A Look Forward: CA Heavy Duty Regulatory Plans and PEMS Implications

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California Air Resources Board

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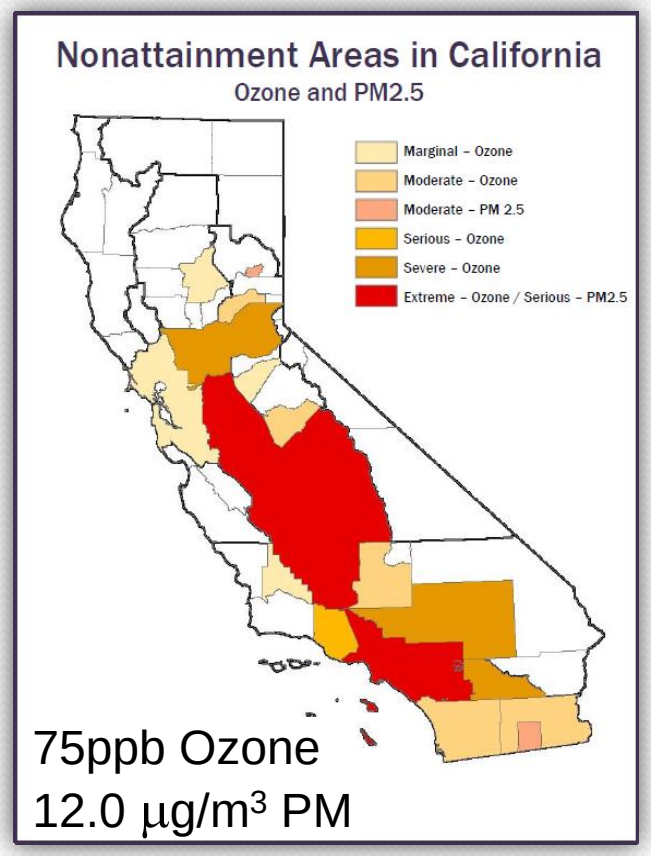
Outline

- Identified HD Emission Challenges
- Regulatory Directions for HD
- PEMS implications
  - Important for understanding In-Use Emissions
  - Increased role in compliance demonstrations and audits
  - Hardware evolution anticipated needs for Low NOx applicability

Challenge: California Needs Significant Reduction in NO_X

- California needs significant reduction in NO_X emissions from today's level to meet the NAAQS for $PM_{2.5}$ and ozone by 2031
  - South Coast Air Basin needs 80% NO_X reduction
  - San Joaquin Valley needs 50% NO_X reduction
- Meeting the NAAQS provides significant health benefits
  - Fewer premature deaths, hospital admissions, and emergency room visits
- Additional 70ppb Ozone NAAQS coming



Heavy Duty Sector a major emissions contributor

- Goods movement a vital economic sector in CA
- Heavy duty trucks represent 33% of statewide NOx emissions

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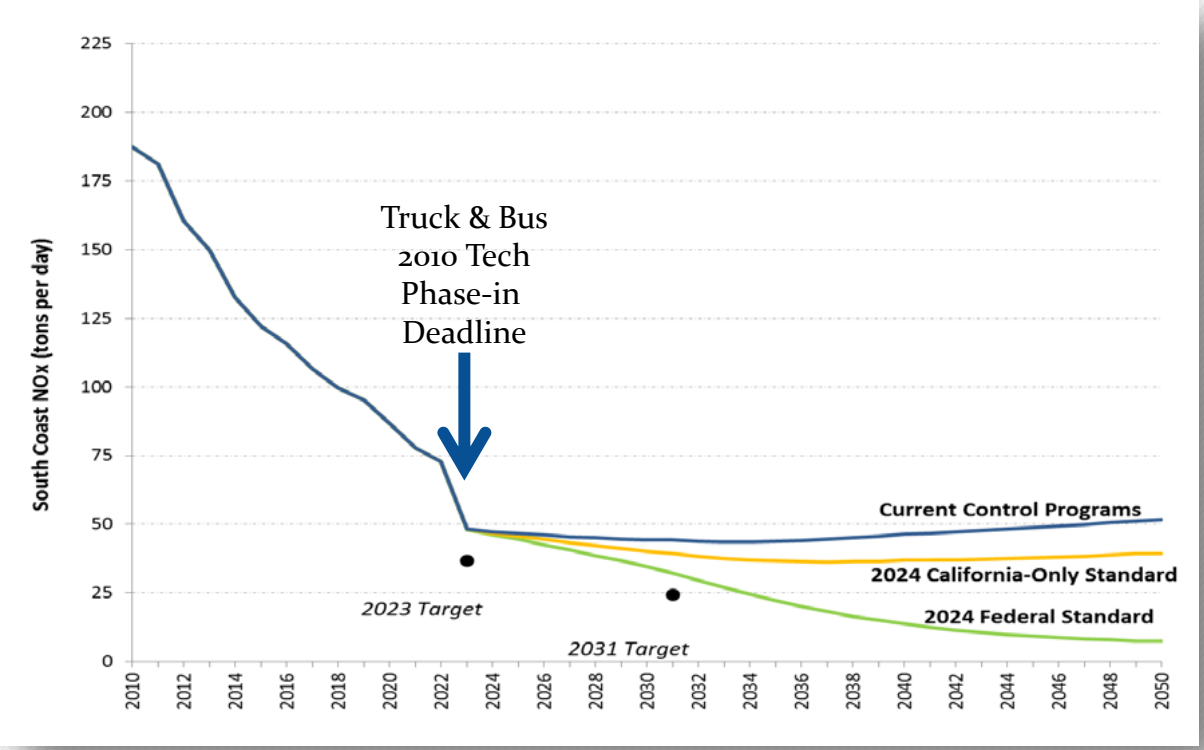
Need for Low NOx HD Engines

- Current 2010 NOx standards insufficient to reach attainment of Ozone 75ppb NAAQS. (Planning for 70ppb just starting)
- Pre-2010 On-Road Fleet Turnover: Necessary but insufficient
- Low NOx operating HD engines needed and with Federal cooperation



Certified and Incentivized:

Research & Tech Demos for other Low NOx engine sizes and fuels underway
Sponsored by CARB, SCAQMD, CEC, SoCalGas and others

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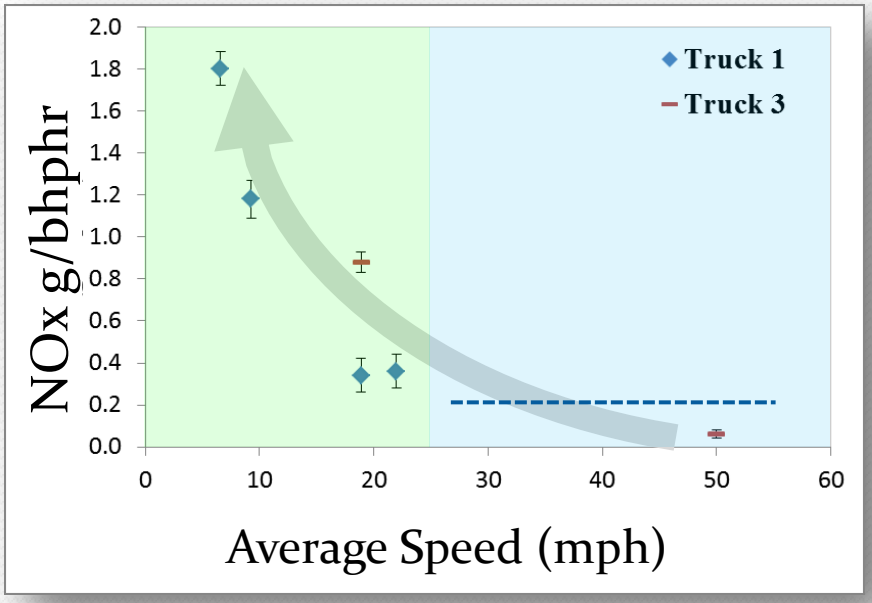
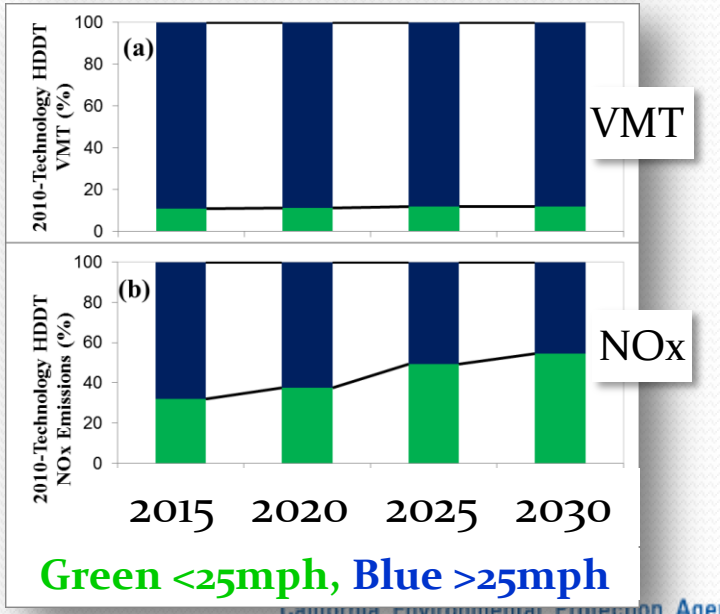
Need for NOx Control across Dutycycles

- 'NOx vs Load Factor' relationship diverging at Low Load for current engine technology/calibration packages
- Increasing Low Load NOx as Fraction of Inventory
- Improved In-use Emissions performance vital





Yoon et al. (2017, Transportation Research Board presentation #P17-20763)

Considerations for Regulatory Direction

- What should 'Certification for the 21st Century' look like?
  - Providing Assurances: Initial design performance, Durability, In-use emissions relative to cert
  - Balance of Efforts: Front-loaded certification vs. Back-loaded 'inverted pyramid' of in-use assessment
    - Better and higher throughput volume screening
    - PEMS in-use investigation of 'interesting' models
    - Lab testing

Expanding role for PEMS

- In-use Emissions increasingly important:
  - Understanding Real World emissions critical to efficient emissions requirements
  - Adapting to growing complexity of engine control and vehicle integration strategies challenging fixed scenario evaluation methods
  - Examining 'Off Cycle' and 'Low Load' emission impacts and the robustness of control strategies to typical dutycycle operation

Expanding role for PEMS

- Applications in Certification and Compliance
  - PEMS for Certification early application:
    Innovative Technology Regulation for HD hybrids and conversions
  - HD In-use Compliance Program Updates for covering broader range of operations in the (currently NTE)
  - Evaluating Connected & Autonomous Vehicle operations and potential emissions saving schemes
  - Future potential at intersection of downsized PEMS-like functionality, OBD, and telematics:

    Possibilities for radically different population wide approaches to inventory, compliance, and certification?

Regulatory Development Schedule

Hearing	Action	PEMS Tie-in
Adopted	Optional Low NOx Standards (50%, 75% & 90% lower)	Examples informing PEMS design & use
	Innovative Technology Regulation	PEMS for hybrid certification
2017	Updates to Smoke Opacity Programs	
	Warranty Updates	
	CA Heavy Duty Phase 2 GHG alignment	PEMS for GEM verification
2019 (2023 implementation)	Low NOx Engine Performance Requirements	Low NOx levels become the norm
	Low Load Certification Requirements	In-use Driver
	In-Use Compliance Program (what is currently NTE)	Broader dutycycle coverage
	Warranty/Durability/ Useful Period Definitions	
2020	HD Inspection/Maintenance Program	Program Effectiveness

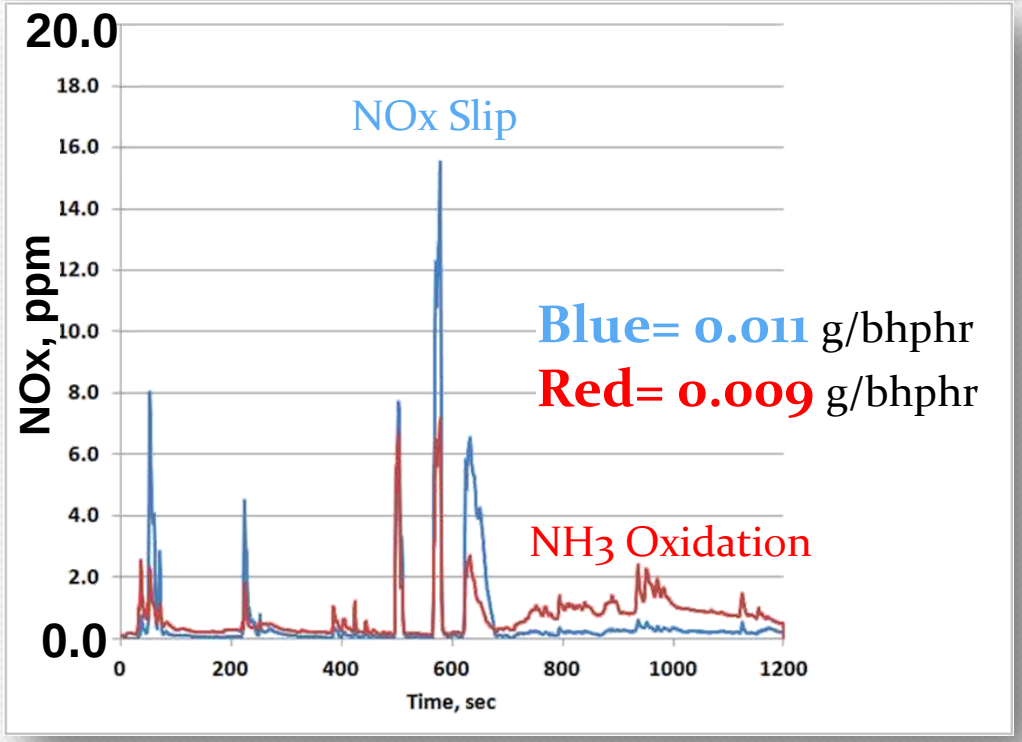
Evolving needs from PEMS hardware

- Hardware evolutions needed
  - Low NOx relevant PEMS measurement levels
    - Different detection methods?
    - Sampling systems considerations?
    - Background/zeroing field considerations?
  - Continued increases in durability and usability needed in current compliance grade instruments
  - Overall size/weight in LD applications: getting down to FTP test weight can be a serious challenge
  - New applications approaching fleet-wide measurement enabled by Downsized PEMS or vehicle integrated PEMS-like functionality

PEMS in a Low NOx World

- Quantifying NOx in many passing NTE events already challenging
- Low NOx Operation characterized by
  - Quickly gaining NOx control
  - Minimizing NOx breakthroughs
  - Maintaining NOx efficiency across dutycycles
- Tailpipe NOx becoming more engine independent:
  - Slipping Engine Out NOx or
  - Oxidizing NH_3 to NOx on ASC?
- Cold Start peak to Hot Operation an Instrument Range challenge, but:
  - The standard bounds max Peak Height X Duration

Raw Diesel Exhaust NOx, Hot FTP repeats



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Conclusions

- California facing tough challenges in GHG & NOx
- Technology pathways toward meeting these goals will continue to require grounding in reliable In-use Emissions Data
- PEMS methods are positioned to deliver the awareness needed to craft regulation and assess compliance
- Bright future for innovative strategies leveraging diverse, broadly-applied in-use emissions measurement

Contact Information

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