CALIFORNIA
AIR RESOURCES BOARD

Tier 5 Rulemaking Workshop II

Off-Road In-Use Program

October 30-31, 2023

CARB

Off-Road In-Use Program

Outline

- CARB Testing Authority for Off-Road In-Use Compliance (ORIUC)
- Manufacturer-Run Off-Road In-Use Testing (ORIUT)
- Screening Data Reporting Requirements
- Analysis Method: 3 Bin-Moving Average Window (3B-MAW)
- Off-Road Real Emissions Assessment Logging (OR-REAL)
- Portable Emissions Measurement System (PEMS) Testing
- Implementation Timeline

CARB's Testing Authority for ORIUC

ORIUC Authority

- Add clarification of CARB's authority to conduct ORIUC testing in the California Code of Regulations (CCR)
- Applies to Tier 5 engines
  - ORIUC test procedures would follow the proposal in this presentation for our upcoming regulatory proposal and would be included into the "**California Exhaust Emission Standards and Test Procedures for New 2029 and Later Tier 5 Off-Road Compression-Ignition Engines"** used in the ORIUT program
- Add language similar to On-Road in 13 CCR 2139(g) and 2139.5

Manufacturer-Run ORIUT

Purpose of In-Use Screening

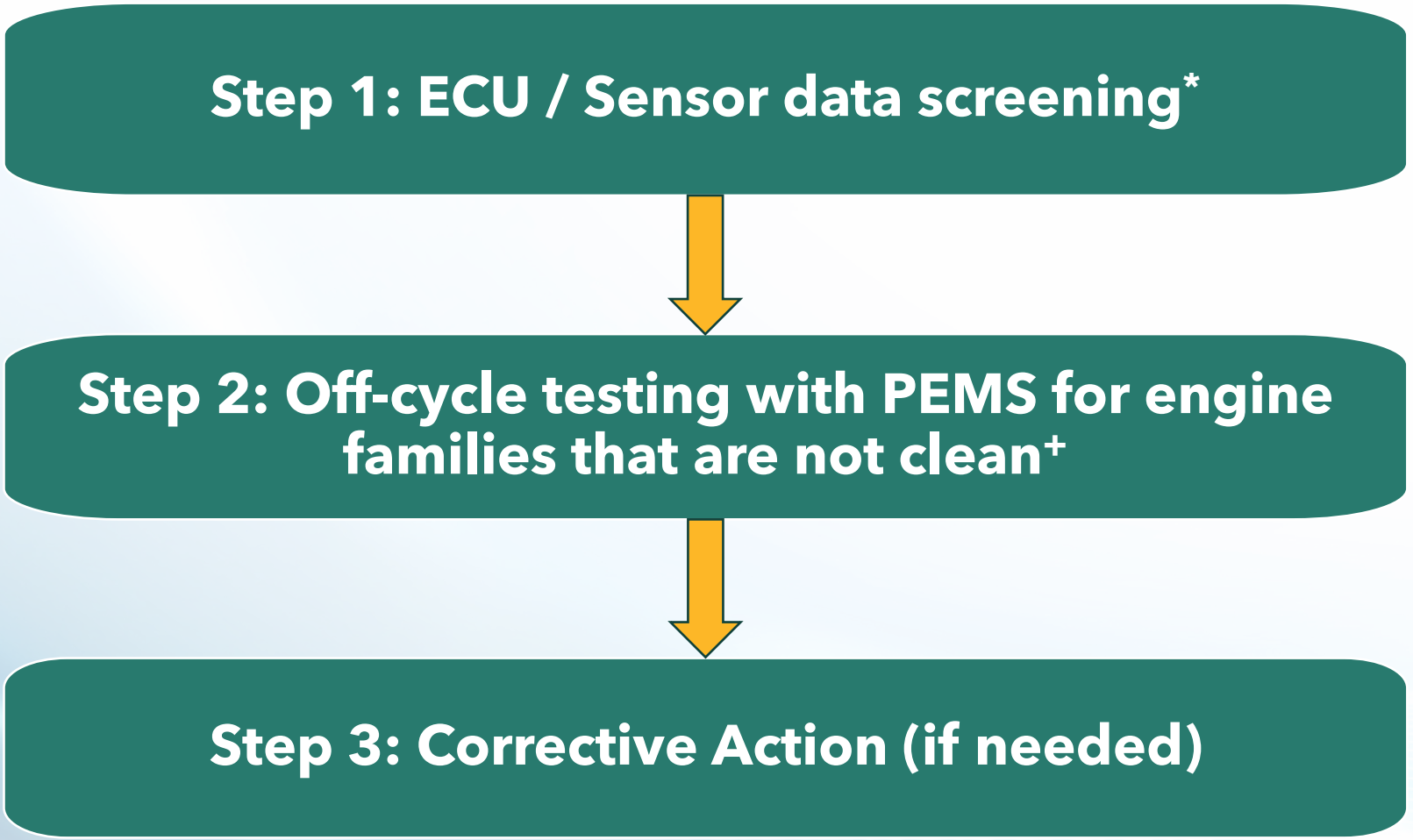
- Diesel oxides of nitrogen (NO_x) and particulate matter (PM) emissions contribute to adverse health effects
  - NO_x contributes to respiratory illness, ozone and secondary PM formation, and acid rain
  - Diesel PM exposure contributes to cardiovascular illness and cancer
- To ensure emissions control, a screening method using onboard sensors is proposed to evaluate real-world NO_x emissions and the condition of the diesel particulate filter (DPF)
- In-use screening is expected to identify any engine families with potential widespread difficulty in NO_x or PM control
- In-use screening would exempt clean engine families from unnecessary PEMS testing

Manufacturer-Run ORIUT Proposal

- Introduce a new ORIUT program applicable to Tier 5 engine families $56 \leq kW \leq 560$
  - Engine manufacturers would demonstrate in-use emissions control of NO_x and PM
- Leverage onboard NO_x sensors and DPF monitors using OR-REAL on Tier 5 engines
  - Clean engine families would be exempted from PEMS testing based on Engine Control Unit (ECU) / Sensor data (OR-REAL)
- Reduce the PEMS testing burden due to:
  - Expense, difficulty in finding fleets, mounting, finding appropriate terrain, various equipment applications, duty cycles, etc.

Note: The screening phase of ORIUT specifically targets NO_x and PM, while the PEMS testing phase encompasses all the criteria pollutants.

Flow Chart of ORIUT



* NO_x and PM
\+ All criteria pollutants

Step 1 ECU / Sensor Data Screening Overview

Step 1: ECU / Sensor data screening

- NO_x screening criteria:
  - Engine manufacturers would collect OR-REAL data on 100% of the engine families (EF)
  - Annually submit OR-REAL data for at least 75% of engines per EF that are certified and sold in California (CA)
  - NO_x emissions would be evaluated based on the in-use screening bins in the OR-REAL structure
- PM screening criteria:
  - Engine manufacturers would annually submit DPF fault code history for at least 75% of engines per EF that are certified and sold in CA
  - A DPF fault code tracker* would store fault codes and their associated engine hour timestamps
- An EF that meets both the NO_x and PM criteria would be identified as a "clean EF," may fulfill the in-use testing requirements based on the EO's assessment
  - If a manufacturer cannot fulfill the minimum OR-REAL data requirement for an EF, the Executive Officer (EO) may request additional testing that does not count towards the EF's PEMS testing cap

*Discussed in more detail in the OBD slides

Step 1 Continued: Screening Plan

Step 1: ECU / Sensor data screening

- Manufacturers would be required to annually submit a screening plan to the EO for review and approval
- The screening plan would include:
  - Engine selection method, the number of engines to be sampled, a timeline to collect data, and a reporting format
  - List of EFs and potential applications
  - Demonstrate that the data is representative of EF applications in CA and does not exclude or include only specific data from engines with the lowest in-use emissions
- Upon request, the EO may for good cause extend the deadline for data submission up to 6 months
  - If extensions are granted, manufacturers must submit an interim report on all data collected within the 12 months

Step 2 and 3

Step 2: Off-cycle testing with PEMS*

- The EO would issue test orders for EFs not passing screening criteria for either NO_x or PM
- The EO would request PEMS testing from up to 25% of total Tier 5 EFs from each engine manufacturer
- Additionally, if 80% of engines of a specific EF do not meet either NO_x or PM screening criteria, the EO would request additional PEMS testing without counting it as part of the selected EFs mentioned above
- If PEMS testing demonstrates compliance, then the in-use testing requirements for the EF would be fulfilled

Step 3: Corrective Action (if needed)

- If PEMS testing shows an EF is not compliant, then the manufacturer would take steps to correct the non-compliance
- Manufacturers could opt to go directly to corrective action without conducting PEMS testing if they identify emission control problems based on ECU / sensor data in Step 1

CARB

*Small Sales Volume is discussed in later slides

Screening Data Reporting Requirements

Reporting Rate of Sensor Data Screening

- The goal of the in-use compliance program is to understand how well off-road engines are performing in the real world
- Having OR-REAL data would enable staff to assess the real-world performance
  - The ORIUT proposal requires that OR-REAL data would be accessible on all Tier 5 engines, and manufacturers would annually report OR-REAL data for a minimum of 75% of engines per EF that are certified and sold in CA
- CARB staff is concerned that lower reporting rates could yield an inaccurate evaluation of real-world emissions and make the screening program ineffective

Staff Concerns About the Potential for Self-Selected Reporting

- By reporting less than 75% of engine data per EF, the integrity of submitted data could potentially be compromised
  - High emitters could potentially be considered outliers and excluded from reporting
  - Potential emissions tampering may compromise data and defeat the data screening purpose
- NO_x sensors might not function as expected
  - NO_x sensors might not monitor emissions over the entire duty cycle, and thus omit high emission events
  - Manufacturers may pause NOx tracking when a NOx sensor malfunction is detected

Simulation of Reporting Rates to Identify the Minimum Amount of Data for Screening

- Objective: to determine the minimum reporting rate required for the accurate identification of a specific EF to evaluate whether it would need PEMS testing
  - The simulation does not account for NO_x sensor accuracy, and thus no margin was used for screening
- Potential scenarios that staff considered:
  - Reported data are randomly selected without intentional omission
  - Reported data are intentionally self-selected by removing the highest-emitting engines

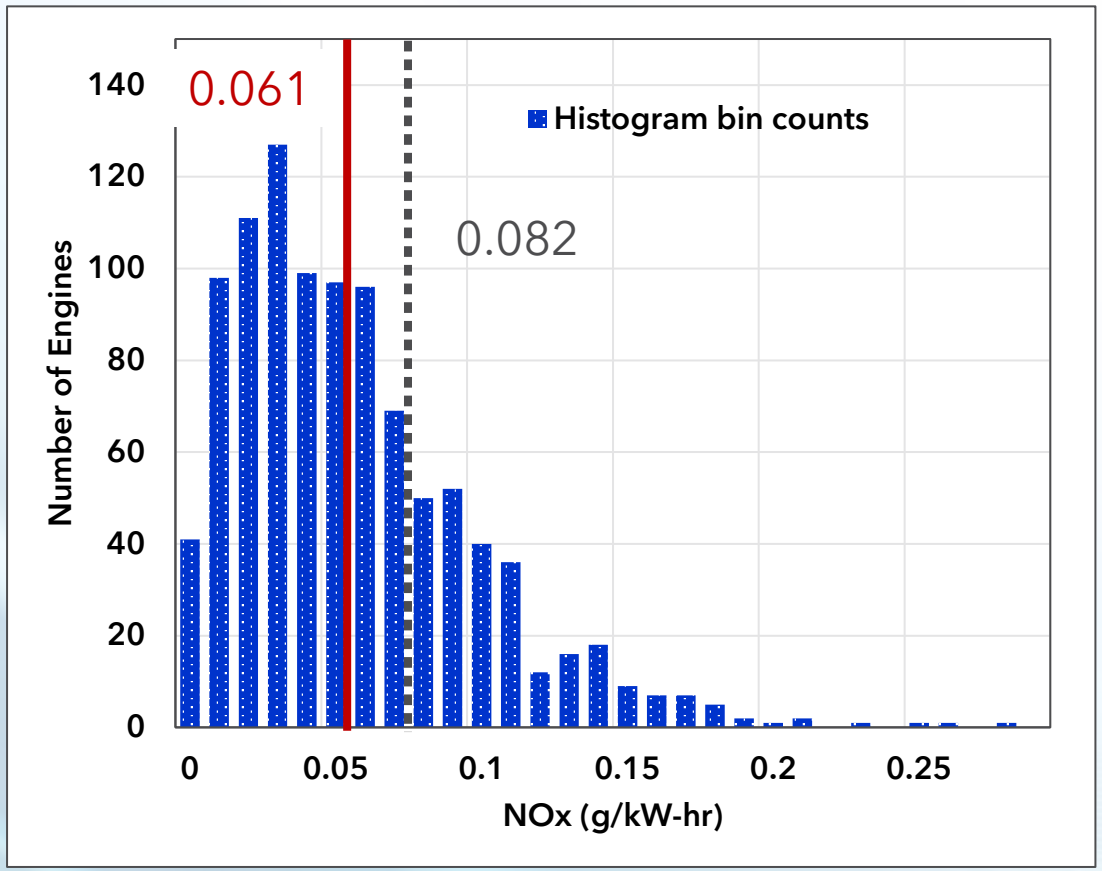
Simulation of Reporting Rates to Identify a Minimum for the Screening

- Staff conducted a Monte Carlo simulation to identify the minimum reporting rate
  - Staff modeled three sizes of EFs: small (50), medium (200), and large (1,000)
  - Emissions were assumed to have gamma distributions
    - A literature review revealed that vehicular NO_x emissions follow a gamma statistical distribution function*
    - A gamma distribution signifies that "dirty" engines are different from "clean" engines, with a few "broken" engines that contribute disproportionately to the total emissions
  - Staff conducted 1,000 simulations for each combination of reporting rate, EF size, emissions distribution, and self-selection rate
  - Staff set a binary outcome of pass/fail if the EF either had an average NO_x emission of 0.060 g/kW-hr (criterion 1) or 25% of engines emitted above 0.080 g/kW-hr (criterion 2)

**Automobile Emissions Are Statistically Gamma Distributed (https://pubs.acs.org/doi/pdf/10.1021/es00056a029) Characterization of On-Road Vehicle NO Emissions by a TILDAS Remote Sensor (DOI:10.1080/10473289.1999.10463814)*

g/kW-hr = grams per kilowatt-hour

Simulation Example: A Large Failing EF

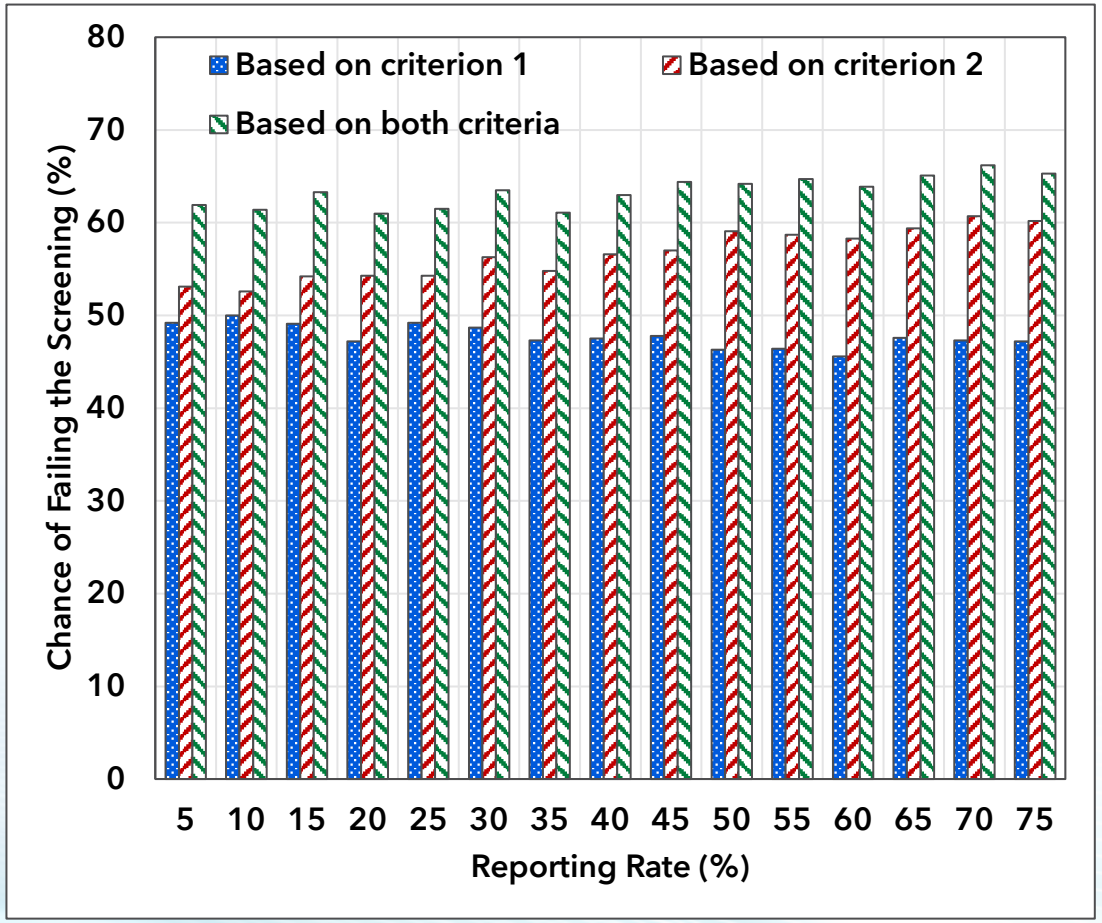


The solid red line indicates the average emission of the EF, and the dashed black line indicates the 75th percentile of NO_x emissions

- The EF has 1,000 engines
- The average NO_x emission is 0.061 g/kW-hr,
- The 75th percentile of NO_x emissions is 0.082 g/kW-hr, 26% engines are higher than 0.080 g/kW-hr
- The EF should be flagged for off-cycle PEMS testing

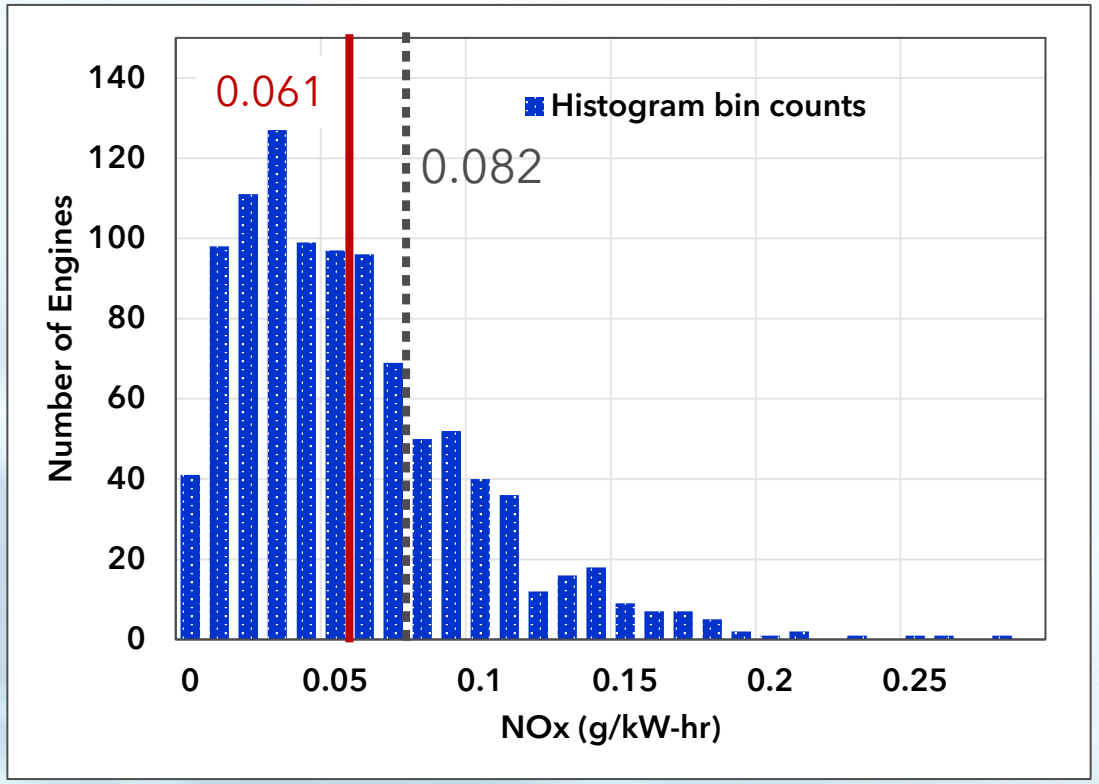
Random Reporting without Self-Selection

- Random reporting assumes that a manufacturer would report NO_x sensor data without intentional data omission
- Lower reporting rates are less likely to result in flagging the fleet for PEMS testing
- Using a single criterion for screening is less effective than using both criteria

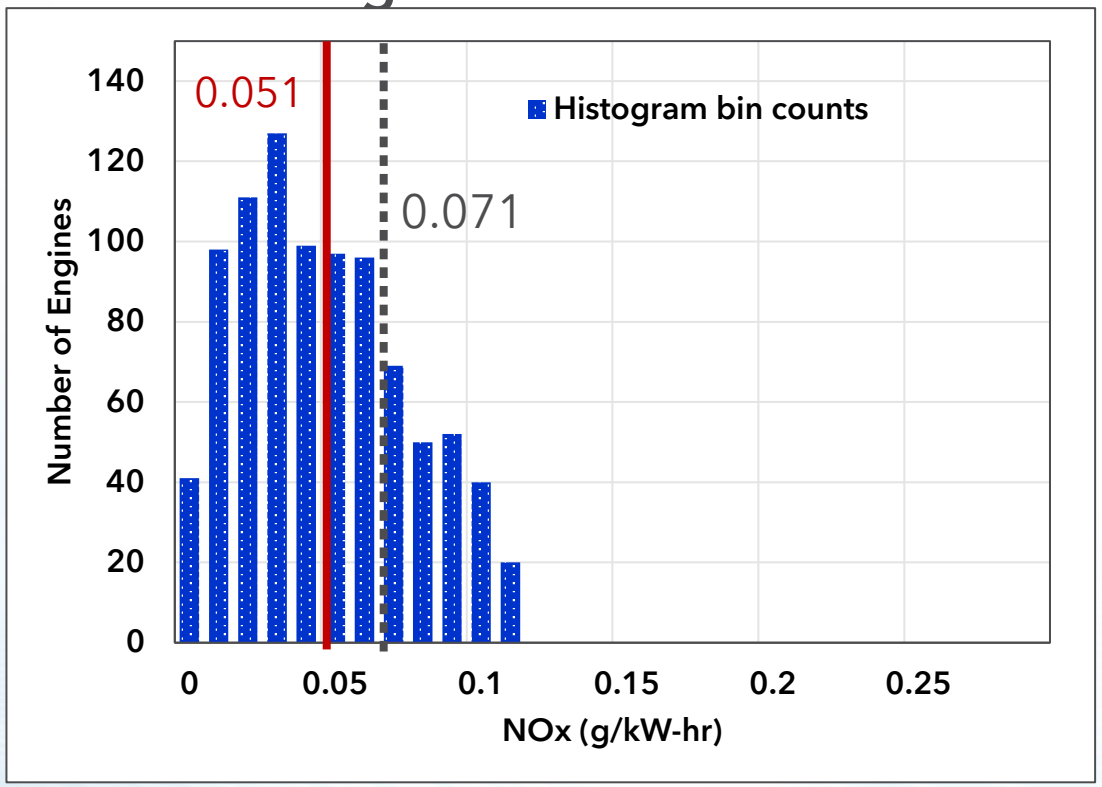


Self-Selected Reporting on a Large Failing EF

Original Data (Full Population)



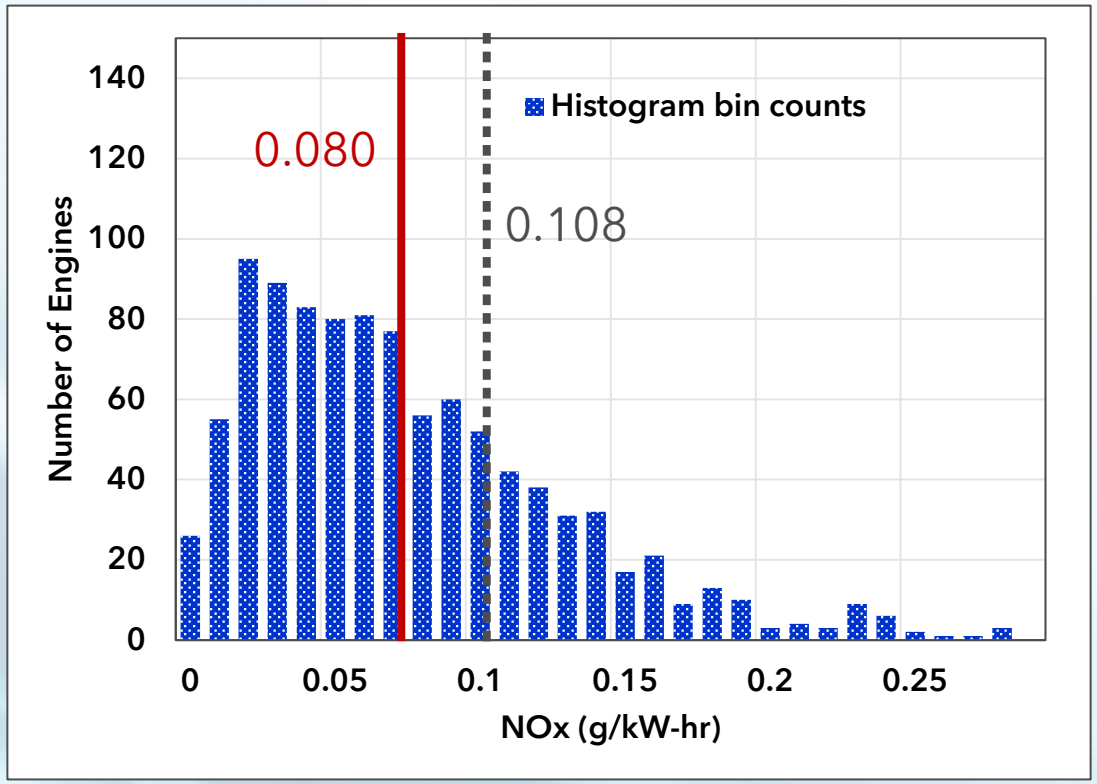
Self-Selected Data – Dirtiest 10% of Engines Removed



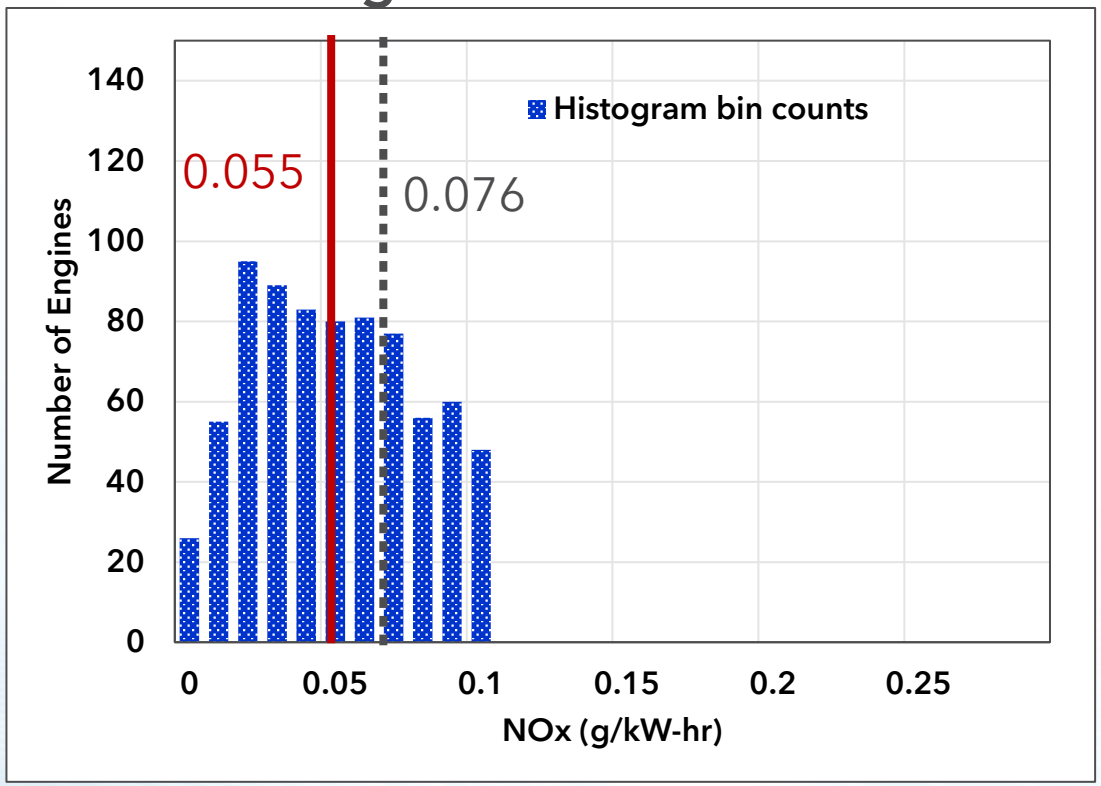
The dirtiest 10% of the EF is intentionally excluded from reporting, which makes the EF appear cleaner and would be exempted from PEMS testing. The solid red line indicates the average emissions of the EF, and the dashed black line indicates the 75th percentile of NO_x emissions.

Self-Selected Reporting on a Large Dirty EF

Original Data (Full Population)



Self-Selected Data – Dirtiest 25% of Engines Removed

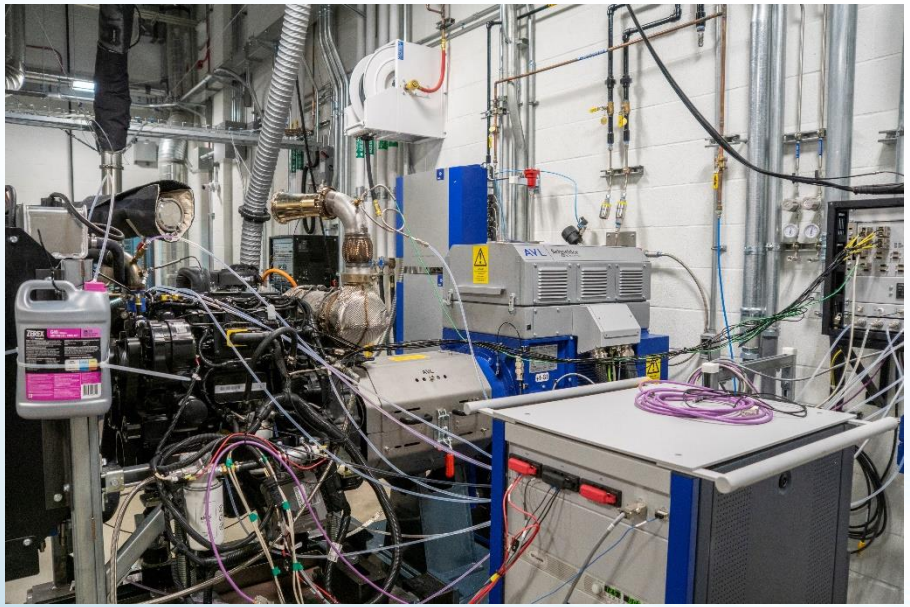


The dirtiest 25% of the EF is intentionally excluded from reporting, which makes the EF appear cleaner and would be exempted from PEMS testing. The solid red line indicates the average emissions of the EF, and the dashed black line indicates the 75th percentile of NO_x emissions.

Self-Selected Sampling

- Intentionally removing the dirtiest engines would significantly increase the chance of falsely identifying clean EFs
- While CARB staff recognizes that it may be challenging for manufacturers to report data from all the engines for some applications, a minimum 75% reporting rate would avoid potential bias in the screening outcome due to the possibility of self-selection

3B-MAW Analysis Method for Sensor Data Screening and PEMS

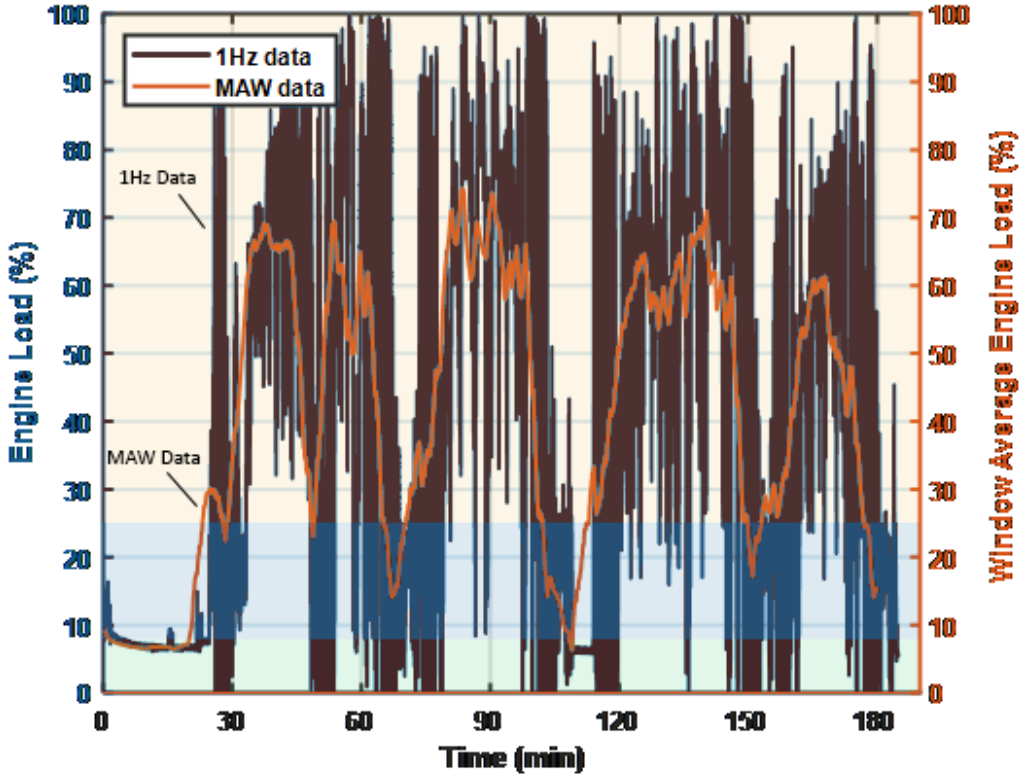


Analysis Method: 3B-MAW

- A 3B-MAW method would be used to evaluate emissions at the ECU/Sensor Data Screening and off-cycle PEMS testing steps
  - In step 1, the 3B-MAW would be used for NO_x screening only. PM screening would be based on pending and malfunction indicator light (MIL)-on fault codes for DPF only.
  - In step 2, the 3B-MAW would be used for evaluating all criteria pollutant emissions in off-cycle PEMS testing.
- The three bins are intended to evaluate emissions during the operation in each of the three major modes of operation:
  A. Engine idle
  B. Low load operation
  C. High load operation

Moving Average Window

- Operation and emissions data is broken into overlapping 300 second windows
- The windows would be binned into one of three bins
- Important parameters are the sum total of NO_x mass, the total time, and the total work collected in each bin
- Sum-Over-Sum (SOS) NO_x emissions would be calculated for each bin



This figure shows the 1Hz engine load (blue trace) and the MAW engine load (orange trace) from a PEMS test. The MAW engine load shows engine operation transitioning to the three bins: idle (light green zone), low load (light blue zone), and high load (light yellow zone) when crossing the 8% and 25% engine load bin limits.

Idle Bin Development

- The idle bin would focus on low idle conditions
- Engine load of low idle varies by manufacturer design and equipment application
- Staff analyzed the operation of 240 engines, including a mix of agricultural tractors and construction equipment
  - For this analysis, idle was defined as operations at the manufacturer-declared low idle speed for more than 10 seconds
  - The load of idle operation was calculated for the 240 engines
  - 90% of idle events had a calculated 7.5% engine load or lower
- Staff proposes to set the cutoff between idle and low load operation at 8% engine load

Low Load Bin Development

- The certification test cycle for Low Load Cycle (LLC), has been developed by CARB staff by analyzing data from real-world operation of 240 engines from the original equipment manufacturers (OEMs) and Center for Environmental Research and Technology at University of California, Riverside (CE-CERT) contract
- The analysis identified representative low load operation segments followed by combining low load segments into an LLC
- The development of the LLC focused on operation segments with an engine load less than 25% of max power
- Staff proposes to set the cutoff point between the low load and higher load bins at 25% engine load

Updates to the In-Use Bin Structure

- Based on staff's evaluation of off-road equipment real-world activity, staff proposes new cutoff points for the in-use Bins A-C
  - **Bin A (Idle bin):** ≤8% engine load, based on the analysis of engine load at low idle speeds
  - **Bin B (Low load bin):** >8% and ≤25% engine load, based on the average engine loads of low load windows in the development of low load cycle
  - **Bin C (Higher load bin):** >25% engine load

In-Use Bins	Engine Load (%)
Bin A	≤8%
Bin B	>8% to ≤25%
Bin C	>25%

$$Engine\ output\ power(kW) = 2\pi \times \frac{engine\ speed(RPM)}{60} \times \frac{actual\ percentage\ torque - nominal\ friction\ torque}{100} \times \frac{reference\ torque\ (N \cdot m)}{1000}$$

$$Engine\ load(\%) = {}^{Window\ average\ engine\ output\ power}/_{Engine\ rated\ power} \times 100\%$$

In-Use Binned Emissions Evaluation for Screening and PEMS

- After windowed emissions and activity data are placed into bins, SOS emission rates would be calculated for each bin and compared to emissions thresholds for the stored 50-hour and lifetime arrays.

$$e_A\left(\frac{mg}{hr}\right) = \frac{sum\ of\ NOx\ per\ bin}{sum\ of\ time\ in\ bin}$$

$$e_{B,C}\left(\frac{mg}{kw \cdot hr}\right) = \frac{sum\ of\ criteria\ pollutant\ per\ bin}{sum\ of\ work\ per\ bin}$$

- Testing would be valid only if:
  - There are at least 2,400 windows for Bin A
  - There are 10,000 windows for Bin B and Bin C combined
    - If either Bin B or Bin C has less than 2,400 windows, the testing would be valid but the corresponding bin would not be evaluated and
    - The engine manufacturer would have to provide OR-REAL data demonstrating that the test engine operates less than 20% of the time in the bin not evaluated
- Each of the three in-use bins would need to be evaluated at least once per EF

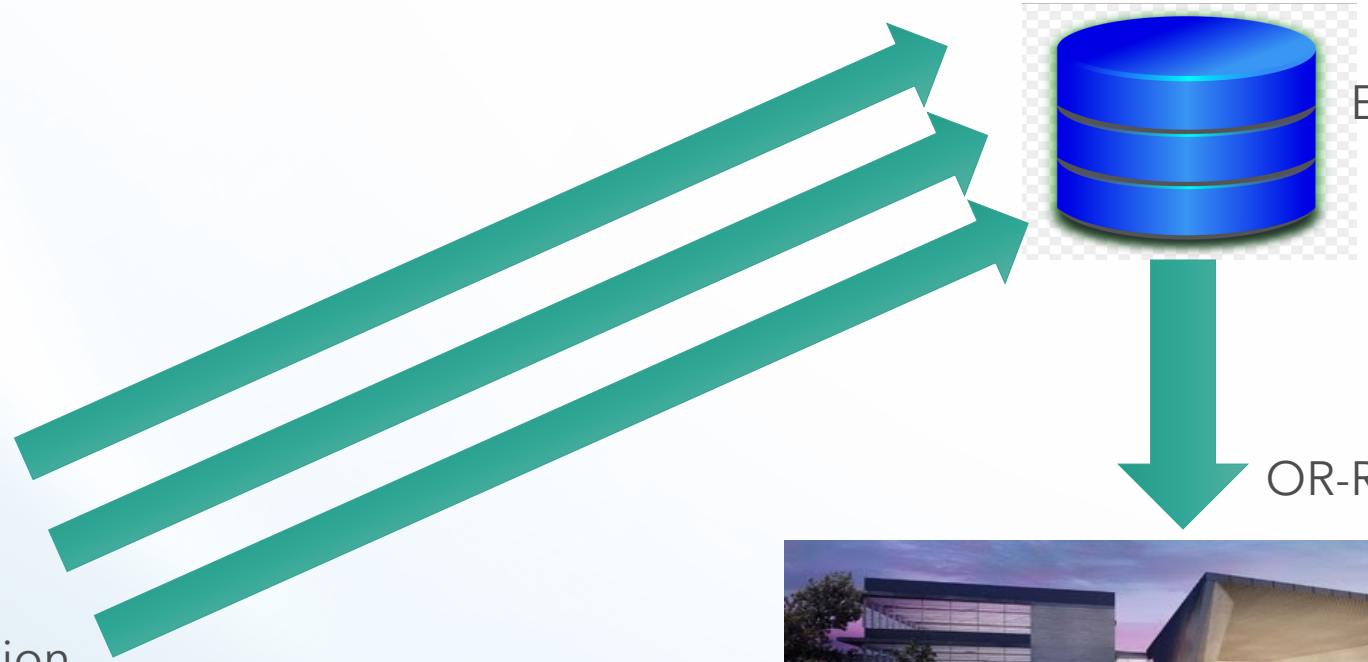
e_A = emission rate of Bin A, $e_{B,C}$ = emission rates of Bins B, C

OR-REAL and Screening

Transfer of In-Use Screening Collected Data

- Manufacturers would choose telematics or other methods approved by the EO to collect On-Board Diagnostic (OBD) data including OR-REAL
  - Telematics devices would be installed in engines to wirelessly transmit collected data to the engine manufacturers' central server or cloud-based platform
  - Data would be transmitted at regular intervals, depending on the configuration of the telematics system to engine manufacturer's server
  - Data integrity would be preserved (tamper-resistant)
  - Data would not be altered prior to submittal
  - The data file would be encrypted and transmitted securely

In-Use Screening Collected Data Submission Flow Chart



Engine OEMs

OR-REAL report 1x annually

Individual engine submission

CARB

Screening Data Collection Requirement

- Engine manufacturers would report annually all collected data (minimum of 75% of each EF) to the EO for a clean EF screening assessment
- An annual report would contain the following elements:
  - OR-REAL
    - Tabular format (i.e., comma-separated values file or Excel spreadsheets)
  - OBD Parameters Snapshot
    - The collected data would contain the data fields as specified in the off-road OBD presentation

Proposed Requirements for the Annual OR-REAL Data Screening Report

- Manufacturers would provide an annual report of all OR-REAL data and an OBD snapshot for each engine, along with a summary report by April 30th of the year following the end of the model year* including for each EF:
  - The number of engines produced, the number of engines sold in California, and the number of engines reporting valid data
  - The average NO_x emissions of the in-use screening bins for the Stored 50-hour and Lifetime Arrays
  - The number of engines with NO_x emissions higher than the bin threshold [Conformity Factor $(CF)_{screening}$=2.0] for either of the Stored 50-hour and Lifetime Arrays
  - The number of engines with a DPF pending or MIL-on fault code
- The submittal would include:
  - Attestation letter that indicates the information is complete and accurate,
  - Determination of whether each EF is exempted or not from PEMS testing,
  - Explanation for all missing data, and
  - Statement that no data has been purposefully excluded

*e.g., for data collected during calendar year 2029, data would be due April 30th, 2030

Step 1 NO_x Screening: Reporting Requirements

- OR-REAL data would be collected on all engines for each engine family and submitted to the EO annually by engine manufacturers
  - Manufacturer would submit all collected OR-REAL data
  - Report at least 75% of engine sales per engine family [based on California (CA) sales]
  - Would apply to Tier 5i and Tier 5f engines within 75% of useful life
  - Data reports would not be required for engines exceeding 75% of useful life
  - Small and Very Small- sales volume engine families would have the flexibility to opt out of the screening and perform PEMS testing directly
  - Data would be accepted for Tier 5 compliant engines operating outside of CA, only if California data is insufficient
  - Data would be submitted electronically

Step 1: ECU / Sensor Data Screening

- The in-use screening program would utilize the OR-REAL structure* on Tier 5 engines:

% Rated Power	SCR outlet temperature			
	≤200 °C	200-250°C	250-400°C	>400 °C
≤25%	bin 2	bin 3	bin 4	bin 5
>25% to ≤50%	bin 6	bin 7	bin 8	bin 9
>50%	bin 10	bin 11	bin 12	bin 13

Total Bin 1
Regen Bin 14
MIL Bin 15

In-Use Bins
Screening Bin A
Screening Bin B
Screening Bin C

PM Fault Code

Regen = DPF Regeneration
MIL = Malfunction Indicator Light

*The OR-REAL structure will be discussed in more detail during the OBD presentation.

OR-REAL Parameters and Arrays for In-Use Screening

Parameter	Active 50-Hour Array[1]	Stored 50-Hour Array[1]	Lifetime Array[1]	Lifetime Engine Activity Array[2]
NO_x mass – engine out (g)				
NO_x mass – tailpipe (g)	A,B,C[3]	A,B,C	A,B,C	
Engine output energy (kWh)	B,C	B,C	B,C	B,C
Engine Run time (hours)	A, B, C	A, B, C	A, B, C	A, B, C
Vehicle fuel consumption (liters)				

1. Tracks engine activity only when NO_x sensors are on.
2. Would continuously track engine activity. Data from this array would indicate the amount of activity that would have no NO_x data.
3. **A, B, C refers to in-use screening Bins A, B, and C. Other bins will be discussed further in the OBD presentation.**

In-Use NO_x Screening: Emissions Evaluation

- A clean EF would be identified if both criteria 1 and 2 are met for each of the three in-use screening bins A, B, and C for both the Stored 50-hour and Lifetime Array[1]:
  - Criterion 1: The arithmetic average emissions of the EF is less than the screening thresholds ($CF_{screening\ 1}$ =1.5 plus a potential accuracy margin) **and**;
  - Criterion 2: The combined number of engines with no reported data and engines with emissions higher than the screening threshold ($CF_{screening\ 2}$=2.0 plus a potential accuracy margin) is less than or equal to 25% of total CA sales
- Clean EFs would be exempted from PEMS testing.
- EFs not passing the clean EF screening criteria above would be placed on a potential list for PEMS testing to verify emissions control.

[1]The lifetime array will be used when the stored 50-hr array is not available.

In-Use NO_x Screening: Emissions Evaluation

In-Use Bins	% Rated Power	NO_x Emission Screening Threshold
Screening Bin A	≤8%	$CF_{screening\,(1,2)}$ x Idle standard[A] + $m_{Sensor\,Accuracy}$[B]
Screening Bin B	>8% to ≤25%	$CF_{screening\,(1,2)}$ x 0.060 g/kW-hr+ $m_{Sensor\,Accuracy}$[B]
Screening Bin C	>25%	$CF_{screening\,(1,2)}$ x 0.040 g/kW-hr+ $m_{Sensor\,Accuracy}$[B]

* $CF_{screening\ 1}$=1.5 for criterion 1 and $CF_{screening\ 2}$= 2.0 for criteria 2

[A] NO_x idle standard is equation-based, ranging from 5.0 g/hr to 15.8 g/hr for engine families 56 ≤ kW ≤ 560

[B] Sensor accuracy margin is pending. CARB staff has an ongoing contract with Southwest Research Institute (SwRI) to analyze onboard NO_x sensor performance and it may be used to inform a sensor accuracy margin, as necessary.

Sensor Technology for the PM Screening Program

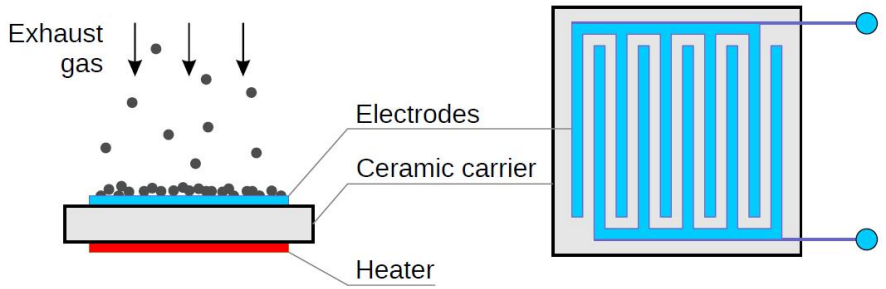
- CARB staff expects that manufacturers would use PM resistive sensors to satisfy OBD requirements for DPF monitoring.
- Advantages over Delta Pressure Sensors:
  - Lower detection thresholds
  - Higher monitoring frequency
  - Insensitive to the DPF failure mode

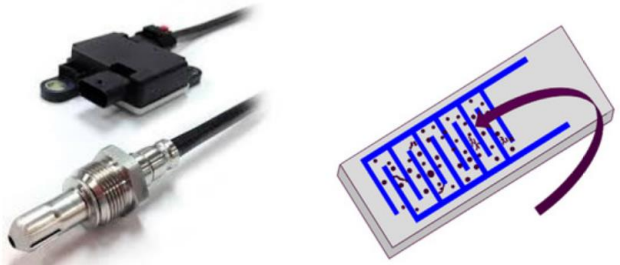
Technical Background on Resistive Sensors

- Provide better data quality for OBD decision-making
- Enable better detection of DPF failures than monitors based on delta P sensors
- Implemented for DPF monitoring in the On-Road sector starting from model year 2016

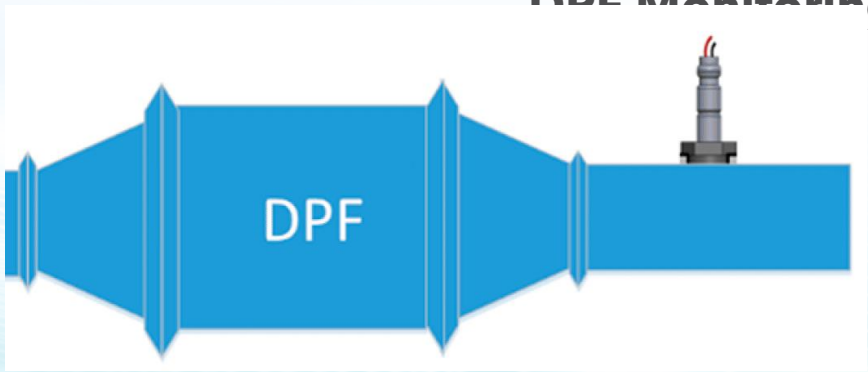
Function:

- Operate based on electrical resistance
- Accumulate sufficient PM to generate an electrical current, which would be employed by the DPF monitor for assessing excessive PM leakage levels
- Relay the sensor's signal to the vehicle's OBD system





PM Sensor
DPF Monitoring



Step 1 PM Screening Proposal

- The PM screening process would rely on the ECU and the PM filtering performance monitor given that direct measurement of PM is not a viable option
- **Proposal:**
  - For each engine, any pending or MIL-on fault codes would be incrementally recorded and counted
  - A tracking parameter on each engine would retain the five most recent fault codes, each with an engine-hour timestamp
  - Precautionary steps are necessary to prevent intentional data deletion

Step 1 PM Screening Proposal

- If an EF exceeds the PEMS testing sales threshold, then the engine manufacturer would be required to conduct PEMS testing

EF Sales Volume (SV)	PEMS Testing Threshold (% of engines with DPF fault codes)
>200	5% of Total Sales
50≤SV<200	5% of Total Sales or 8, whichever is greater
<50	5% of Total Sales or 2, whichever is greater

Special Cases for NO_x and PM Screening

- If a significantly high number of flagged engines for an EF are observed, engine manufacturers would begin discussion with the EO to investigate the cause
  - Would be triggered if the 80% or greater of reported engine families are not designated clean EFs.
- If the NO_x emissions of more than 25% of engines are 10 times higher than the standard in any in-use screening bins, manufacturers would begin discussion with the EO to investigate the cause of extremely high emissions
- If more than 50% of engines data is missing or not reported for a particular EF:
  - EO would have the discretion to determine whether PEMS testing would be required beyond the PEMS testing cap,
  - Engine manufacturers would begin discussions with the EO to develop a feasible plan to improve data reporting in the future.

PEMS Testing

Step 2: Off-Cycle Testing with PEMS

- CARB staff may request EFs for off-cycle PEMS testing based on EF sales volume
- There are three major groups for EFs for each power rating category:
  - Large sales volumes
  - Small sales volumes
  - Very small sales volumes

Tier 5 Power Category	Large Sales Volume[1]	Small Sales Volume[1]	Very-Small Sales Volume[1]
56≤kW<130	>45	10 ≤ sales ≤ 45	<10
130≤kW≤560	>22	5 ≤ sales ≤ 22	<5

[1]Sales volume cut-off points were determined using 2020 Reported California sales with preempted engine sales volume were removed for the analysis.

PEMS Testing Proposal

- The EO would issue test orders annually to an engine manufacturer, as needed, requesting up to 25% of engine families from each of the three categories:
  - Large-volume sales EFs
  - Small-volume sales EFs
  - Very small-volume sales EFs
- EO could request EF testing outside of the 25% caps:
  - If 80% or greater of engines of a specific EF in step 1 exceed the thresholds
  - If 50% of engines within an EF in step 1 are not reported on
  - If there is a clear evidence of non-conformity for NO_x and/or PM outside of screening data [+]
- A random number generator would be used to select engines for PEMS testing and manufacturers would be responsible for completing PEMS testing within one year

[+]Excludes screening data

Proposed ORIUT Engine Family Pass and Fail Criteria for PEMS

- Large EFs
  - Start with 4 engines and if 4 pass, then the EF passes
    - If an engine fails, then test an additional engine (total 5)
    - if 4/5 pass tests → EF passes
    - If 2/5 fail → 5 more engines are tested (total 10)
    - If 3 or greater engine tests fail, the EF would be non-compliant
- Small and Very-Small Engine Families
  - Start with 2 engines and if 2 pass, then the EF passes
    - If an engine fails, then test an additional engine (total 3)
    - If 2/3 pass tests → EF passes
    - If 2/3 fail → 6 more engines are tested (total 10)
    - If 3 or greater engine tests fail, the EF would be non-compliant
  - Very-Small EFs with fewer than 10 CA engines may stop testing at their total sales volume
- If 10 engines are tested and the arithmetic mean of the SOS bin emissions for each bin is less than or equal to the Off-Cycle PEMS in-use thresholds for either the 50-hour stored array or the lifetime array, then the EF would be deemed compliant

Very Small-Volume Sales Engine Families

- Challenges
  - Locating and finding willing fleets for testing
- Very Small-Volume families would be selected if:
  - Emissions data from other sources indicate a concern
  - Similar technology to that is used in another engine family with problems
  - A disproportionately large environmental impact
  - Engineering design issues (e.g., engine or AT warranty issues)
  - Large disparities between projected and actual production numbers
  - Known issues with the integrity or performance of parts from a vendor

Off-Cycle Emission Standards

- An engine test would pass or fail depending on whether the SOS bin emissions are above or below the in-use threshold for PEMS testing
- An engine would be considered passing if SOS emissions are less than or equal to the in-use thresholds

In-Use Bins	% Rated Power	In-Use PEMS Thresholds
Screening Bin A	≤8%	CF x Idle standard + $m_{PEMS\ Accuracy}{}^{A}$
Screening Bin B	>8% to ≤25%	CF x OR-LLC standard + $m_{PEMS\ Accuracy}{}^{A}$ + $m_{interim}{}^{B}$
Screening Bin C	>25%	CF x NRTC standard + $m_{PEMS\ Accuracy}{}^{A}$ + $m_{interim}{}^{B}$

[A]PEMS Accuracy Margin	NO_x	PM	HC	CO
Bin A	0.4 g/hr	-	-	-
Bin B and Bin C	0.007 g/kW-hr	0.008 g/kW-hr	0.013 g/kW-hr	0.034 g/kW-hr

[A]PEMS accuracy margins are from Clean Trucks Plan

[B]Interim margin for NO_x only through 2036: 0.020 g/kW-hr (0.015 g/bhp-hr) NO_x

Step 3: Corrective Action

- If after Step 2, PEMS testing, it is determined an EF is non-compliant,
- Then the manufacturer would begin discussions with the EO on pathways for corrective action.
- Manufacturers would be responsible for completing the investigation within one year.
- Manufacturers could opt to go directly to corrective action without conducting PEMS testing if they identify emission control problems based on ECU / sensor data in Step 1
- Corrective action would be similar to the on-road HD requirements

Implementation Timelines

Implementation Timeline

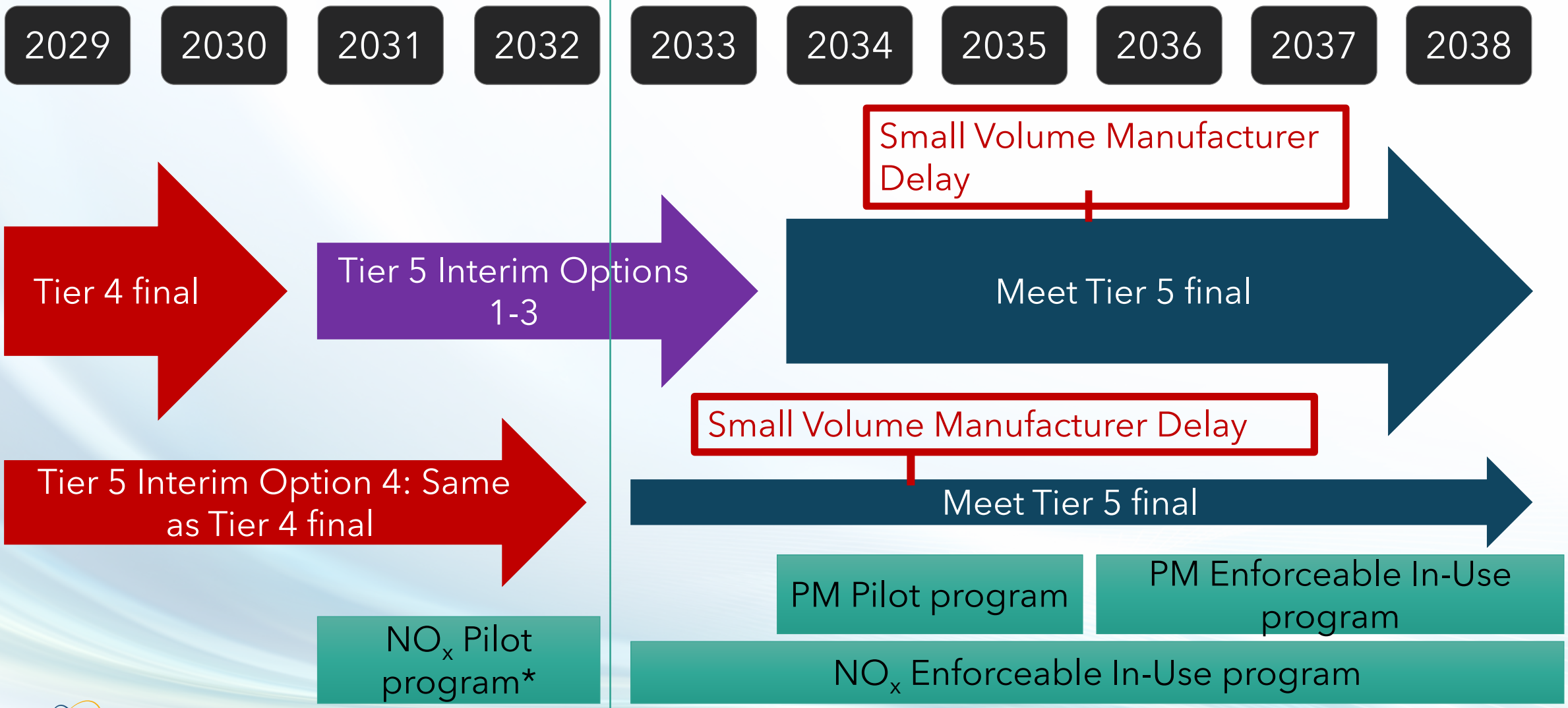
- A pilot program is proposed for engine manufacturers to collect and submit in use data to the EO. The pilot program data would not be subject to enforcement and would allow industry and staff to identify challenges when implementing the novel in-use program for Tier 5
- For the applicable power categories, the **2-year pilot program for Tier 5 interim and/or final** would align with the start of production of Tier 5 engines:
  - 130 to 560 kW
    - Pilot program: 2029 to 2030 Model Year engines
    - Enforceable Program: 2031+ MY engines
  - 56 to 130 kW
    - Pilot program: 2031 to 2032 MY engines
    - Enforceable Program: 2033+ MY engines

Pilot Program Data Reporting

- The pilot program would apply to EFs with large sales volumes for two model years and begins in 2029 or 2031 (depending on power category) during either Tier 5 interim or final based on the implementation option chosen by the manufacturer.
- The EO would not request PEMS testing based on pilot program screening data results
- Manufacturers would collect data during the first year and provide all the collected OR-REAL data along with a summary report for applicable EFs by April 1st of the second year of the pilot including:
  - Data from a snapshot including REAL bins 1-15 and in-use screening bins A, B, and C in all four data arrays
  - Manufacturers would identify EFs that meet criteria 1 only
  - PM fault code reporting would not be required

Tier 5 Standards Phase-In for < 130 kW

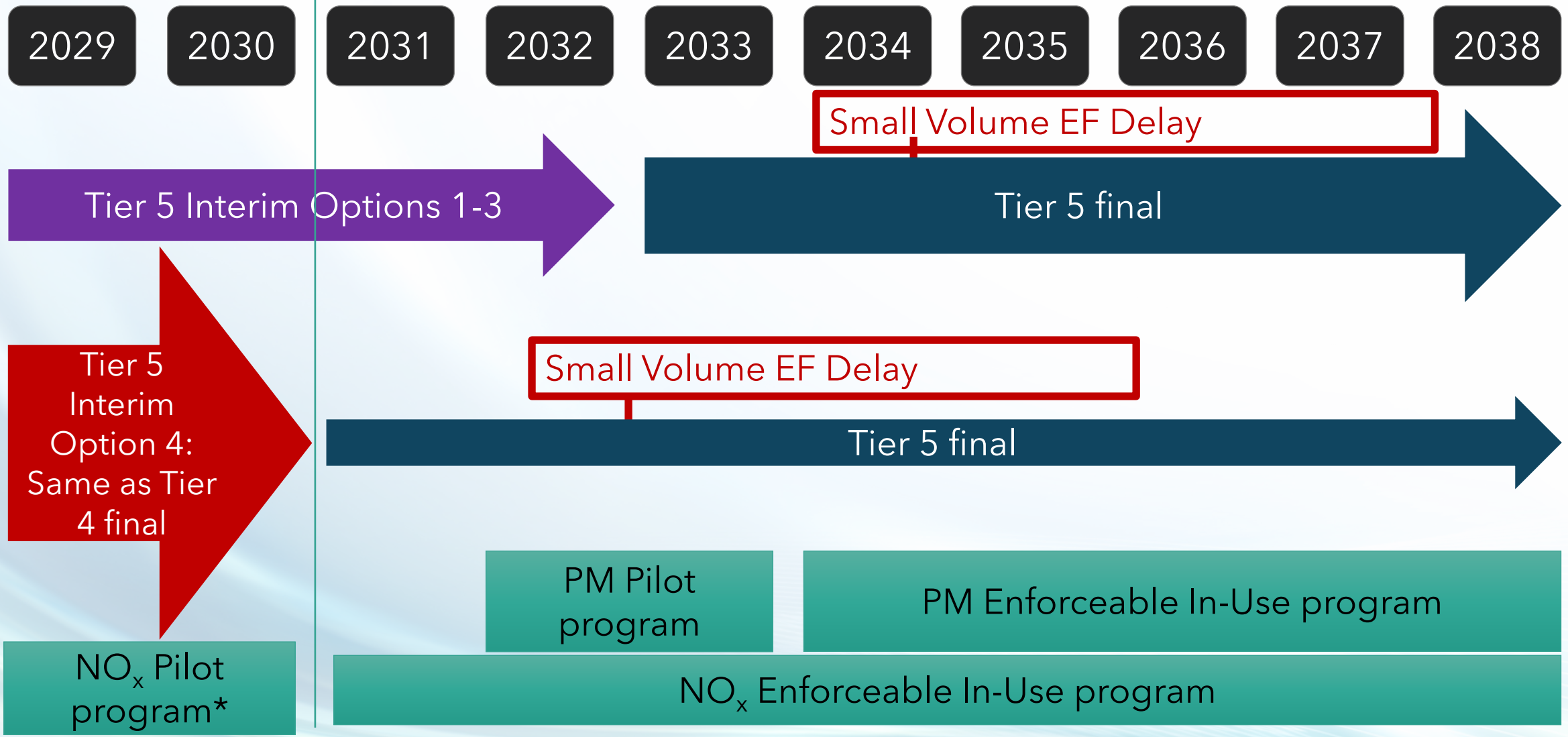
by Model Year



*Option 4 would not have a NO_x Pilot program

Tier 5 Standards Phase-In for 130 ≤ kW ≤ 560

by Model Year



CARB

*Option 4 would not have a NO_x Pilot program

Questions?