Workshop on Heavy-Duty Vehicle Regulations

U.S. AND CALIFORNIA HEAVY-DUTY TRUCK PROGRAM

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California Air Resources Board

Delhi, India –
April 29, 2015

California Environmental Protection Agency
Air Resources Board

Outline

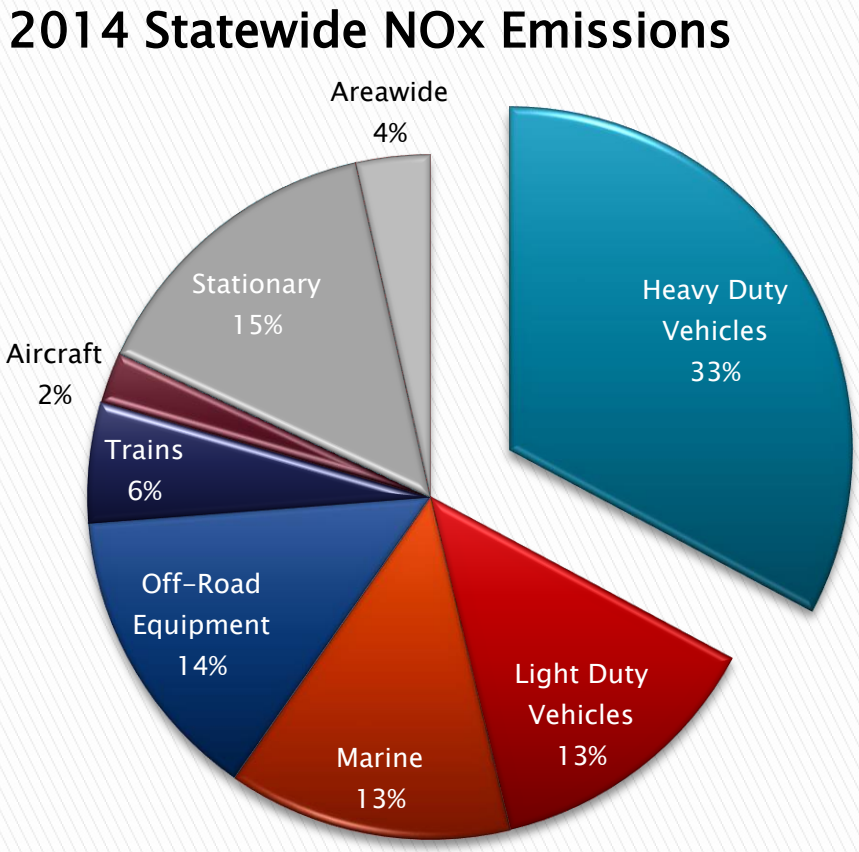
- Heavy-Duty Truck Background
  - Emissions Contribution
  - Drivers for Reducing GHG and Criteria Pollutants
  - NOx & PM Standards History
  - Current Engine Technologies
- Greenhouse Gas Control in U.S./California
  - U.S. EPA SmartWay Program
  - ARB Tractor-Trailer GHG Regulation
  - Phase 1 GHG Standards
- Development of Phase 2 GHG Standards
- Conclusions
- Contact Information

Heavy-Duty Truck Background

- Emissions Contribution , Drivers for Reducing Emissions, NOx & PM Standards History, Current Emission Controls in U.S.

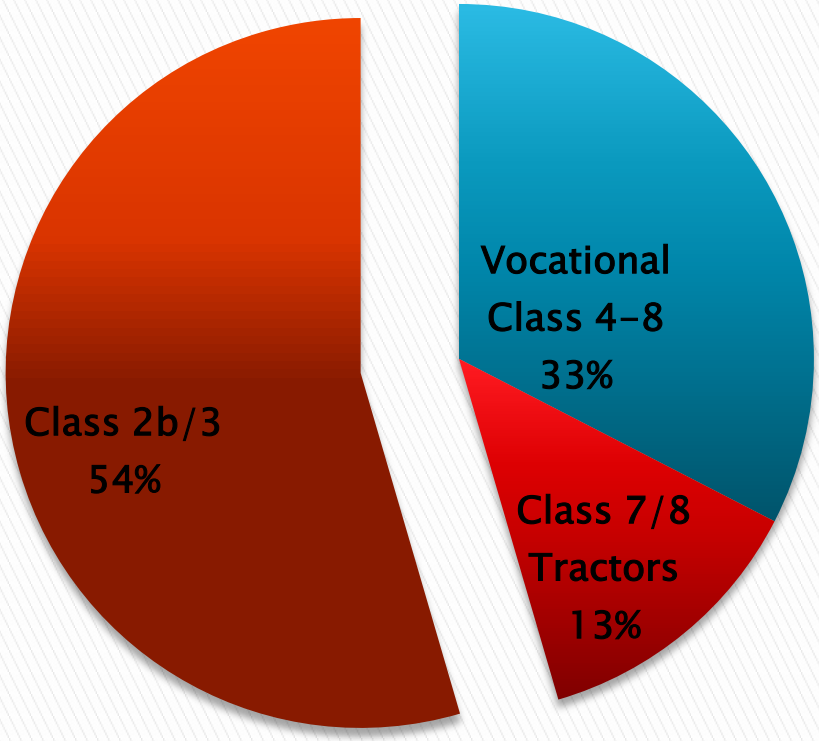
Heavy Duty Trucks: Significant Source of Emissions

- 33% of statewide NOx emissions
- 26% of statewide diesel PM2.5 emissions
- 8% of statewide GHG emissions



Class 2B/3 Dominate the Populations of Heavy Duty Trucks

Population by Heavy Duty Truck Type

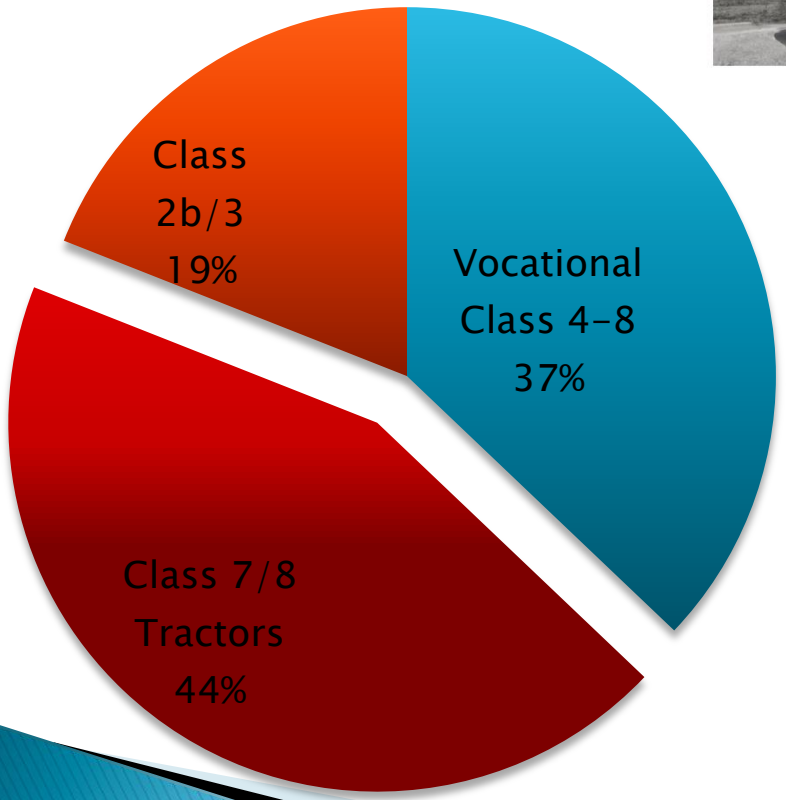


EMFAC 2014, CALENDAR YEAR 2014

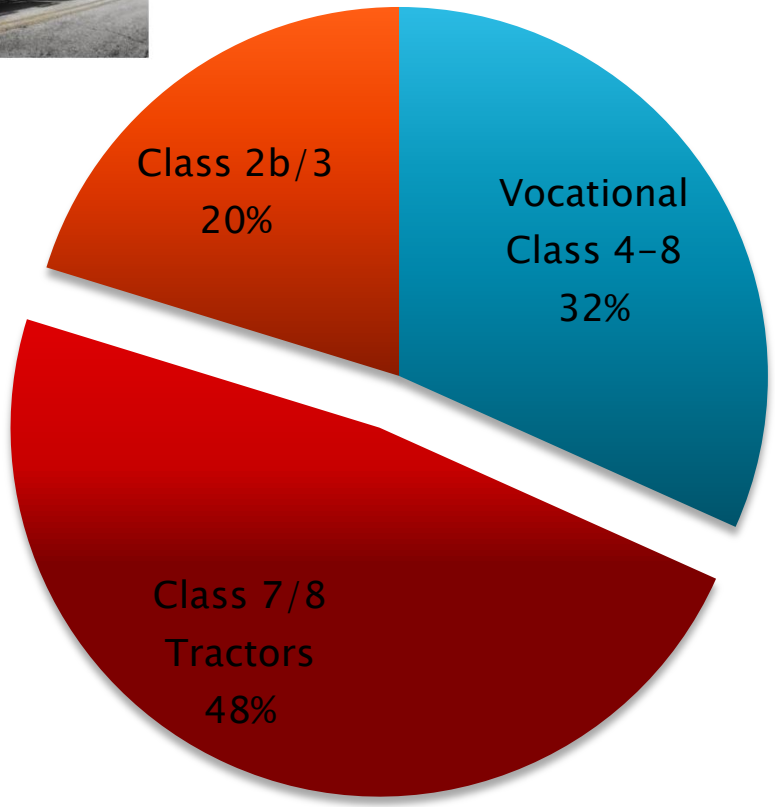
Nearly 2 million Heavy Duty Trucks (GVWR >8500 lbs.) Operating in California

Class 7/8 Trucks Dominate Emissions

NOx Emissions



CO2 Emissions



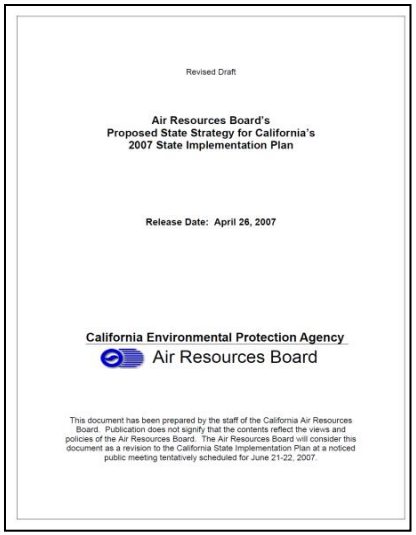
*Emissions for Calendar Year 2014

Drivers for Reducing GHG and Criteria Pollutants in U.S.

- Clean Air Act of 1970 (amended in 1977 and 1990)
  - National Ambient Air Quality Standards
    - ✓ Ozone, fine particulate matter, etc.
  - Control of motor vehicle emissions
- 2007 U.S. Supreme Court action
  - Defines greenhouse gases as "air pollutants"
  - Directs EPA to conduct scientific review
- 2009 U.S. EPA endangerment finding
  - Climate change "an enormous problem"
  - Six gases identified – carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride
- President's Climate Action Plan, June 2013
  - Reduce U.S. greenhouse gas emissions ~17 % below 2005 levels by 2020.
  - Fuel economy standards
  - Biofuels

Drivers for Reducing GHG and Criteria Pollutants – California

- State Implementation Plans for Ozone, PM
  - 2023 and 2032 federal Ozone standards
  - 90% further reduction in NOx needed
- Assembly Bill 32 – Back to 1990 GHG level emissions by 2020


Revised Draft

Air Resources Board's
Proposed State Strategy for California's
2007 State Implementation Plan

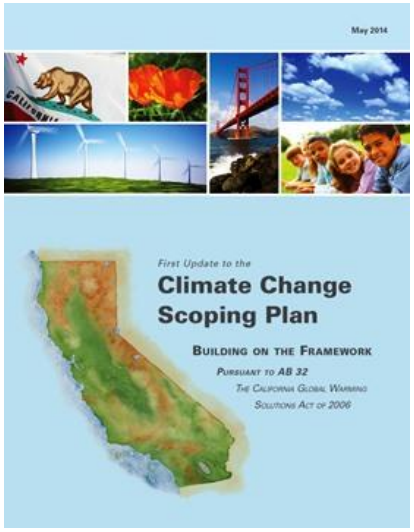
Release Date: April 26, 2007

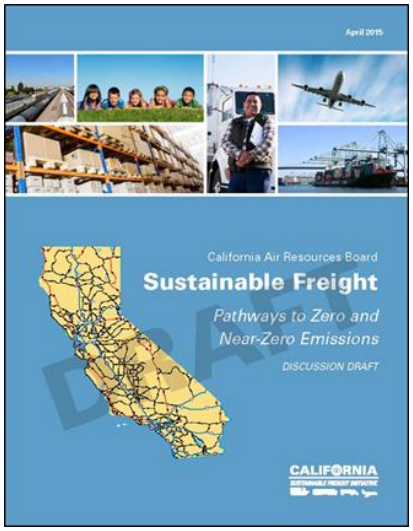
California Environmental Protection Agency
Air Resources Board

This document has been prepared by the staff of the California Air Resources Board. Publication does not signify that the contents reflect the views and policies of the Air Resources Board. The Air Resources Board will consider this document as a revision to the California State Implementation Plan at a noticed public meeting tentatively scheduled for June 21-22, 2007.

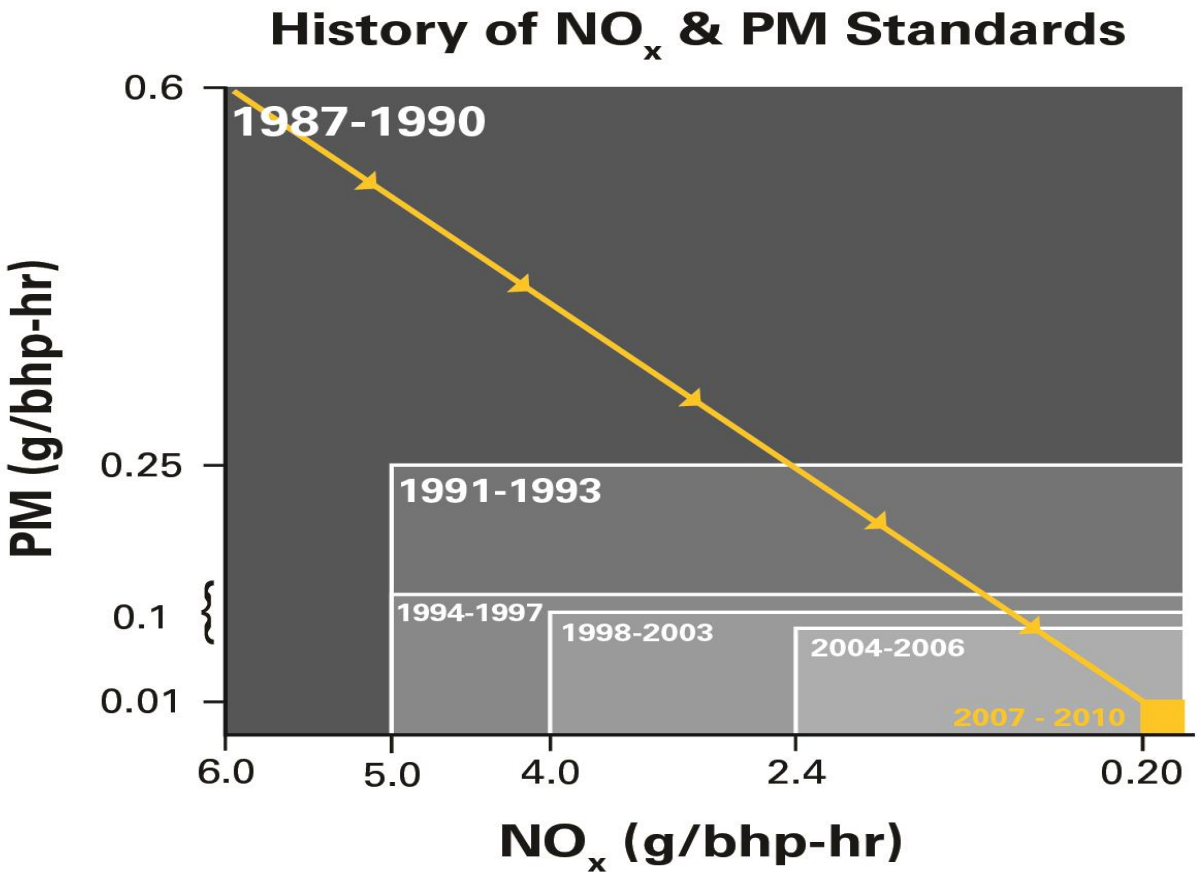
•E.O. S-3-05 – Reduce GHG 80% below 1990 by 2050

•Reduce petroleum usage by ~50% by 2030 (Governors' directive)





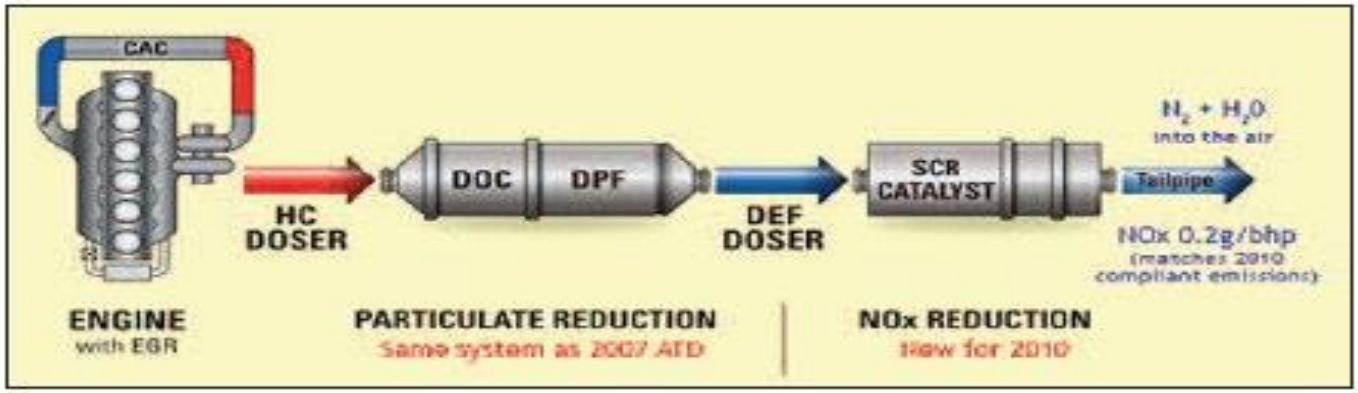
NOx & PM Engine Standards



About 97% reduction in 20 years

Current U.S./California On-road Heavy-Duty Engine Technologies

- 2010 model year engine standards:
  - NOx: 0.20 g/bhp-hr (0.27 g/kWh) & PM: 0.01 g/bhp-hr (0.013g/kWh)
  - Use of Selective Catalytic Reduction (SCR) and Diesel Particulate Filter (DPF), requires low-sulfur diesel fuel



- California in-use programs require turnover to vehicles with these engines

Heavy-Duty Truck Greenhouse Gas Control in U.S./California

Voluntary U.S. EPA Smartway program, ARB Tractor Trailer GHG reg, Phase 1 standards

SmartWay® Transport Partnership
U.S. Environmental Protection Agency

Progression of U.S./California GHG Control

2003	• Voluntary Federal Program, began MY 2003
2010	• Mandatory California Program – Retrofits and new tractor/trailers
2011	• Phase 1 adopted federally – Federal New Vehicle standards – model year 2014+, ratchet down in 2017; based on "off the shelf" technologies
2013	• Phase 1 adopted in California
2016	• Phase 2 to be adopted federally – MY 2018+ to be regulated
2017	• Phase 2 to be adopted in California

U.S. EPA SmartWay Voluntary Program

U.S. EPA SmartWay Program

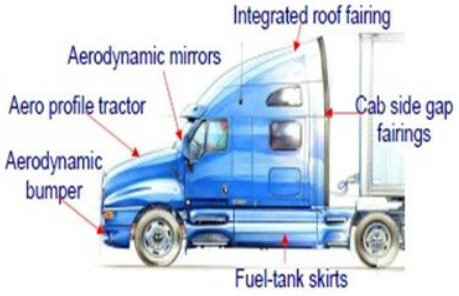
- Developed in 2003
- Government/industry collaboration
- Voluntarily improve fuel efficiency and reduce environmental impact from freight transport
- EPA Technology Verification for SmartWay Designation: quantify emissions reduction and fuel saving from available technologies
  - Tractor
  - Trailers
  - Idle reduction
  - Low rolling resistance tires

http://www.epa.gov/smartway/

U.S. EPA SmartWay Program Cont'd

- SmartWay Trailers and Aerodynamic Devices:
  - Verified to have 1%–9%+ fuel savings

- SmartWay Tractors: Design features including:
  - Model Year 2007 or later engine;
  - Integrated sleeper cab high roof fairing;
  - Tractor-mounted side fairing gap reducers;
  - Tractor fuel-tank side fairings;
  - Aerodynamic bumper and mirrors;
  - Idle reduction;
  - Low-rolling resistance tires
- SmartWay Tires:
  - Low rolling resistance
  - 3%+ fuel consumption reduction



http://www.epa.gov/smartway/

ARB Mandatory Tractor-Trailer GHG Regulation

ARB Tractor-Trailer GHG Regulation

- Adopted 2008, effective 2010
- Reduce GHG emissions from tractor-trailers using aerodynamic devices and low rolling resistance tires
- In-use fleet rule applies to:
  - Tractors pulling 53’ or longer trailers
  - 53’ or longer box-type trailers
- Based on elements of U.S. EPA SmartWay program

ARB Tractor-Trailer GHG Regulation Cont'd

Vehicle Category	Current TTGHG Rule Requirements
Tractor (MY 2011 and newer)*	• Aerodynamic • Low Rolling Resistance Tires
Tractor (MY 2010 and older)	• Low Rolling Resistance Tires
Trailer (53 foot box-type)	• Aerodynamic • Low Rolling Resistance Tires

* - California-specific MY2014 requirements removed when California adopted Phase 1 program, to remove duplication

U.S. EPA Mandatory Phase 1 New Vehicle/Engine Standards

U.S. EPA Phase I Standards: Overview

- Establishes GHG standards for engines, vehicles
- Begins in MY2014, stringency increases to 2018
- Vehicle standards in three categories
  - Combination tractors (class 7 and 8)
  - Vocational vehicles (class 2b – 8)
  - Heavy-duty pickups and vans (class 2b, 3)
- Engine standards: HD gasoline and diesel engines
- Advanced technology and early compliance credits
- Flexibility with averaging, banking, trading (ABT)

http://www.epa.gov/otaq/climate/regs-heavy-duty.htm

U.S. EPA Phase I: Combination Tractors

- Vehicle CO2 standards (gCO2/ton-mile):

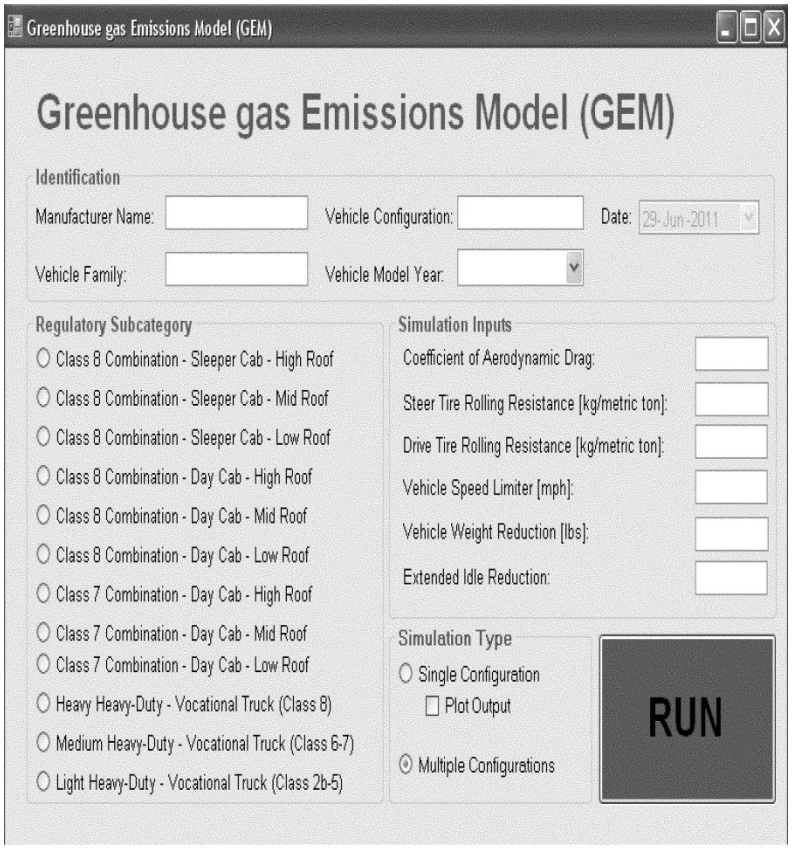
HD Combination Tractor Vehicle Standards (gCO2/ton-mile)						
	2014-2016 MY			2017 MY and beyond		
	Class 7	Class 8		Class 7	Class 8	
		Day Cab	Sleeper Berth		Day Cab	Sleeper Berth
Low Roof	107	81	68	104	80	66
Mid Roof	119	88	76	115	86	73
High Roof	124	92	75	120	89	72

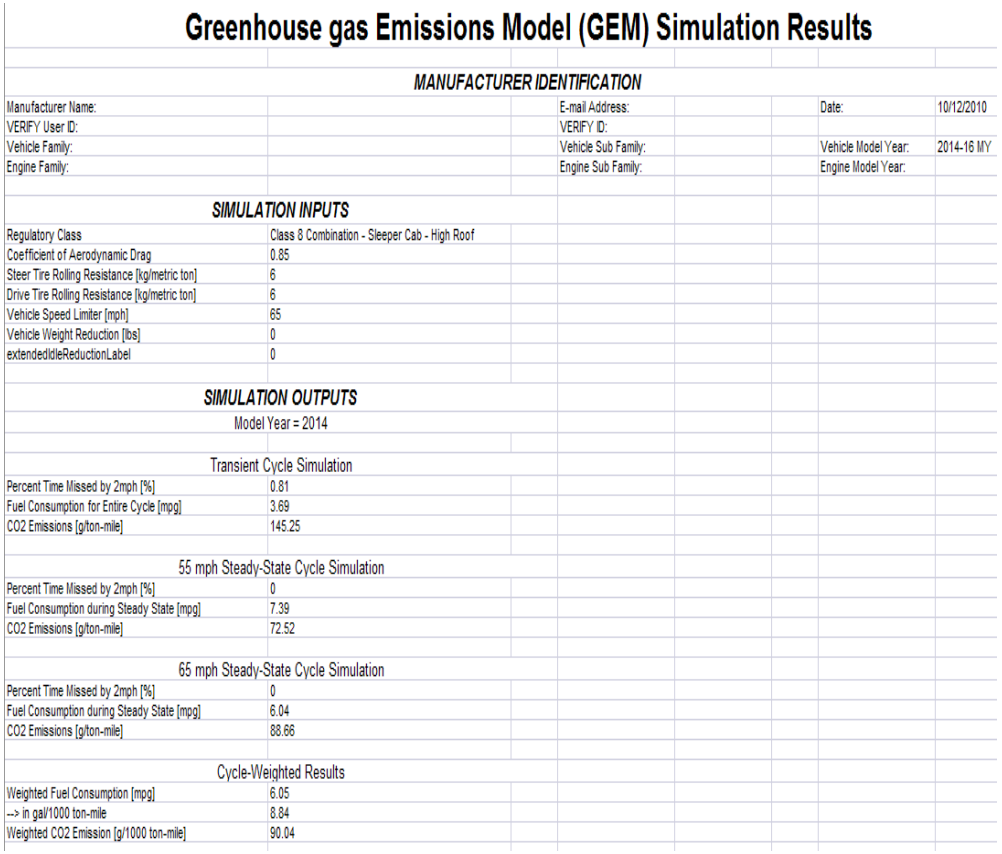
- Estimated 10-23% reduction by 2018 vs. 2010

U.S. EPA Phase I: Combination Tractors (cont.)

- Demonstrate compliance with GHG Emissions Model (GEM):
  - U.S. EPA model evaluates impact of tractor strategies
- Input variables include:
  - Coefficient of drag;
  - Tire rolling resistance coefficient;
  - Weight reduction;
  - Vehicle speed limiter;
  - Extended idle reduction strategies

GHG Emissions Model (GEM) – Graphical User Interface





Greenhouse gas Emissions Model (GEM) Simulation Results

MANUFACTURER IDENTIFICATION

Manufacturer Name:		E-mail Address:		Date:	10/12/2010
VERIFY User ID:		VERIFY ID:			
Vehicle Family:		Vehicle Sub Family:		Vehicle Model Year:	2014-16 MY
Engine Family:		Engine Sub Family:		Engine Model Year:	

SIMULATION INPUTS

Regulatory Class	Class 8 Combination - Sleeper Cab - High Roof
Coefficient of Aerodynamic Drag	0.85
Steer Tire Rolling Resistance [kg/metric ton]	6
Drive Tire Rolling Resistance [kg/metric ton]	6
Vehicle Speed Limiter [mph]	65
Vehicle Weight Reduction [lbs]	0
extendedIdleReductionLabel	0

SIMULATION OUTPUTS

Model Year = 2014

Transient Cycle Simulation

Percent Time Missed by 2mph [%]	0.81
Fuel Consumption for Entire Cycle [mpg]	3.69
CO2 Emissions [g/ton-mile]	145.25

55 mph Steady-State Cycle Simulation

Percent Time Missed by 2mph [%]	0
Fuel Consumption during Steady State [mpg]	7.39
CO2 Emissions [g/ton-mile]	72.52

65 mph Steady-State Cycle Simulation

Percent Time Missed by 2mph [%]	0
Fuel Consumption during Steady State [mpg]	6.04
CO2 Emissions [g/ton-mile]	88.66

Cycle-Weighted Results

Weighted Fuel Consumption [mpg]	6.05
--> in gal/1000 ton-mile	8.84
Weighted CO2 Emission [g/1000 ton-mile]	90.04

Source: U.S. EPA, GEM User Guide

U.S. EPA Phase I: Combination Tractors (cont.)

- Anticipated compliance strategies:
  - Engine improvements
  - Auxiliary power units
  - Mass reduction
  - LRR tires
  - Improved aerodynamics
  - Reduced AC leakage

U.S. EPA Phase I: Vocational Vehicles

- Vehicle CO2 standards (gCO2/ton-mile):
  - Estimated 10% reduction on average by 2018 vs. 2010

Vocational Vehicle CO2 Standard (gCO2/ton-mile)			
	LHD Class 2b-5	**MHD Class 6-7**	**HHD Class 8**
2014 MY	388	234	226
2017 MY	373	225	222

- Examples of vocational vehicles:
  - Delivery, refuse and cement trucks
  - Transit, shuttle and school buses
  - Emergency vehicles, motor homes and tow trucks

U.S. EPA Phase I: Vocational Vehicles (cont.)

- GHG Emissions Model (GEM) Compliance:
  - Standards apply to chassis manufacturer (not vehicle)
  - Input variable: Tire rolling resistance coefficient
  - May alternately certify the same way as Class 2b-3 HD pickup trucks and vans through fleet average standard
- Anticipated compliance strategies:
  - Engine improvements
  - Increased use of LRR tires

U.S. EPA Phase I: HD Pickups and Vans

- Separate CO2 targets for SI and CI powered vehicles
- Estimated 15% lower CO2 by 2018 for CI engines; 10% lower CO2 for SI engines (vs. 2010)
- Fleet average standard for manufacturer that applies to combined HD pickups and vans produced in each model year
- Unique standard for each model year, dependent upon load capacity and production volume of each vehicle model

U.S. EPA Phase I: HD Pickups and Vans (cont.)

- N2O and CH4 standards (1037.104(c)):
  - N2O Vehicle Standard: 0.05 g/mile
  - CH4 Vehicle Standard: 0.05 g/mile
- Effective with 2014 and subsequent MYs
- Light-duty FTP and HFET drive cycle testing
- CO2 credits can be used to offset this requirement

U.S. EPA Phase I: HD Pickups and Vans (cont.)

- Certification:
  - Dynamometer testing
  - No GEM model simulation

- Anticipated compliance strategies:
  - Engine improvements, improved transmissions
  - Reduced accessory loads
  - LRR tires, mass reduction

U.S. EPA Phase I: HD Engine CO2 Standards

- Gasoline engine CO2 standard:
  - 627 gCO2/bhp-hr (MY 2016 and beyond)
- Diesel engine CO2 standards (gCO2/bhp-hr):

Final HD Diesel Engine Standards (gCO2/bhp-hr)					
	LHD (2b-5)	MHD (Class 6-7)		HHD (Class 8)	
		Vocational Veh	Tractors	Vocational Veh	Tractors
2014-2016 MY	600	600	502	567	475
2017 and Later	576	576	487	555	460

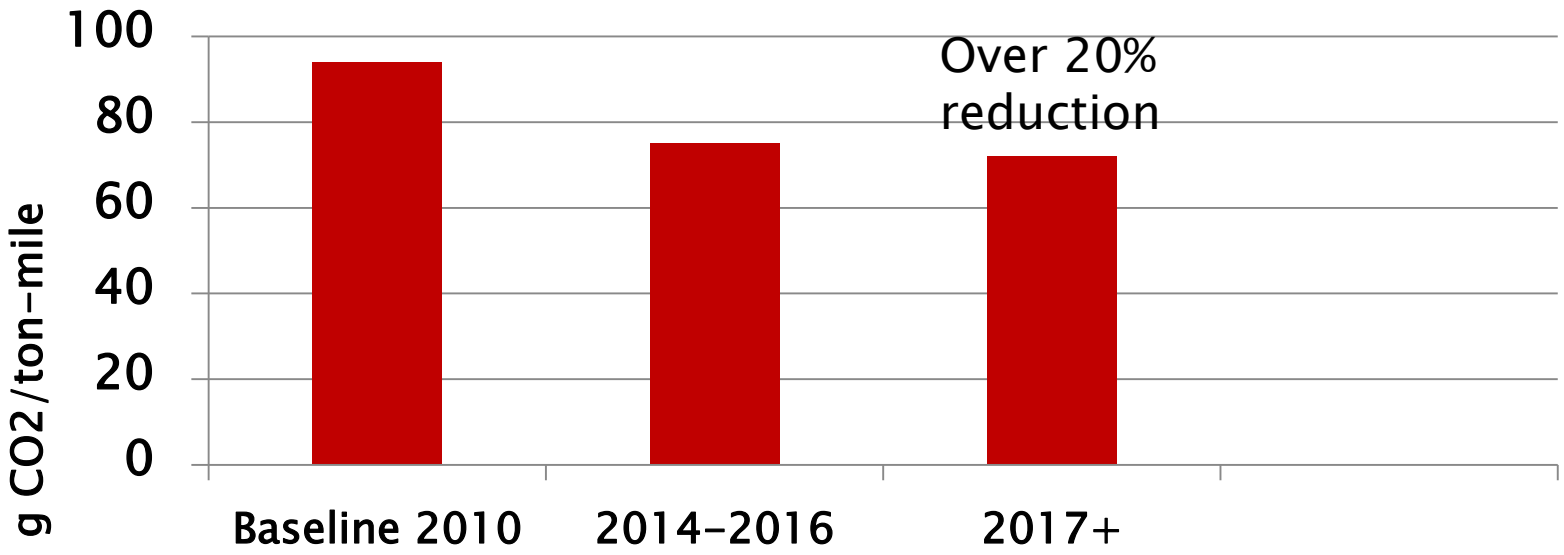
U.S. EPA Phase I: HD Engines – Other Pollutants

- N2O and CH4 standards for all HD engines:
  - 0.10 g/bhp-hr (N2O) and 0.10 g/bhp-hr (CH4)
  - Effective for 2014 MY and later CI engines
  - Effective for 2016 MY and later SI engines
- HFC Standards (Tractors, HD Pickups & Vans)
  - Effective for 2014 MY tractors and later
  - Leakage limits

ARB Phase 1 GHG Standards

- In 2013, California adopted Heavy-duty Phase 1 GHG regulations:
  - Harmonized with the federal standard in 2013
  - Substantially identical to the federal program
- Allows ARB to enforce program in California

Phase 1 Standards Cut GHG > 20%



* g CO2/ton-mile Phase 1 standards for Class 8 high-roof sleeper cabs

Development of Phase 2 GHG Standards

- Ongoing now

Development of Phase 2 GHG Standards – Anticipated Schedule

- U.S.EPA, the National Highway Traffic Safety Administration, and ARB working jointly
- U.S. EPA: Adopt GHG Phase 2 final rule in 2016
  - Proposal expected in May–June 2015
- ARB: Adopt in 2016

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NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Technologies for GHG Reduction

ENGINE BASED TECHNOLOGIES

1. Advanced Transmissions/Engine Downspeeding
2. Advanced Combustion Cycles
3. Waste Heat Recovery
4. Engine Downsizing
5. Stop-Start
6. Automatic Neutral Idle
7. Combustion and Fuel Injection Optimization
8. Higher-Efficiency Aftertreatment
9. Reduced Friction and Auxiliary Load Reduction
10. Air Handling Improvements
11. Variable Valve Actuation/ Cylinder De-activation

VEHICLE BASED TECHNOLOGIES

1. Aerodynamics
2. Lightweighting
3. Low-Rolling Resistance Tires
4. Automatic Tire Inflation System
5. Vehicle Speed Limiters
6. Connected Vehicles (Platooning, predictive cruise control)
7. Axle Efficiency
8. Idle Reduction
9. Improved Air Conditioning System

For details, please see the technology assessment presentations at http://www.arb.ca.gov/msprog/tech/presentation.htm

Payback on many technologies is short

Heavy Duty Class 7-8 Tractors Key Technologies
Over-The-Road Tractor Trailers

	KEY TECHNOLOGIES	Potential GHG/FC Reduction (per Vehicle) from 2010 baseline		Incremental Cost from 2010 baseline	
		Tech. Assessment	Post-Phase 1	Tech. Assessment	Post-Phase 1
Engine/ Drivetrain	• Combustion and Fuel Injection Optimization • Air Handling Improvements • Reduced Friction and Auxiliary Load Reduction • Downsizing • Higher efficiency aftertreatment • Advanced Transmissions /Engine • Downspeeding • Waste Heat Recovery	43% (25%-60%)	**22%*** (8%-36%)	$37,550 ($16,800-$58,300)	**$29,100** ($8,700-$49,500)
Vehicle	• Aerodynamics • Low-Rolling Resistance Tires • Automatic Tire Inflation System • Air Conditioning System Improvements • Axle Efficiency • Predictive Cruise Control • Idle Reduction				

*$14,200 savings after first year

Daimler SuperTruck Recently Demonstrated 12.2 mpg

- 312-mile round trip on Texas Interstate 35 between San Antonio and Dallas at an average of 65 mph.
- Engine/Powertrain: **50%** Brake Thermal Efficiency improvement*
  - Improved technologies: combustion, turbocharging, waste heat recovery, engine downsizing, controllable/electrified auxiliary systems, hybridization
- Freight: **115%** Freight Efficiency improvement*
  - Improved technologies: aerodynamic (skirts, gap reduction, boat tail, active grill, tractor and cab redesign), 6X2 axles, single wide tires, solar roof on trailer, 1500 lbs. weight reduction and eCoast.

*as compared to 2009 engine/freight efficiency

Issues During Development of Phase 1/2 Standards

- Engine vs. vehicle standards
- Potential NOx/GHG tradeoff
- Small business impacts
  - Lots of small businesses build vocational vehicles, make trailers
- Form of standard – g/ton-mile
- Differing standards for gas vs. diesel?

Issues During Development of Phase 1/2 Standards Cont'd

- How to reflect benefits of transmission improvements
- Vocational vehicles – how to regulate, given one company makes chassis, another makes body
- How/whether to include trailers
- How to incorporate vehicle performance when there are near infinite vehicle designs, tractor/trailer combinations
- Tire labeling/enforcement

Conclusions and Contacts

- Phone and Email

Conclusions

- Heavy duty vehicles are a significant source of emissions in California and U.S.
- Technology advances and regulations, including the Phase 1 standards, have led to much improvement in reduction of criteria and GHG emissions
- Need large further improvements, so much work ahead

Contact Information

- Websites:
  - U.S. EPA: http://www.epa.gov/otaq/climate/regs-heavy-duty.htm

    *Phase 1: See Federal Register 76 FR 57106, September 15, 2011, 40 CFR Parts 1036, 1037, 1065, 1066; and 49 CFR Parts 523, 534, 535

  - ARB: http://www.arb.ca.gov/homepage.htm

    *Phase 1: http://www.arb.ca.gov/msprog/onroad/phaselghg/phaselghg.htm

    *Phase 2: http://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm

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- California ARB:

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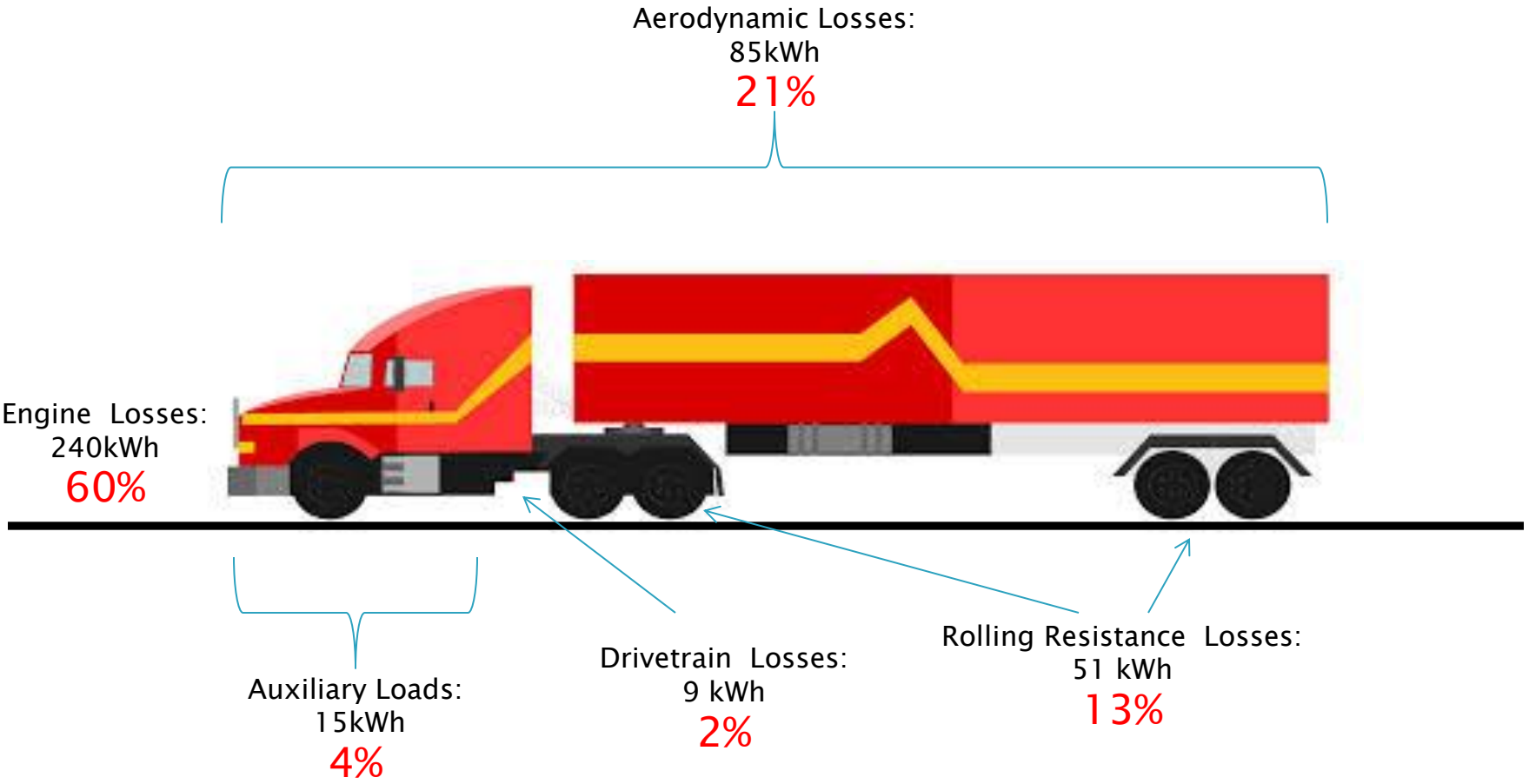
Backup slides

Key Sources of Energy Losses



Based on Data from U.S. DOE (21st Century Truck Partnership). 2006