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

• CO$_2$, CH$_4$, and N$_2$O 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 (NOx) aftertreatment emission control technologies can increase N$_2$O if not properly engineered.
GHG Pollutant Comparison

- **Carbon Dioxide (CO\textsubscript{2})**
  - Reference gas for characterizing global warming potential (GWP)
  - Typically lasts 20-200 years in the atmosphere
  - GWP = 1

- **Methane (CH\textsubscript{4})**
  - Typical lifetime: 12 years
  - GWP 27-30 (100 year)

- **Nitrous Oxide (N\textsubscript{2}O)**
  - Typical lifetime: 100 years
  - GWP 273 (100 year)

- **Water Vapor (H\textsubscript{2}O)**
  - 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 NOx.
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

*CV: coefficient of variation
## Summary of Conceptual GHG Standards
(Based on MYs 2020 to 2022 Certification Data)

### Conceptual Tier 5 Tailpipe GHG Standards (Full Useful Life)

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<tr>
<th>POLLUTANT</th>
<th>POWER CATEGORIES</th>
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<td>130 ≤ kW ≤ 560 (g/kW-hr)</td>
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<td>CO₂ Reducing</td>
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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)?