

# **The Role of OSAR in moving Towards a Sustainable Transportation Future**

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# Environmental Impacts of Transportation Emissions

- Mitigating the environmental impacts of transportation emissions is one of the biggest challenges of ours and future generations
- Transportation accounts for approximately 24% of worldwide and 33% of U.S. CO<sub>2</sub> emissions, with about 75% of this from on-road sources.<sup>1</sup>
- World Health Organization (WHO) estimates of air quality impacts include<sup>2</sup>
  - In 2019, 99% of the world's population was living in places where the WHO air quality guidelines levels were not met.
  - Ambient (outdoor) air pollution was estimated to have caused 4.2 million premature deaths worldwide in 2019.
  - The combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually.

<sup>1</sup> <https://ourworldindata.org/co2-emissions-from-transport>; <https://www.epa.gov/ghgemissions/global-greenhouse-gas-overview>

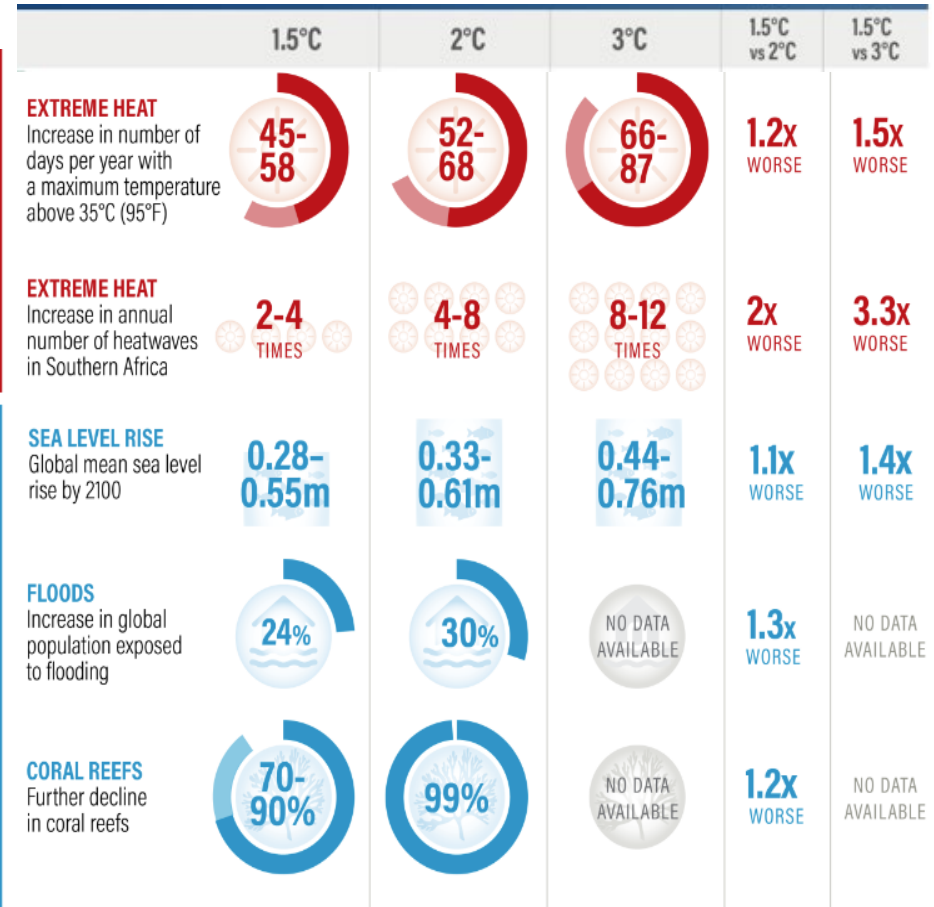
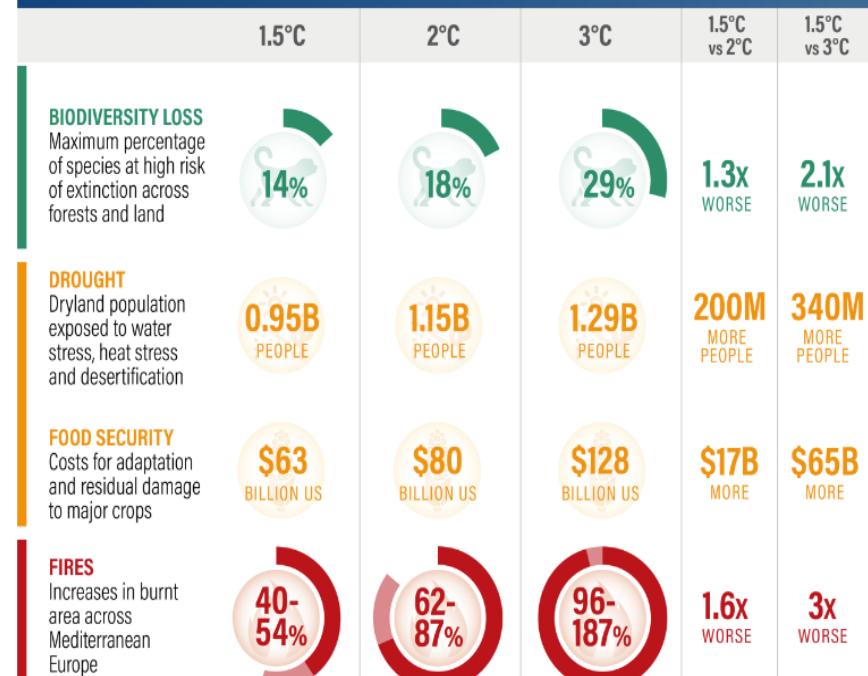
<sup>2</sup> [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)

# Global Warming – Potential Impacts


 WORLD RESOURCES INSTITUTE

## COMPARING RISKS FROM RISING TEMPERATURES:

EXPLAINING THE IPCC'S WORKING GROUP II REPORT (AR6)



## Costs of Global Warming

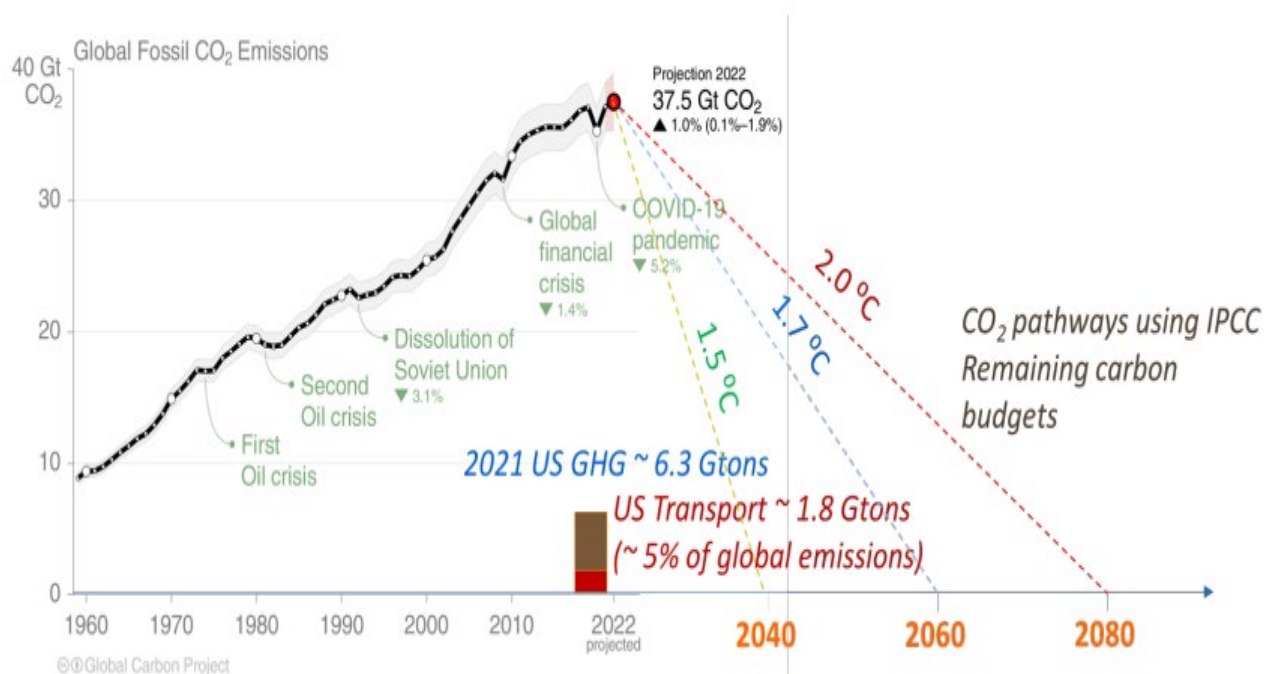
- **Costs of US\$ 143 billion per year attributable to extreme events due to climatic change.<sup>1</sup>**
- **In U.S., 400 weather /climate disasters since 1980 where overall damages/costs reached or exceeded \$1 billion (including CPI adjustment to 2024). The total cost of these 400 events >\$2.785 trillion.<sup>2</sup>**
- **From 2000 to 2019, extreme weather events globally, like hurricanes, floods and heat waves, have cost an estimated \$2.8 trillion. This is around \$143 billion/year or \$16.3 million/hour.<sup>3</sup>**
- **The global cost of climate change damage is estimated to be between \$1.7 trillion and \$3.1 trillion per year by 2050. <sup>3</sup>**

1. Newman, R., Noy, I. The global costs of extreme weather that are attributable to climate change. *Nat Commun* **14**, 6103 (2023). <https://doi.org/10.1038/s41467-023-41888-1>.

2. National Centers for Environmental Information (NCEI) <http://www.ncei.noaa.gov/access/billions>

3. World Economic Forum. <https://www.weforum.org/stories/2023/10/climate-loss-and-damage-cost-16-million-per-hour/>

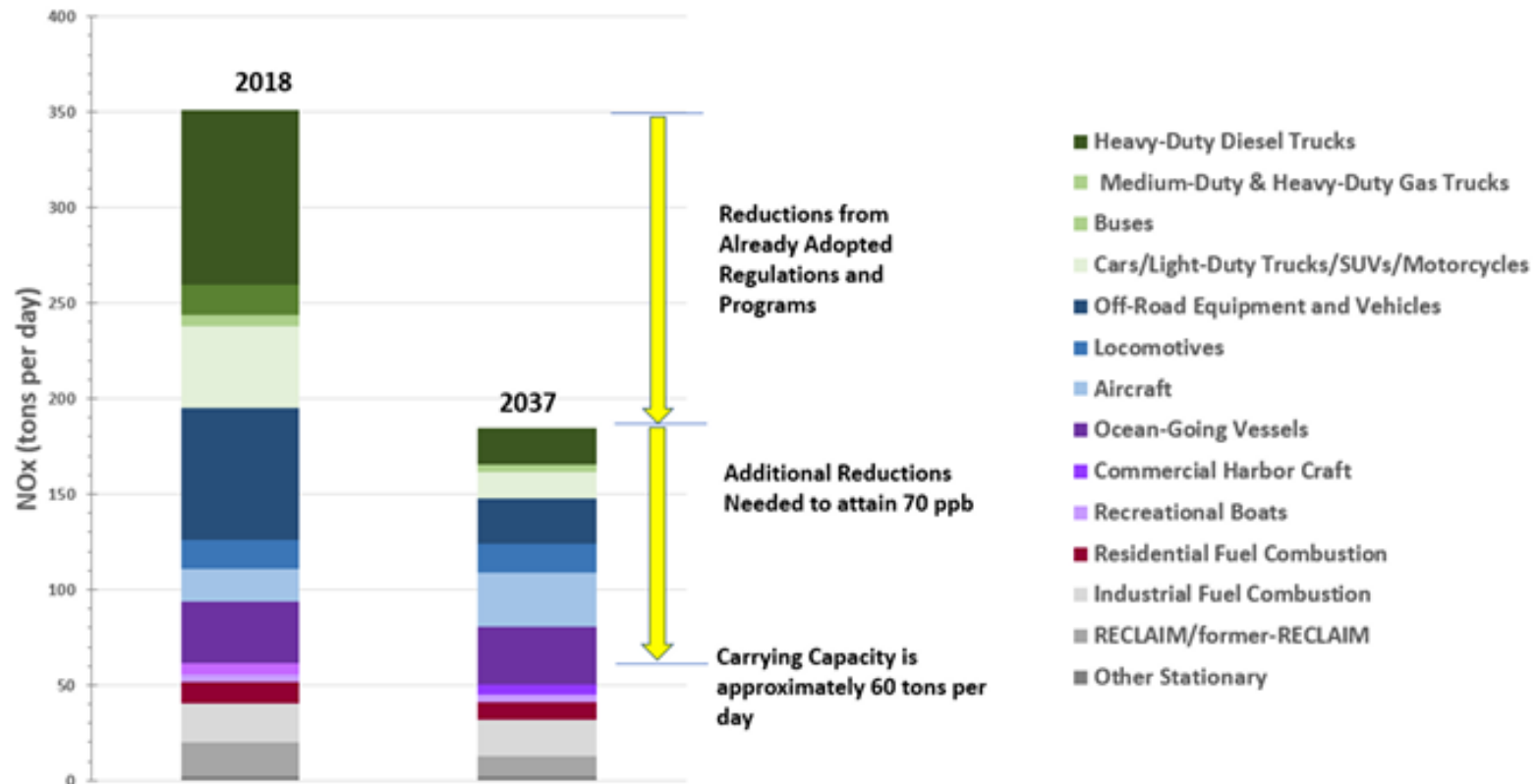
# Global Warming – Mitigation Goals



Source: Global Carbon Project 2022 - chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/[https://www.globalcarbonproject.org/carbonbudget/22/files/GCP\\_CarbonBudget\\_2022.pdf](https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pdf)

- **But some studies suggest global costs of net zero goal on order of \$200 (BloombergNEF)<sup>1</sup> to \$275 (McKinsey Global Institute)<sup>2</sup> trillion.**
  - **Global assets: stock market \$115T<sup>3</sup> residential real estate \$300-500T<sup>4</sup>**

# Need for Further Emission Reductions in LA



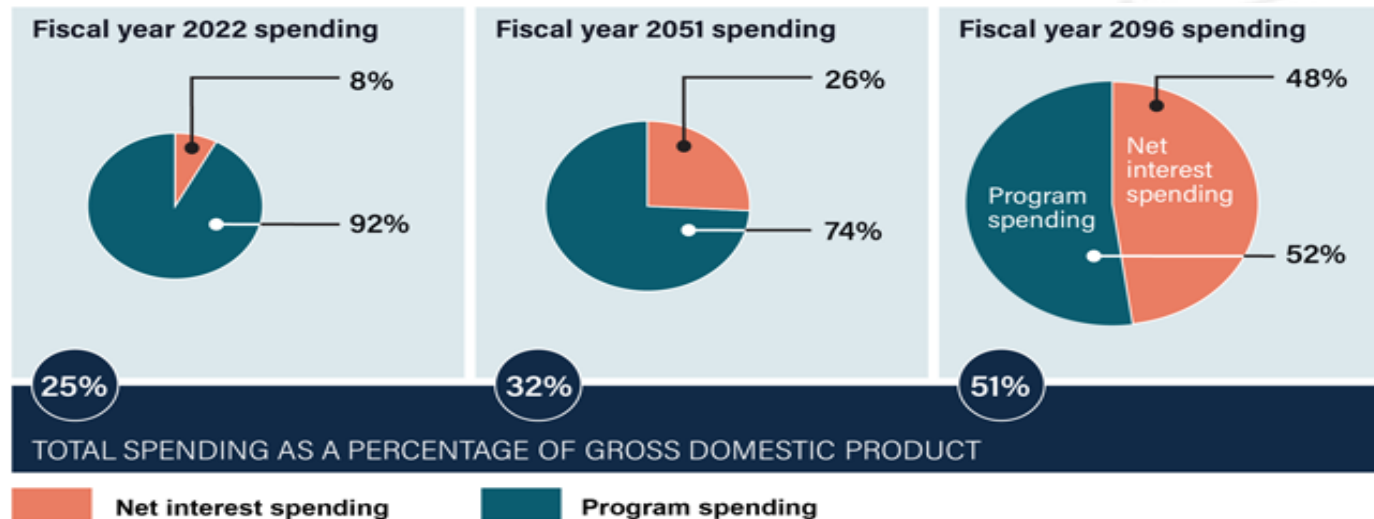
Source: South Coast Air Quality Management District, 2022 Air Quality Management Plan, Adopted December, 2022.

## Economic Challenges going into 2030s - I

- **Government debt is increasingly becoming a problem**
  - CFOs, bankers (Jamie Diamond), the Fed and others see government debt as looming crisis<sup>1</sup>
  - Overall debt \$36.7 trillion<sup>2</sup> 1/10/24, U.S. stock market \$52.0 T,<sup>3</sup> U.S. residential real estate - \$49.7T<sup>4</sup>
- **Federal Government Spending is very high and continuing to grow**
  - \$6.75 Trillion for 2024<sup>5</sup> (\$52,656 per household), 51.8% higher than pre-COVID levels
  - Social Security/Medicare/Medicaid + Interest \$2.51 Tril. (\$19,640/house) in 2019 to \$3.89 Tril. (\$30,307/house) in 2024
  - ~ All private real estate in 12 mid-west states (IL, IM, IA, KS, NE, MN, MI, MO, OH, WS, ND,SD)<sup>6</sup>
  - ~ Market cap Autos, Oil, Telecom/TV, Retail (Major+specialty), + many Food Companies combined<sup>7</sup>
  - ~ U.S. Retail sales revenue minus motor vehicles, auto parts & gas stations<sup>8</sup>
- **Federal government deficit is growing at historic levels**
  - \$1.83 Tril. in 2024<sup>5</sup> (\$14,275/house) (~\$3,000/house Aug 2024<sup>9</sup>), 86% higher than pre-COVID levels
  - Equivalent to the value of all residential real estate in Colorado and Oregon combined
  - All profits of the 220 most profitable U.S. companies in 2022<sup>10</sup>

## Economic Challenges going into 2030s - II

- Solutions will be problematic - higher taxes / slower economy, increase money supply /inflation, probably in combination with less services
  - Interest payments
    - \$892 B in 2024 - \$6,958 per household<sup>1</sup>
    - 2051 - 8% of GDP - \$16,486/household<sup>2</sup>



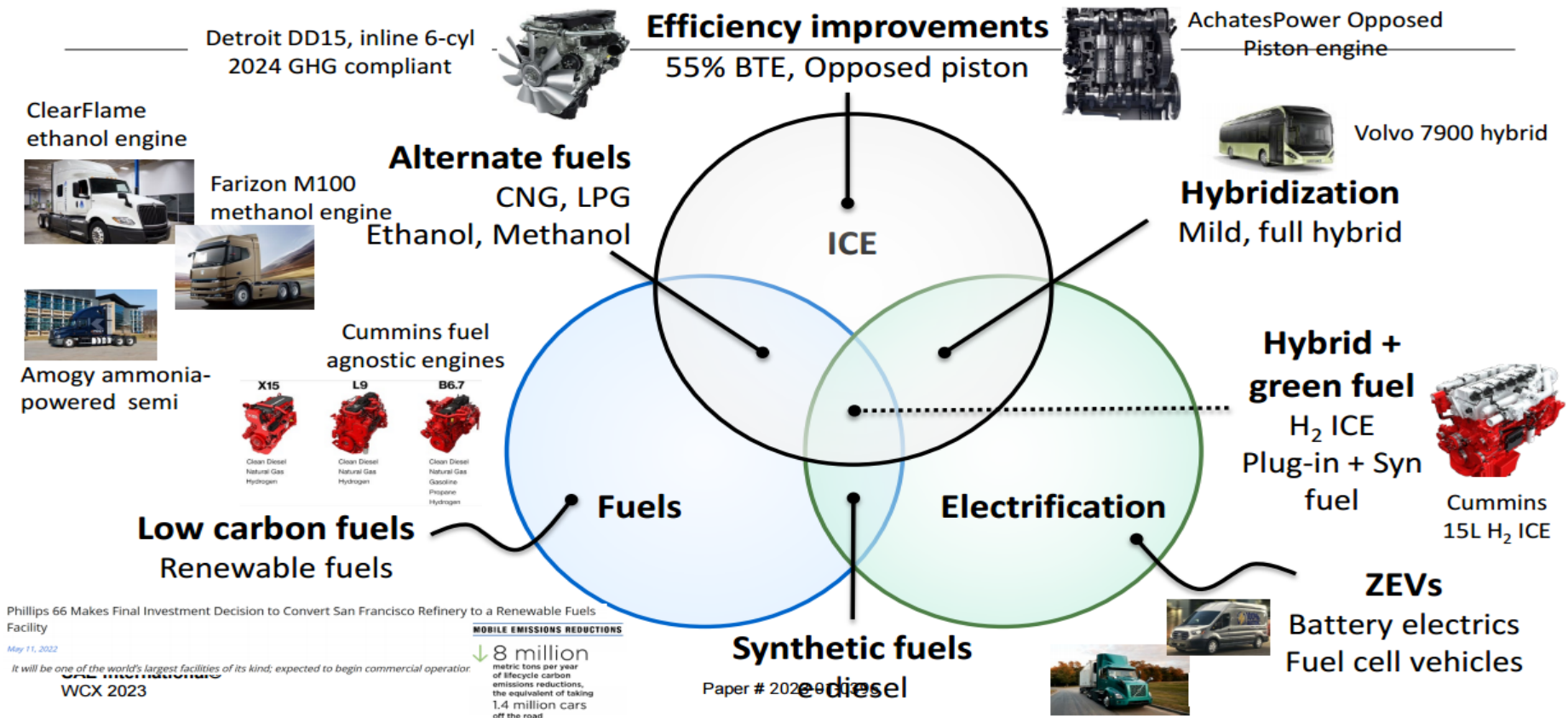
Source: Congressional Budget Office data and GAO simulation. | GAO-23-106201

- Economic constraints / cost effectiveness will continue to play an important role in environmental policy for the foreseeable future

1 /<https://www.cbo.gov/system/files/2024-11/60843-MBR.pdf>

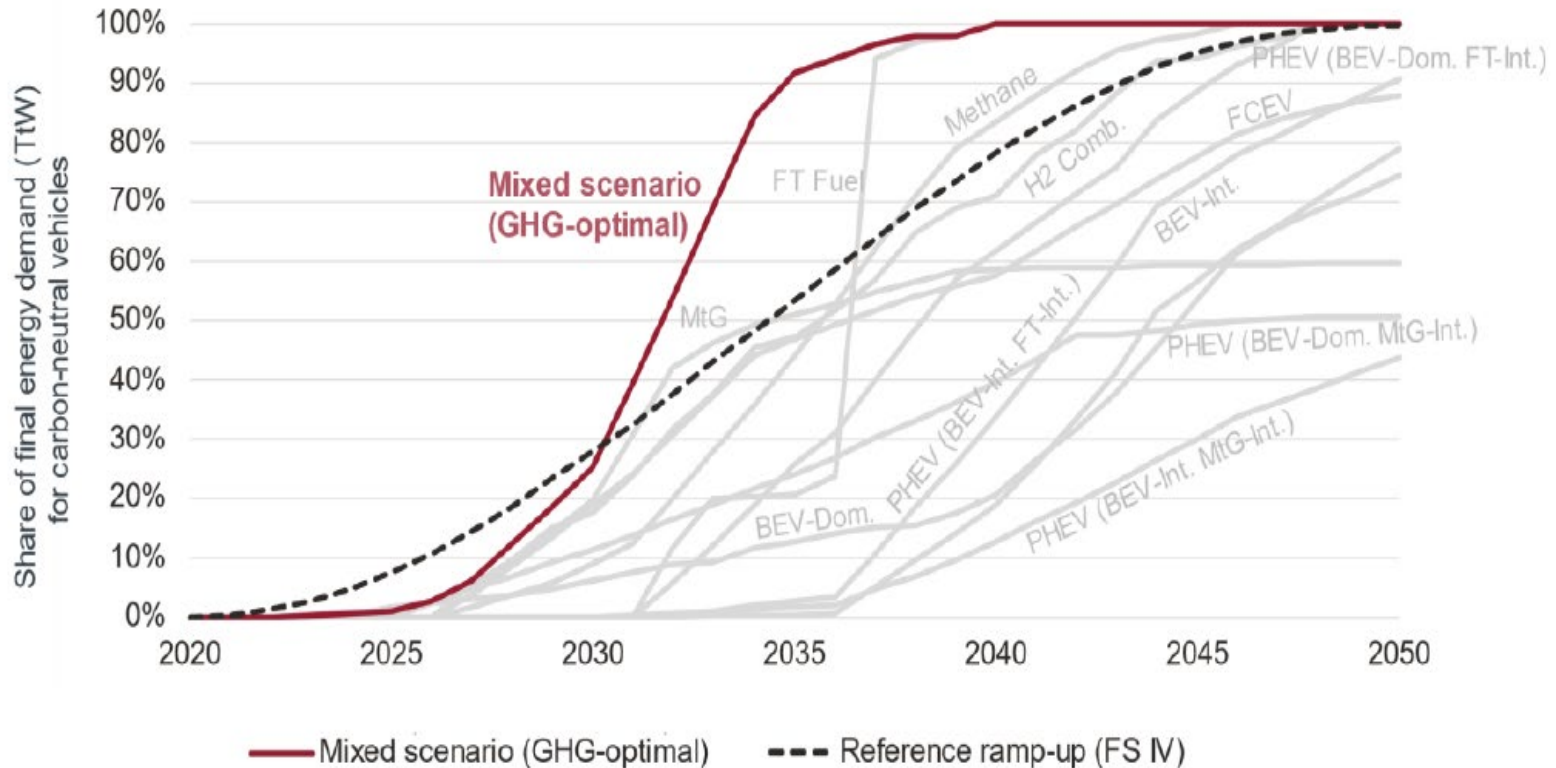
2. U.S. Government Accountability Office, 2023, <https://www.gao.gov/assets/gao-23-106201.pdf>

# In a challenging environment, various pathways will likely needed to be pursued for transport decarbonization



Source: Joshi, A., 2023, "Year in review – Progress towards decarbonizing transportation and zero emissions," presentation at Society of Automotive Engineers, WCX conference, Detroit, MI, April.

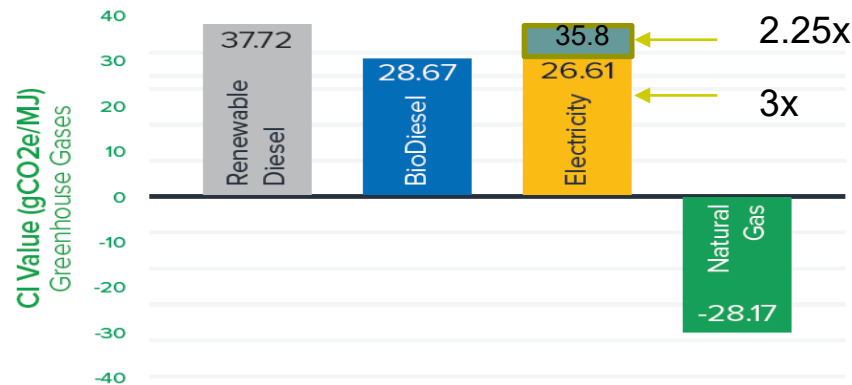
# Various pathways will need to be pursued for transport decarbonization



Source: Krammer, U. Bothe, D., Gatzen, C, et al., 2022, FVV eV // Science for a moving society (FVV), Future Fuels: FVV Fuel Study IVb Follow-up study: Transformation of Mobility to the GHG-neutral Post-fossil Age, Project. No. 1452.

# Renewable Fuels

- › In California, over 50% of diesel fuel is comprised of renewable fuels [Q1 2023]<sup>1</sup>, with diesel fuel for off-road equipment required to be renewable
- › Renewable Diesel (RD) has ~70% (100%?) carbon intensive benefit of electricity (basis CA current grid)
- › Biofuels provide carbon intensity benefits equivalent to electrifying
  - › 35%-50% of the Heavy-duty vehicles (HDVs) + off-road engines (OREs) in CA
  - › 70%-100% of off-road equipment (since RD required for off-road in CA)



Source: California Air Resources Board Low Carbon Fuel Standard Program Q3 2021 Data

Diesel  
102

Base  
Electricity  
80.55

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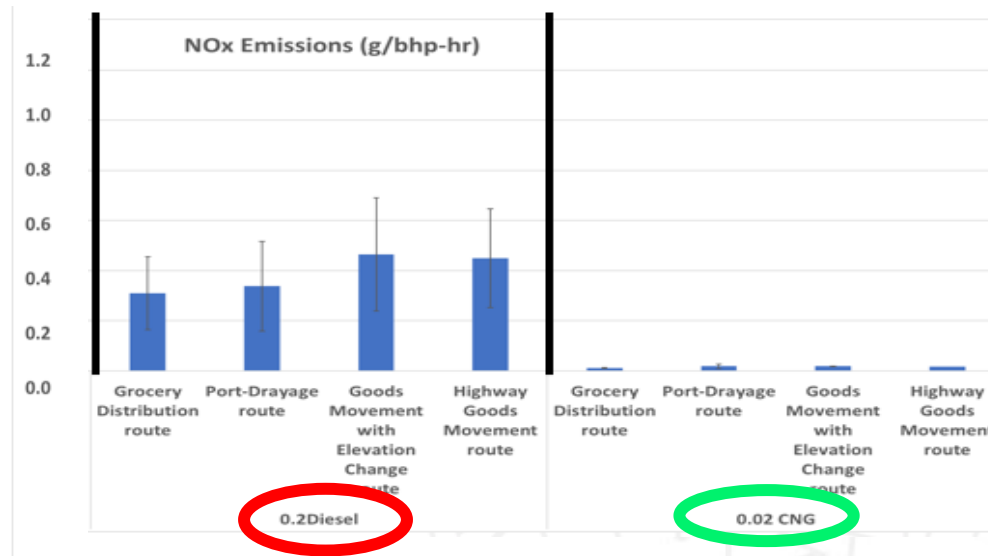
--- Diesel fuel = 102 gCO<sub>2</sub>e/MJ

--- Electricity value from electrical grid value of 80.55 gCO<sub>2</sub>e/MJ w/ BEVs being 3x more efficient. Probably overstated as diesel engines are getting towards 40% efficient now

--- Note negative carbon intensity for RNG is due to avoided methane emissions into the atmosphere

## Biofuels + Ultraclean engines

- When biofuels are combined with ultralow NOx HDVs there is a potential for significant near and intermediate term benefits in both GHGs and exhaust pollutants, as the market transitions towards BEVs
- This could include both 2027+ diesel vehicles and current technology 0.02 g NOx CNG vehicles

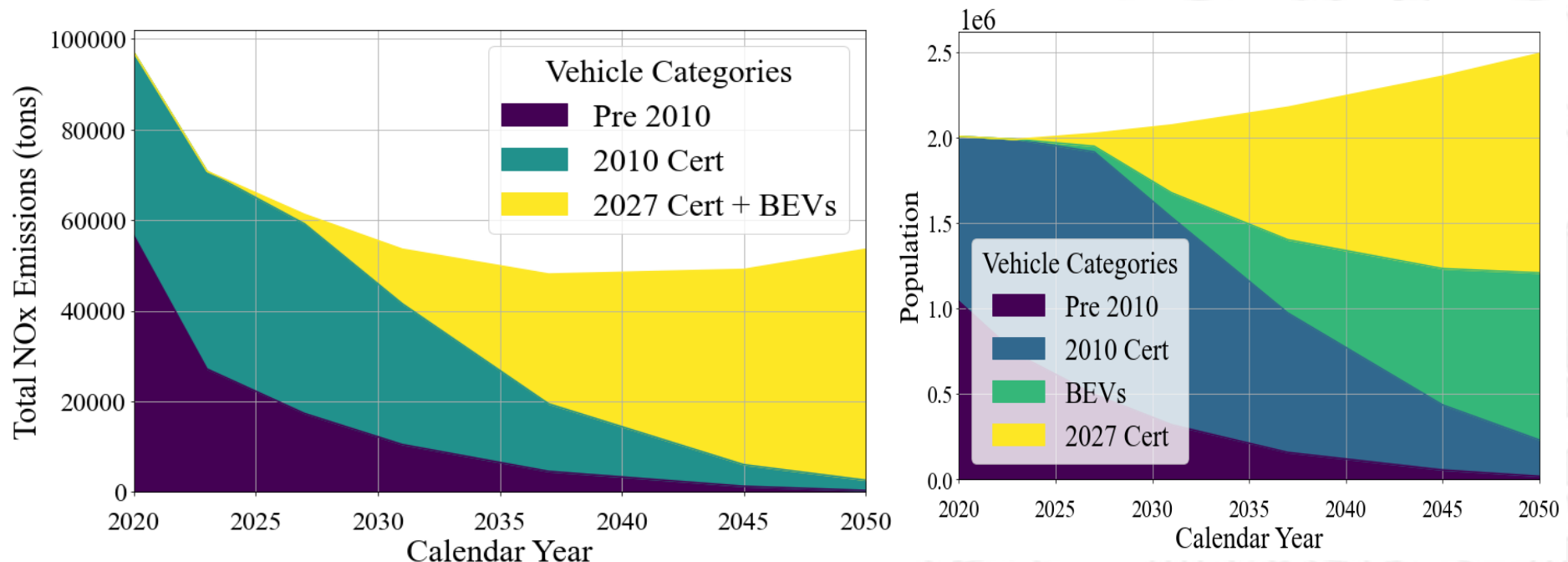


2010 SCR-equipped Diesels

2027+ Diesels + 0.02 CNG

# Understanding In Use Emissions and Emissions Inventories

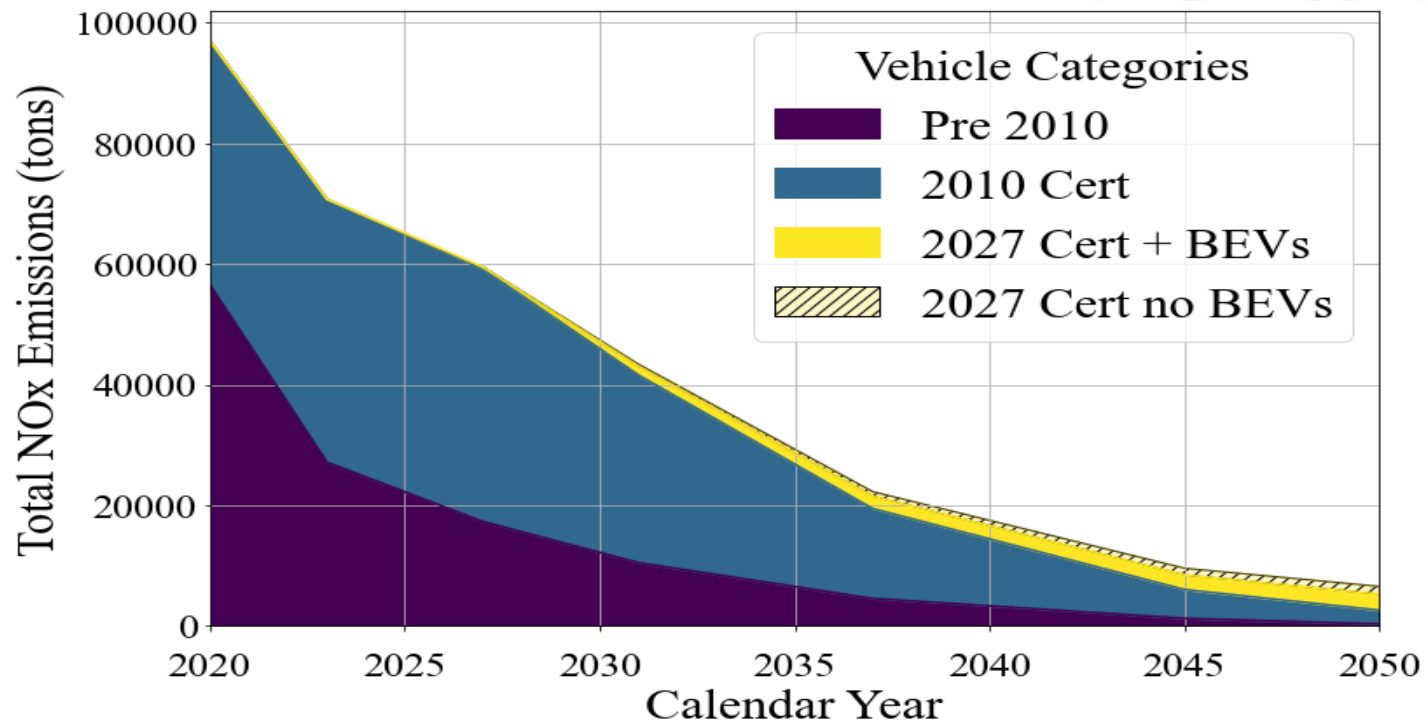
- Base case EMFAC emissions inventory modeling (without ultralow NOx diesel engines) shows increases in vehicle population could be an important contributing factor to emissions inventories



# Potential Importance of Ultralow NOx Engines

- Incorporating ultralow NOx diesel engines could have a dramatic impact on emissions inventories.
- 95% of the NOx emissions reductions between 2025 and 2040 for heavy-duty vehicles could come from fleet turn over with ultralow NOx diesel vehicles.....

If we can keep the vehicles clean

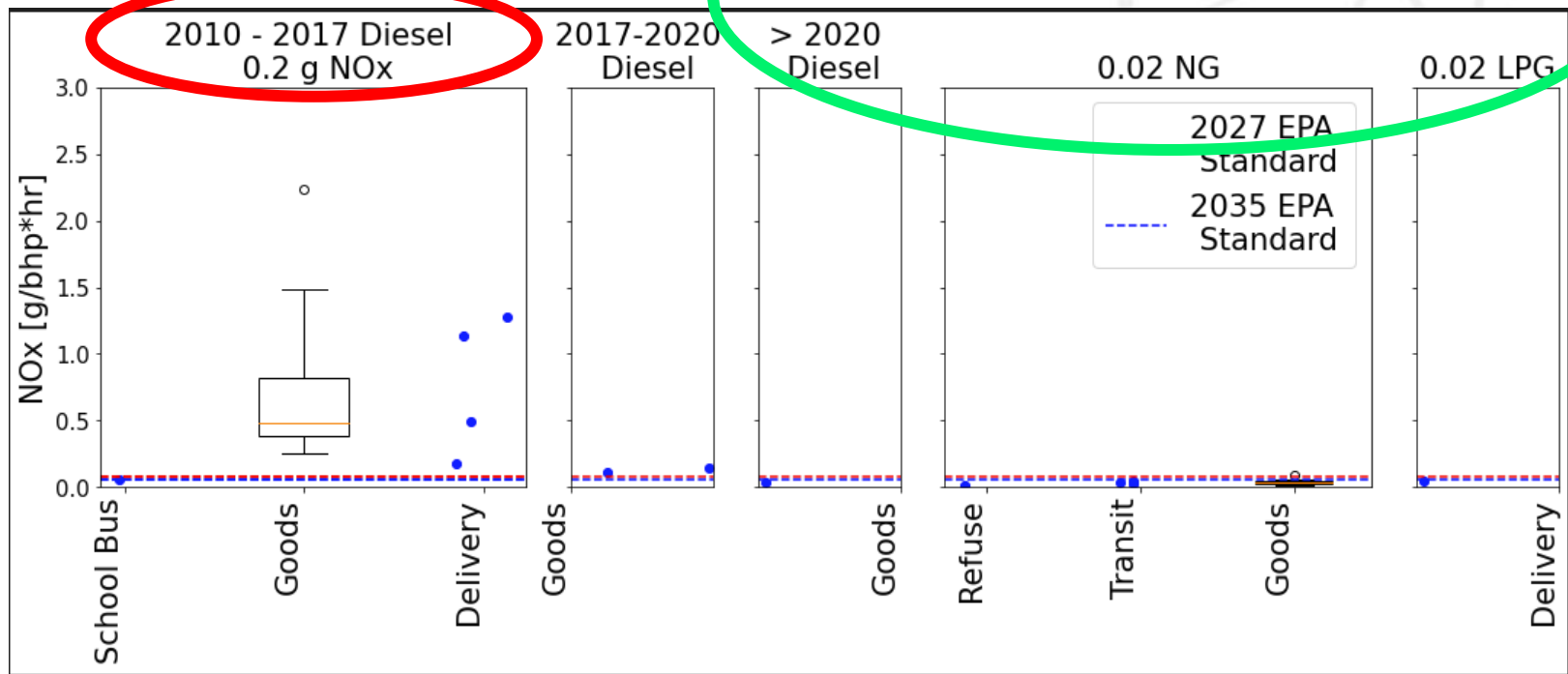


Source: Troy Hurren; Thomas D. Durbin; Kent C. Johnson, Georgios Karavalakis, 2025, The Impacts of improving heavy-duty internal combustion engine technology on reducing NOx emissions inventories going into the future, submitted to Science of the Total Environment.

# Trends CE-CERT is examining in heavy-duty vehicle emissions

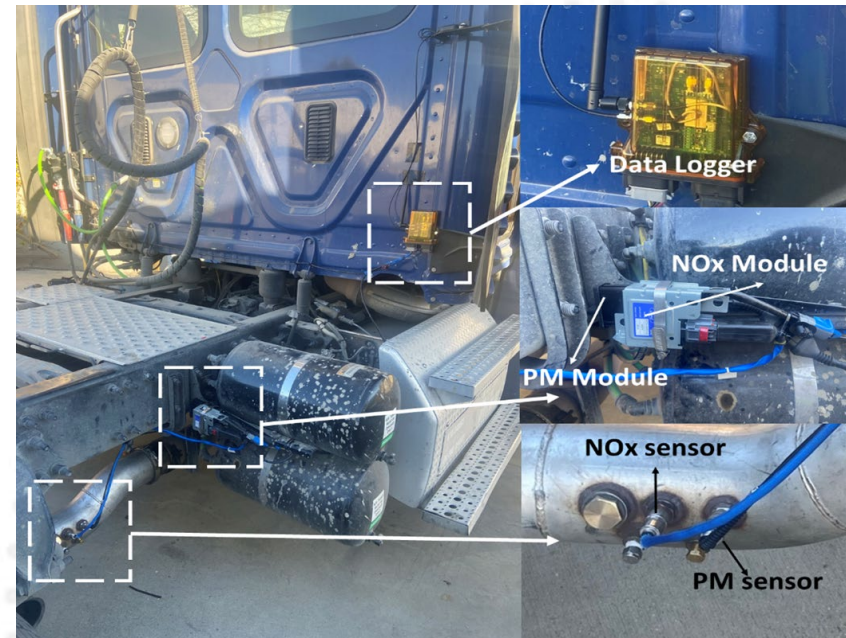
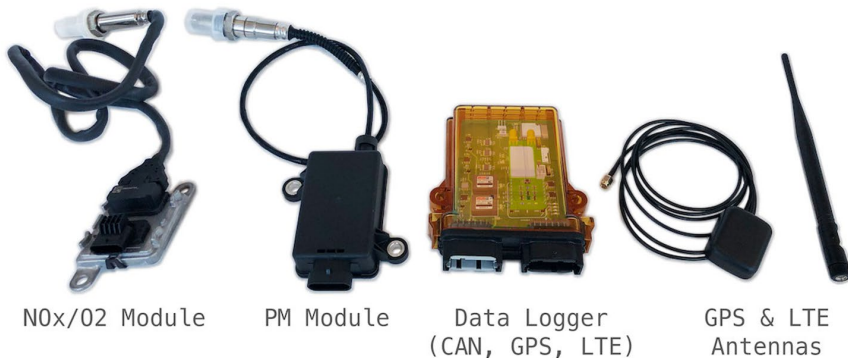
Regulations

Available  
Now



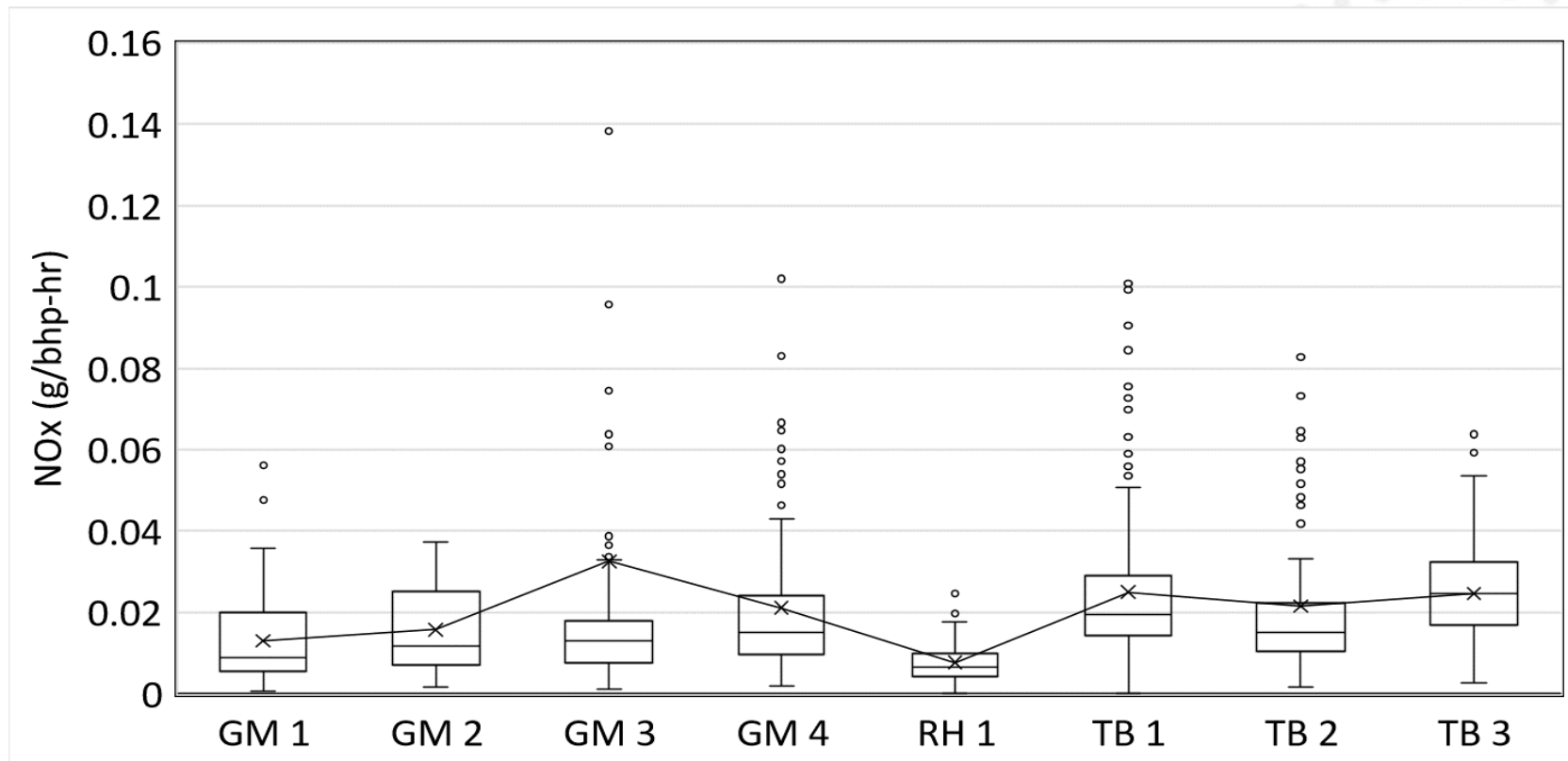
# CE-CERT Methodology is On Board Sensing and Reporting (OSAR)

- Onboard Sensing Analysis and Reporting (OSAR) was developed for continuous monitoring of diesel technologies annually
- OSAR started out as a consortium lead research initiative, but has now grown to over nine funded programs
- OSAR includes
  - NOx, PM, GPS, CAN, and other sensors
  - Auto starting and shutdown to capture cold starts and all truck operation



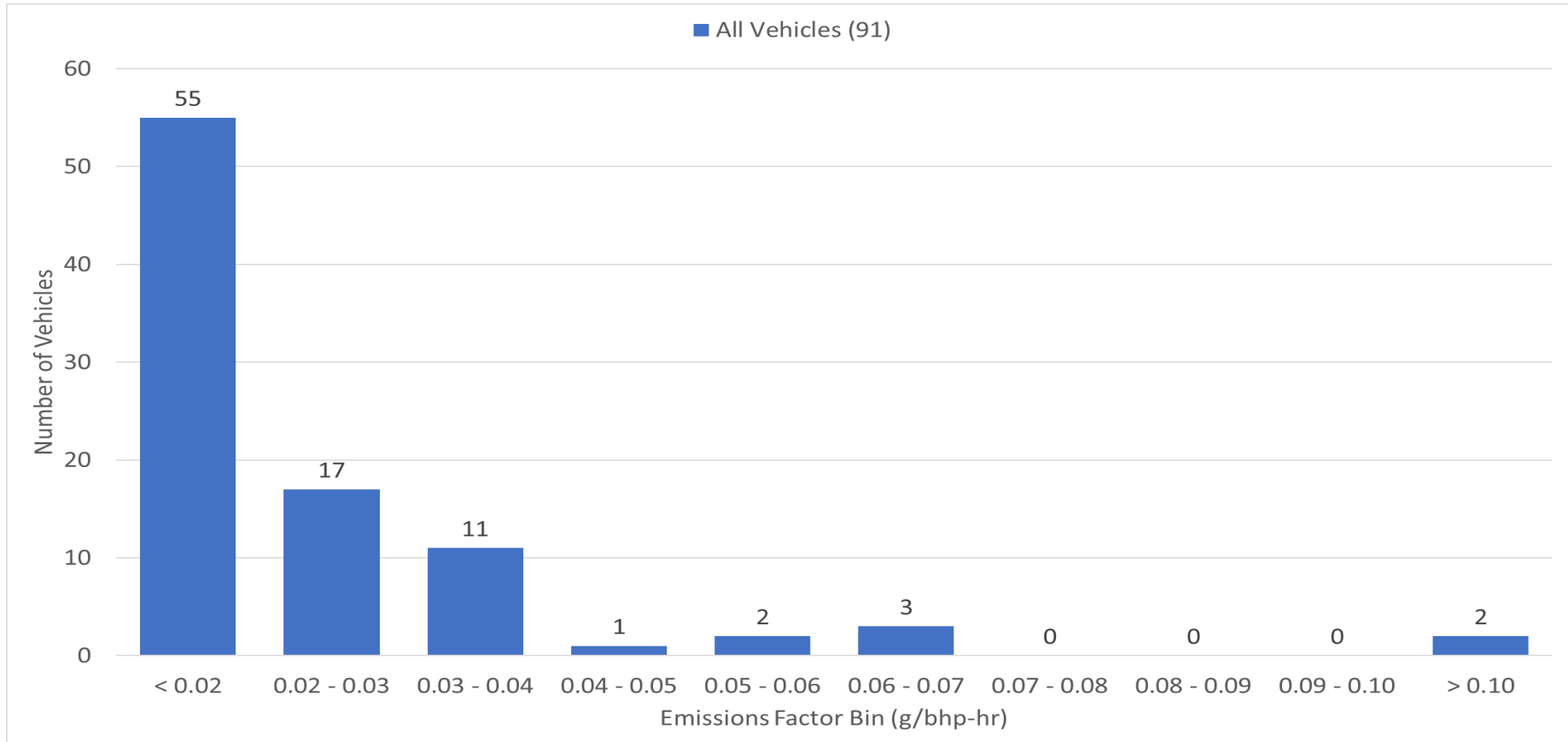
# OSAR Monitoring of CNG Vehicles - I

- The average trip emissions for most fleets are on the order of the 0.02 g/bhp-hr level
- But there are outliers that have higher emissions



## OSAR Monitoring of CNG Vehicles - II

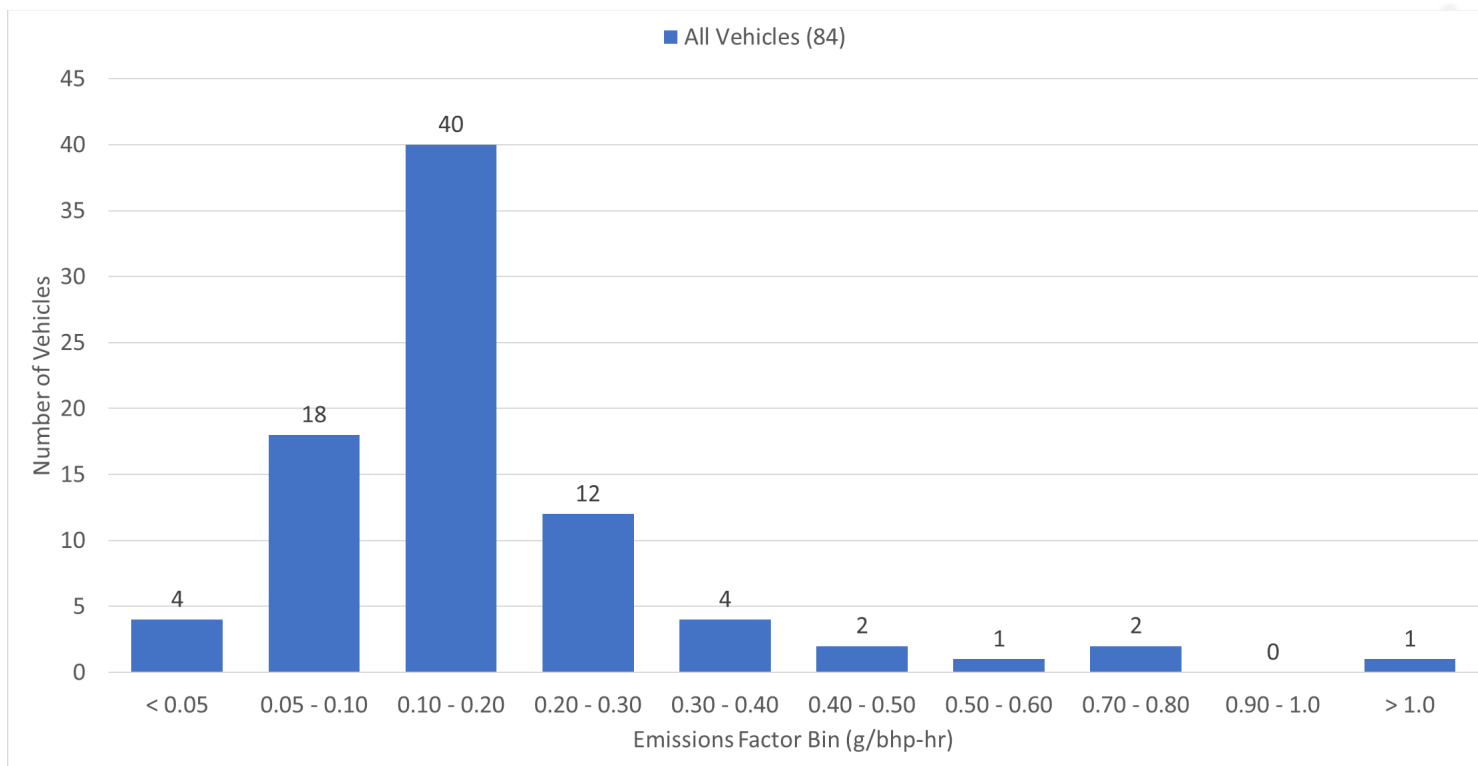
- Based on sum of all NO<sub>x</sub> emissions over all work for each vehicle
- Most vehicles are operating within 2x of the 0.02 g/bh-hr limit
- But more investigation is needed for vehicles with > 0.1 NO<sub>x</sub> g/bhp-hr



# CNG Vehicle Histogram

## NH<sub>3</sub> Emissions

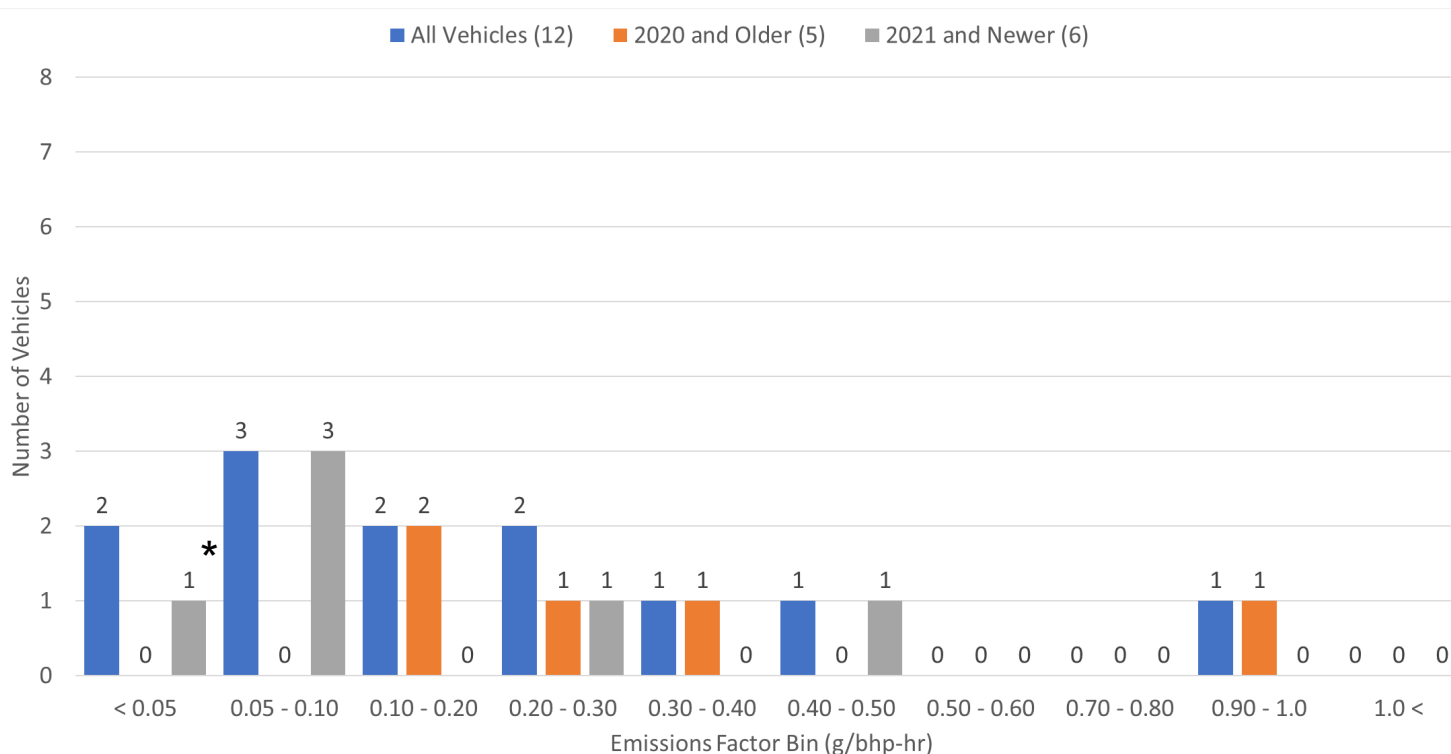
- To the extent that ultralow NOx CNG vehicles expand into the fleet, control of NH<sub>3</sub> emissions would likely need to be addressed more aggressively



Average NH<sub>3</sub>  
(g/bhp-hr)

# Preliminary Diesel Vehicle Emissions Histogram

- Initial data is suggesting lower emission rates than found in “200 vehicle study, with some vehicles showing higher emissions than others.



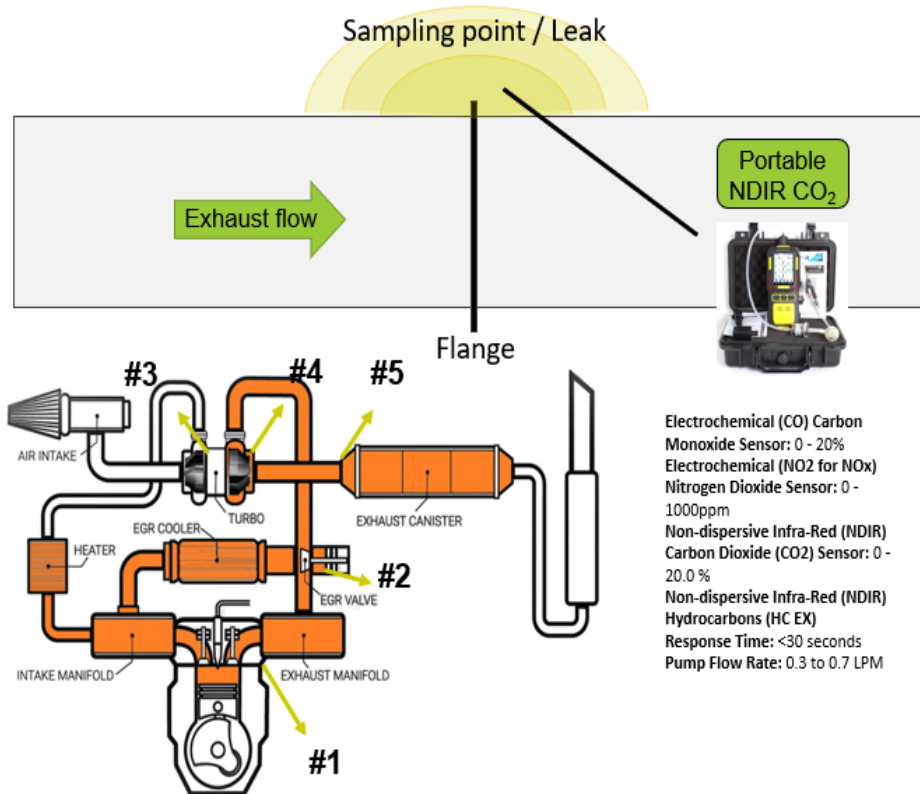
Sum NOx g all trips  
Sum Work all trips

20

\*The vehicle missing from this section is from the OEM fleet. We have not been given this information

# Monitoring for Leaks

- The potential for exhaust leaks prior to the aftertreatment system could add significantly to in-use emission rates
- CE-CERT is currently working on a CARB-funded project to evaluate the potential extent on more than 300 heavy-duty vehicles



Electrochemical (CO) Carbon Monoxide Sensor: 0 - 20%  
 Electrochemical (NO<sub>2</sub> for NO<sub>x</sub>) Nitrogen Dioxide Sensor: 0 - 1000ppm  
 Non-dispersive Infra-Red (NDIR) Carbon Dioxide (CO<sub>2</sub>) Sensor: 0 - 20.0 %  
 Non-dispersive Infra-Red (NDIR) Hydrocarbons (HC EX)  
 Response Time: <30 seconds  
 Pump Flow Rate: 0.3 to 0.7 LPM

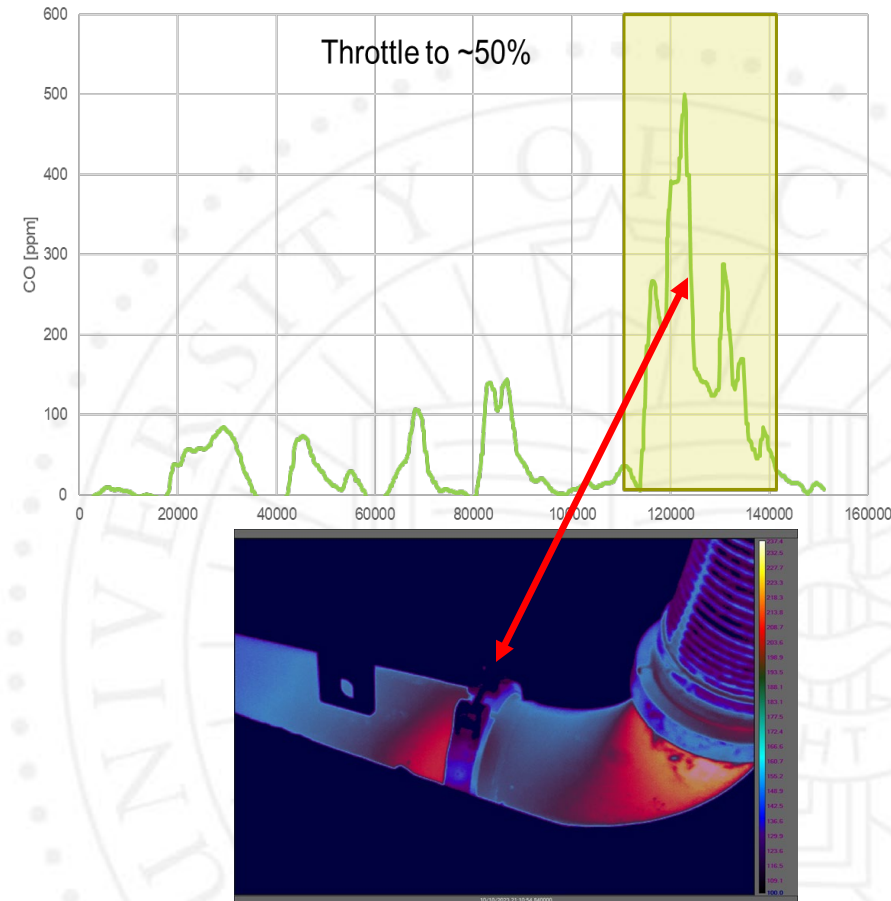


Figure 1 Illustration of sampling system methodology

## **Inspection and Maintenance Programs can play a big role in keeping emissions low**

- **High emitters in-use will remain a key consideration for ICEs**
- **The CARB Clean Truck Check program is expected to be one of the most impactful programs approved in decades.**
- **Projected emissions reductions include:**
  - Reductions of 8.6 tons per day (tpd) NO<sub>x</sub> and 0.09 tpd PM emissions in San Joaquin Valley (SJV) in 2024.
  - Reductions of statewide NO<sub>x</sub> emissions by 81.3 tpd and PM emissions by 0.7 tpd in 2037.
- **Benefits of these PM and NO<sub>x</sub> emissions reductions include**
  - Roughly 7,500 avoided premature deaths
  - 6,000 avoided hospitalizations statewide
  - Equivalent monetized health benefits of \$75.8 billion for 2023-2050 period.
- **Clean Truck Check would reduce NO<sub>x</sub> from HDVs >14,000 lbs.**
  - Reductions of 50% in 2031, increasing to a 56% reduction by 2037 compared to baseline.

# Inspection and Maintenance Programs can play a big role in keeping emissions low

- Trucks “caught” having high emissions will have to be brought to inspection locations to be evaluated
- UC Riverside CE-CERT involved in the CARBTest “referee” part of this of the program to CE-CERT in part because of our reputation as being an honest broker



- **Climate change will likely remain one of the most significant challenges facing the world for the foreseeable future.**
- **An “All hands on deck” will be needed in the drive to a sustainable transportation future.**
- **Conventionally-fueled technology vehicles will play an important part in the intermediate term in achieving environmental metrics.**
  - **Some early data show trends towards lower in-use emissions with later generation vehicles, with some vehicles still having higher emissions.**
  - **If the vehicles can maintain ultralow emissions during operation, fleet turnover could provide 95% of emissions reductions from 2025 to 2040.**
  - **This could be coupled with greater renewable fuels use for reducing GHGs.**
- **Ensuring conventionally fueled vehicles can maintain low or ultralow emissions levels will likely be the key to ensuring continued progress towards achieving future air quality goals.**
- **Emissions monitoring and inspection will continue to play an important role as we continue our journey to a fully sustainable transportation sector.**