

Cleaning Up Existing Diesel Engines

Tom Cackette

California Air Resources Board

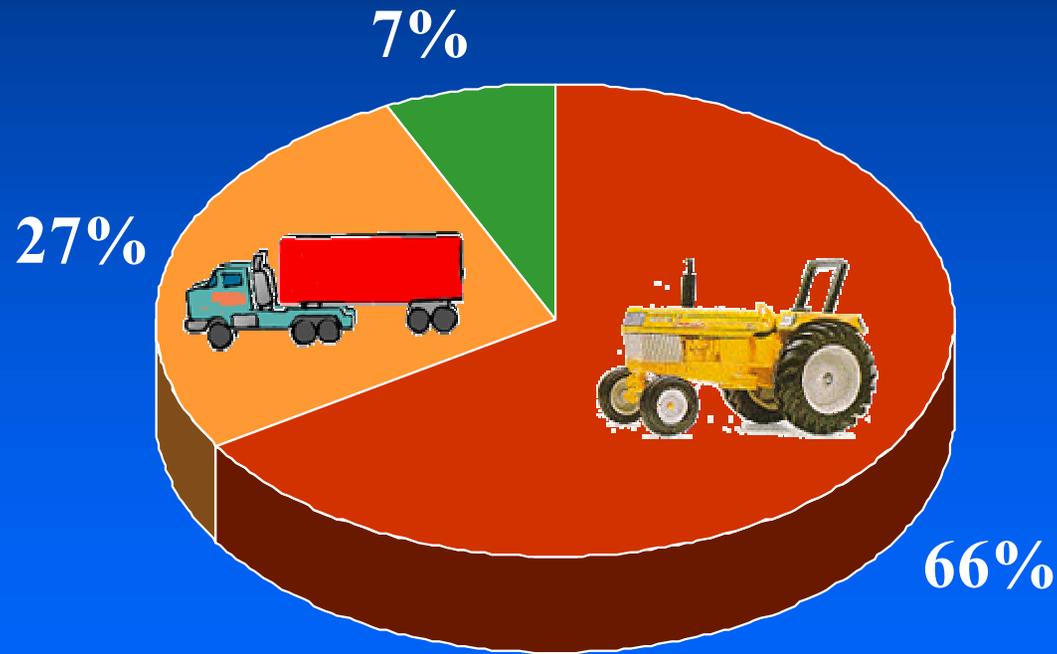
FACA Mobile Source Subcommittee

December 3, 2003

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

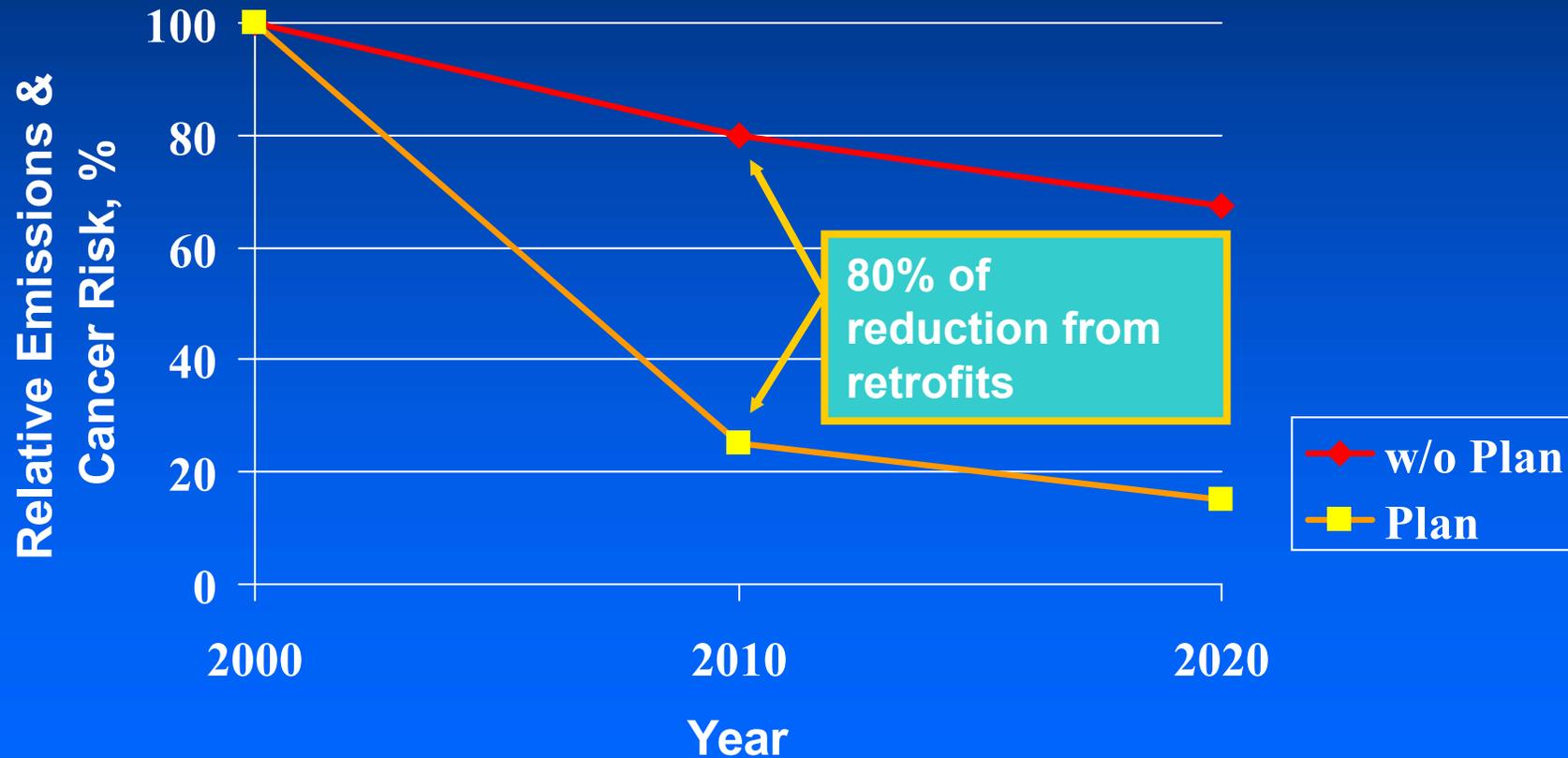
Diesel PM Emissions 2000



Diesel Risk Reduction Plan

- Established a goal
 - 75% reduction in diesel PM by 2010
 - 85% reduction in diesel PM by 2020
- Multiple strategies
 - On- and off-road vehicles and equipment
 - New engine standards - 98+% reduction
 - Cleaner diesel fuel - 15 ppm S
 - Retrofit of existing engines with filters
 - Ensure in-use compliance

PM Emissions and Risk Reduced 75+% w/ Plan



Status of Implementation

Diesel Risk Reduction Plan

- Reduce emissions from new engines
 - Trucks - **ADOPTED**
 - Off-road - **STANDARDS PROPOSED**
- Provide ultra-low sulfur fuel (<15ppm)
 - Available now, + **ADOPTED (2006.5)**
- Ensure in-use emission performance
 - Recall testing - **AGREEMENT REACHED**
 - OBD - **PROPOSAL: APRIL, 2004**
- Require retrofit of existing engines
 - Transit - **ADOPTED**
 - Trash trucks - **ADOPTED**
 - 7 Others - **PLANNED 2003 - 2005**

Mandatory Retrofit Programs Adopted

- Based on use of BACT
 - Repower, Retire, Replace, Retrofit
- Transit buses (8,000)
 - Retrofits begin 2003, complete 2009
- Trash trucks (13,000)
 - Retrofits begin 2004, complete 2011

Schedule for Adopting Additional Retrofit Regulations

- 2003 (remainder of)
 - Stationary engines
 - Transportation refrigeration units
 - Chip re-flash

Schedule for Adopting Additional Retrofit Regulations

- 2004
 - Fuel delivery trucks
 - Public fleets
- 2005+
 - Private on-road fleets
 - Private off-road fleets

Anatomy of the Trash Truck Rule

- Use best available retrofit technology
- Long phase-in: 2004-2010
 - Start with 1988-2002 engines - retrofits available (filters; catalysts)
 - Old engines next - re-engine or replacement
 - Newer engines last - filters
- Compliance flexibility
- Early compliance credit

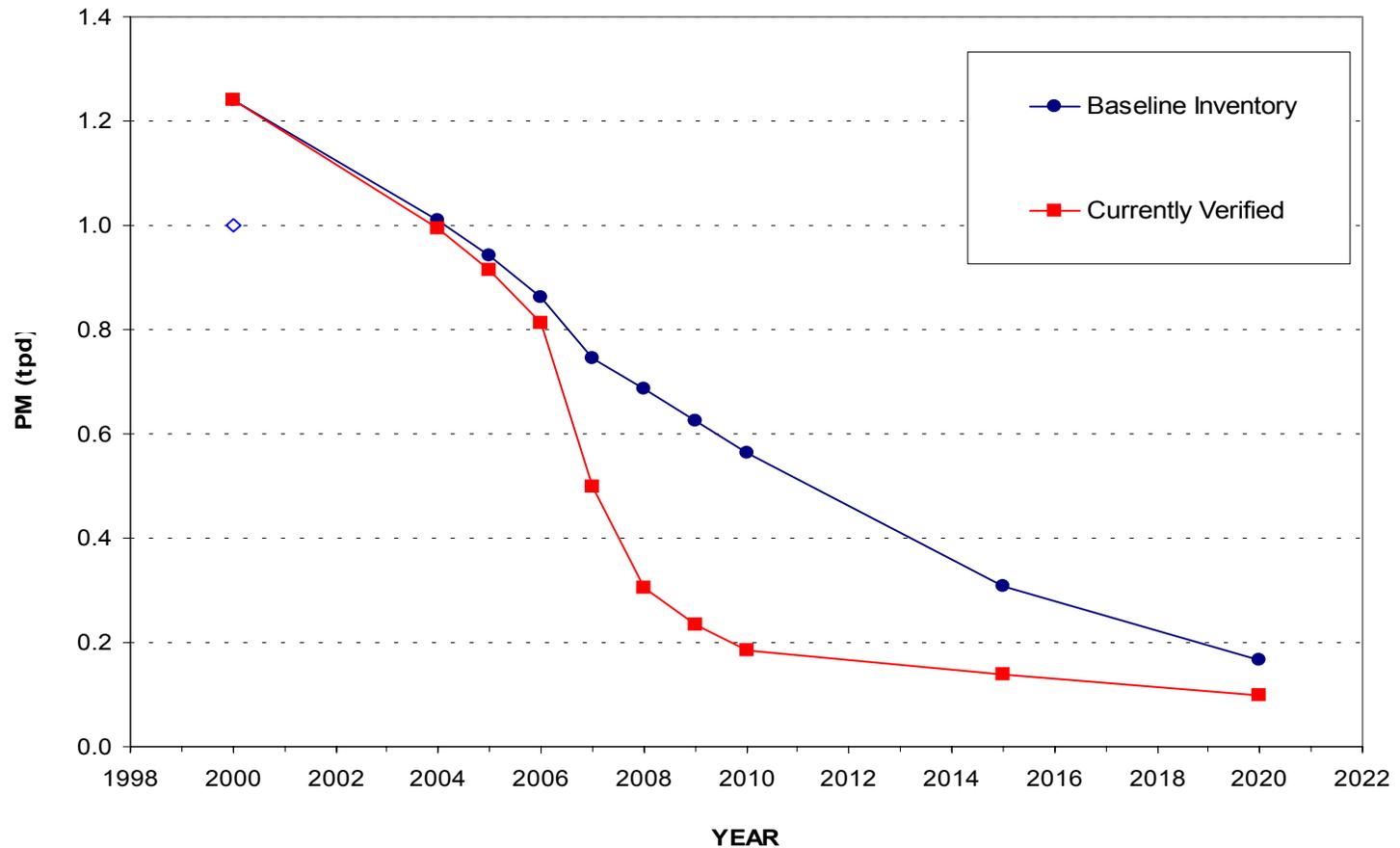
Possible Implementation Scenario -Trash Trucks*

Eng MY	Level 1-catalysts	Level 2-fuels	Level 3-DPFs	Repower
1960-1987	n.v.	n.v.	n.v.	100%
1988-1990	n.v.	n.v.	n.v.	100%
1991-1993	95%	n.v.	n.v.	5%
1994-2002	66%	n.v.	29%	5%
2003-2006	70%	n.v.	30%	0

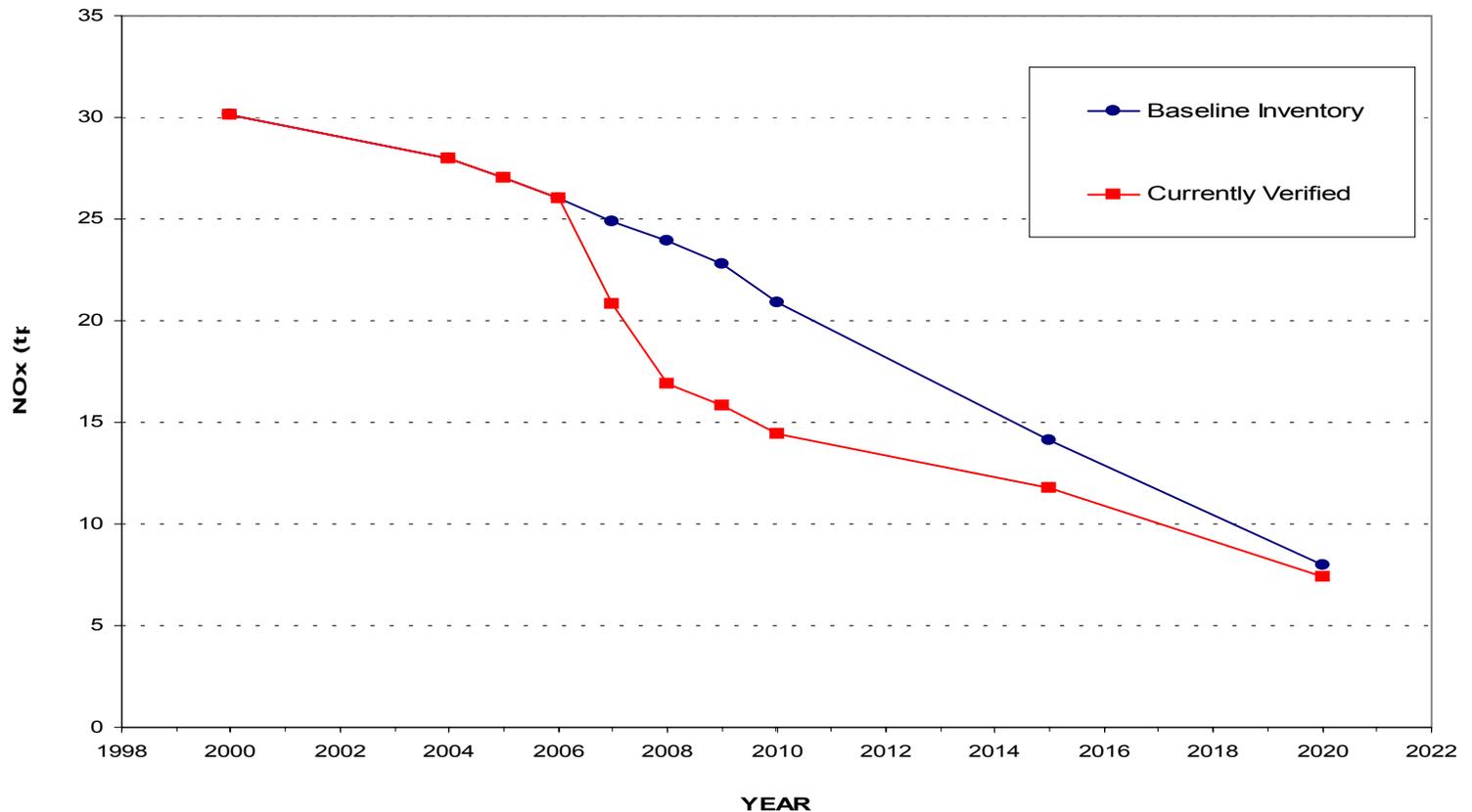
N.V. = not verified

* Based on currently verified equipment only

PM Emission Reductions: Trash Truck Rule



NO_x Emission Reductions: Trash Truck Rule



Cost and Cost Effectiveness (based on trash truck rule)

- Cost
 - PM filters -- \$5,500
 - PM + NOx reduction -- \$14,000
 - Oxidation catalysts -- \$3,100
 - Re-engine -- \$50,000
 - Replace vehicle - \$150,000-\$250,000
- Cost effectiveness
 - PM: \$32/lb; \$900,000/death avoided
 - NOx+HC: \$1.80/lb

Worldwide Experience with PM Filters

- Retrofit Programs in Sweden, Germany, Switzerland, Hong Kong, Taiwan, London, Paris, Mexico City, Tokyo, and California -
 - Over 100,000 as of 2003
 - Transit Buses, Sanitation Trucks, Delivery Trucks, Construction Equipment, etc.

Experience with PM Filters

- BP-Arco Demo
 - Grocery Trucks, Fuel Tanker Trucks, Buses, Delivery Trucks
 - Over 3 million miles driven since 2000
 - Fuel Delivery Truck
 - >500,000 miles w/ filter*
 - Grocery Truck
 - >350,000 miles w/ filter*

* As of late 2003

Experience with PM Filters

- Sanitation Trucks
 - City of Los Angeles
 - >350 Refuse Trucks Retrofitted
- School Buses
 - >500 Retrofits
- Conclusions
 - Transparent to End User
 - Reliable
 - Durable
 - No Fuel Penalty

Retrofit Verification Requirements

- Required PM Reduction - 25% Minimum
- Optional NOx Reduction - 15% Minimum
- Emission Testing
- Durability Demonstration
- Emission Control Group/Applicability
- Warranty
- In-Use Compliance Testing
 - Consistent with U.S. EPA Requirements

Fuel Based Strategies

- Require Multimedia Assessment
- Fuel Additives
 - Must be used with diesel particulate filter unless proven safe to use alone
 - Additional tests at high dose
 - Require review of environmental and health-related data every two years
 - On-board monitor of fuel additive level

Harmonization of CARB and EPA Verification Procedures

- **Harmonized Items**
 - Test Cycles
 - Test Fuels
 - Durability Demonstration
 - In-Use Compliance Testing
 - Use of Existing Data to Support Extension
- **Items Not Yet Harmonized**
 - Third Party Testing
 - Engine Testing/Chassis Testing
 - Multimedia Assessment
 - Warranty Requirements
 - NO₂ Limit
- **On-going joint efforts to further harmonize and streamline**

Current Verification Status

- Level 1: 25% or greater PM reduction
 - DOC's
- Level 2: 50% or greater PM reduction
 - No Systems Verified Yet
- Level 3: 85% or greater PM reduction
 - Active and passive DPF's
- On-going application process
 - 102 applications received to date
 - 38 applications currently in active review process

Status of Technology Verification

- **PM Filter (85+% PM reduction)**
 - **94 + on-road/NOx Reduction**
 - **94 + on-road dual-fuel**
 - **94-2002 Cummins/Navistar on-road + NOx**
 - **96 stationary emergency generators**
- **Oxidation catalyst (25+% PM reduction)**
 - **91+ on-road 4 strokes**
 - **93 + Cummins on-road + NOx**
 - **96 + off-road port equipment**
- **Fuel reformulation - None**
- **New replacement engine - Many available**

Status of Retrofit Technology - Summary

- **On-road**
 - 94-2003
 - Filters, OxyCats
 - 91-2003
 - OxyCats
 - Pre-91 - none yet
- **Off-road**
 - 96-2003
 - OxyCats
 - Filters for SS emergency generators
 - Pre-96 - None yet

Current Verifications

By Company/Level

- **Level 3:**

- Johnson Matthey CRT DPF
- Engelhard DPX DPF
- Cleaire Flash and Catch CRT (**25% NOx Reduction**)
- Cleaire Flash and Catch DPX (**25% NOx Reduction**)
- Cleaire Longview DPF + Lean NOx (**25% NOx Reduction**)
- Clean Air Partners DPF
- CleanAIR Systems DPF

- **Level 1:**

- Cleaire Flash and Match (**25% NOx Reduction**)
- Donaldson DOC Spiracle
- Donaldson DOC + Spiracle
- Donaldson DOC Spiracle + USLD

Other Technologies Undergoing Verification

- Fuel Water Emulsion
- Alternative Diesel Fuel
- Fuel Borne Catalysts
- Additives
- Water Injection Systems
- Active Regeneration Systems
- Off-Board Regeneration System
- Flow Through Filters
- SCR

Summary

- Passive filter application 1994+, not all applications
- Catalysts 1991+
- Older vehicles: re-engine or replace
 - Achieves PM and NOx reduction
- Mandatory fleet retrofit rules evolving from filter based to modernization w/ filters for newer engines
- Reductions cost effective