

# *Regulatory Activities for On-road Vehicles in the U.S.*

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*March 21, 2023*

*13th VERT Forum*

*EMPA, Dübendorf, Switzerland*



# Outline

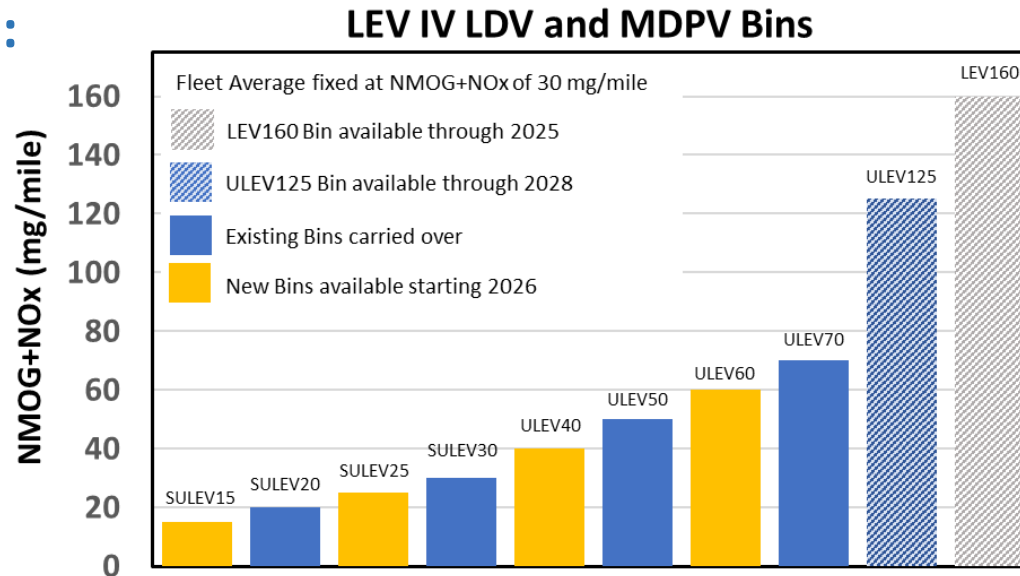
- **Light-Duty Vehicles**
  - CARB LEV IV vs. soon to be released EPA LD Multipollutant Rule
- **Heavy-Duty On-Road Engines**
  - CARB Omnibus vs. EPA Clean Trucks
  - SwRI Technology Demonstration Program
- **Off-Road Engines**
  - CARB Tier 5 Regulatory Development
  - SwRI Technology Demonstration Program

# LD and MD Passenger Vehicles - CARB ACC II LEV IV

- Standards based on Cost Effective Emissions Reduction in & Best Performing Vehicles

## LEV IV LDV NMOG+NOx requirements:

- Declining % ZEV inclusion in 30 mg/mile FTP Fleet Average from 2025 to 2030
- Standalone US06 and SC03 Limits
- Partial Soak, Quick Drive-Away, 10°C NOx Limits
- PHEV Minimum Technical Requirements
- High Power Cold Start Limits for PHEVs
  - Exempt for >40 mile US06 capable PHEVs



## %ZEVs in Fleet Average

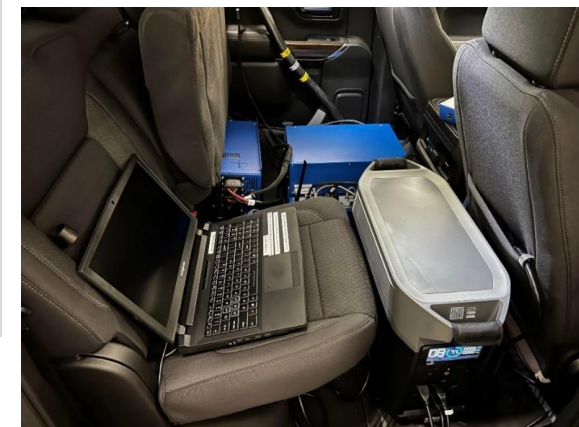
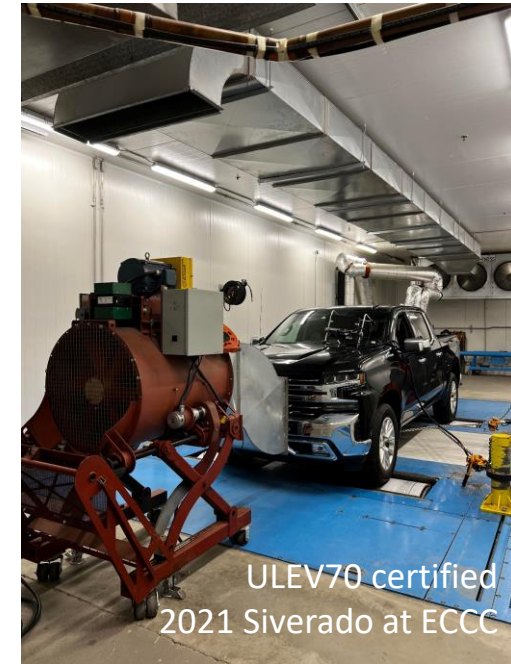
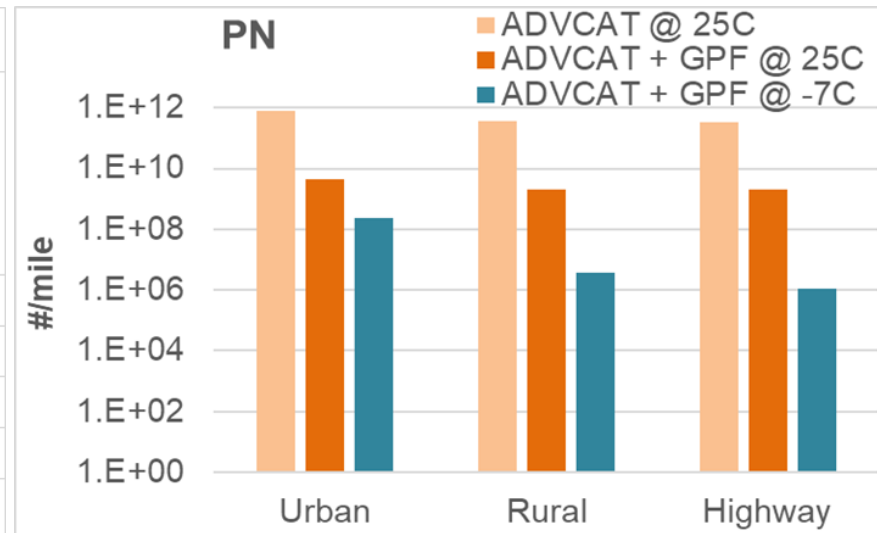
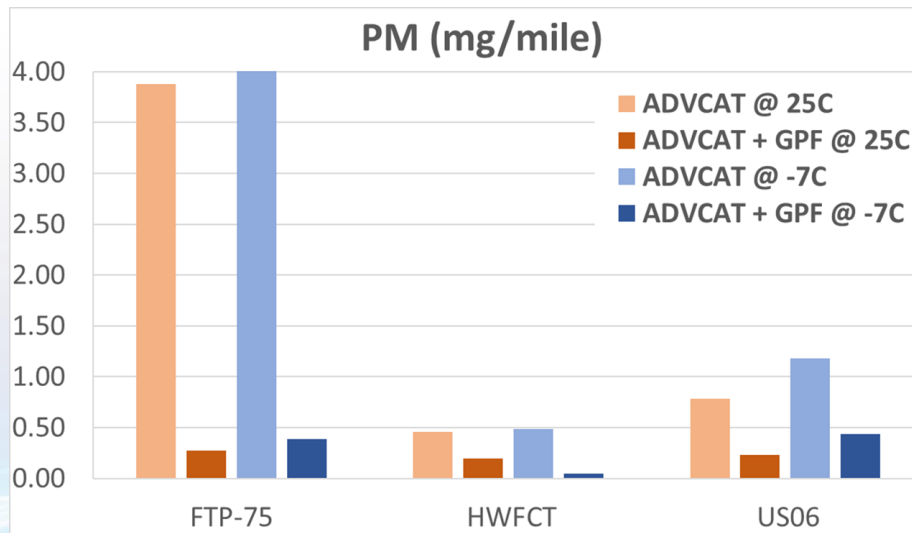
Model Year	Maximum Percent ZEVs+"emission-adjusted PHEVs" <sup>1</sup>
2025 <sup>2</sup>	100%
2026	60%
2027	30%
2028	15%
2029+	0%

## LD PM Limits:

- FTP: 1 mg/mile (50% in MY2026, 75% in MY2027 and 100% in MY2028+)
- US06: 3 mg/mile
- MDV Class 2b and 3 trucks at 8 and 10 mg/mile!!

# Testing in Support of EPA Multipollutant Rule Development

- MECA provided updated catalysts and gasoline particulate filters to **US EPA** and **Environment and Climate Change Canada** to:
  - quantify emission reductions potential, and
  - to confirm technical ability to measure PM at levels  $<0.5\text{mg/mile}$ 
    - aged to full useful life / tested at ambient &  $-7\text{ }^{\circ}\text{C}$  / in-use



- **Testing confirmed the ability to measure PM emissions to  $<0.5\text{ mg/mile}$  over all test cell certification cycles at  $25\text{ }^{\circ}\text{C}$  and  $-7\text{ }^{\circ}\text{C}$**

# What to Expect in EPA's LD Multipollutant Proposed Rule

- Expect release about mid-April
- CO<sub>2</sub> standards expected to factor in President's 2030 EV penetration rate ~50%
- Single vehicle standards with no ZEV averaging at vehicle level
- **LD Tier 4 Standards for MY 2027-2032**
  - Expect NMOG+NO<sub>x</sub> fleet average phase down from 30 mg/mile & include ZEVs
  - FTP and US06 phased-in PM standard to potentially as low as 0.5 mg/mile
  - Expect to see Cold FTP (-7°C)
- **Expect to require further ICE technology with increasing penetration of GPFs, advanced fuel injection, and hybrid powertrains**



# HD Highway CARB Omnibus vs. EPA Clean Trucks Regulation

Duty Cycle	CARB – HHD			EPA - HHD
	MY 2027-2030		MY 2031+	MY 2027+
	Intermediate Useful Life 435,000 miles	Full Useful Life 600,000 miles	Full Useful Life 800,000 miles	Full Useful Life 650,000 miles (750,000 miles cert tested)
FTP / RMC (mg/hp-hr)	20	35	40	35
LLC (mg/hp-hr)	50	90	100	50
Idle (g/hr)	5	5	5	10

## EPA Streamlining and Compliance Flexibilities

- Single Stage in 2027 – no interim 2024
- 2-Bin Moving Average Window:
  - Bin 1 is <6% power and Bin 2 is >6%
- PEMS Accuracy Margin: 5 mg/hp-hr
- Interim Compliance Margin: 15 mg/hp-hr
- Ambient temperature correction - (above right)

**PM standard:** 5 mg/hp-hr for FTP/RMC/LLC cycles

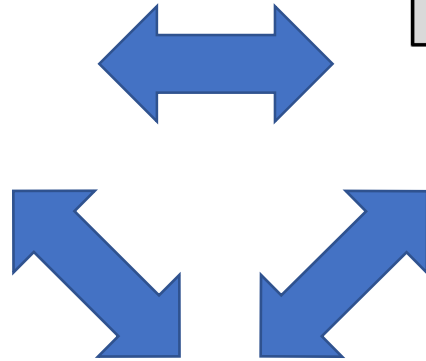
**NMHC standard:** 60 mg/hp-hr for FTP/RMC/LLC cycles

# EPA Stage 3RW Low NO<sub>x</sub> Demonstration Engine at SwRI

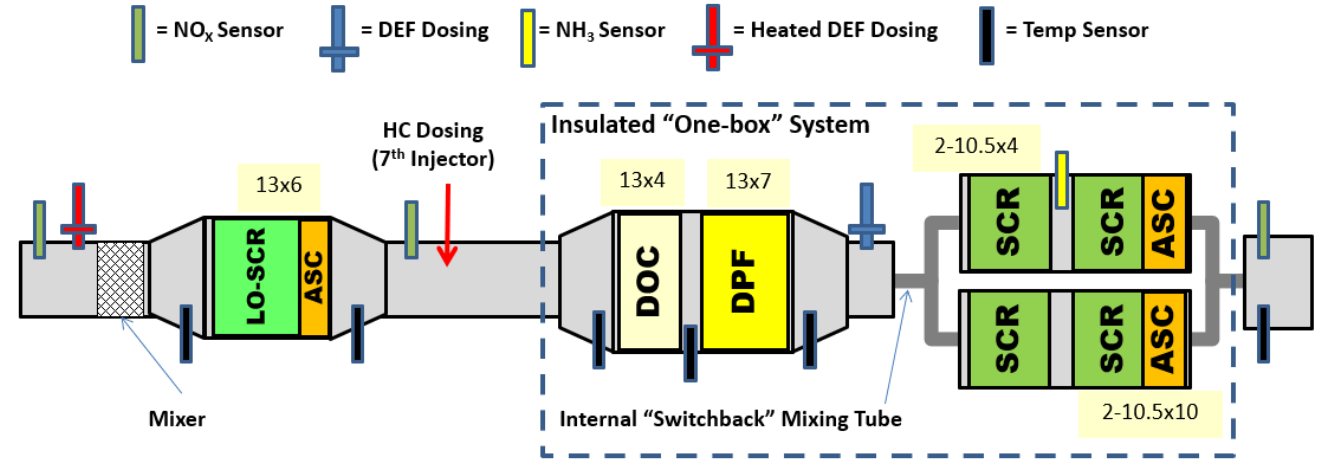
## 2017 Cummins X15 Engine



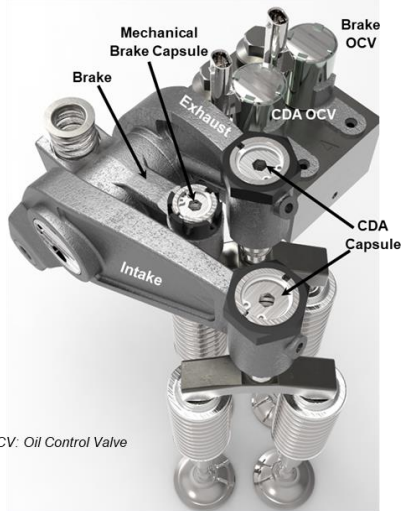
Full System Details  
SAE Paper  
2021-01-0589



## Advanced Low NO<sub>x</sub> Aftertreatment (Dual SCR-Dual Dosing)



## Cylinder Deactivation

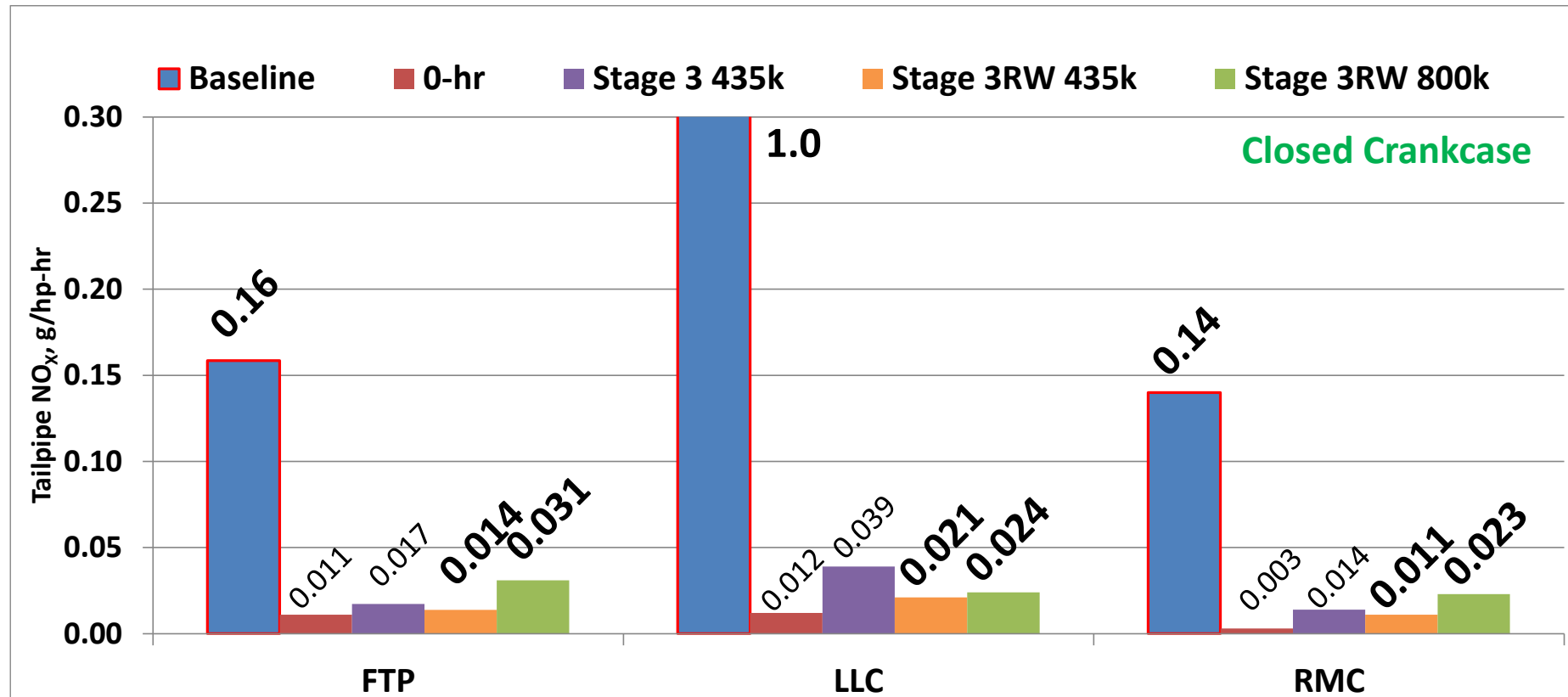


OCV: Oil Control Valve

- Targets:**
- FTP/RMC NO<sub>x</sub> 0.02 g/hp-hr
  - Lowest feasible LLC and in-use NO<sub>x</sub>
  - No adverse GHG impact

- EPA Updates**
- Change zCSF to DOC+DPF
  - Improved downstream DEF mixing

# HD Low NO<sub>x</sub> Program Results at SwRI



## NO<sub>x</sub> Tailpipe emissions 90%+ <Baseline

- Low Load emissions (LLC) are 25X lower and comparable to high load

## Moved to Closed Crankcase Ventilation (CCV)

- Reduced NO<sub>x</sub> by additional ~ 0.006+ g/hp-hr



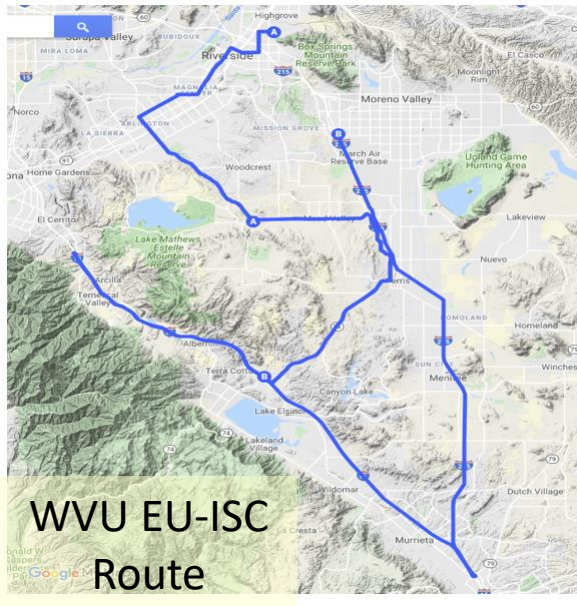
# Real-World Duty Cycles Measurements



CARB Southern NTE Route

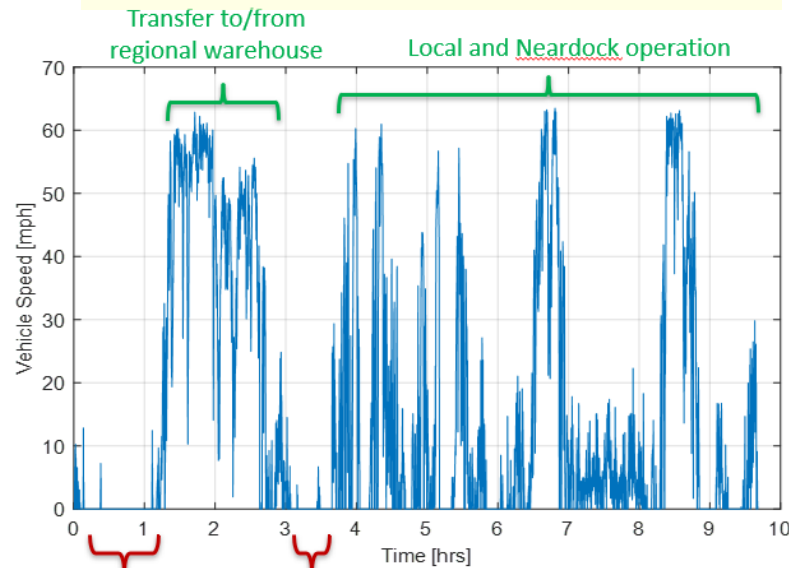


WVU Grocery Delivery Route



WVU EU-ISC Route

WVU Drayage Route



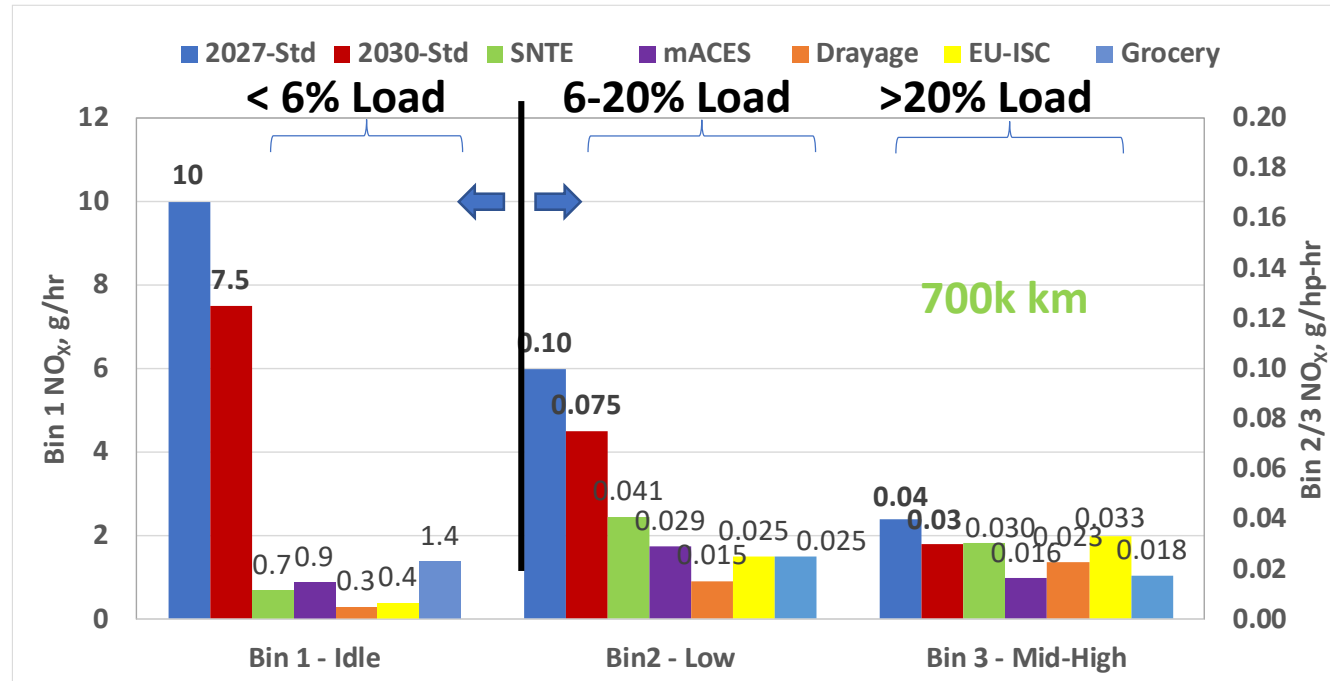
Inside port or drayage yard operation => extended idle operation

Each of these cycles is a real working route that was driven with multiple actual Class 7 and Class 8 trucks

Cycles represented a wide variety of different kinds of vehicle operations

Recorded Vehicle Data was used to develop speed/load profiles that could be translated to Laboratory dynamometer

# Field Duty Cycle Results (3B-MAW) - Stage 3RW 700k km



- Real-World Duty Cycles were transposed to Test Cell Cycles
  - covers all operations, no low power exclusions, includes cold-start
- NO<sub>x</sub> emissions were evaluated over Real-World Duty Cycles using 3Bin-MAW method
  - well below CARB 2027 (dark blue) are CARB 2031 (dark red) in-use standards shown on left
  - Idle and Low Load emissions (Bins 1&2) comparably controlled as mid-high load (Bin 3)

# Nonroad Low NO<sub>x</sub> Demonstration Program

Overall goal of Nonroad Low NO<sub>x</sub> effort is to demonstrate production feasible technologies to reduce emissions:

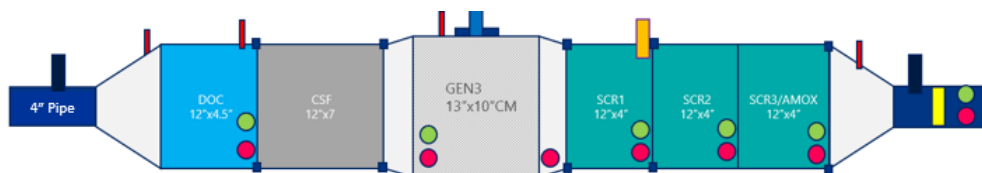
- NO<sub>x</sub> by 90% (nominal target of 0.04 g/kw-hr)
- PM by 75% (nominal target of 0.005 g/kw-hr)
- Extended Useful Life target at 12,000 hours (test at 8,000 hours)

## GHG Standards Concepts:

- 56kw to 560kw 5% to 8.6% reduction
- N<sub>2</sub>O and CH<sub>4</sub> caps

## Other Elements

- Nonroad Low Load Cycle
- 3B-MAW In-Use standard & possible OBM?
- Longer Useful Life (12k hours > 56kw ?)
- Some form of OBD



John Deere 6068 (6.8L) Tier 4f Engine

## Preliminary Results with 12k hour hydrothermally aged parts

Cycle	EO NO <sub>x</sub> g/kw-hr	TP NO <sub>x</sub> g/kw-hr	NO <sub>x</sub> Efficiency, %	CO <sub>2</sub> , g/kw-hr	Baseline CO <sub>2</sub> , g/kw-hr
Cold NRTC	2.3	0.138	93.9	763	761
Hot NRTC	2.4	0.004	99.8	741	747
Composite NRTC	2.4	0.011	99.5	745	748
RMC C1	2.7	0.009	99.7	689	697
LLAC	4.1	0.011	99.7	832	836



# Summary and Conclusions

- With next set of regulations, US is finalizing the last set of criteria pollutant standards from combustion engines.
- Emission control technology evolution supporting significant further pollutant reductions
- Predominant GHG reductions to come from EV penetration into fleet
- Regulations are targeting tighter criteria standards to achieve cleanest possible remaining ICE vehicles.

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