Keeping it REAL in California

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TRUE Symposium

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Vehicles meet Euro V with SCR only

Mercedes-Benz Buses Meet EEV Emissions Standard Without Diesel Particulate Filter

15 April 2010

Mercedes-Benz buses are now available in EEV (Enhanced Environmentally Friendly Vehicle) versions. Mercedes-Benz achieved the low emissions solely by means of internal engine measures and without an additional particulate filter in the case of the Mercedes-Benz BlueTec engines or a fuel economy penalty.

RENAULT TRUCKS GIVES ITS CUSTOMERS ACCESS TO LOW EMISSION ZONES WITH ITS "EEV" RANGE

In 2010, this range will be extended to include DXi5 engines (180hp) and DXi7 engines (270hp and 310hp). It is important to emphasise that these vehicles offer the same levels of payload, maintenance and reliability as all other Renault Trucks vehicles.In order to meet EEV requirements, Renault Trucks has used SCR (Selective Catalytic Reduction) technology which allows post-treatment of exhaust gases. Using AdBlue, a high quality urea solution, through catalysis, nitrogen oxide emissions from diesel burn are reduced. The big advantage of this system, which was recently tested on the Cape to Cape Expedition under extreme conditions of heat and cold (from -30 to +50°C), is that it does not require particulate filters or other additional components.

Pre-story to Dieselgate

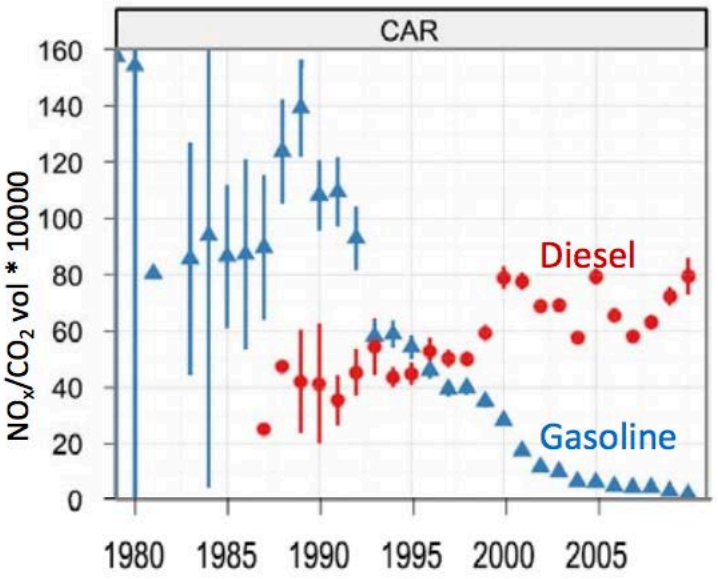


Fig. 3: NOx emission factors of gasoline (blue triangles) and diesel (red dots) passenger cars by manufacturing year from RS in the UK (Carslaw et al. 2011). The high standard deviation for model years <1988 is because of low sample size. In addition older vehicles have been subject to deterioration due to usage as compared to younger vehicles. Copyright © 2011 by Elsevier. Reprinted with permission by Elsevier.

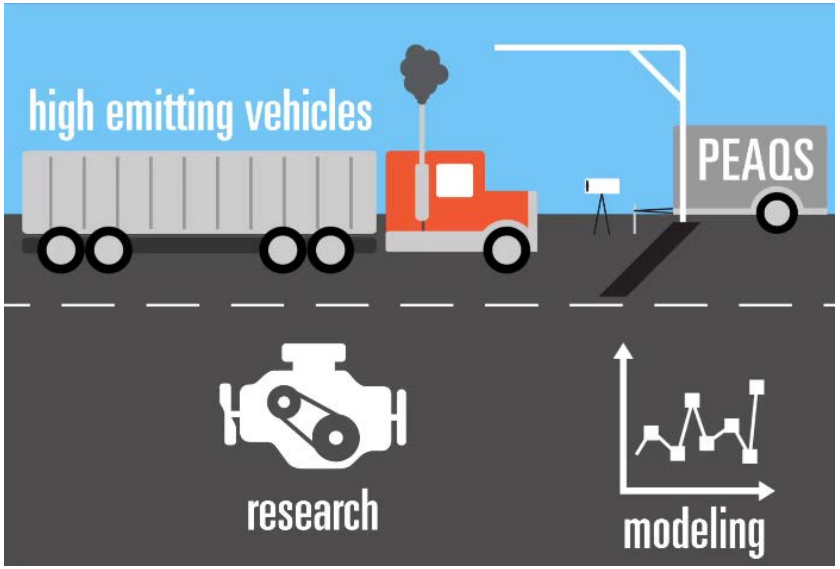
- Remote sensing made it clear that regulations had not been effective in reducing diesel emissions in the real world.

Borken-Kleefeld, 2013, for the ICCT.
https://www.theicct.org/sites/default/files/publications/RSD_Guidance_BorKlee.pdf

California ARB: real-world emissions

- California is working with a variety of additional tools to understand and control real-world emissions
- Remote sensing
  - ~20-year remote sensing campaign for tracking fleet trends
  - Compliment to and check on other programs (PEMS, OBD, Dyno testing)
  - Check on heavy-duty emissions
  - Tracking in-use compliance
  - Focus on environmental justice communities
- Newest program: REAL (Real Emissions Assessment Logging)
  - California will require NOx, HC, or emissions tracking systems in every new vehicle.
  - Light-duty vehicles have real-world GHG data tracking requirements (2019).
  - Fall proposal to require NOx tracking & logging onboard all HDVs (~2022).
- Implementation and compliance programs will evolve around the use of these tools.

EJ Focus: Community Emission Inventories



- Community level emission inventories are needed to identify community-specific reduction strategies
- Real-time on-road emissions estimation and monitoring systems may be utilized (remote sensing)

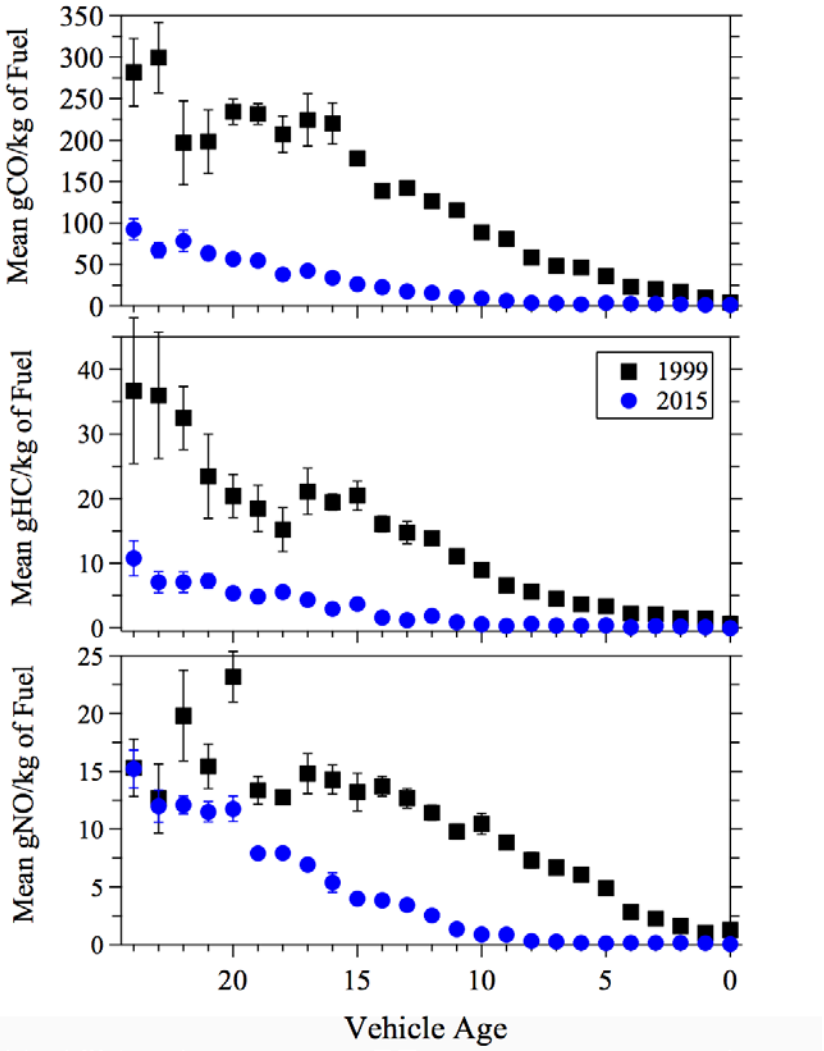
ARB current research agenda for remote sensing

- Identification of high emitting light-duty vehicle makes and models
  - Use existing data from remote sensing in other states to search for higher-emitting vehicle makes and models
  - Use to inform inventory estimates, guide future regulation development and as the basis to initiate targeted investigations of manufacturer's makes and models to support regulatory compliance actions.
- Light-duty vehicle trends from a remote sensing measurement campaign
  - Remote sensing measurement campaign in West Los Angeles, measuring emissions of CO, HC, NO, NO2, SO2, and NH3 (spring 2018). This is the 8th campaign conducted since 1999.
  - Use to verify the effectiveness of light-duty vehicle emission reduction programs, improve the understanding of deterioration of emission controls, identify issues important to air quality compliance, and assess disproportionate exposure in disadvantaged communities.

Real Emissions Assessment Logging

- Heavy-duty vehicles are becoming a major focus
  - Largest source of NOx emissions
  - Passenger vehicles getting cleaner
  - I/M systems not as robust
- In the fall Board meeting of the ARB, will adopt requirements that HDVs track and log NOx emissions using OBD: Real Emissions Assessment Logging
- Goal is to ensure actual in-use emissions are well controlled
  - When vehicles aren't clean, durable or maintained, they need to be identified sooner and resolved more quickly
  - Could be used for individual vehicles (repair, retrofit or scrap), enforcement of regulations, and identification of needs for regulatory improvements

California: Success reducing LDVs emissions

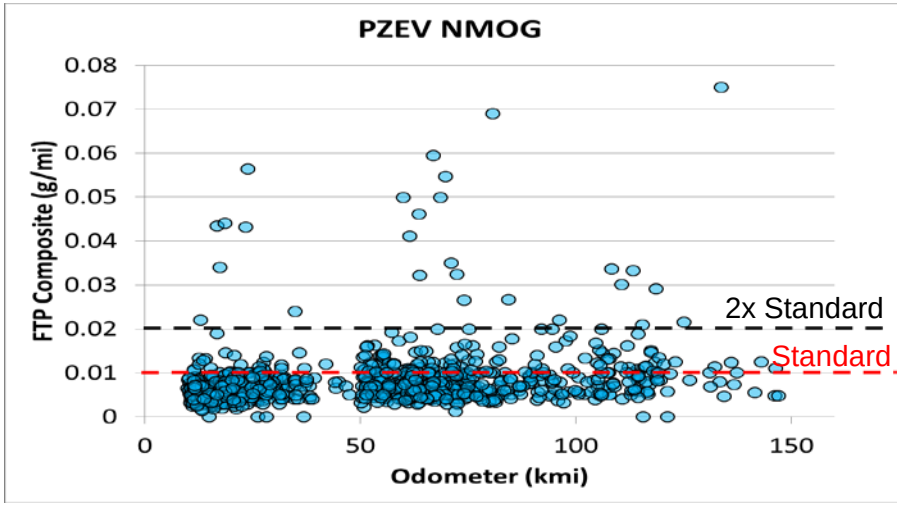


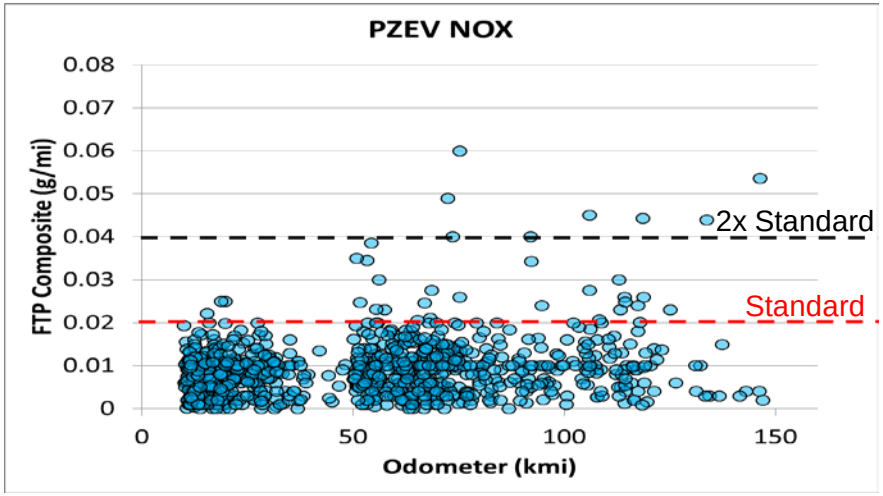
- Latest remote sensing campaign shows that durability of emissions controls has improved.

Source: Bishop and Stedman, 2016, Contract No. 12-303 to ARB, https://www.arb.ca.gov/research/apr/past/12-303.pdf

Yet durability still falls short of regulations

IUVP FTP testing data





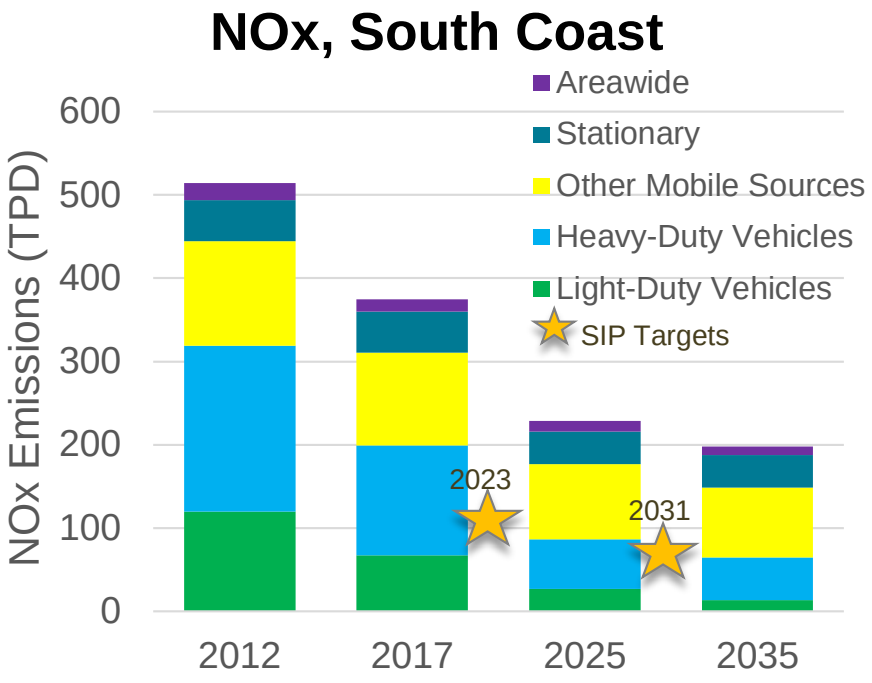
Regimes	Mileage Bin		Total
	<100k	above 100k	
H	22	7 (7%)	29 (3.0%)
M	99 (11%)	29 (29%)	128 (13.3%)
N	744	63 (63%)	807 (83.7%)
Total	865	99	964

Regimes	Mileage Bin		Total
	<100k	above 100k	
H	2	6 (6%)	8 (0.8%)
M	19 (2%)	10 (10%)	29 (3.0%)
N	839	83 (83%)	922 (96.1%)
Total	860	99	959

H = greater than 2x standard
M = 1x-2x standard
N = 1x or less than standard

Source: McCarthy, 2017, SAE presentation

HDVs are the largest NOx source

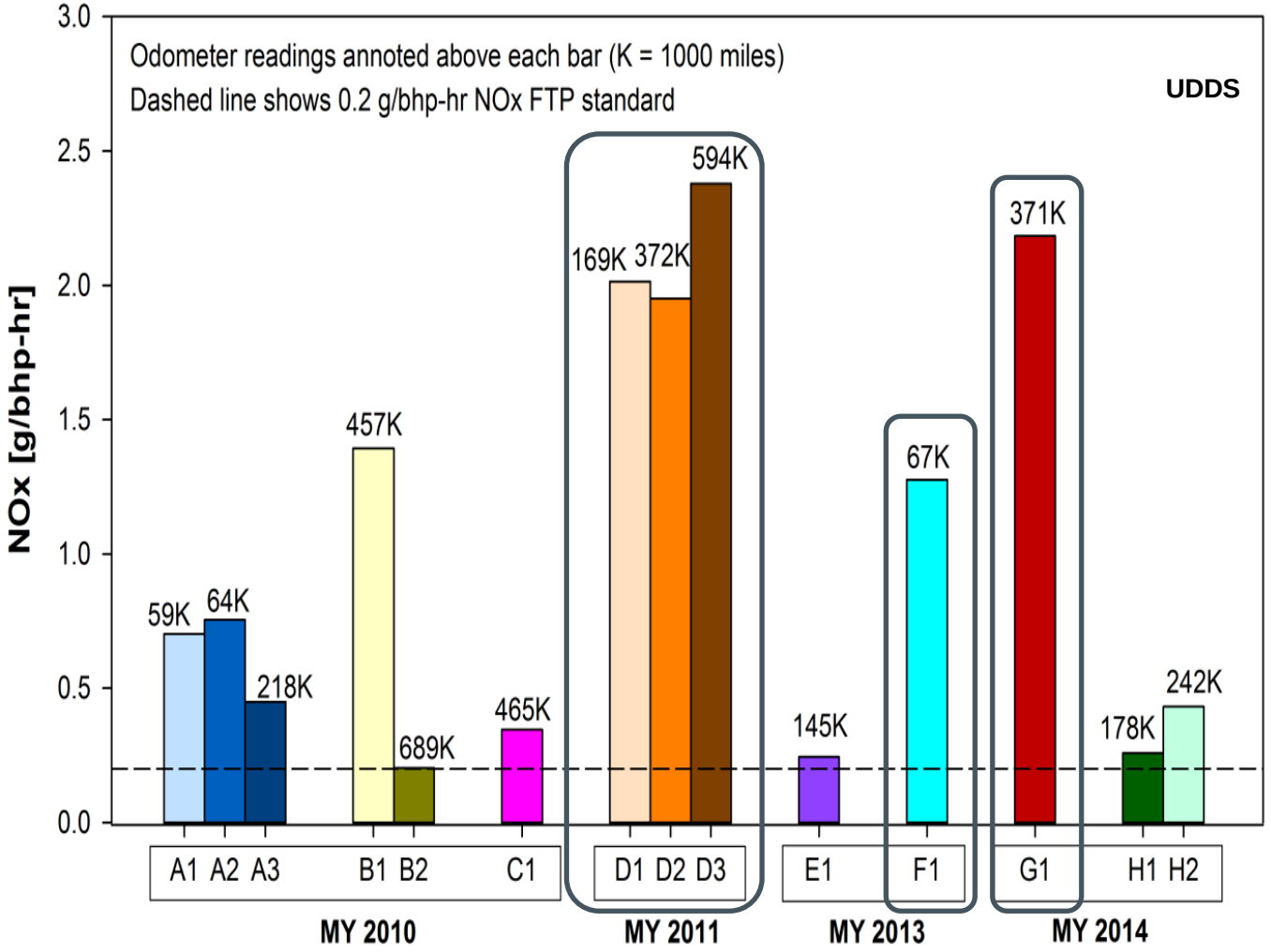


Source: CEPAM 2016 SIP,
https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

Many programs in place to assess emissions

- Certification
- Warranty Reporting
- Manufacturer In-Use Testing
  - Light Duty In Use Verification Program (IUVP)
  - Heavy-Duty In-Use Testing (HDIUT) Program
  - HD OBD Manufacturer Self Testing program
- Laboratory Dynamometer Testing
  - Engine and chassis dynamometer testing
  - Confirmatory and compliance testing
- On-Road Emission Measurements
  - Portable Emissions Measurement Systems
  - Remote Sensing
- Vehicle and Smoke Inspections
  - Smog Check
  - Periodic Smoke Inspection Program (PSIP)
  - Heavy-Duty Vehicle Inspection Program (HDVIP, opacity testing)

High NOx on city cycles (lab testing)



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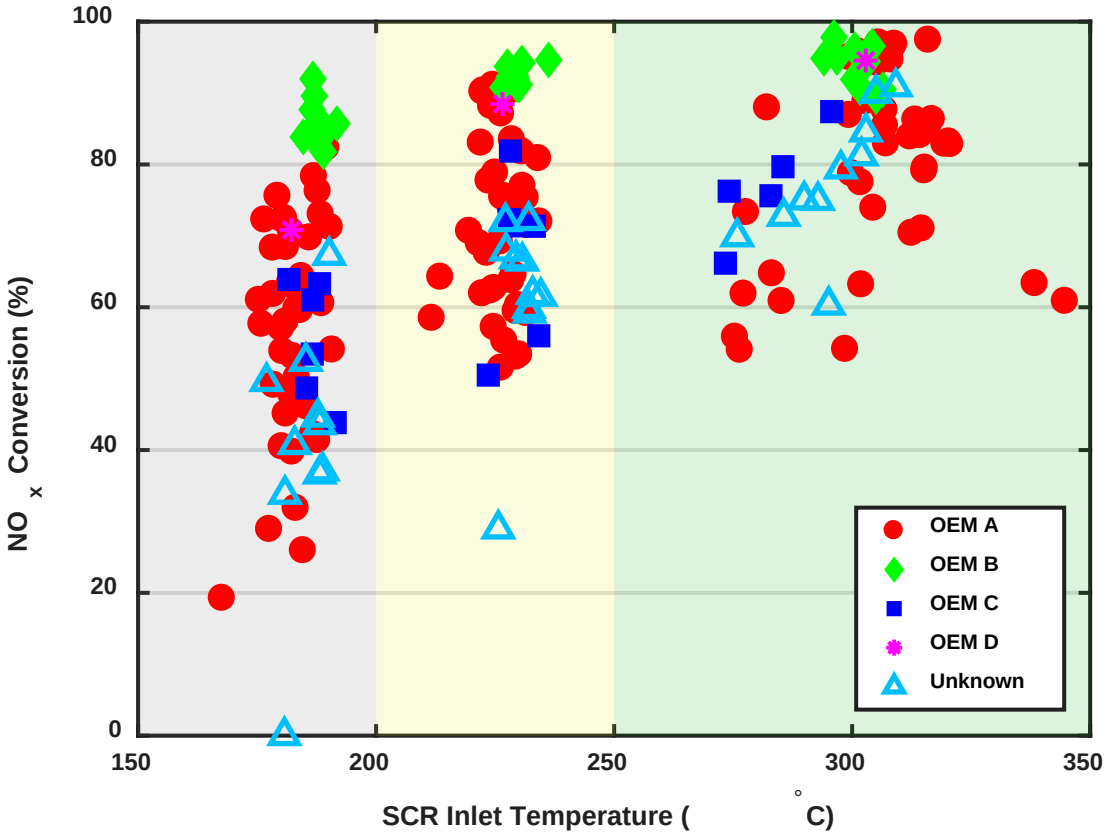
D. Quiros, CRC 2017

REAL: continuous monitoring of emission performance

- Concept:
  - Use on-board sensors and algorithms to measure, track, and report in-use emission performance
- Potential uses/benefits:
  - Motivate optimal control during all driving conditions
  - Powerful feedback on actual performance
  - Faster and cheaper testing
  - Potential for streamlined certification or in-use compliance
  - New approaches to diagnostics and repair

REAL pilot results

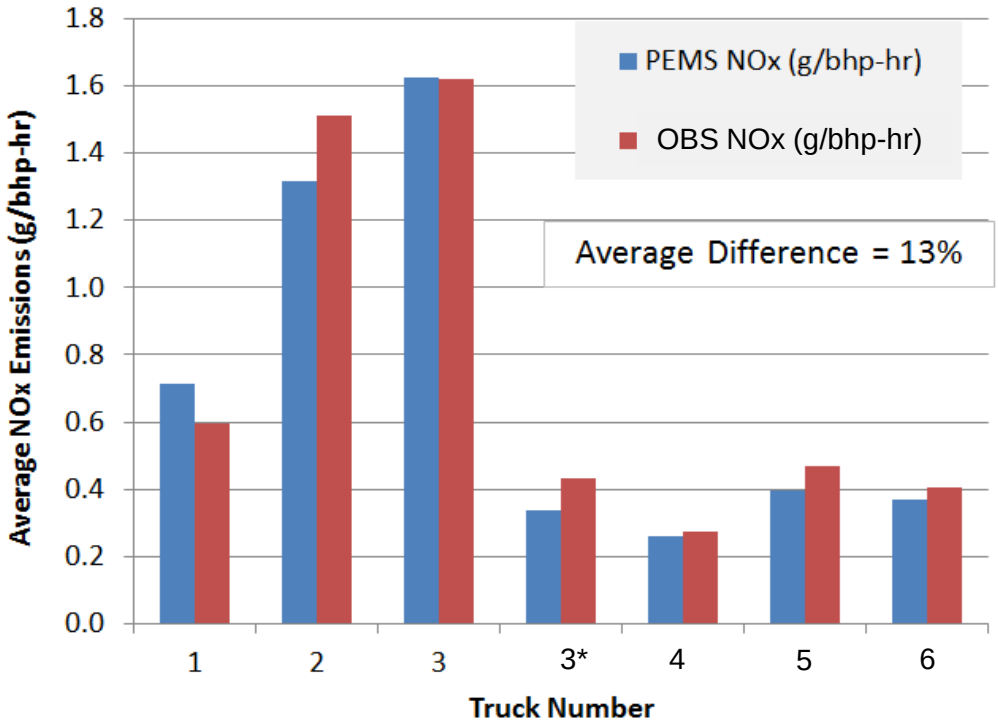


- 68 vehicles outfitted with OBD data logging
- NO_x conversion efficiency of ~80% of the vehicles was <80% with SCR inlet less than 200°C
- NO_x conversion efficiencies of ~40% trucks were below 80% with SCR inlet above 250°C
- Some manufacturers did much better than others

Source: Montes, 2018, SAE symposium presentation

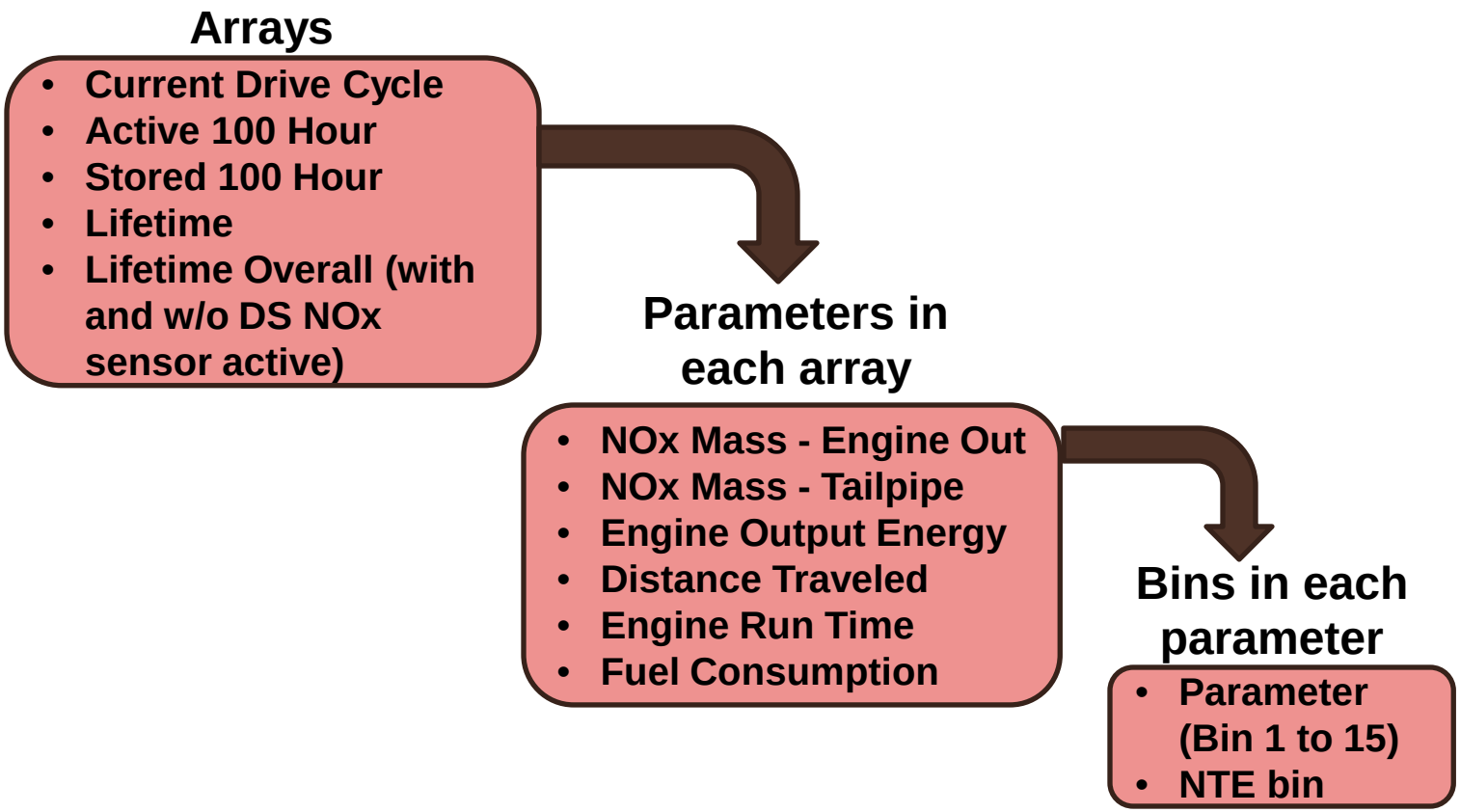
REAL results confirmed by PEMS testing

- In-Use Compliance Program
- 7 trucks
  - 2 engine families
  - All SCR-equipped
- Mostly freeway driving
- Much worse in urban driving conditions!



*Truck 3 tested as received and after new SCR system installed

REAL: HD OBD NOx tracking proposal



How can REAL data be used

- Screening
  - Simpler way to identify problems for follow-up investigation/testing
- Compliance
  - Develop in-use standards to compare the stored data to
  - Limit and confirm emission impact of IRAFs and AECDs
  - Retroactively adjust (up or down) certified emission levels
- Certification
  - Use past data to support certification
- Future Regulatory Development
  - Use data to identify areas of needed improvement
- Inventory Modeling
  - Improve accuracy of inventory to better inform future policies

Implementing REAL

- Near term: Adopt requirement to track and report
  - Downstream NOx sensors already on all diesels
  - Consider relevant tracking for gasoline with available information
    - Use lambda sensor? Track non-stoichiometric time?
  - Standardized OBD data stream
  - Could be reported to ARB as part of required post-certification activities
  - ARB/contractor could get data from vehicles
  - Could eventually be collected during Smog Check or HD IM program inspections
- Longer term
  - Data collected remotely?
  - Quickly and thoroughly identify underperforming vehicles for corrective action
  - Redesign certification and compliance
  - Likely need refinement of sensors
    - Explore NOx sensors on gasoline
    - New sensor technologies (e.g., HC sensor?)

Other Heavy-Duty Measures to Reduce NOx

- Equipment replacement and upgrade
  - From 2008 to 2017 replaced or retrofit: 38,000 trucks, 10,000 refrigeration units, 300 marine vessels, 160 locomotives, 128 cargo handling equipment, 37 shorepower berths for ships
- Establish Low-NOx Heavy-Duty Engine Certification Standard and Low–Load Test Cycle
  - Aim for 90% reduction
  - Board date: 2019, Implementation: 2023 – 2027
- Improve In-Use Emission Performance
  - Revise warranty (Step 1, Summer 2018) and useful life requirements later
  - Revise In-Use Testing Protocol (NTE)
  - Comprehensive Heavy-Duty I/M (pending legislative authority)
  - Board date: 2018 – 2020, Implementation: 2018-2022
- Zero Emission Proposal Concept
  - Some % of medium- and heavy-duty sales by manufacturers must be zero emission capable vehicles
  - Optional credits for Class 8 vehicles can be applied to Class 4-7 obligation

Thank you to ARB!

- Annette Hébert, who is “very very passionate about the evolution of our programs to get at better control in real world emissions context”.
- Tom Montes
- Mike McCarthy

Euro limits for HDVs

EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m^{-1})

Tier	Date	Test	CO	HC	NOx	PM	Smoke
Euro I	1992 (< 85 kW)	R-49	4.5	1.1	8.0	0.612	
	1992 (> 85 kW)		4.5	1.1	8.0	0.36	
Euro II	October 1996		4.0	1.1	7.0	0.25	
	October 1998		4.0	1.1	7.0	0.15	
Euro III	*Voluntary EEV (October 1999 to January 2013)*	*ESC & ELR*	*1.5*	*0.25*	*2.0*	*0.02*	*0.15*
	October 2000	ESC & ELR	2.1	0.66	5.0	0.10 0.13[a]	0.8
Euro IV	October 2005		1.5	0.46	3.5	0.02	0.5
Euro V	October 2008		1.5	0.46	2.0	0.02	0.5
Euro VI	January 2013	WHSC	1.5	0.13	0.4	0.01	

Notes:a – for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}

EEV – enhanced environmentally-friendly vehicles

Emission Standards for Diesel and Gas Engines, Transient Test, g/kWh

Tier	Date	Test	CO	NMHC	CH_4[a]	NOx	PM[b]
Euro III	*Voluntary EEV (October 1999 to January 2013)*	*ETC*	*3.0*	*0.40*	*0.65*	*2.0*	*0.02*
	October 2000	ETC	5.45	0.78	1.6	5.0	0.16 0.21[c]
Euro IV	October 2005		4.0	0.55	1.1	3.5	0.03
Euro V	October 2008		4.0	0.55	1.1	2.0	0.03
Euro VI	January 2013	WHTC	4.0	0.16[d]	0.5	0.46	0.01

Notes:a – for gas engines only (Euro III-V: NG only; Euro VI: NG + LPG)

b – not applicable for gas fueled engines at the Euro III-IV stages

c – for engines with swept volume per cylinder < 0.75 dm^3 and rated power speed > 3000 min^{-1}d – THC for diesel engines

Particle number limit

Euro VI stage, PN limits applicable to diesel engines:

- 8.0×10^{11} per kWh (WHSC)
- 6.0×10^{11} per kWh (WHTC)