Bin (mph)

Legend:
- Delivery
- Line haul
- UBUS
- EMFAC2021 UBUS Diesel
- EMFAC2021 T7
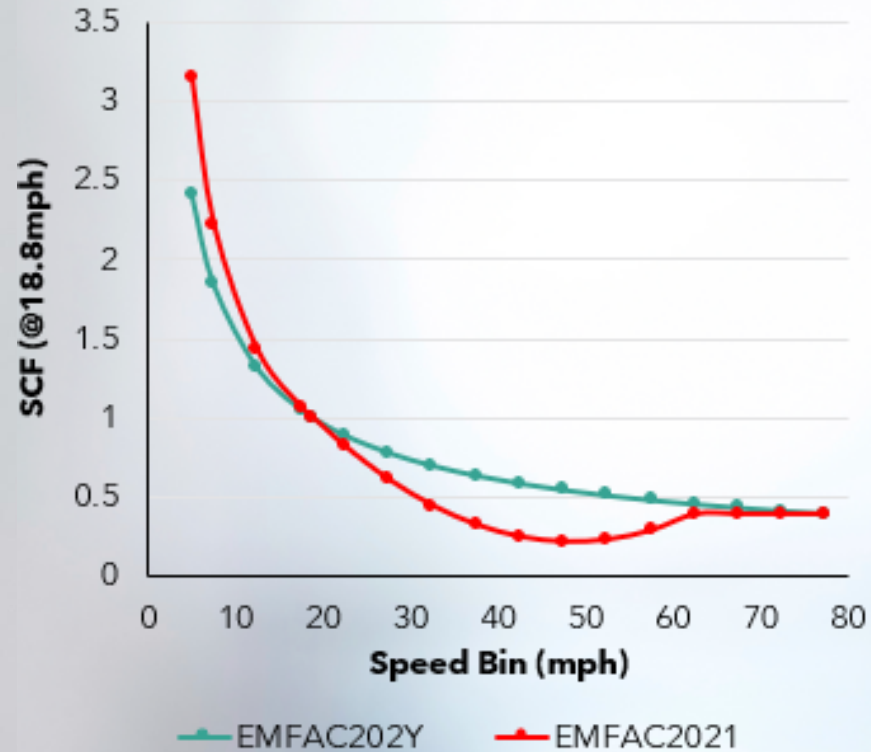
Sample size:
- UBUS: 7
- Delivery: 19
- Line haul: 84

Engine Model Year pre2010

SCF (@18.8mph) vs Speed Bin (mph)

Legend:
- Concrete/Transit Mix
- Line haul
- Terminal Tractor
- MH
- Delivery
- SWCV
- Utility
- EMFAC2021

Sample size:
- Concrete/Transit Mix: 5
- Delivery: 13
- Line haul: 72
- Utility: 2
- MH: 5
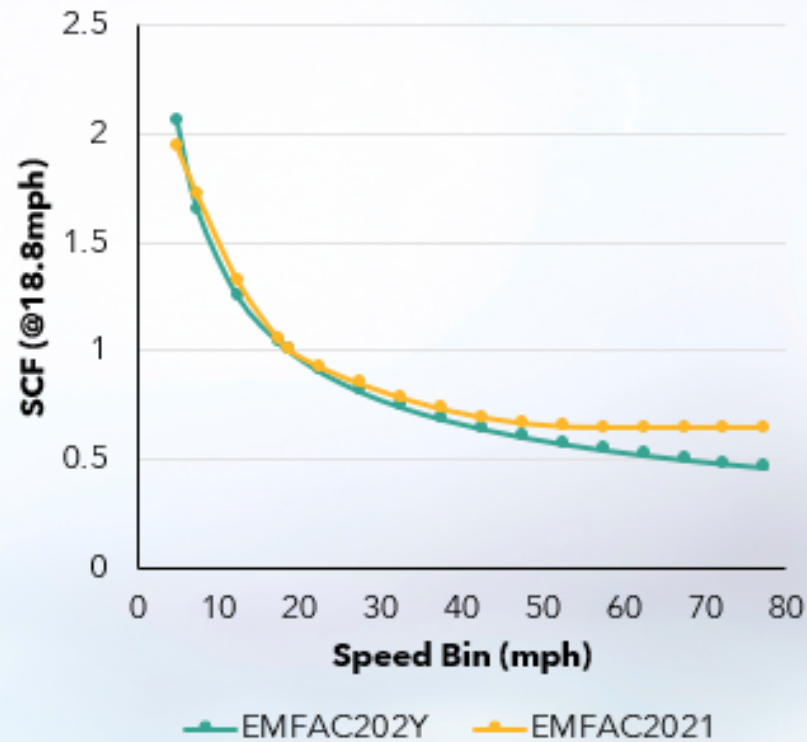- SWCV: 9
- Terminal Tractor: 2

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Proposed SCFs for Heavy HDV (Class 8) in EMFAC202Y
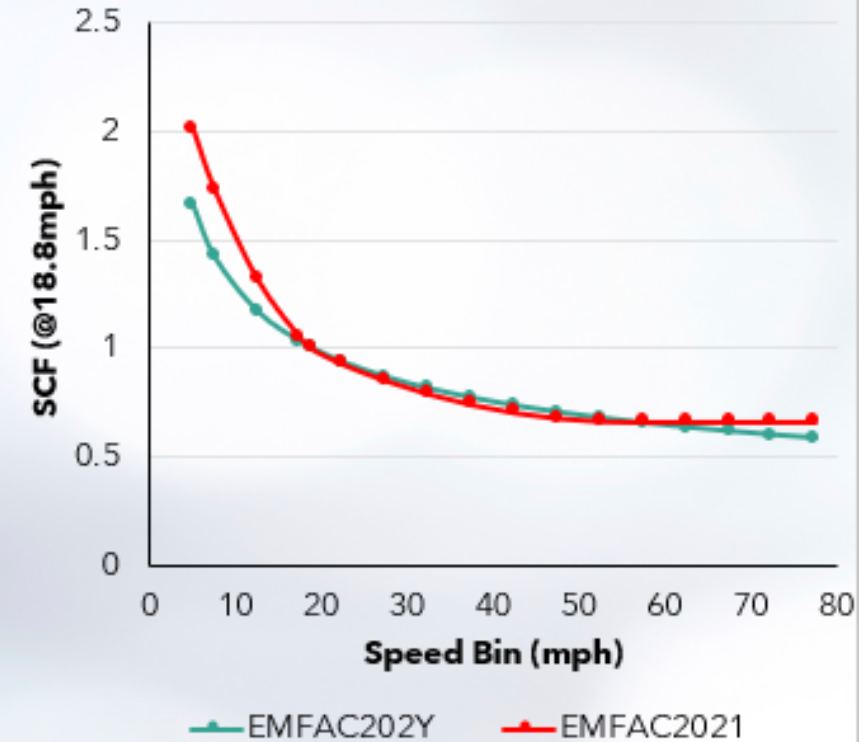

Engine Model Year 2013+
Sample size: 73

Engine Model Year 2010-2012
Sample size: 113

Engine Model Year pre2010
Sample size: 125

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Summary

- On average, chassis dyno emission rates are comparable with PEMS at 18.8 mph.

- Removing recalled vehicles from EMFAC2021 sample pool decreases HHD 2013+ base emission rate by 6%.

- Adding new test vehicles and PEMS data points, base emission rates of HHD 2013+ vehicles slightly decrease by 8% compared to EMFAC2021 w/ recalled vehicles removed.

- Using the new PEMS analysis method, with new data points from HDIUT added, SCFs in low speed range (5-20mph) decrease compared to EMFAC2021, high speed range (40-60mph) SCFs increase.

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Next steps

- Acquire more PEMS data through CARB internal testing programs and extramural contracts for further analysis.
- Update emission rates for Natural Gas HD vehicles in EMFAC202Y
- Keep improving the PEMS data analysis method, e.g.,
  - assess repeatability of PEMS test
  - Locating major influencing factors

User Survey
Summer 2021

1st Public Workshop
Oct 2022

2nd Public Workshop

Jan 2024

Alpha Release
Summer 2024

3rd Public Workshop
Fall 2024

Public Beta Release
Fall 2024 (data cutoff
July 31st, 2024)

4th Public Workshop
Spring 2025

Final Release
Spring 2025

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Thank You!

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