



**Potential Tier 5 Rulemaking Greenhouse Gas
(GHG) Reducing and Capping Standards
August 8, 2022**

Outline

- Potential Carbon Dioxide (CO₂) Reducing Standards
- Need for GHG Capping Standards
 - CO₂
 - Nitrous Oxide (N₂O)
 - Methane (CH₄)
- Setting Potential Capping Standards
 - Statistical Analysis of:
 - Certification Data
 - Power Categories
 - Duty Cycles
- Potential Alternatives and Requests

Potential CO₂ Reducing Standards

- California Air Resources Board (CARB) staff introduced the concept of first-time CO₂ standards at the Tier 5 Kickoff Workshop on November 3, 2021.
- As envisioned, the new standards would conceptually apply to:
 - Non-preempted off-road Tier 5 diesel engines
 - 56 to 560 kilowatt (kW) power categories
 - Nonroad Transient Cycle (NRTC) and Steady-State certification cycles
- These potential new CO₂ standards could represent a 5 to 8.6 percent decrease from current certification averages for each power category based on 2020-2022 data from manufacturers.

Need for Potential GHG Capping Standards

- CO₂, CH₄, and N₂O are the most abundant GHGs that contribute to global warming (excluding water vapor).
- GHGs trap heat in the atmosphere, causing extreme weather, fires, droughts, and food supply disruptions.
- Some Oxides of Nitrogen (NO_x) aftertreatment emission control technologies can increase N₂O if not properly engineered.

GHG Pollutant Comparison

- Carbon Dioxide (CO₂)
 - Reference gas for characterizing global warming potential (GWP)
 - Typically lasts 20-200 years in the atmosphere
 - GWP = 1
- Methane (CH₄)
 - Typical lifetime: 12 years
 - GWP 27-30 (100 year)
- Nitrous Oxide (N₂O)
 - Typical lifetime: 100 years
 - GWP 273 (100 year)
- Water Vapor (H₂O)
 - Strongest infrared absorption
 - Typical lifetime: hours to weeks
 - GWP Negligible

Exhaust Aftertreatment N₂O Tradeoff

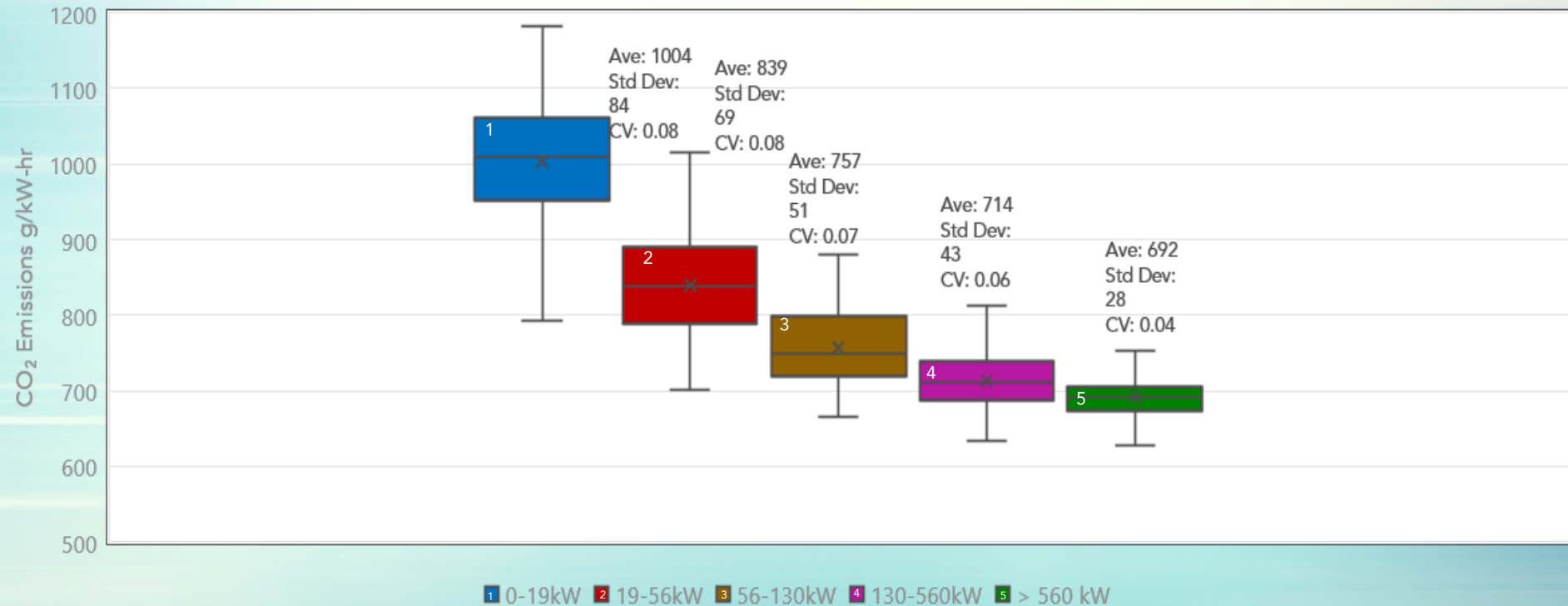
- Platinum diesel particulate filters (combined oxidation catalyst plus diesel particulate filter) can produce N₂O during low temperature light-off and in the presence of hydrocarbon emissions.
- Selective Catalytic Reduction with advanced copper zeolites
 - Ammonia (NH₃) and nitrogen dioxide (NO₂) form ammonium nitrate (NH₄NO₃) that subsequently decomposes to N₂O at low temperatures (< 250 degrees Celsius (C)).
 - NH₃ oxidizes to N₂O at high temperatures (> 450 degrees C).
- Ammonia Oxidation Catalysts can oxidize NH₃ to N₂O during lean operation (e.g., acceleration, in instances of excess ammonia slip).
- Proper emission control system engineering is necessary to minimize increases in N₂O when reducing NO_x.

Setting GHG Capping Standards

- Engine manufactures are currently required to provide CO₂, CH₄, and N₂O emission measurements to CARB under 1039.235(g) of the California Test Procedures for Off-Road Diesel Engines.
- CARB staff aggregated these data from all manufacturers by pollutant and power category between the 2020 and 2022 model years.
- The data used in staff's analyses represent the highest reported emissions measurements between NRTC and steady-state certification testing cycles.
- The conceptual tailpipe capping standards for N₂O and CH₄ were calculated as averages based on the concatenation of data > 19kW across all power categories respective to each pollutant.
- The conceptual CH₄ standard is expressed as a range from average to 50 percent above average to compensate for possible measurement variations due to the limited amount of available data.
- The conceptual tailpipe capping standards for CO₂ represent discrete, interquartile-filtered power category averages rounded upwards to the nearest 10 g/kW-hr.

Statistical Analysis of California CO₂ Certification Data

Model Years (MYs) 2020 to 2022 CO₂ NRTC/ Steady State Emissions Analysis



Summary of Conceptual GHG Standards

(Based on MYs 2020 to 2022 Certification Data)

CONCEPTUAL TIER 5 TAILPIPE GHG STANDARDS (FULL USEFUL LIFE)

POLLUTANT	POWER CATEGORIES				
	kW < 19 (g/kW-hr)	19 ≤ kW < 56 (g/kW-hr)	56 ≤ kW < 130 (g/kW-hr)	130 ≤ kW ≤ 560 (g/kW-hr)	kW > 560 (g/kW-hr)
CO ₂ Reducing	n/a	n/a	700 to 720 5 to 8.6% below Tier4F	660 to 680 5 to 8.6% below Tier4F	n/a
-	-	-	-	-	-
CO ₂ Capping	n/a	840	n/a	n/a	700
N ₂ O Capping	n/a	0.120	0.120	0.120	0.120
CH ₄ Capping	n/a	0.010-0.017	0.010-0.017	0.010-0.017	0.010-0.017

Alternatives and Requests

- Are there other or additional metrics to consider in formulating appropriate capping standards?
- Staff requests that industry share additional emissions data with CARB by October 7, 2022, especially N₂O and CH₄ data, to be considered for setting the potential Tier 5 capping and CO₂ reduction standards.
- Staff also requests CH₄ data on natural gas or dual fuel engines certified to the Compression Ignition standards.
- Should GHG capping standards be considered for engines < 19 kW?
- How can we encourage equipment-based GHG improvements under Tier 5 without adopting equipment-specific standards, which is beyond the scope of this potential rulemaking (but possible for a future rulemaking)?