The Expanding Role of PEMS and On-Board Sensors in Mobile Source Emission Inventory Development

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Onboard Sensing, Analysis, and Reporting (OSAR) Workshop
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Mobile Source Emission Inventory

EMFAC on-road vehicles

+16 off-road models

https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory

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South Coast Air Basin – NOx Reductions Critical for 70 ppb Ozone Attainment

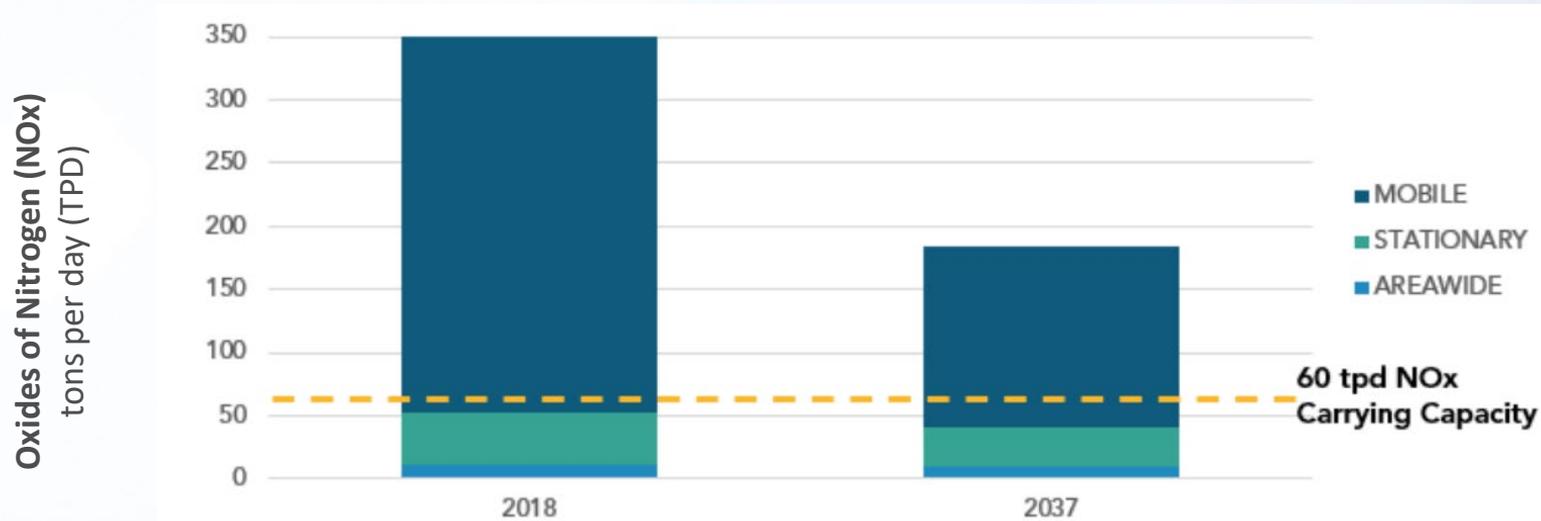Figure from the 2022 State Strategy for the State Implementation Plan, available at:
https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

Applications of EMFAC

Mobile Source Strategy

Community Air Protection

State Implementation Plans

Regulatory Development
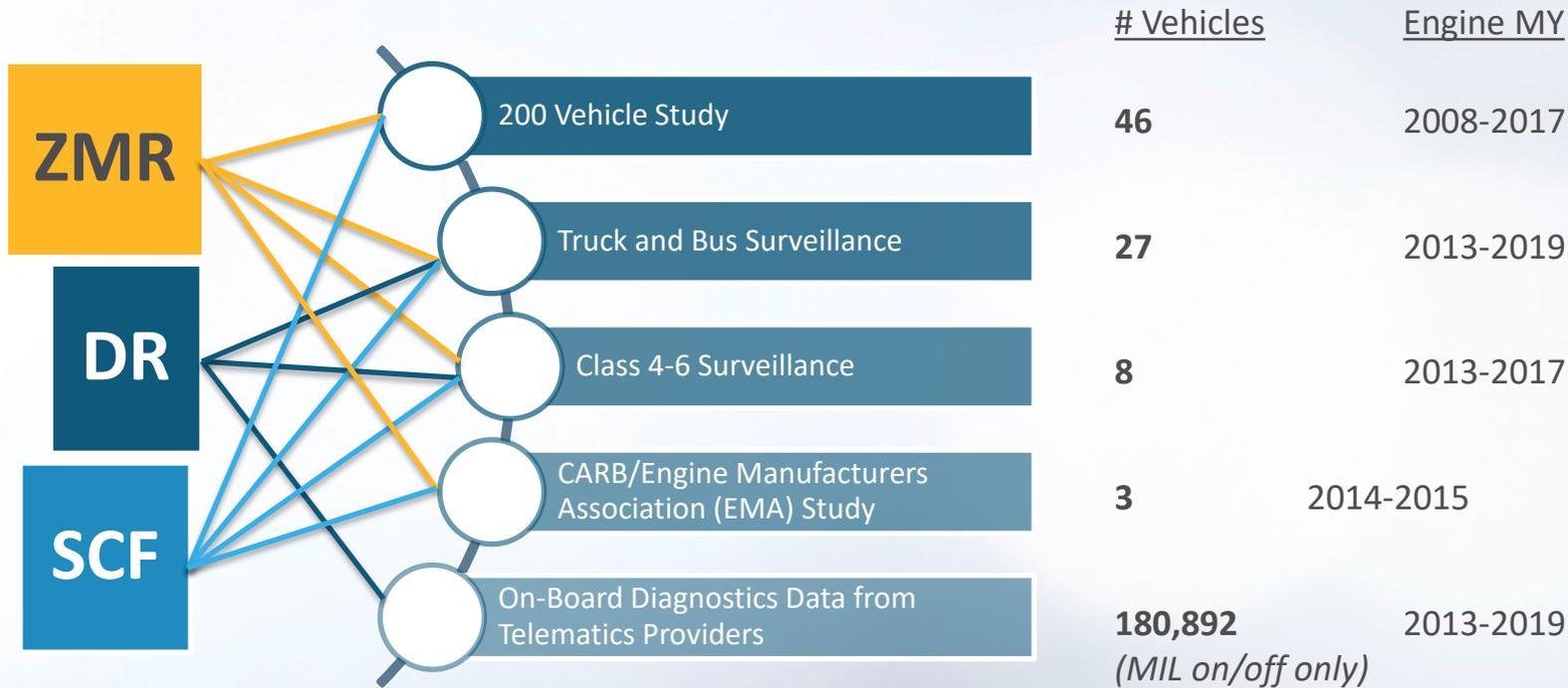
Presentation Focus

- Heavy-duty vehicle emission rates

- Outline of past and current data heavy-duty emission rate data sources

- Analysis of opportunities to expand vehicle data inputs

- Next steps for EMFAC and off-road models

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How Are Heavy-Duty Vehicle Emissions Calculated in EMFAC?

Emissions Rate (g/mi) = (ZMR + DR x Odometer) x SCF
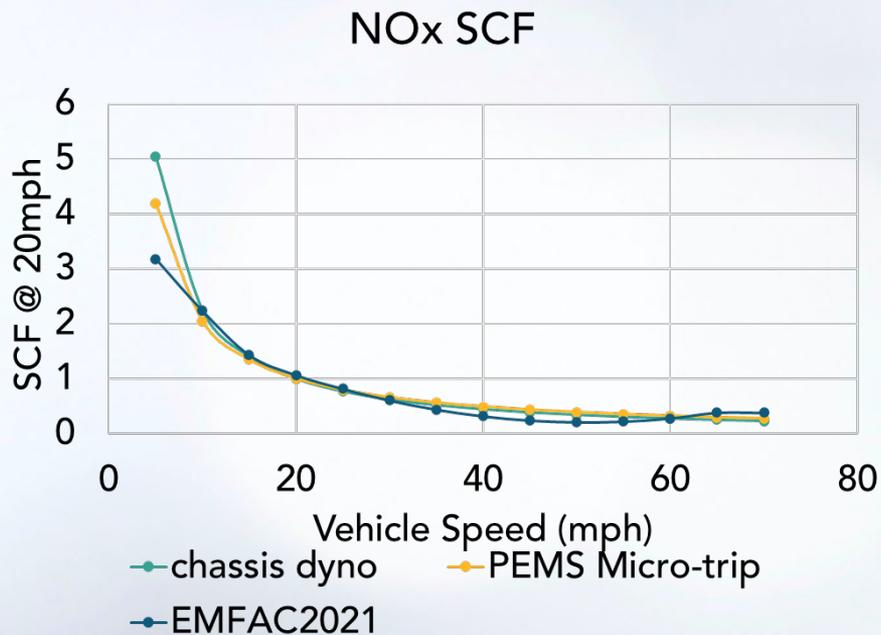
- **ZMR (Zero-Mile Rate)** – Emission rate for new trucks over the Urban Dynamometer Driving Schedule (UDDS) at 18.9 mph

- **DR (Deterioration Rate)** – Increase in emissions due to deterioration and mal-maintenance of the in-use fleet (g/mi/10 K mi)

- **SCF (Speed Correction Factor)** – Ratio of emission rates at different cycle average speeds relative to UDDS at 18.9 mph

Sources OF Heavy-Duty Emissions Rate Updates in EMFAC2021

	# Vehicles	Engine MY
200 Vehicle Study	46	2008-2017
Truck and Bus Surveillance	27	2013-2019
Class 4-6 Surveillance	8	2013-2017
CARB/Engine Manufacturers Association (EMA) Study	3	2014-2015
On-Board Diagnostics Data from Telematics Providers	180,892 *(MIL on/off only)*	2013-2019

ZMR

DR

SCF

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EMFAC Inputs Will Rely Upon Manufacturer-Collected PEMS Data

- Presentation at CRC from Mo Chen exploring use of Heavy-Duty In-Use Testing (HDIUT) data for updating SCFs

- CARB exploring use of HDUIT data for base emission rates, and whether PEMS data can wholly replace chassis dyno data
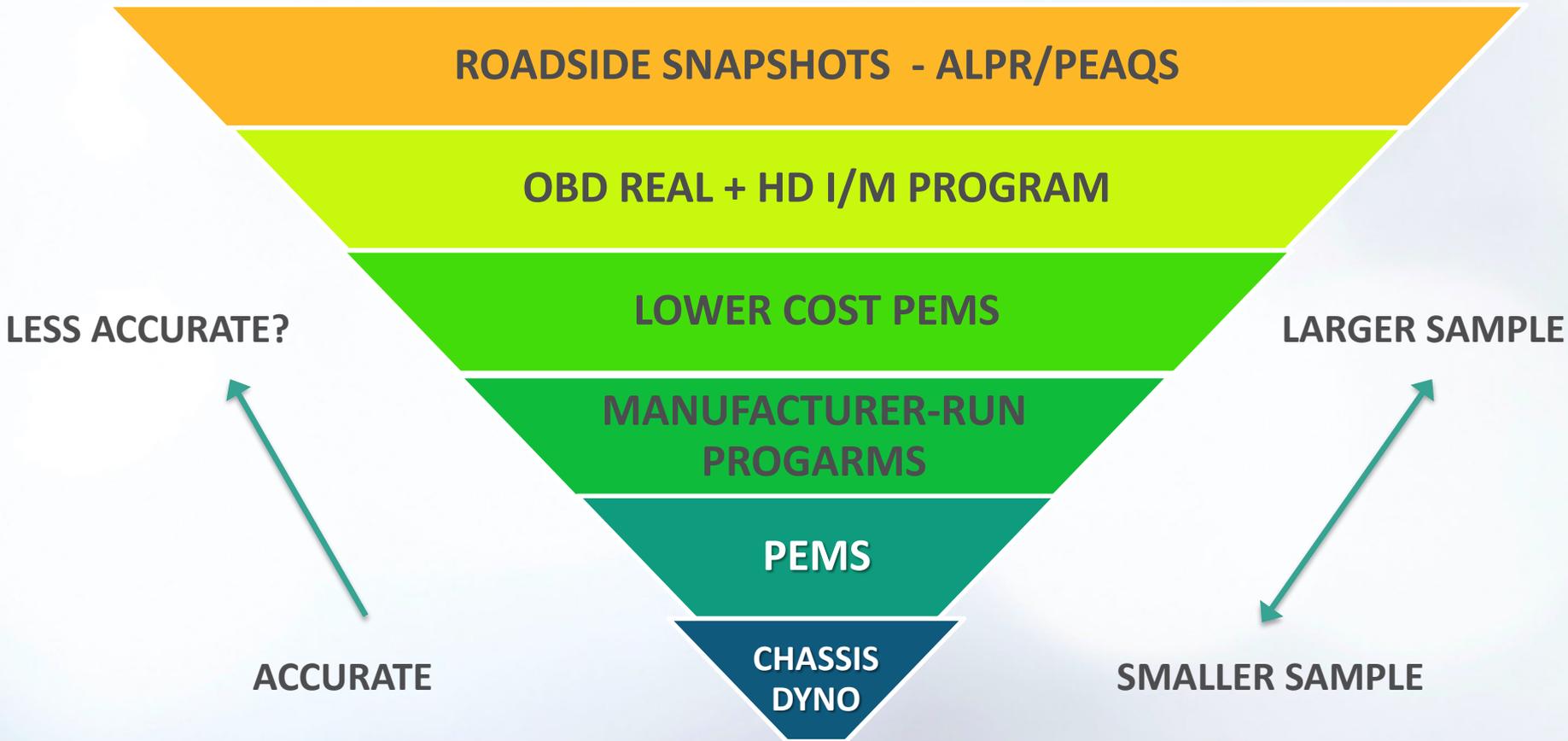
NOx SCF

Chart: SCF @ 20mph (y-axis, 0 to 6) versus Vehicle Speed (mph) (x-axis, 0 to 80)

Legend: chassis dyno, PEMS Micro-trip, EMFAC2021

Increasing Number of Vehicles Sampled with Each Update to EMFAC

EMFAC2014	EMFAC2017	EMFAC2021	EMFAC202Y (2024-25)	EMFAC202Z (2028-29)
+16 vehicles	+25 vehicles	+84 vehicles	+372 vehicles	❓

- 19 vehicles from CARB research + surveillance testing
- 29 from recently completed 200-vehicle study
- 324 vehicles from manufacturer-run HDIUT program (SCFs only)

**DOES THE TESTED SAMPLE REPRESENT THE
1 MILLION VEHICLES
THAT OPERATE IN CALIFORNIA?**

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ROADSIDE SNAPSHOTS - ALPR/PEAQS

OBD REAL + HD I/M PROGRAM

LOWER COST PEMS

MANUFACTURER-RUN PROGARMS

PEMS

CHASSIS DYNO

LESS ACCURATE?

LARGER SAMPLE

ACCURATE

SMALLER SAMPLE

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Low Cost PEMS vs. PEMS?

Two Types of Roadside Snapshots

Automated License Plate Readers (ALPR)

License plates passing fixed location (Sara Forestieri CRC presentation)

Informs model inputs for model year distributions (therefore compliance rates) and technology penetration

Portable Emissions AcQuisition System (PEAQS)

Fuel-based emission factors of individual trucks + ALPR data

Higher emitters for enforcement follow-up (e.g. HD Inspection and Maintenance)

Used to assess fleet trends, **but what about emission inventories?**
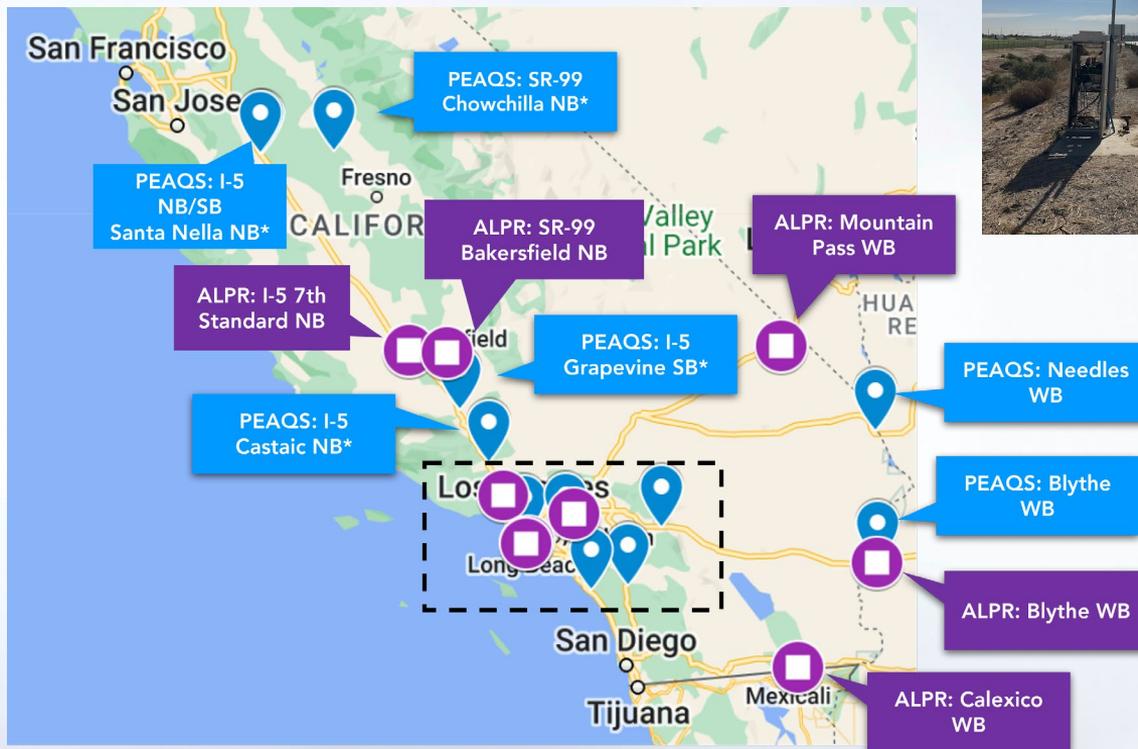
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Network of Roadside Monitors

ALPR

- 10 stations today
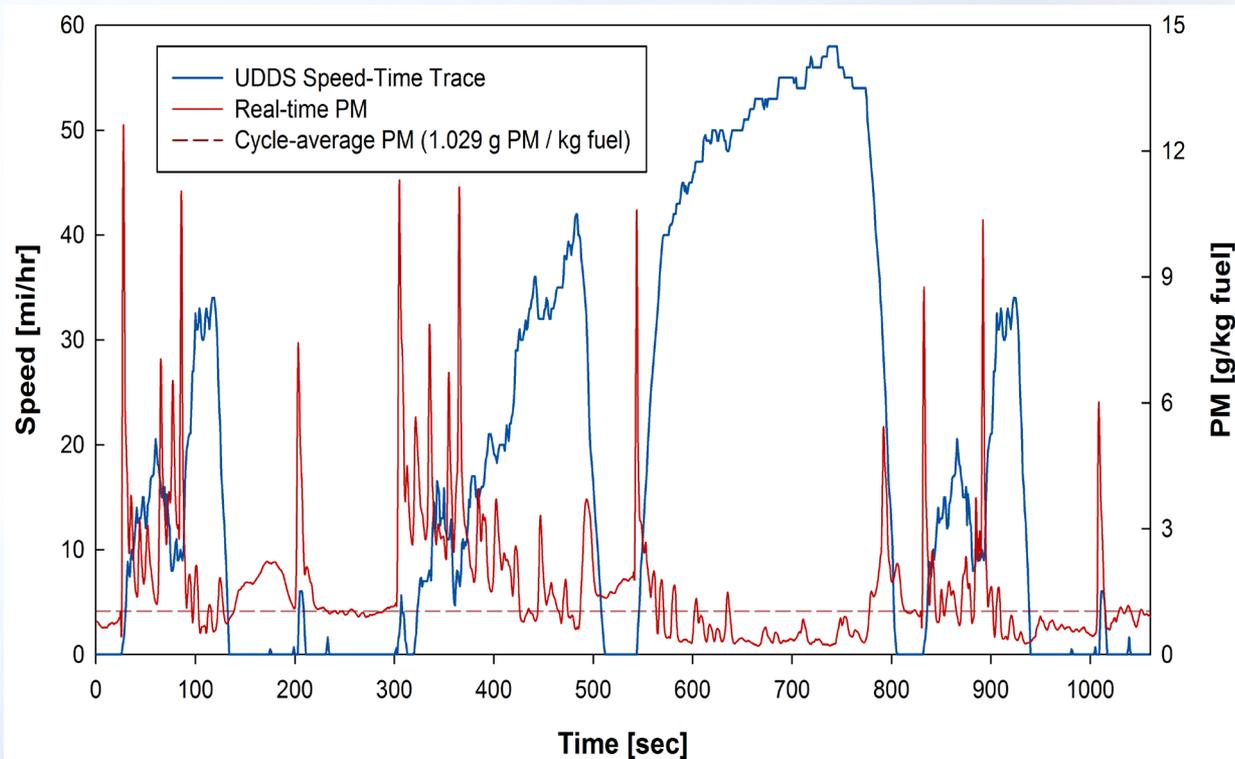- 2-3 more planned
- Two more years with UCI

PEAQS

- 3 stations installed
- 12 more planned in 2023

PEAQS: SR-99 Chowchilla NB*

PEAQS: I-5 NB/SB Santa Nella NB*

ALPR: SR-99 Bakersfield NB

ALPR: Mountain Pass WB

ALPR: I-5 7th Standard NB

PEAQS: I-5 Grapevine SB*

PEAQS: Needles WB

PEAQS: I-5 Castaic NB*

PEAQS: Blythe WB

ALPR: Blythe WB

ALPR: Calexico WB

Which One-Second Snapshot Represents Overall Vehicle Emissions?

- MY 1998 diesel vehicle, no DPF

- CARB is using PEAQS (plume capture system) to identify highest emitters in fleet to implement HD I/M
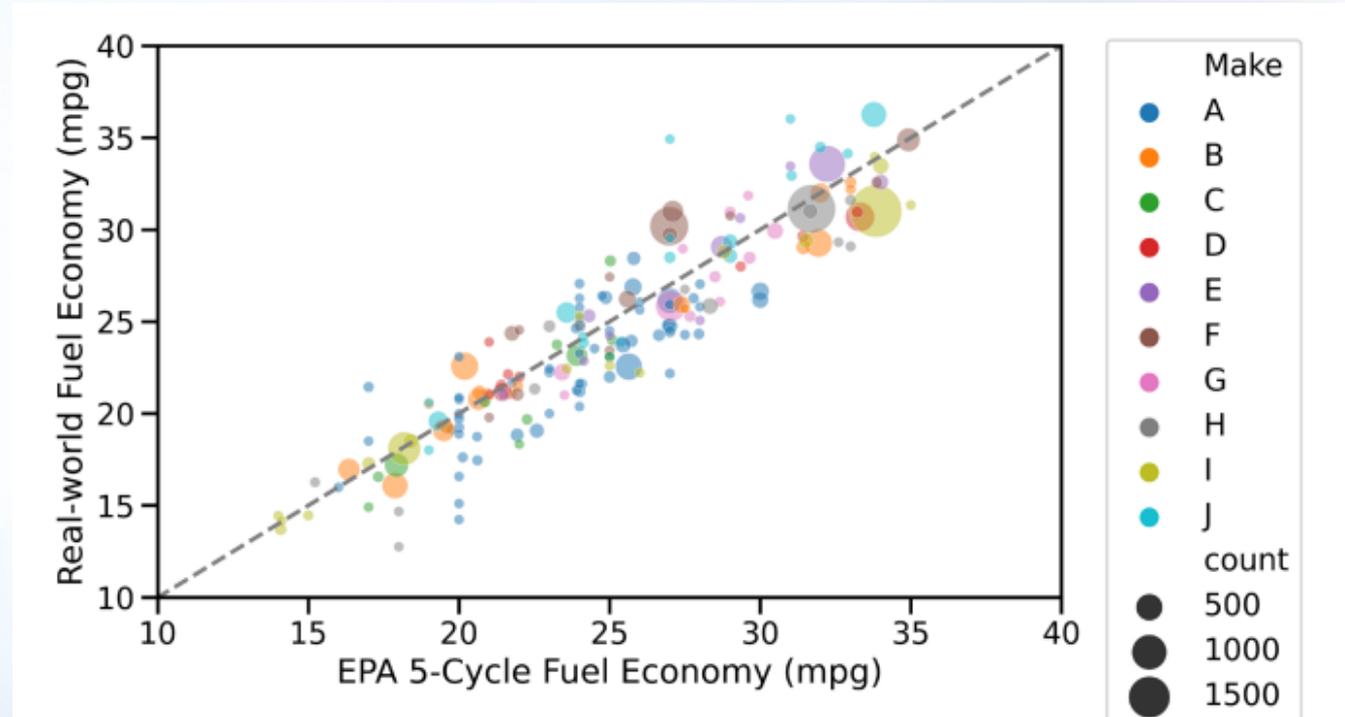

Quiros, et al. (2018) - Deriving fuel-based emission factor thresholds to interpret heavy-duty vehicle roadside plume measurements. JAWMA 68:9, 969-987.

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Real Emissions Assessment Logging (REAL) using On-Board Diagnostics (OBD) to Report NOx and GHG Emissions

	Light Duty (8,500 lbs)	Medium Duty (8,500-14,000 lbs)	Heavy Duty (>14,000 lbs)
NOx Tracking	n/a	Diesel engines MY 2022+	Diesel engines MY 2022+
GHG Tracking (CO2)	All engines MY 2019-2021+	All engines MY 2019-2021+	All engines MY 2022+

Presented previously by Paul Henderick at the 2019 PEMS Conference

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Use of Light-Duty GHG Monitoring Confirms Modeling Assumptions

- CA Smog Check Data on vehicles MY 2019+

- >41,000 vehicles, plot has top 10 OEMs by vehicle

- EMFAC2021 use of EPA 5-cycle fuel economy *validated!*

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OBD REAL NOx Logging Bins

% of Rated Power	Vehicle Speed (km/h)				
	0	> 0 ≤ 16	> 16 ≤ 40	> 40 ≤ 64	> 64
≤ 25%	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
> 25% ≤ 50%		Bin 7	Bin 8	Bin 9	Bin 10
> 50%		Bin 11	Bin 12	Bin 13	Bin 14

Total (Bin 1)

NTE Bin (Bin 15)

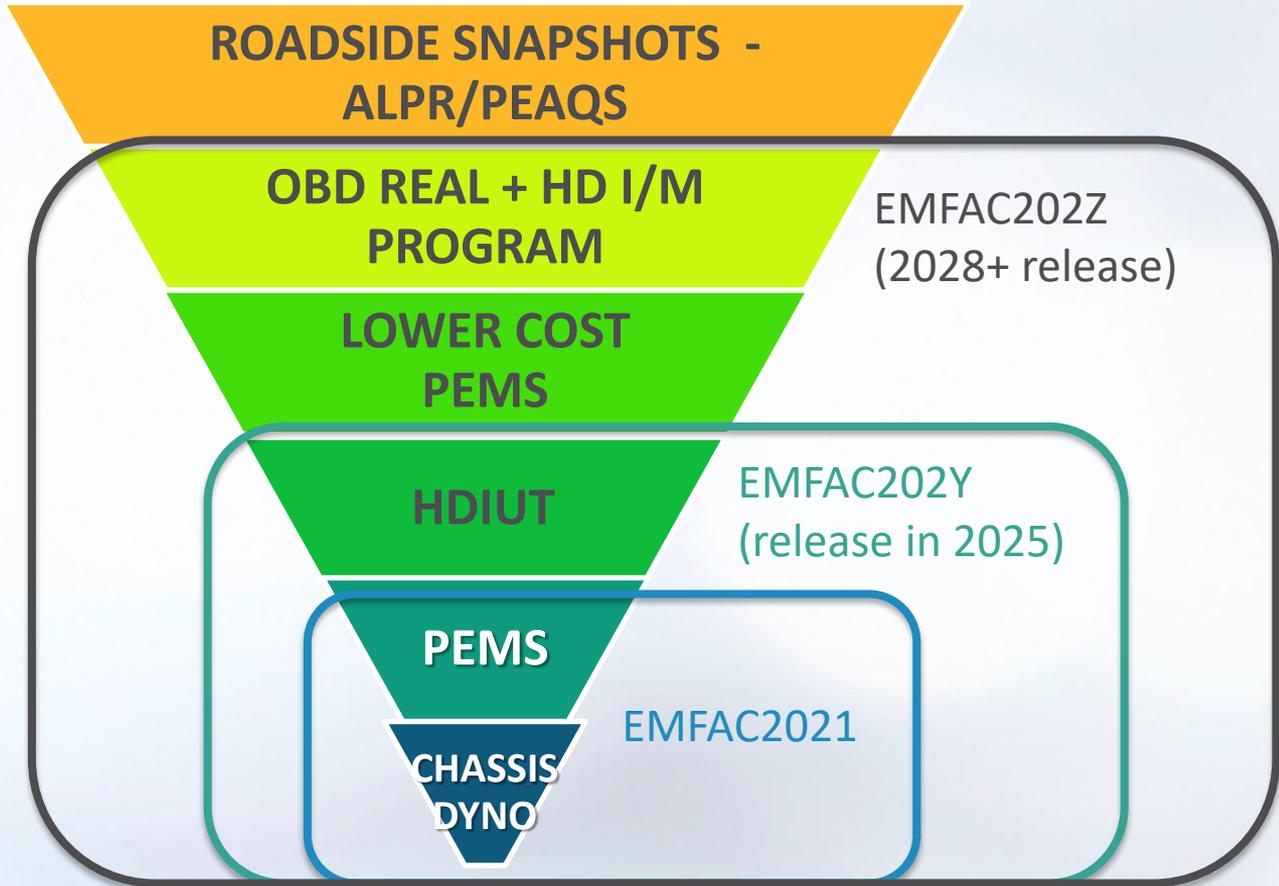**Regen Bin (Bin 16)**

MIL-On Bin (Bin 17)

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Use of Heavy-Duty REAL

- Begins with MY 2022 engines, generally in MY 2023 vehicles

- Heavy Duty Inspection and Maintenance (HD I/M)

  - Applies to non-gasoline vehicles over 14,000 pounds

  - Requires periodic OBD scans and submission to CARB beginning twice per year in 2024, and four times per year in 2027

- In 2024 and after, longitudinal REAL data for real-world NOx and CO2 will be available for to inform inventory updates

EMFAC Heavy-Duty Emission Rate Roadmap

MORE DATA, BUT LESS ACCURATE?

LESS DATA, WITH KNOWN ACCURACY

ROADSIDE SNAPSHOTS - ALPR/PEAQS

OBD REAL + HD I/M PROGRAM

EMFAC202Z (2028+ release)

LOWER COST PEMS

HDIUT

EMFAC202Y (release in 2025)

PEMS

CHASSIS DYNO

EMFAC2021

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EMFAC202Y Recap

- Public process began in Fall 2022

- Next model version, EMFAC202Y, expected in 2025

- Emission rates will expand to use manufacturer-run HDIUT data for speed correction curves

- Heavier reliance upon PEMS data from CARB testing and extramural studies (e.g. 200 vehicle study)

- Next workshop anticipated in second half of 2023

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Off-Road Models Also Transitioning from Certification Data to PEMS

- Deterioration and load factors are applied, but from a constant emission factor

- Ongoing external testing (such as with CE-CERT on marine vessels)

- Two new in-house surveillance programs (gasoline surveillance, diesel surveillance) to expand inventory development

- Load-dependent emission factors under development, release by model starting later this year

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https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory