



# 2004 SIP Summit

## Diesel Engines and Alternatives

**January 13, 2004**

# Outline

- Background
- Emission Inventory
- SIP Strategies
- Mobile Sources
  - New On-Road Engines
  - New Off-Road Engines
  - In Use Strategies
  - Testing and Enforcement
- Stationary Engines
- Fuels
- Federal Sources

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# Diesels Are an Important Part of the World's Economy



- Land and sea transport
- Electrical power
- Farming, industrial, and construction activities

# Diesel Vehicles and Equipment

- Transit buses, long-haul trucks, school buses, refuse trucks, etc
- Bulldozers, wheel loaders, cranes, compressors, generators, etc
- Federal sources – locomotive, marine
- Emergency standby engines, prime power engines

# Over 1 Million Diesels in California

<b>Category</b>	<b>Population (in 2000)</b>
<b>Trucks</b>	700,000
<b>Off-road equipment</b>	500,000
<b>Stationary and portable</b>	65,000

# Why Are Diesel Emissions a Concern?

- Diesel PM is a toxic air contaminant
  - Increases premature deaths, hospital admissions, respiratory diseases
  - Causes cancer
- Diesel NO<sub>x</sub> and ROG contribute to ozone and PM formation

# Harmful Components of Diesel Exhaust

## **Gases**

**Carbon Dioxide**

**Carbon Monoxide**

**Nitrogen Oxides**

**Sulfur Dioxide**

**Hydrocarbons**

**Aldehydes**

**PAHs**

## **Particles**

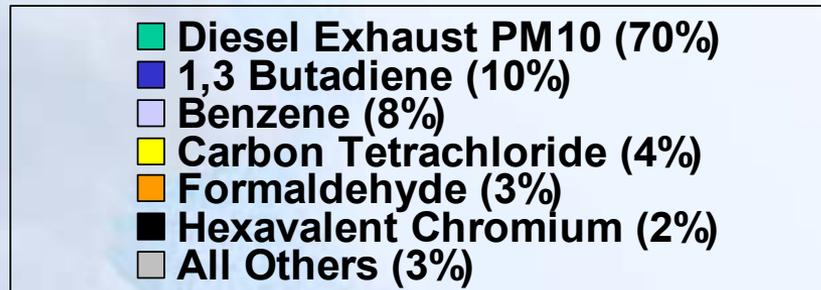
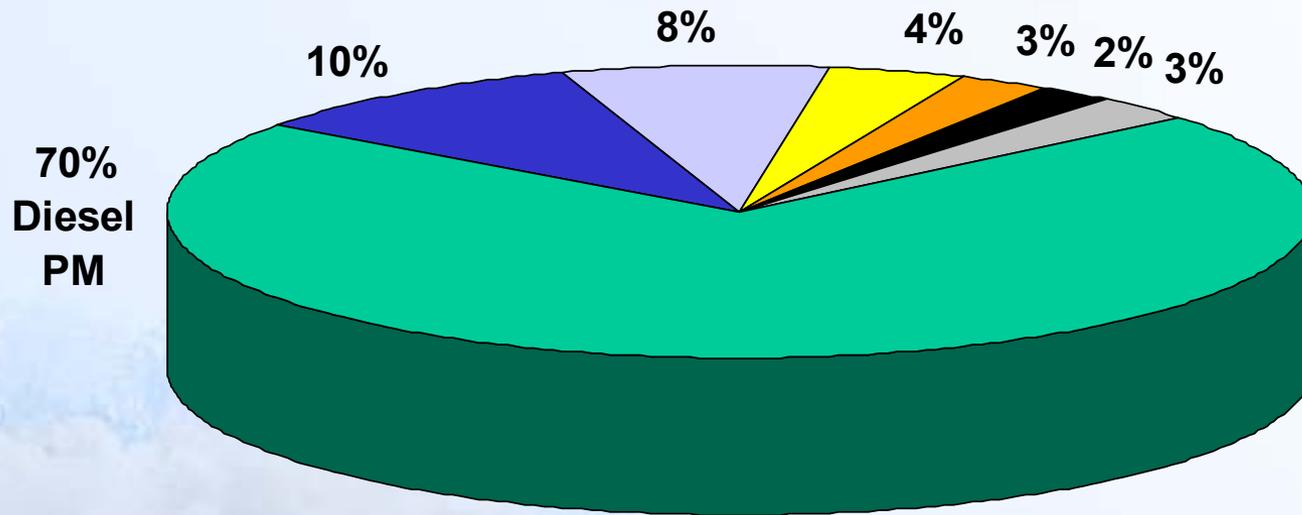
**Elemental Carbon**

**Sulfate**

**Hydrocarbons**

**PAHs**

# Statewide Average Potential Ambient Cancer Risks for 2000



# Health Impacts of Diesels in California

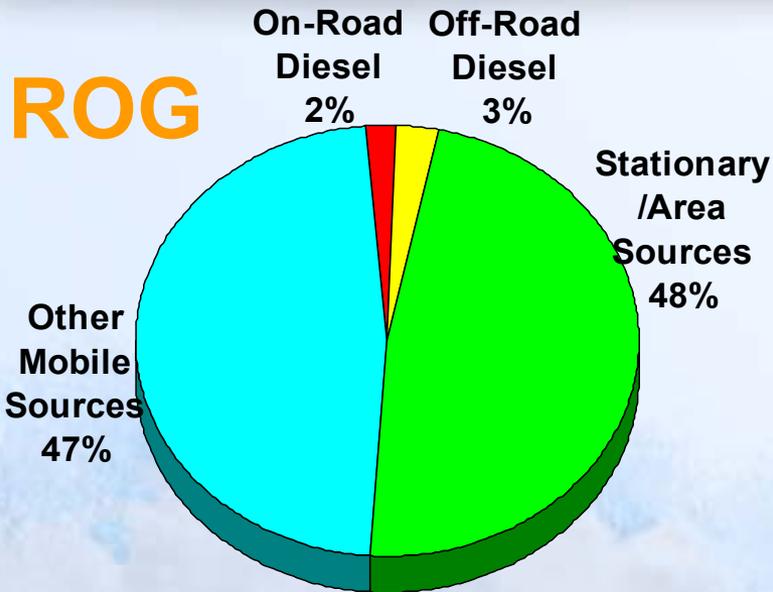
- Annual health impacts
  - 2,900 premature deaths
  - 3,600 hospital admissions
  - 240,000 asthma attacks/respiratory symptoms
  - 600,000 lost days of work
- By comparison
  - 3,700 deaths from car accidents
  - 2,000 homicides

# Outline

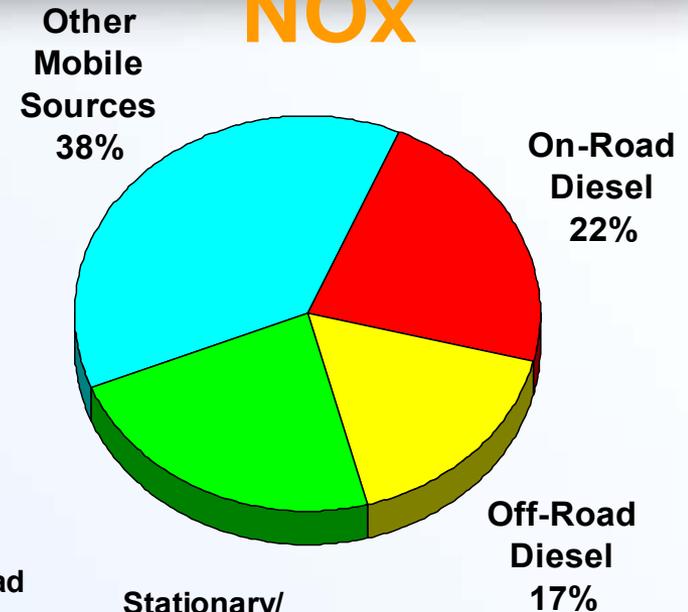
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# Reducing Diesel Emissions is a Priority

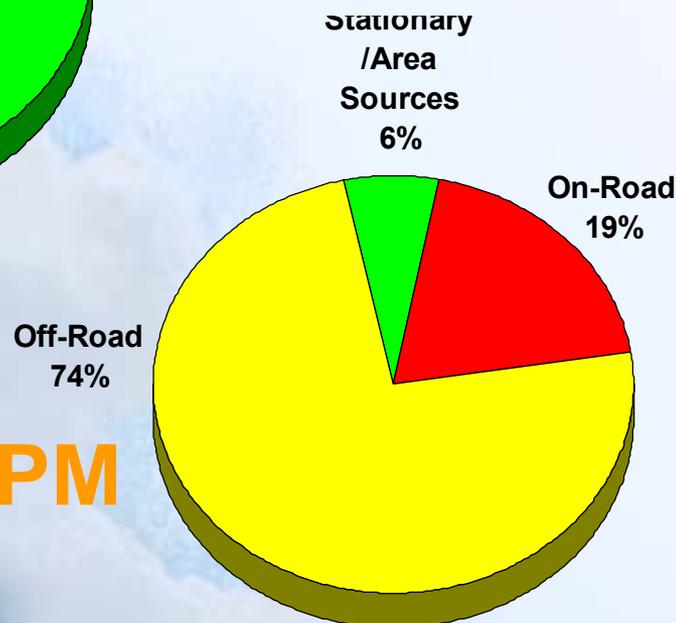
## ROG



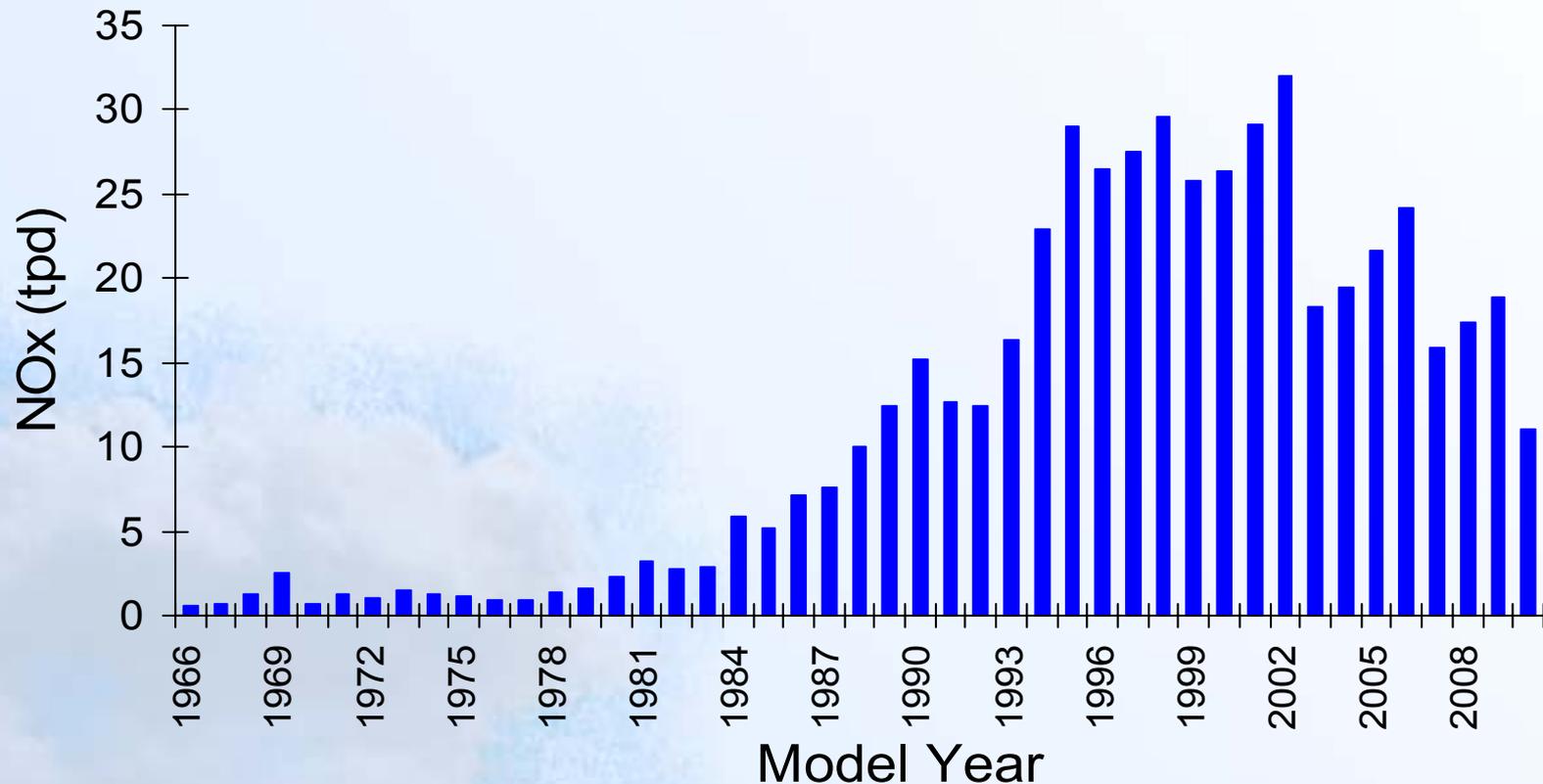
## NOx



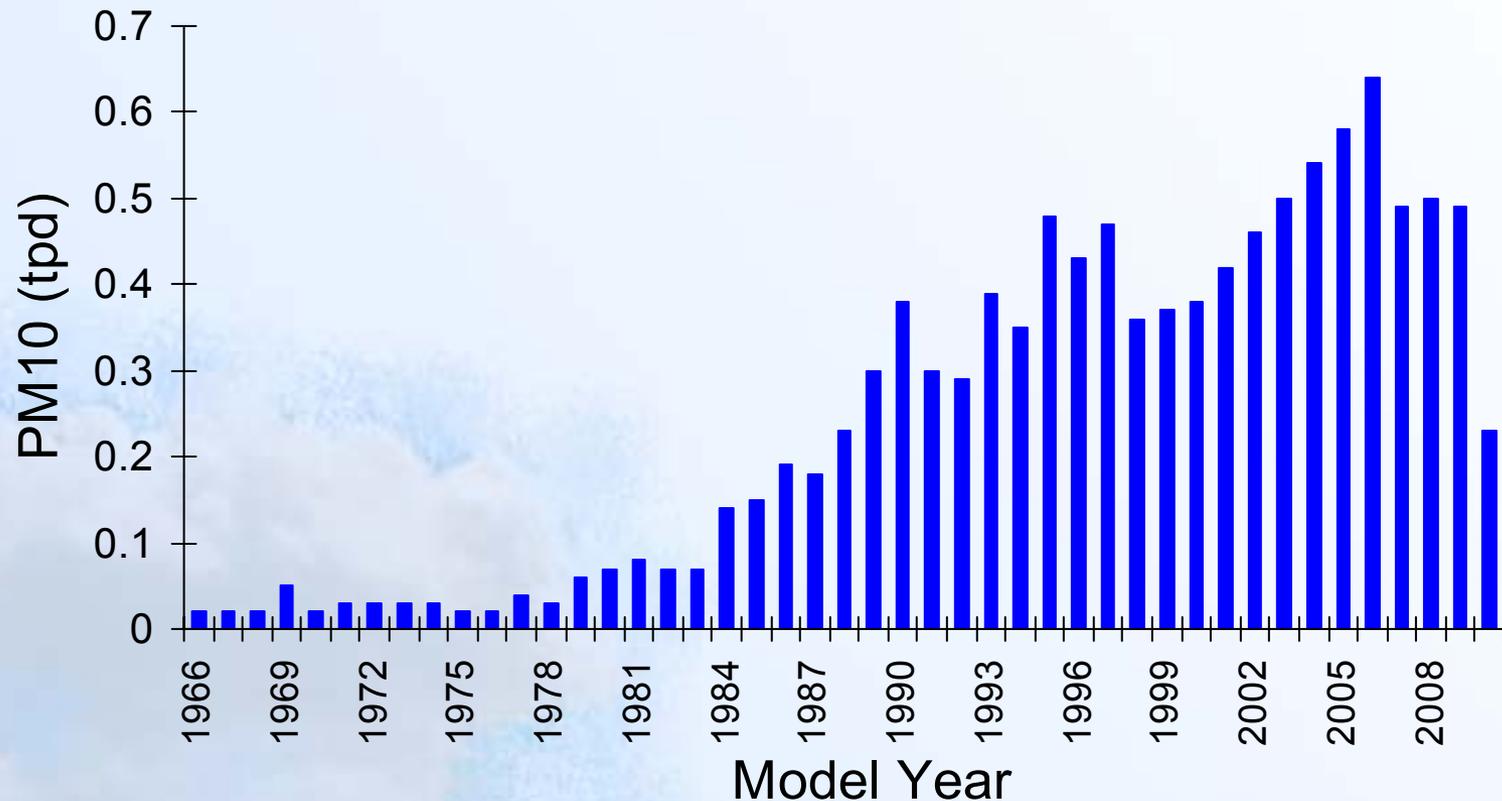
## Diesel PM



# On-Road Heavy-Duty Engines Statewide 2010 (NOx)

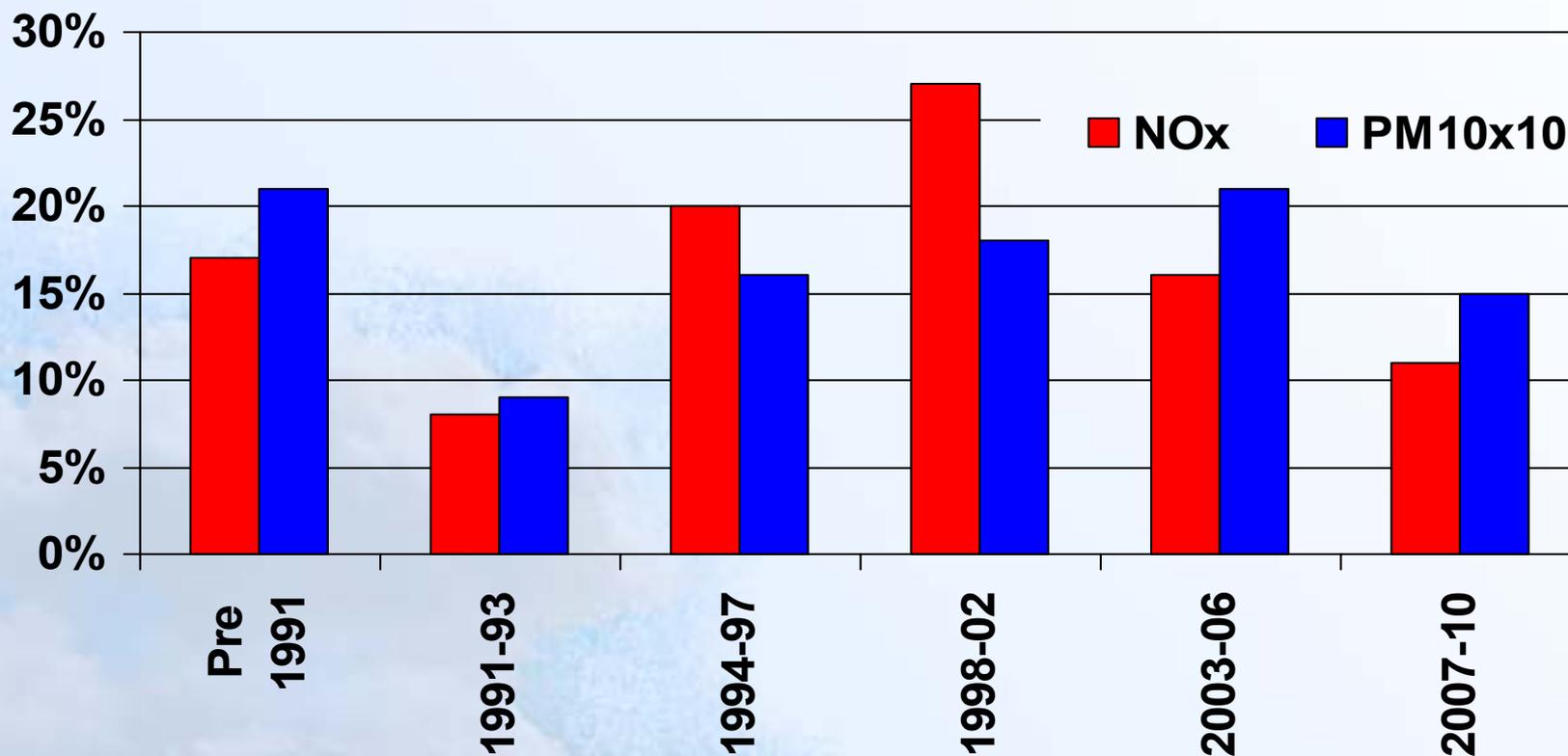


# On-Road Heavy-Duty Engines Statewide 2010 (PM)

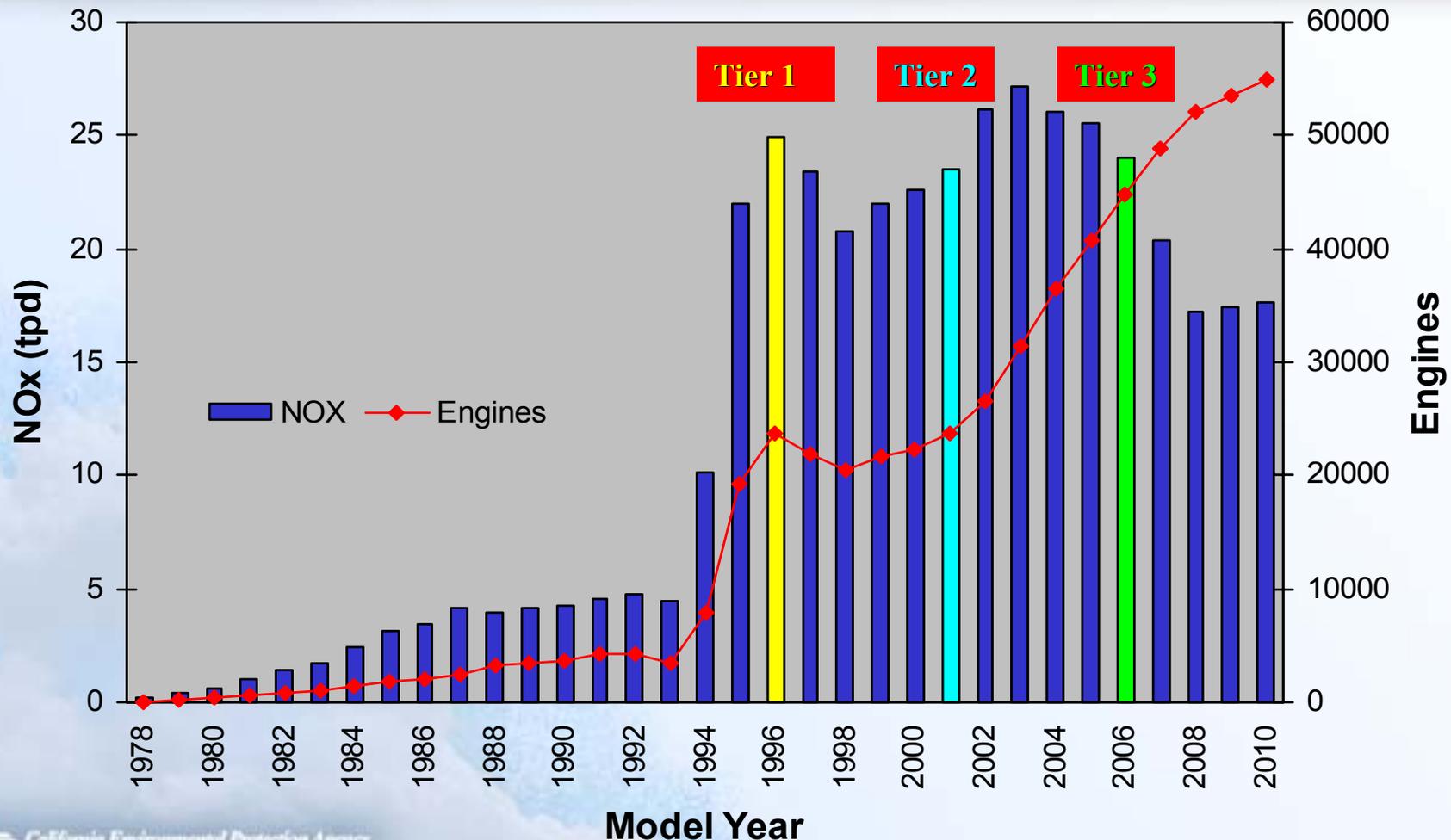


# Older Models Still a Problem

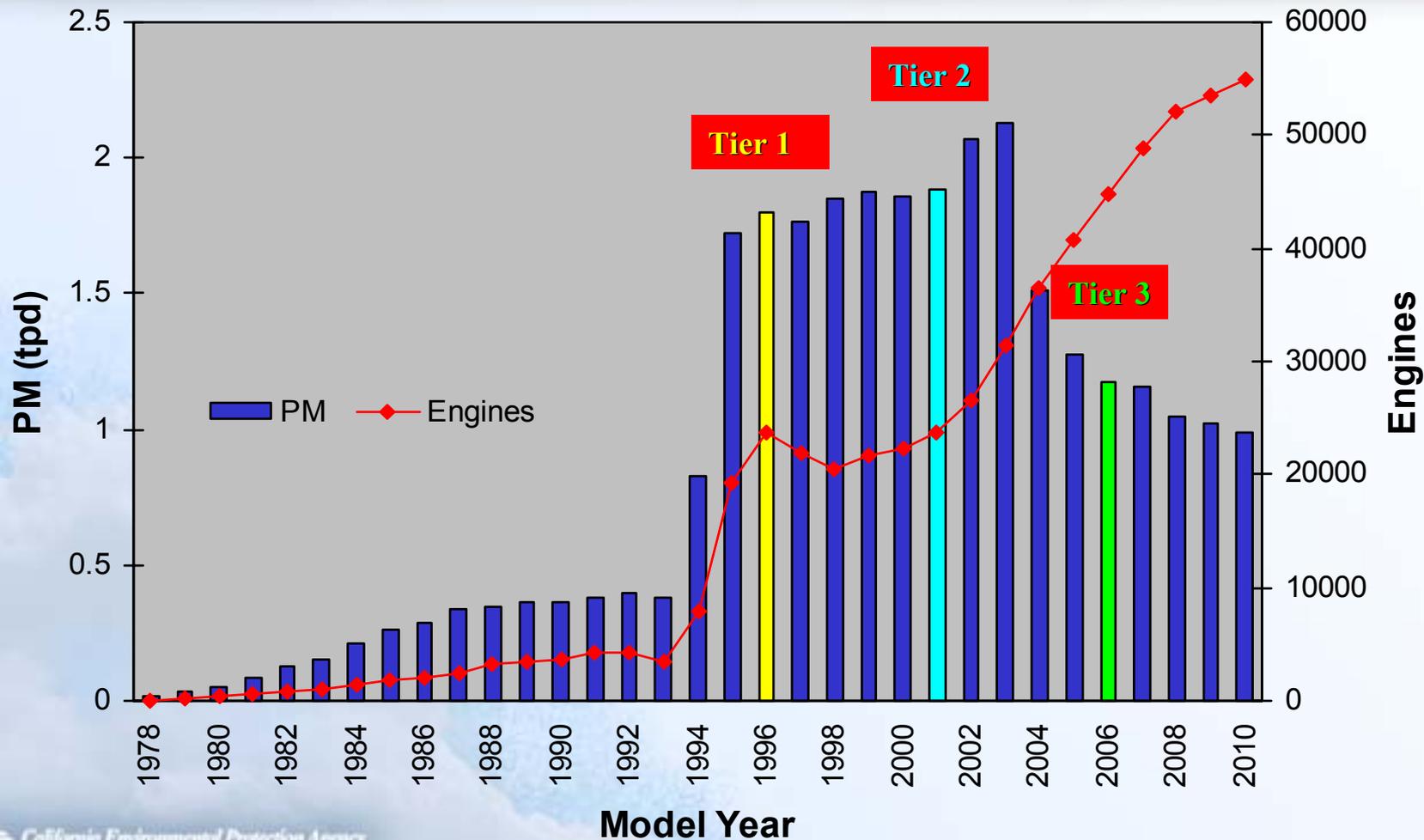
## On-Road Heavy-Duty Diesel Engines - 2010



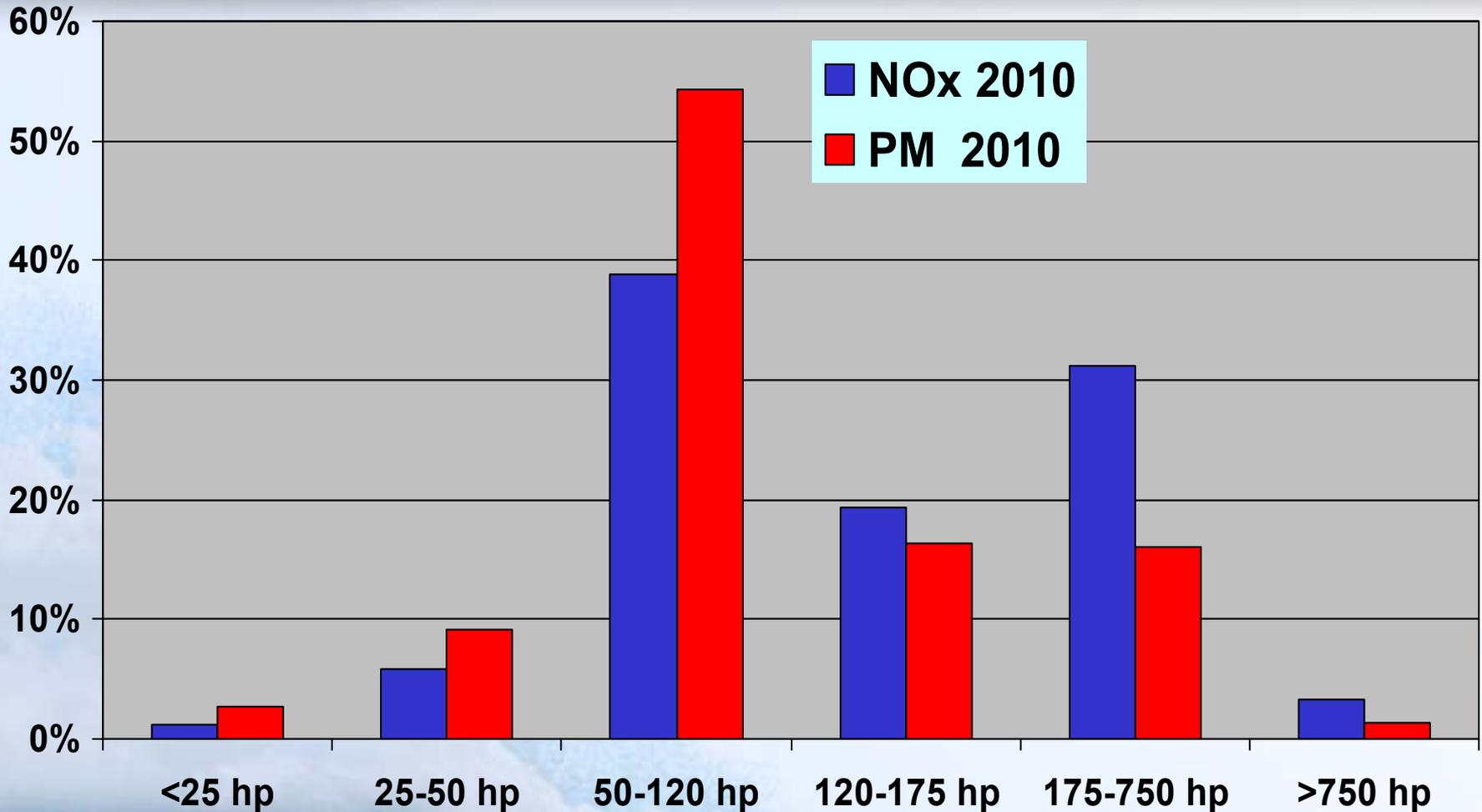
# Off-Road Diesel Statewide 2010 (NOx)



# Off-Road Diesel Statewide 2010 (PM)



# PM & NOx Distribution by Horsepower from the Off-Road Diesel Fleet in 2010



# Stationary Diesel Engine Inventory

<b>Category</b>	<b>Number of Engines</b>	<b>Diesel PM Emissions (tpd)</b>	<b>NOx Emissions (tpd)</b>
Prime Engines	6,600	2.3	34.9
Emergency Standby Engines	19,700	0.3	6.4
<b>TOTAL</b>	<b>26,300</b>	<b>2.6</b>	<b>41.3</b>

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# SIP Strategies

- Pursue Approaches to Clean Up the Existing and New Truck/Bus Fleet
- Pursue Approaches to Clean Up the Existing Heavy-Duty Off-Road Equipment Fleet -- Retrofit Controls
- Augment Truck and Bus Highway Inspections with Community-Based Inspections

# SIP Strategies

- Set Additive Standards for Diesel Fuel
- Set Low-Sulfur Standards for Diesel Fuel for Trucks/Buses, Off-Road Equipment, and Stationary Engines (ADOPTED)

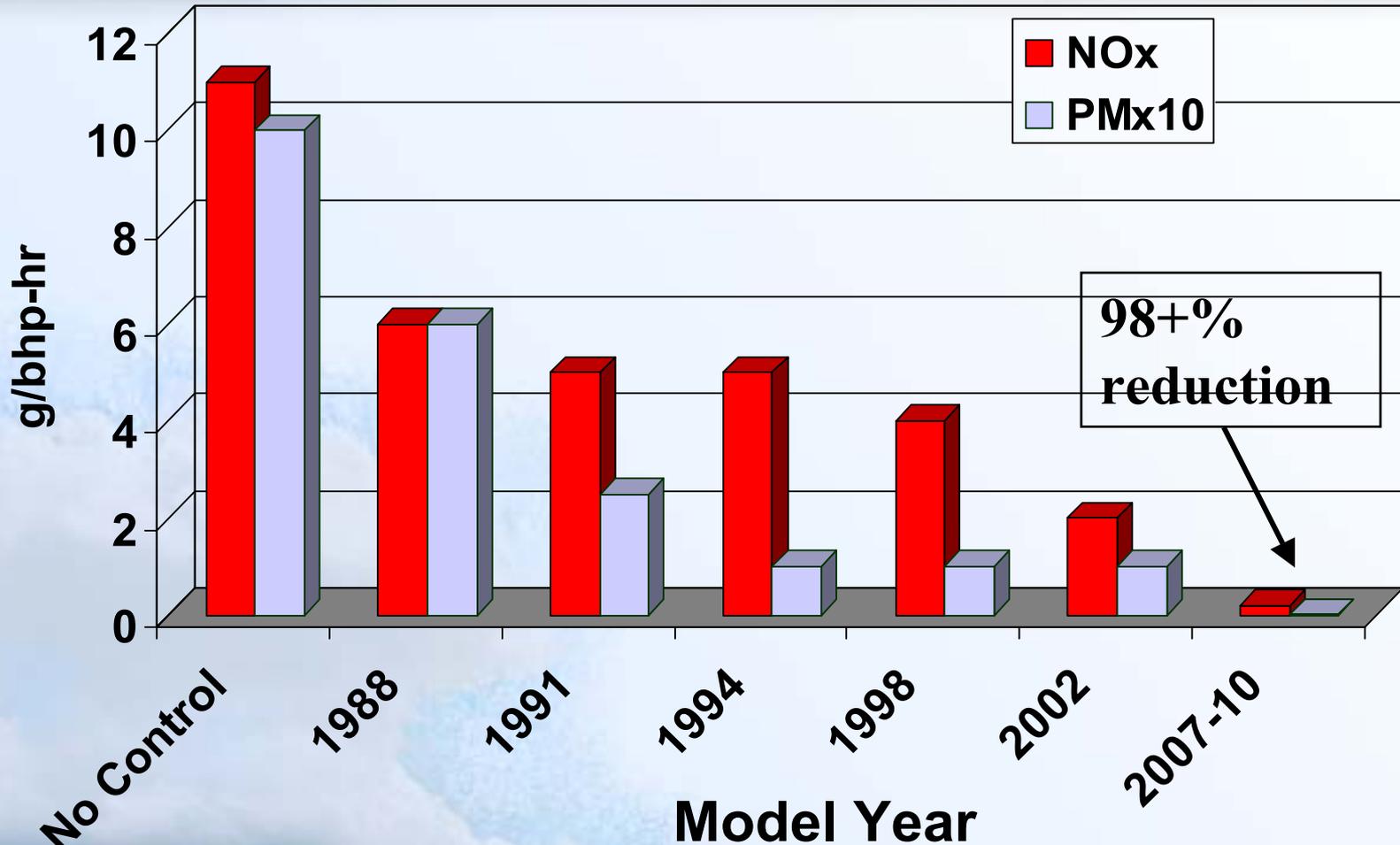
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# On-Road HD Truck Standards

- 2004 Standards
  - 50% reduction in NO<sub>x</sub>
- 2007 Standards
  - 90% reduction in NO<sub>x</sub> and PM

# New Engine Standards On-Road Diesels



# SIP Strategies

## New On-Road Engines

- Pursue Approaches to Clean Up New Trucks
  - HD OBD
  - Truck Idling Restrictions

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# What are Examples of Off-Road Diesel Engines?



# What Have We Done So Far?

- 1996 - First emissions standards began for NO<sub>x</sub> and PM (Tier 1)
- 2001 – Tier 2 standards began for HC+NO<sub>x</sub> and PM
- 2006 – Tier 3 HC+NO<sub>x</sub> standards are scheduled to begin.

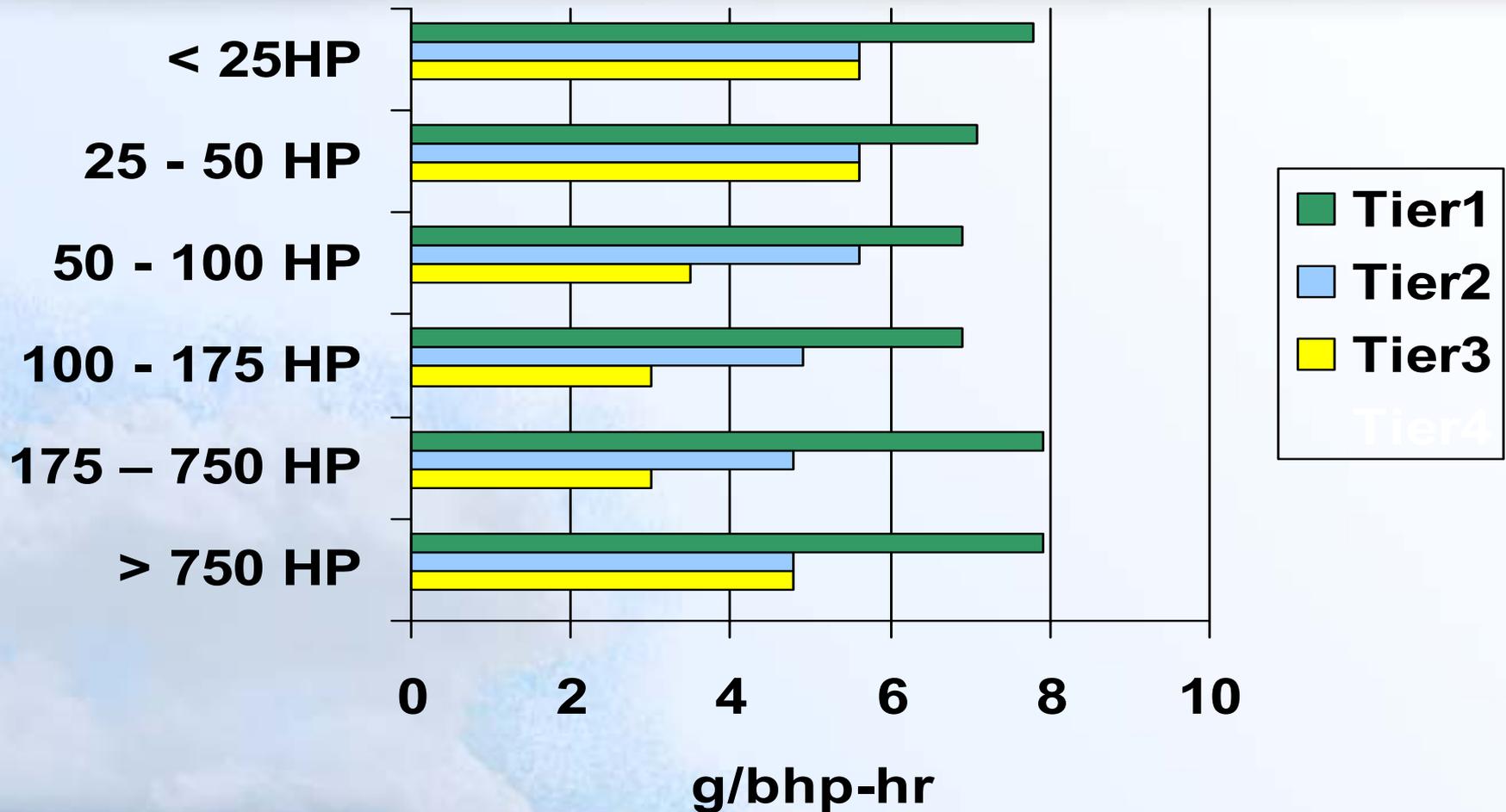
# Why Aren't There New SIP Measures for New Off-Road Diesel Engines?

- Standards are already in place for current and future model years
- More aggressive standards similar to on-road are in the works for 2011 (Tier 4)

# What is the Off-Road Diesel Tier 4 Proposal?

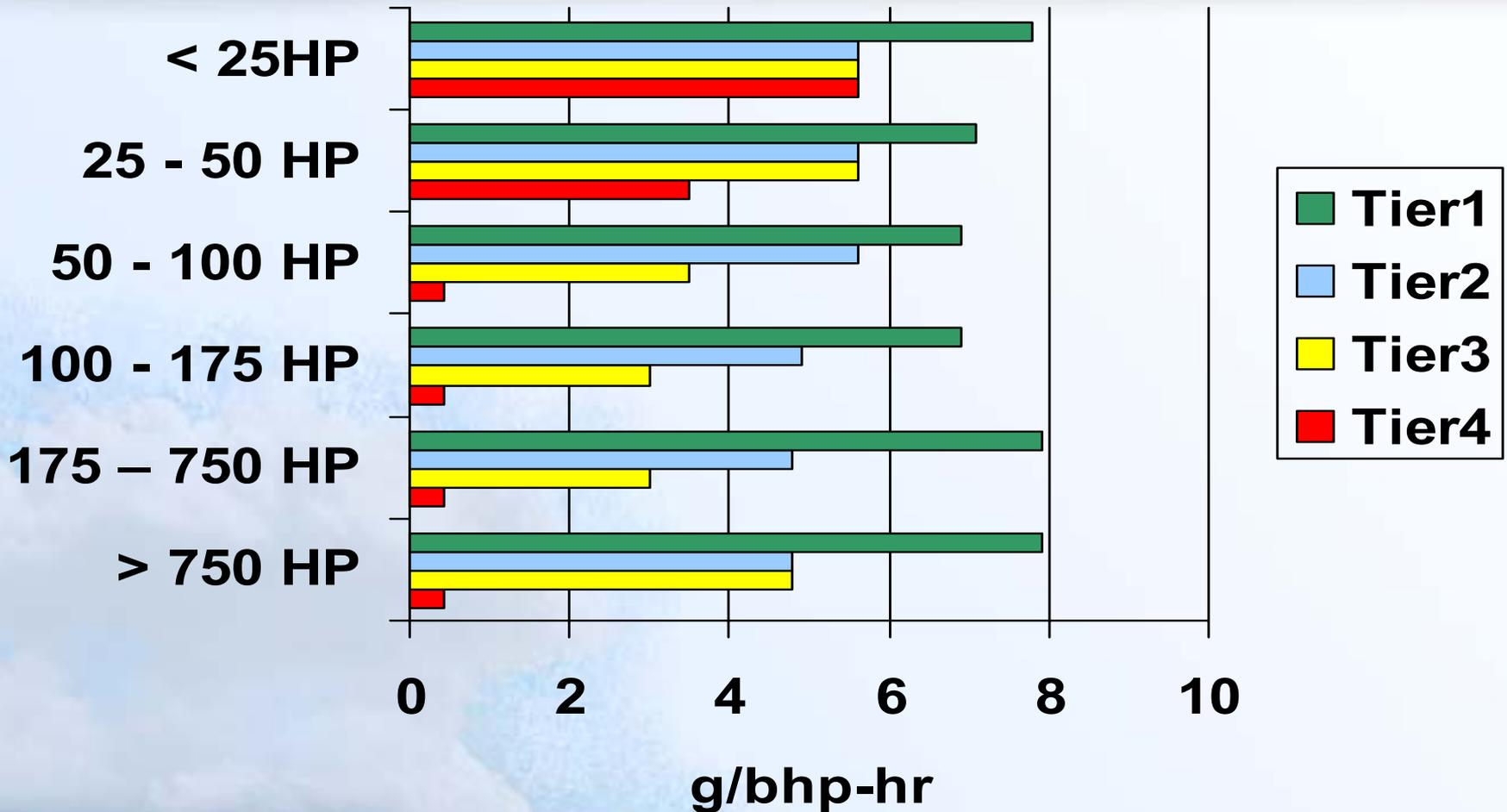
- 15 PPM sulfur diesel fuel would be required in 2010 nationwide
- Aftertreatment standards would begin in 2011 for PM and NOx
- PM inventory would be reduced by 45% in 2020
- NOx inventory would be reduced by 35% in 2020

# What Are Off-Road HC+NOx Standards? (g/bhp-hr)

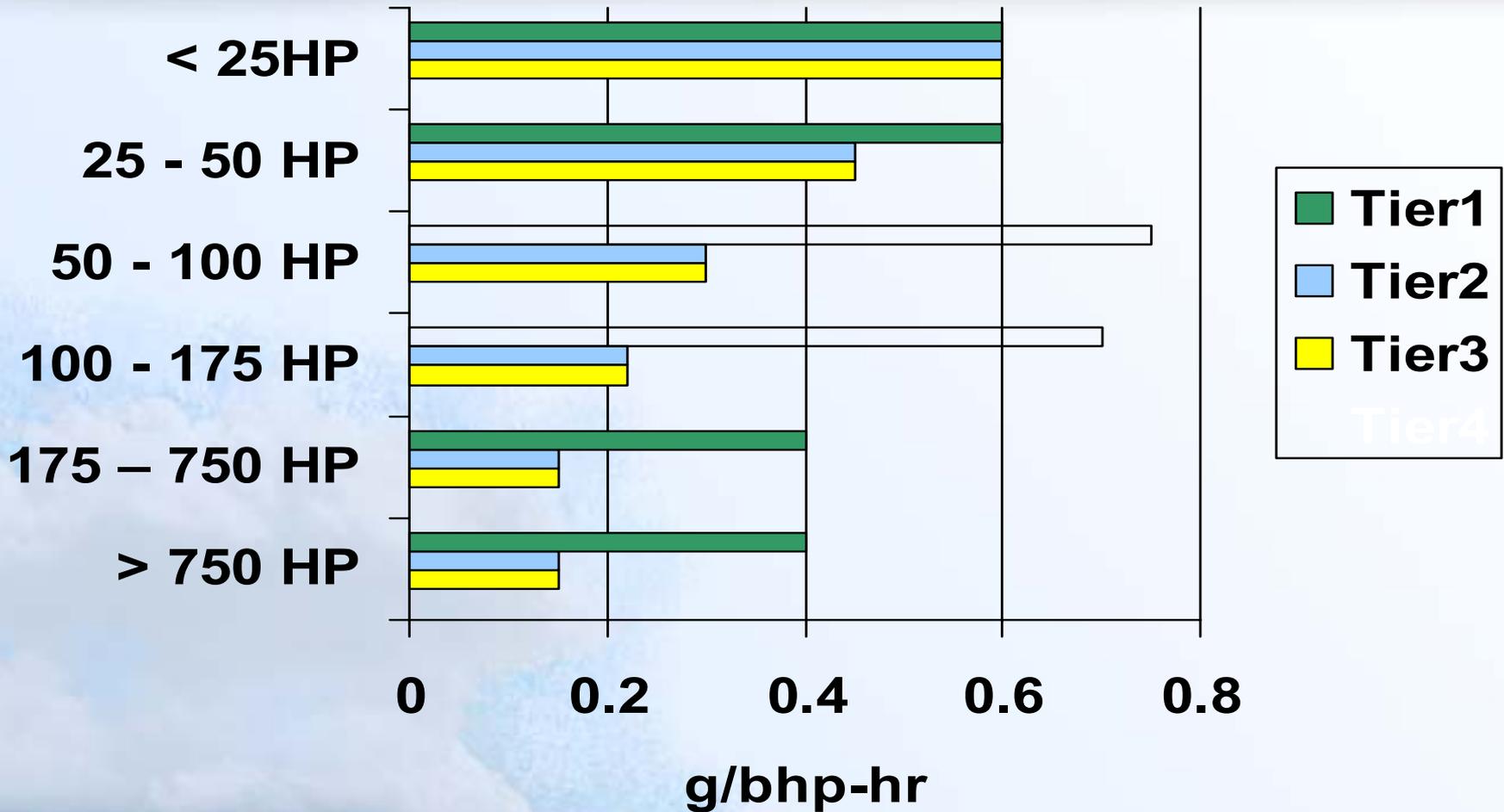


# What Are Off-Road HC+NOx Standards?

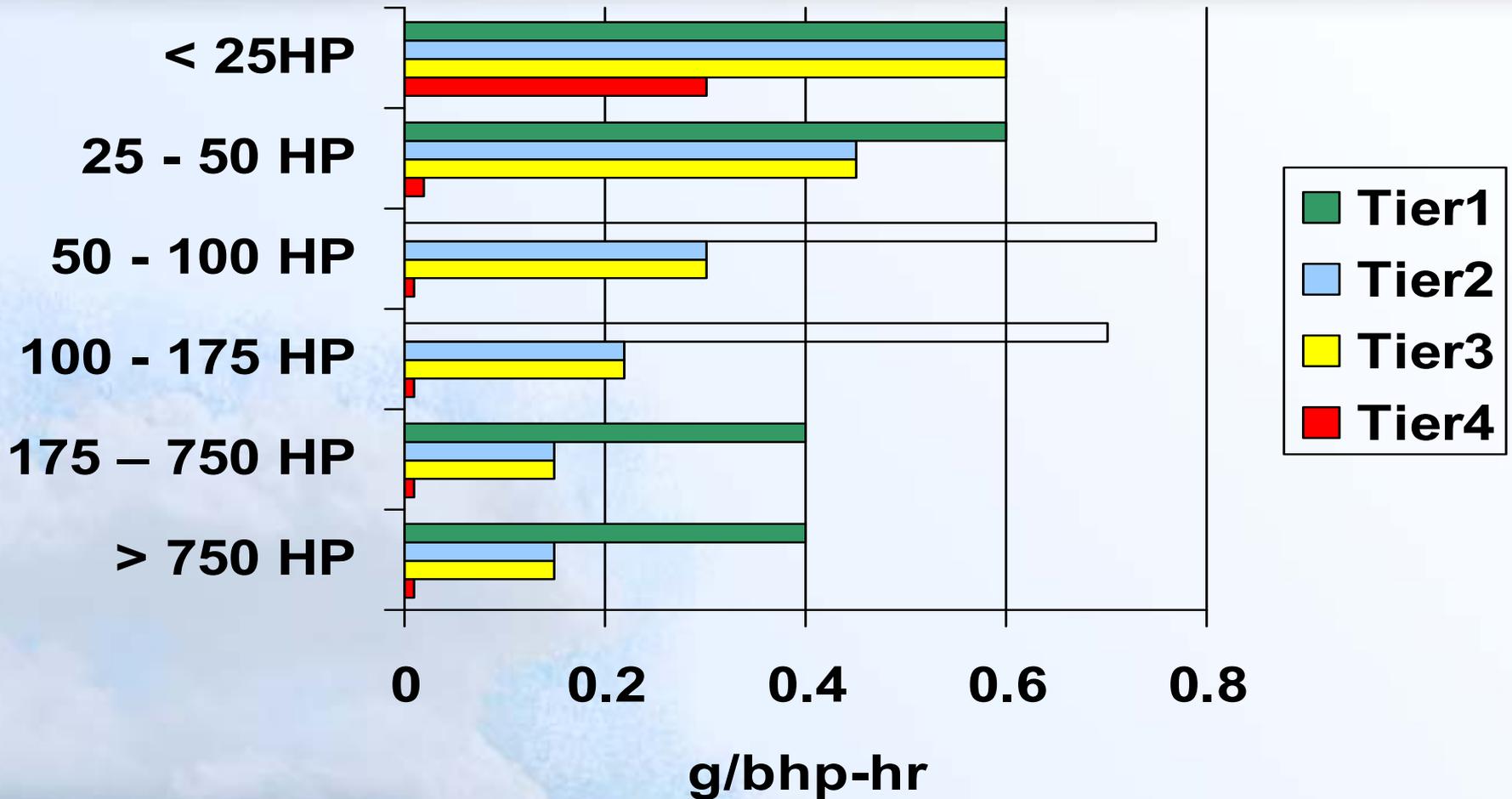
(g/bhp-hr)



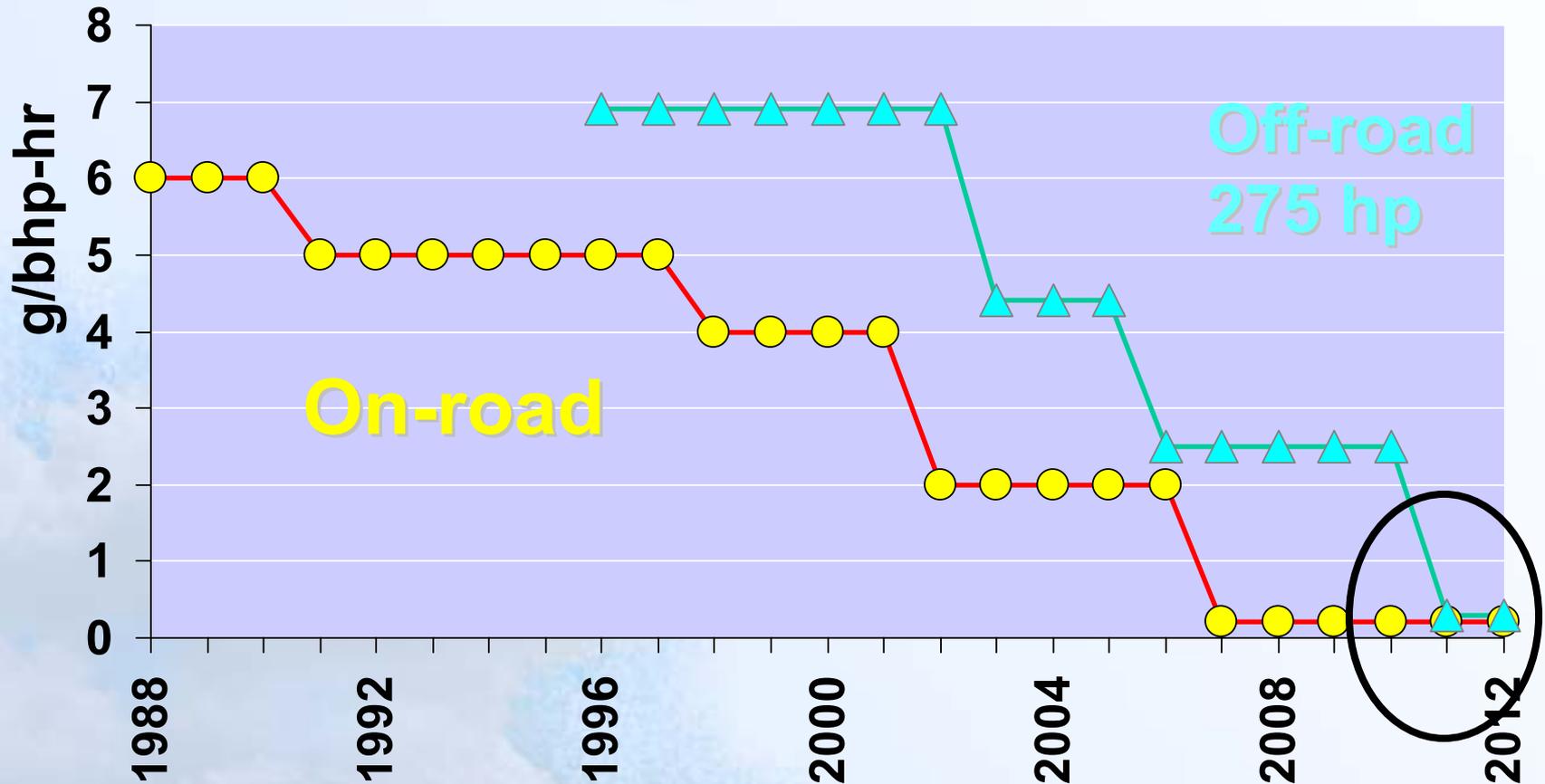
# What Are Off-Road Diesel PM Standards? (g/bhp-hr)



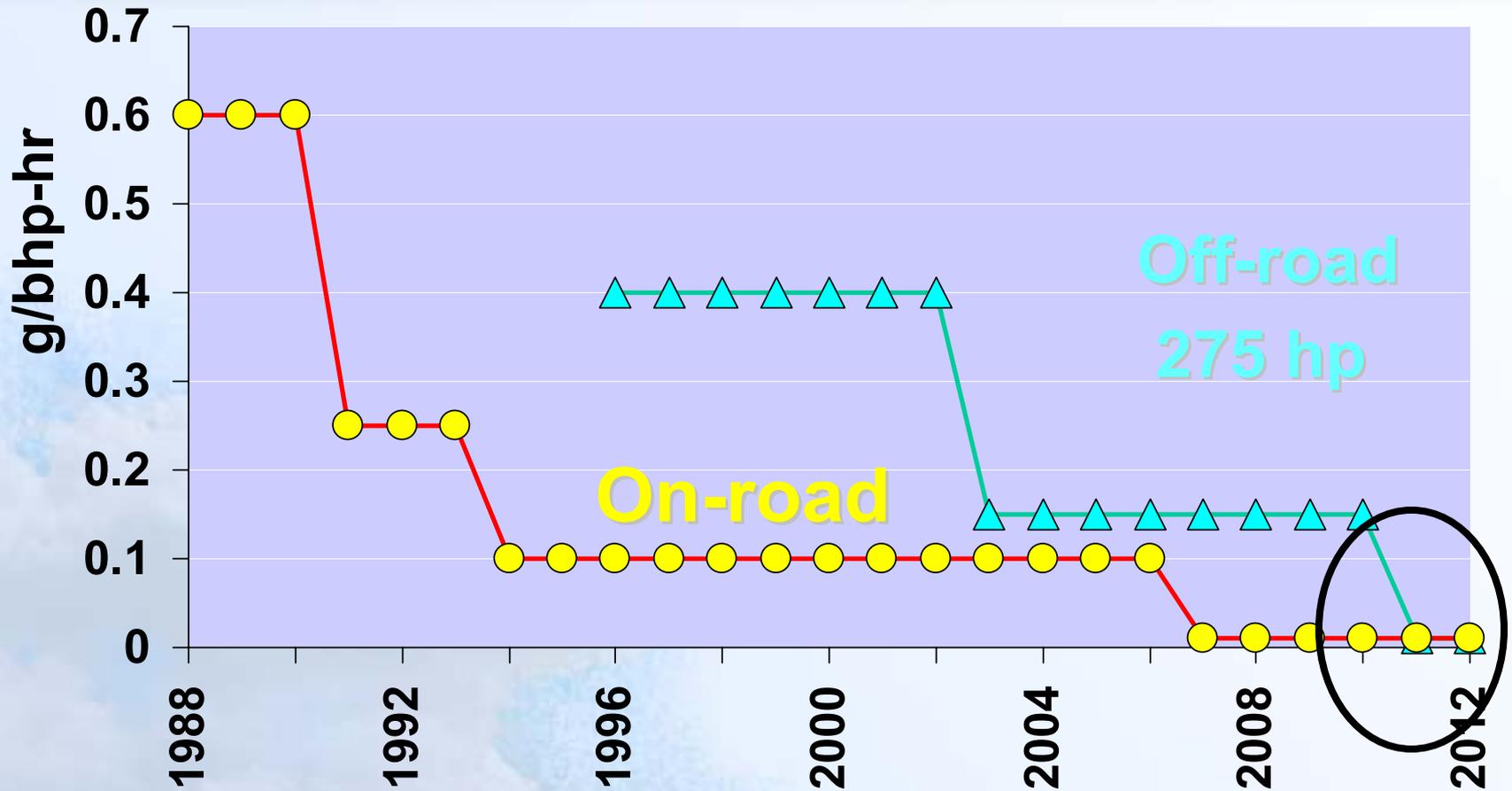
# What Are Off-Road Diesel PM Standards? (g/bhp-hr)



# Off-Road Diesel NOx Standards Catching up to On-Road Standards



# Off-Road Diesel PM Standards Catching up to On-Road Standards



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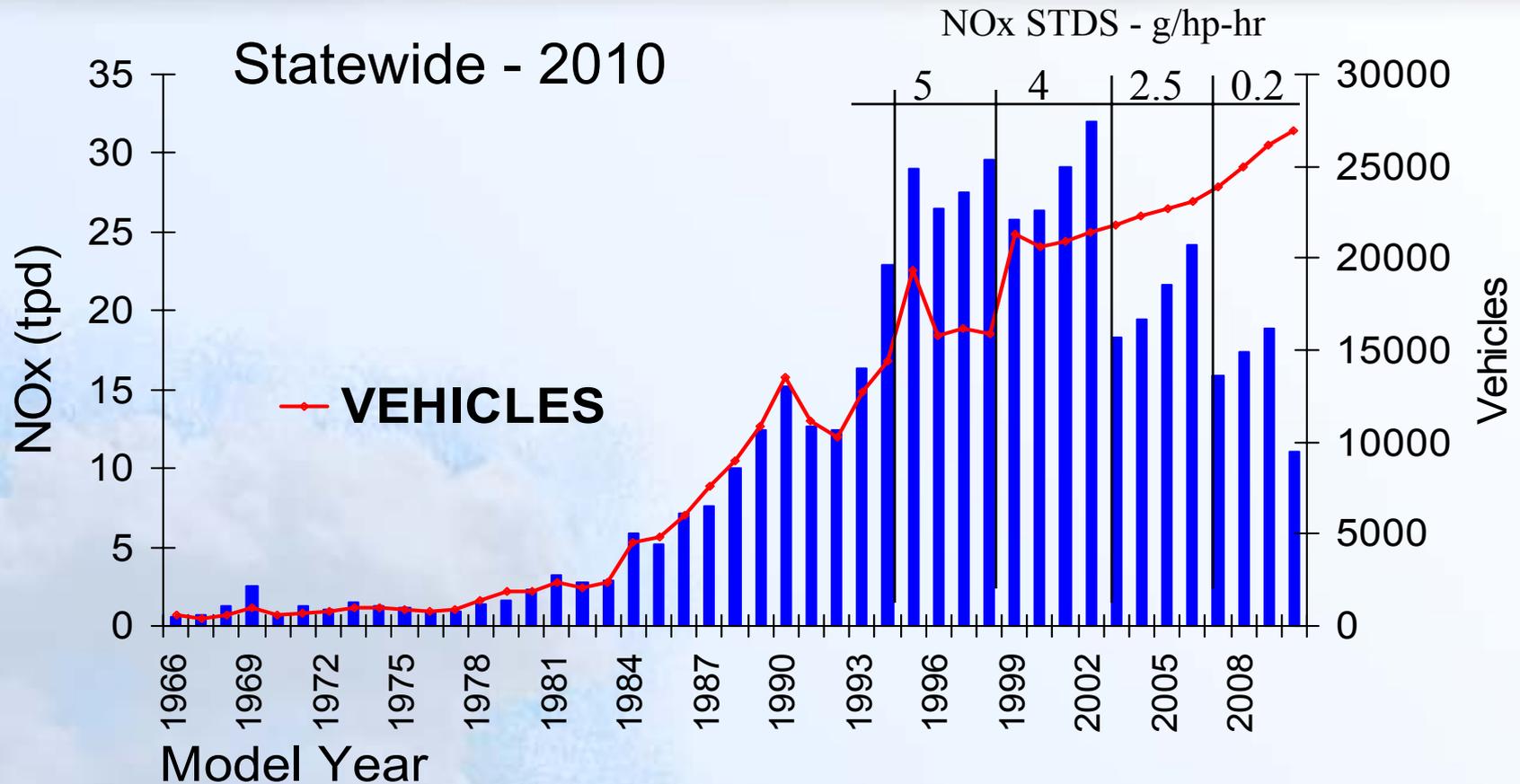
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# Diesel Risk Reduction Plan

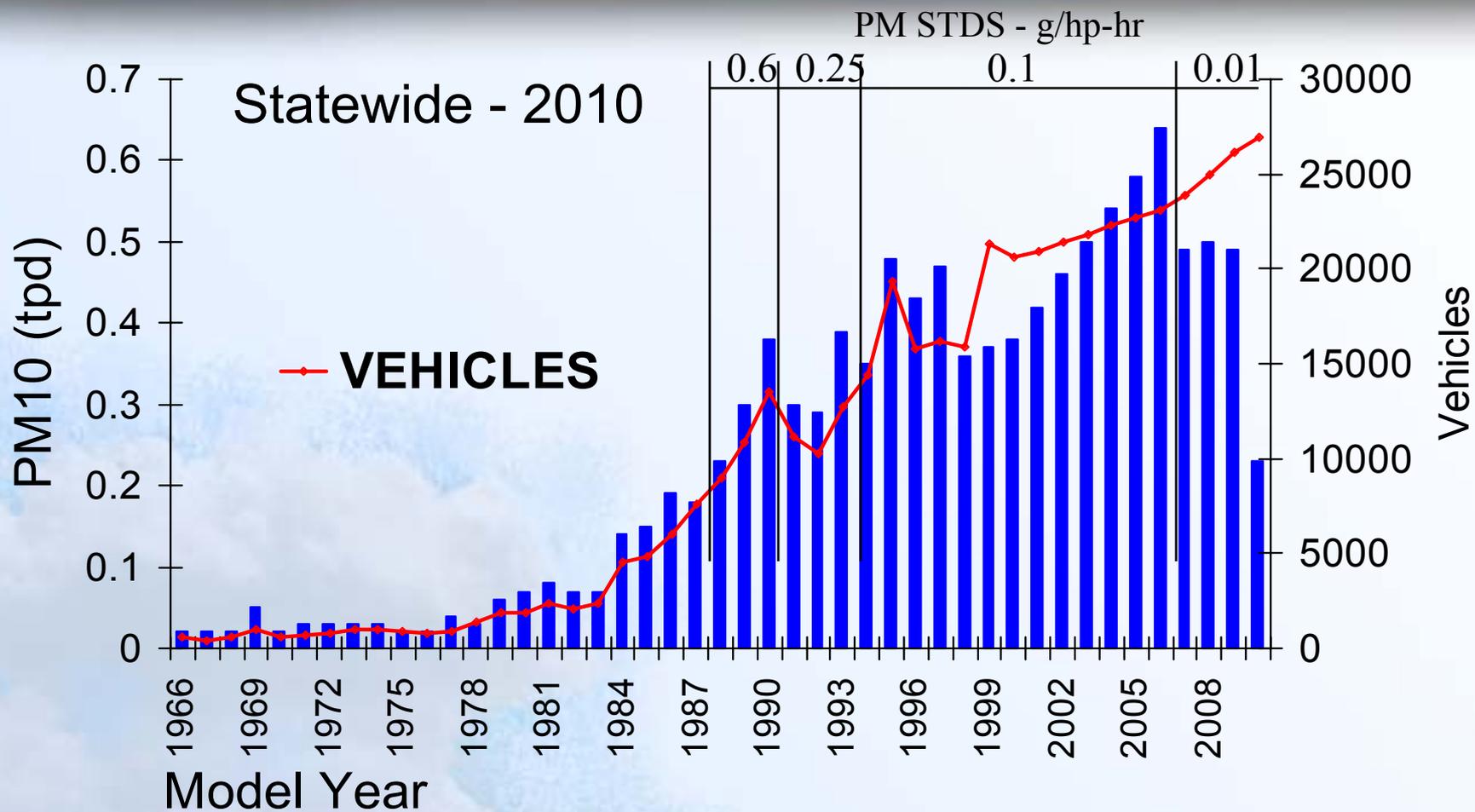
(adopted 2000)

- Established goals
  - 75% reduction in diesel PM by 2010
  - 85% reduction in diesel PM by 2020
  - Additional NOx reductions
- Cleanup of existing engines plays a big role

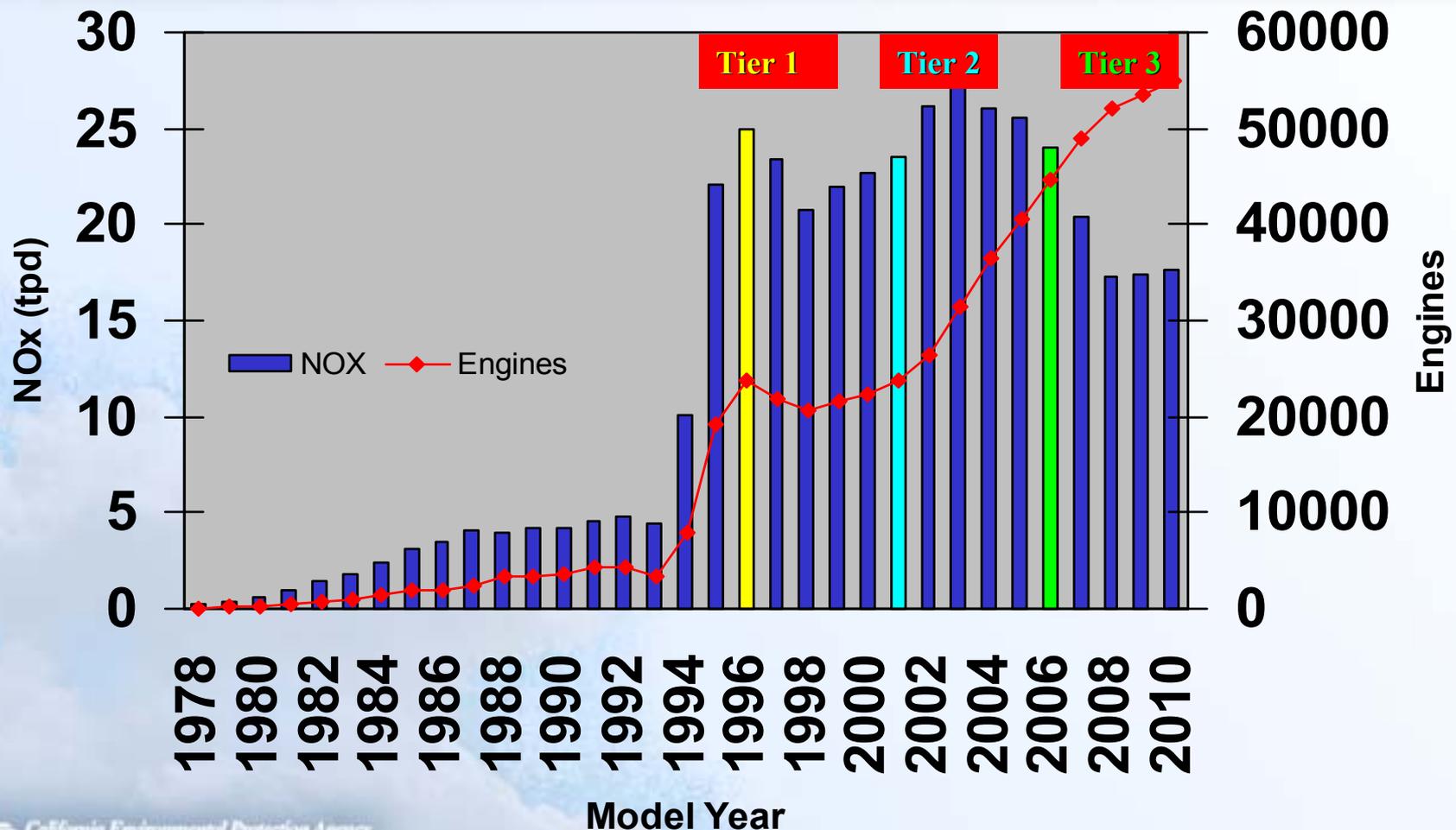
# In-Use On-Road Engines Are A Problem - NOx



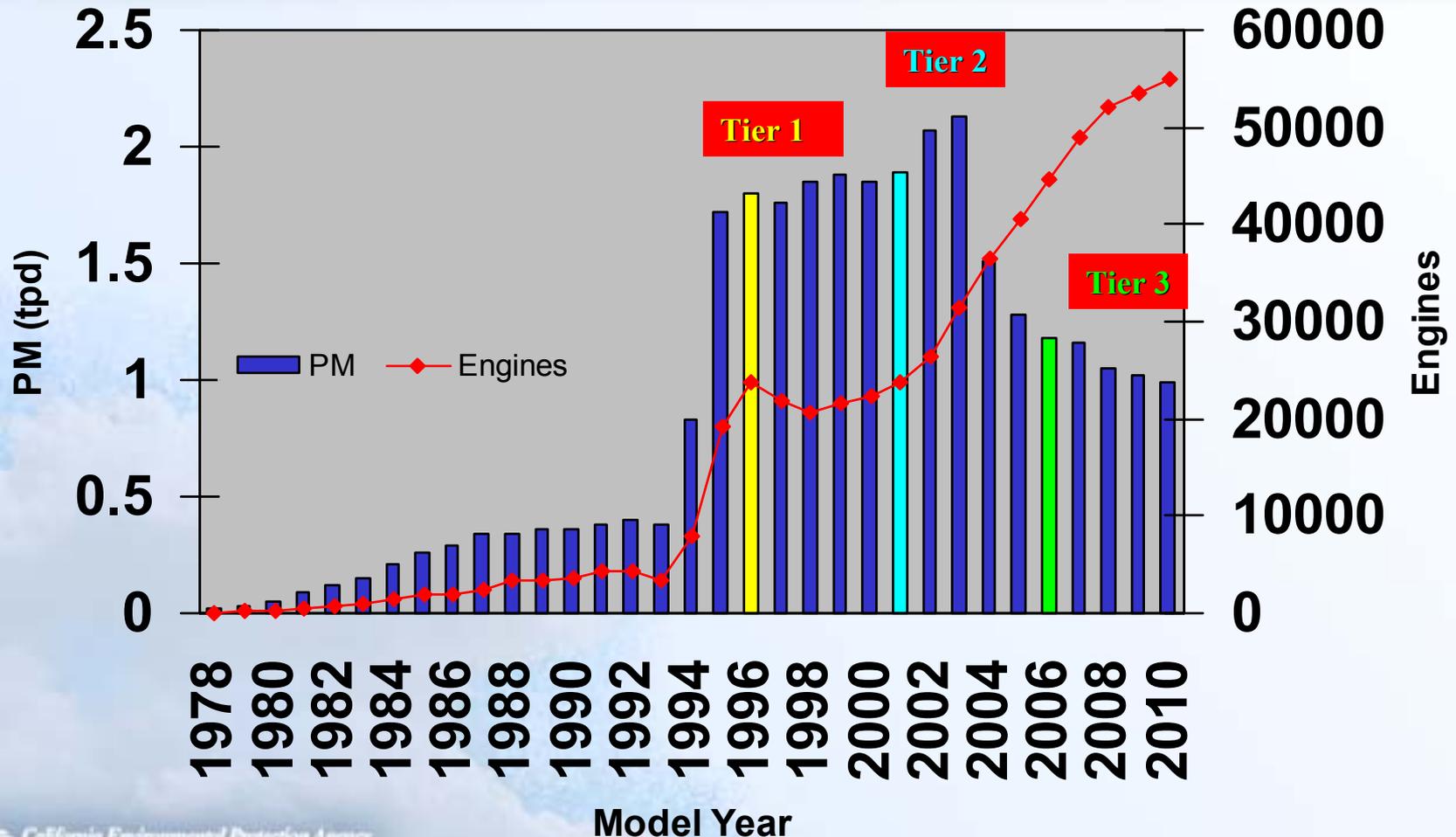
# In-Use On-Road Engines Are A Problem - PM



# In-Use Off-Road Engines Are A Problem - NOx



# In-Use Off-Road Engines Are A Problem - PM



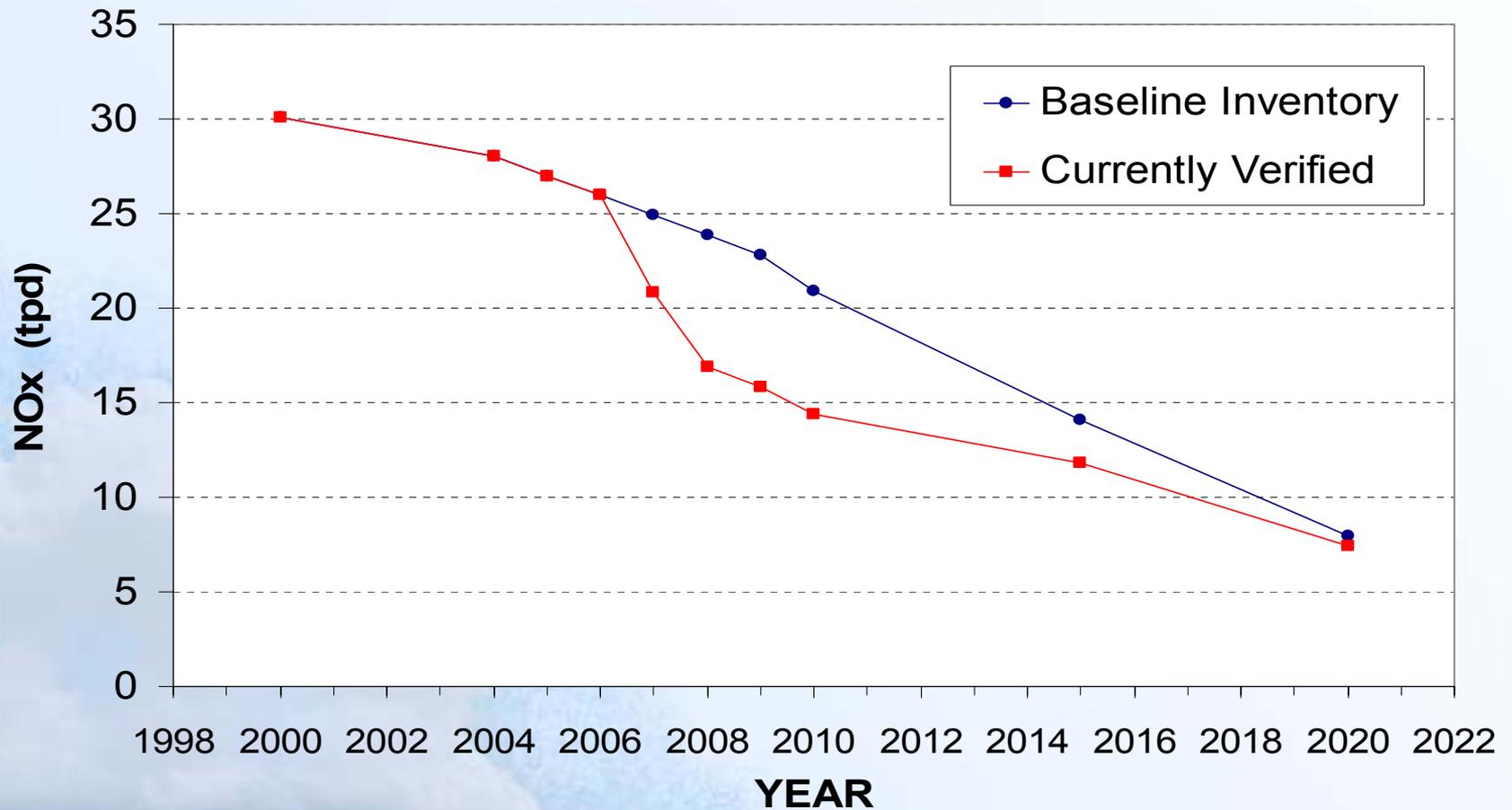
# SIP Strategies: In-Use Engines

- Pursue Approaches to Clean Up the Existing On- and Off-road Vehicles and Equipment
  - Diesel In-Use Fleet Rules
  - Engine Software Upgrade (“Chip Reflash”)
  - Idling Restrictions

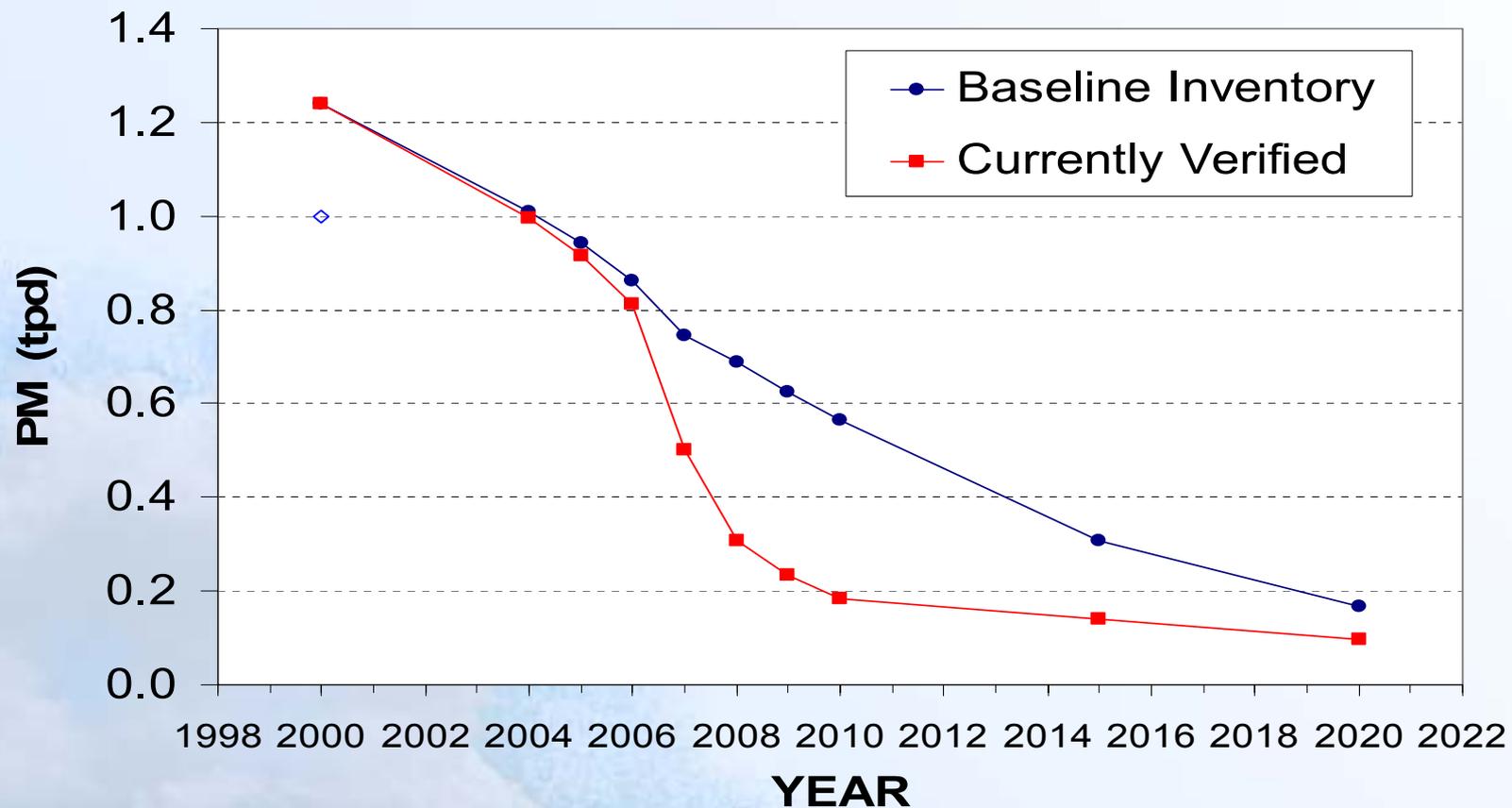
# Best Available Control Technology Reduces PM, NOx, and ROG

- Retrofit
  - Aftertreatment or fuels
- Repower
  - Newer engine
- Replacement
  - New diesel or alternative fuel vehicle
- Retire
  - Reduce diesel fleet size

# NOx Emission Reductions: Trash Truck Rule



# PM Emission Reductions: Trash Truck Rule



# Trash Truck Regulation Benefits 2020

- Prevents 80 premature deaths at \$900,000 per premature death prevented
- Reduces cancer risk
- Eliminates 2,260,000 pounds PM
- Eliminates 30,600 tons NO<sub>x</sub> + HC
- Cost per household <\$1 per year

# Fleet Rule for Transit Agencies

- All transit agencies must reduce NOx and PM emissions
- Fleet emissions reduction method
- Stresses advanced technologies

# Implications for Other Rules

- General framework is established
- Repower/retirement is BACT for old engines
  - Achieves NOx reduction, too
- Meeting risk reduction goal is feasible
- Rules need to “fit” fleets affected

# Proposed Transport Refrigeration Unit (TRU) ATCM

- Establishes emission performance standards for in-use TRUs
- Compliance options
  - Retrofit, replacement, and alternative technologies
- Diesel PM reduction: 65% by 2010
- NOx reduction: 10% to 50%
- ROG reduction: about 30%

# Proposed Portable Diesel Engine ATCM

- Requires all engines (new and in-use) to be EPA-certified by 2010
- Implements increasingly stringent fleet average for PM in 2013 and 2017
- Requires Tier 4 or 85% control of PM by 2020
- Reduces NOx emissions by expediting engine turnover

# Proposed Engine Software Upgrade (“Chip Reflash”)

- 1993 - 1999 model year trucks, school buses, and motor homes
- 36-49 TPD NO<sub>x</sub> reductions statewide
- Initial Board Hearing Dec 11, 2003
  - Continued to Spring 2004

# Proposed In-Use Heavy-Duty Diesel On-Road Idling ATCM

- Establishes idling limits for in-use on-road vehicles of 14,000 GVWR and greater
- Limits address unnecessary idling
- ATCM concept also considers limits to trucks equipped with sleeper cabs
- Board Hearing - May 2004

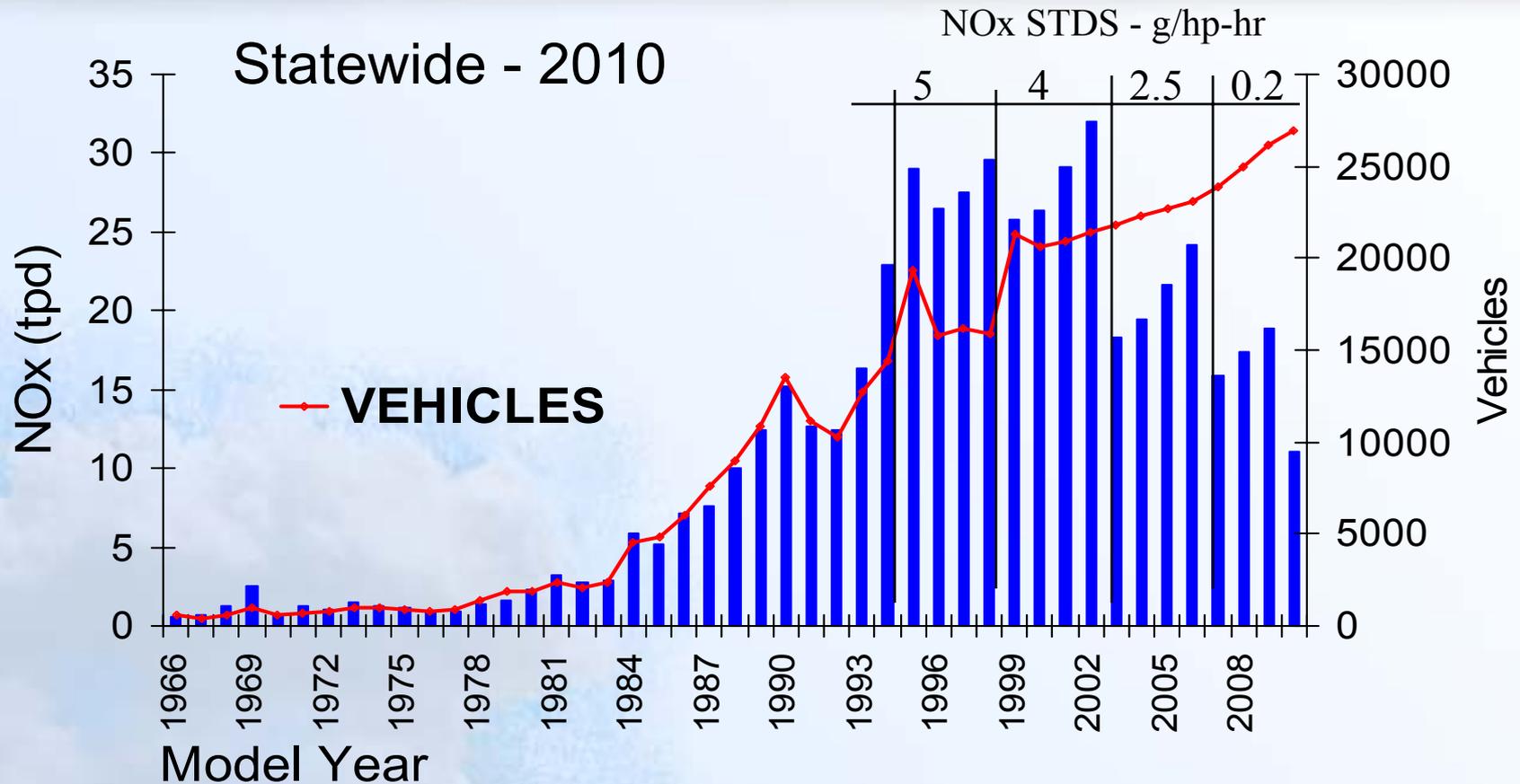
# Other Suggested On and Off-Road Measures

- NOx retrofits
  - Lean NOx catalysts
  - Selective catalytic reduction
  - NOx adsorbers
- Mandatory turnover
  - Require removal of oldest engines from fleet

# What Will It Take?

- Technology
  - Under development
  - Regulations provide a market
- Money
  - State & local support
  - Federal support
  - Private support

# In-Use On-Road Engines Are A Problem - NOx



# In-Use On-Road Engines Are A Problem - PM



# Summary

- Pursue Approaches to Clean Up the Existing On- and Off-road Vehicles and Equipment
  - Diesel In-Use Fleet Rules
  - Engine Software Upgrade (“Chip Reflash”)
  - Idling Restrictions

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# Enforcement of Diesel Emission Standards

- To ensure compliance of emission standards in real-world use
  - Heavy-Duty Vehicle Inspection Program
  - Periodic Smoke Inspection Program

# SIP Strategies: Testing and Enforcement

- Augment Truck and Bus Highway Inspection with Community-Based Inspections
  - HDV Field NO<sub>x</sub> Screening Program
  - HD In-Use Compliance Program

# Development of a Field NOx Screening Test

- Portable dynamometers set up at roadside locations
- En route heavy-duty trucks detached from trailers
- Emissions testing for excess NOx conducted
- Repairs required for failing trucks

# NOx Screening Program Status

- Current data indicates difficulty in developing a NOx screening test
  - Per vehicle emission reductions from repair are minimal
  - No clear cut point to screen out high emitters
- ARB will continue to investigate magnitude and causes of high NOx emissions from HDD vehicles

# HDD In-Use Compliance Program

- Objective: Identify designs that fail to control emissions; correct with recall
- Current Obstacles
  - Need to test engine as it was certified
  - Time consuming: must remove engine
  - Expensive: approximately \$300K-\$700K
- Obstacles can be overcome based on the “Not-to-Exceed” (NTE) concept
- Implementation: 2007

# Possible Measures for Future

- OBD as an enforcement tool to ensure emission compliance
- Remote-sensing for roadside emissions testing
- In-use testing for off-road diesel engines

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# Proposed Stationary Diesel Engine ATCM

- Establishes emission limits and operating requirements for new and in-use stationary engines
- Requirements can be met using BACT
  - Restricted operation, retrofit, repower
- Diesel PM: 45% reduction by 2010 relative to 2002 baseline
- NO<sub>x</sub>: 30% reduction by 2010 (6 TPD)

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# 2004 SIP Summit

## Fuel

**January 13-14, 2004**

# Fuels Program Benefits

Fuels Program	Emissions Reduction				
	HC	NOx	PM	SOx	Toxics
<u>percent</u>					
Diesel	28	7	25	99	25
RFG	30	12	--	95	45
<u>tons/day</u>					
Diesel + RFG	410	200	20	120	na

# Diesel SIP Measures

- FUEL-1:
  - Keep clean measure: diesel deposit control additives
- FUEL-2:
  - Low-Sulfur Standards for On/Off-road motor vehicles and Stationary Engines (ADOPTED)

# Diesel Deposit Control Additives

## FUEL-1

- No current deposit control additive requirement for diesel fuel
- Issue may gain significance for 2007 engine designs

# Deposit Control Additives

## Potential Benefits

- Could reduce potential deposit formation in fuel systems and engines
- Keep engines closer to factory tolerances
- Minimize deterioration rate of engine-out emission levels

# Other Further Diesel Measures for Evaluation

- Enabling measure: reduced sulfur and ash in diesel engine lubricating oils
- Extend applicability of CARB diesel to marine and locomotive

# Diesel Engine Lubricating Oils

- Diesel engines consume (combust) lubrication oils as part of their normal operation
- Need to consider lubricating oil sulfur and ash content
  - Emissions
  - Impact on after treatment control technology

# Industry Efforts to Study Lubricant Effects on Aftertreatment Devices

- Government/Industry workgroup
  - DOE Advanced Petroleum-Based Fuels - Diesel Emissions Control (APBF-DEC) Program
- Private consortium
  - Southwest Research Institute Diesel Aftertreatment Sensitivity to Lubricants (DASL) / Non-Thermal Catalyst Deactivation (N-TCD)

# ASTM Heavy Duty Engine Oil Classification Panel

- Industry developing HD engine oil specifications for use with aftertreatment technology
  - Proposed Category 10 (PC-10)
  - Lower sulfur, phosphorous, and sulfated ash
  - Engine durability issues to be addressed
- Target API licensing: late 2006/early 2007

# Extend Applicability of CARB Diesel to Marine and Locomotive

- Apply to local and regionally fueled equipment
  - Marine
  - Locomotive: short haul and switchers
- Benefits:
  - Enables advanced control technologies
  - Provides criteria and toxic emission benefits
    - NO<sub>x</sub>, SO<sub>x</sub>, and Diesel PM

# Marine and Locomotive Cleaner Fuel Issues

- Challenges for line haul locomotives and oceangoing ships
  - Can fuel prior to arriving in California
  - Fuel storage capacity sufficient to minimize fueling in California
  - Most fuel dispensed in California consumed out-of-state
- Need national and international fuel regulations

# Potential Alternative Fuels Under Consideration

- Hydrogen
- CNG/LNG
- Bio Diesels (includes blends)
- Gas-to-Liquids (Fisher-Tropsch Diesel)
- Water Emulsified Diesel

# Summary of Diesel Measure Issues

- Diesel deposit control additives
  - Need to investigate feasibility of deposit control additives - effectiveness and cost
  - Time frame: 2010+
- Diesel engine lubricating oils:
  - Industry efforts may preclude regulatory need
  - Licensing of new API engine oil category targeted for late 2006/early 2007

# Summary of Diesel Measure Issues (cont.)

- Extend applicability of CARB diesel to marine and locomotive
  - CARB diesel for some marine and short haul locomotives and switchers
  - Adopt late 2004/early 2005
  - Need national and international fuel regulations for line haul locomotives and oceangoing ships

# Summary of Diesel Measure Issues (cont.)

- Alternative fuels under consideration
  - Potential reductions in NO<sub>x</sub> and PM
  - Availability of engine technologies
  - Incremental cost increase in comparison to conventional California diesel fuel

# Conclusions

- Potential for emissions benefits for diesel fuel by extending applicability to marine and locomotive
- Significant issues to be addressed
- Feasibility assessments require additional investigation
- National fuel standards would enhance program

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# Need to Reduce Emissions from Federal Sources

- Federal sources are responsible for one-third of NO<sub>x</sub> and two-thirds of diesel PM emissions
- U.S. EPA must continue programs to clean up new engines as well as the existing fleet
- ARB's diesel strategy is transferable to federal sources