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

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

Population by Heavy Duty Truck Type

- Class 2b/3: 54%
- Vocational Class 4–8: 33%
- Class 7/8 Tractors: 13%

EMFAC 2014, CALENDAR YEAR 2014
Class 7/8 Trucks Dominate Emissions

NOx Emissions

- Class 2b/3: 19%
- Vocational Class 4–8: 37%
- Class 7/8 Tractors: 44%

CO2 Emissions

- Class 2b/3: 20%
- Vocational Class 4–8: 32%
- Class 7/8 Tractors: 48%

*Emissions for Calendar Year 2014
Drivers for Reducing GHG and Criteria Pollutants in U.S.

  - 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
  - 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

History of NOx & PM Standards

PM (g/bhp-hr)

NOx (g/bhp-hr)

1987-1990
1991-1993
1994-1997
1998-2003
2004-2006
2007-2010

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
## Progression of U.S./California GHG Control

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>2003</td>
<td>Voluntary Federal Program, began MY 2003</td>
</tr>
<tr>
<td>2010</td>
<td>Mandatory California Program – Retrofits and new tractor/trailers</td>
</tr>
<tr>
<td>2011</td>
<td>Phase 1 adopted federally – Federal New Vehicle standards – model year 2014+, ratchet down in 2017; based on “off the shelf” technologies</td>
</tr>
<tr>
<td>2013</td>
<td>Phase 1 adopted in California</td>
</tr>
<tr>
<td>2016</td>
<td>Phase 2 to be adopted federally – MY 2018+ to be regulated</td>
</tr>
<tr>
<td>2017</td>
<td>Phase 2 to be adopted in California</td>
</tr>
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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/
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

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Current TTGHG Rule Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor (MY 2011 and newer)*</td>
<td>• Aerodynamic&lt;br&gt;• Low Rolling Resistance Tires</td>
</tr>
<tr>
<td>Tractor (MY 2010 and older)</td>
<td>• Low Rolling Resistance Tires</td>
</tr>
<tr>
<td>Trailer (53 foot box–type)</td>
<td>• Aerodynamic&lt;br&gt;• Low Rolling Resistance Tires</td>
</tr>
</tbody>
</table>

* – 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):

<table>
<thead>
<tr>
<th></th>
<th>2014-2016 MY</th>
<th>2017 MY and beyond</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Class 7</td>
<td>Class 8</td>
</tr>
<tr>
<td></td>
<td>Day Cab</td>
<td>Sleeper Berth</td>
</tr>
<tr>
<td>Low Roof</td>
<td>107</td>
<td>81</td>
</tr>
<tr>
<td>Mid Roof</td>
<td>119</td>
<td>88</td>
</tr>
<tr>
<td>High Roof</td>
<td>124</td>
<td>92</td>
</tr>
</tbody>
</table>

- 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

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

<table>
<thead>
<tr>
<th>Vocational Vehicle CO2 Standard (gCO2/ton-mile)</th>
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<tbody>
<tr>
<td>LHD Class 2b-5</td>
</tr>
<tr>
<td>----------------</td>
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<tr>
<td>2014 MY</td>
</tr>
<tr>
<td>2017 MY</td>
</tr>
</tbody>
</table>

• 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
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):

<table>
<thead>
<tr>
<th></th>
<th>Final HD Diesel Engine Standards (gCO2/bhp-hr)</th>
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<tbody>
<tr>
<td></td>
<td>LHD (2b-5)</td>
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<tr>
<td></td>
<td>Vocational Veh</td>
</tr>
<tr>
<td>2014-2016 MY</td>
<td>600</td>
</tr>
<tr>
<td>2017 and Later</td>
<td>576</td>
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</tbody>
</table>
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
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
## Technologies for GHG Reduction

<table>
<thead>
<tr>
<th>ENGINE BASED TECHNOLOGIES</th>
<th>VEHICLE BASED TECHNOLOGIES</th>
</tr>
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<tbody>
<tr>
<td>1. Advanced Transmissions/Engine Downspeeding</td>
<td>1. Aerodynamics</td>
</tr>
<tr>
<td>2. Advanced Combustion Cycles</td>
<td>2. Lightweighting</td>
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<tr>
<td>5. Stop-Start</td>
<td>5. Vehicle Speed Limiters</td>
</tr>
<tr>
<td>6. Automatic Neutral Idle</td>
<td>6. Connected Vehicles (Platooning, predictive cruise control)</td>
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<tr>
<td>8. Higher-Efficiency Aftertreatment</td>
<td>8. Idle Reduction</td>
</tr>
<tr>
<td>9. Reduced Friction and Auxiliary Load Reduction</td>
<td>9. Improved Air Conditioning System</td>
</tr>
<tr>
<td>10. Air Handling Improvements</td>
<td></td>
</tr>
<tr>
<td>11. Variable Valve Actuation/ Cylinder Deactivation</td>
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For details, please see the technology assessment presentations at [http://www.arb.ca.gov/msprog/tech/presentation.htm](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

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

California Environmental Protection Agency
AIR RESOURCES BOARD
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:**
    *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](http://www.arb.ca.gov/homepage.htm)
    *Phase 1: [http://www.arb.ca.gov/msprog/onroad/phaselghg/phaselghg.htm](http://www.arb.ca.gov/msprog/onroad/phaselghg/phaselghg.htm)*
    *Phase 2: [http://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm](http://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm)*

- **U.S. EPA:**
  - Matt Spears (Center Director – EPA)
    Spears.matthew@Epa.gov
    (734) 214–4921

- **California ARB:**
  - Kim Heroy–Rogalski, P.E. (Manager, Strategic Planning and Development Section – ARB)
    kheroyro@arb.ca.gov
    (916) 327–2200
Backup slides
Key Sources of Energy Losses

- Aerodynamic Losses: 85 kWh (21%)
- Engine Losses: 240 kWh (60%)
- Auxiliary Loads: 15 kWh (4%)
- Drivetrain Losses: 9 kWh (2%)
- Rolling Resistance Losses: 51 kWh (13%)

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