

# Medium- and Heavy-Duty Vehicle Fuel Efficiency and Greenhouse Gas Emission Phase 2 Rulemaking

SAE Government Industry Meeting

January 23, 2014

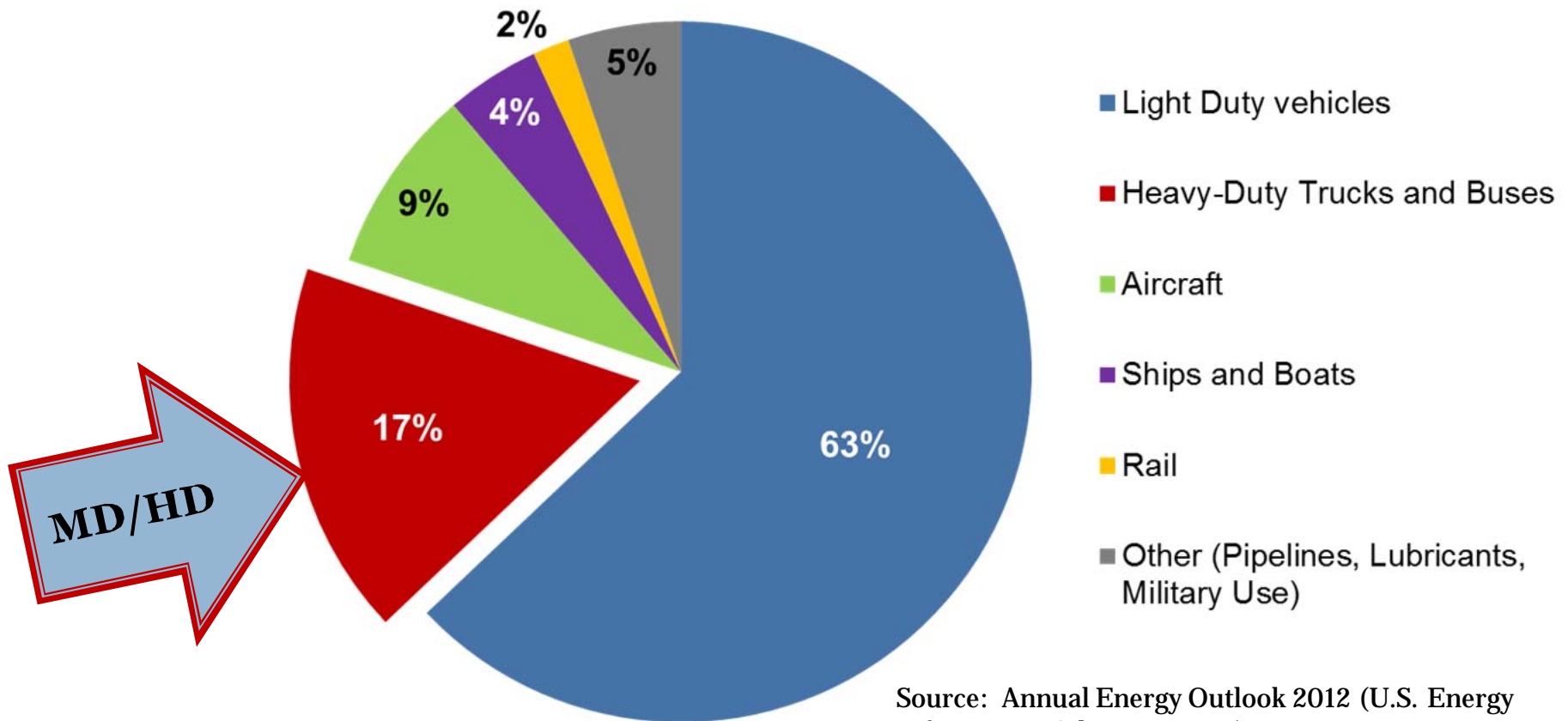
National Highway Traffic Safety Administration

Environmental Protection Agency



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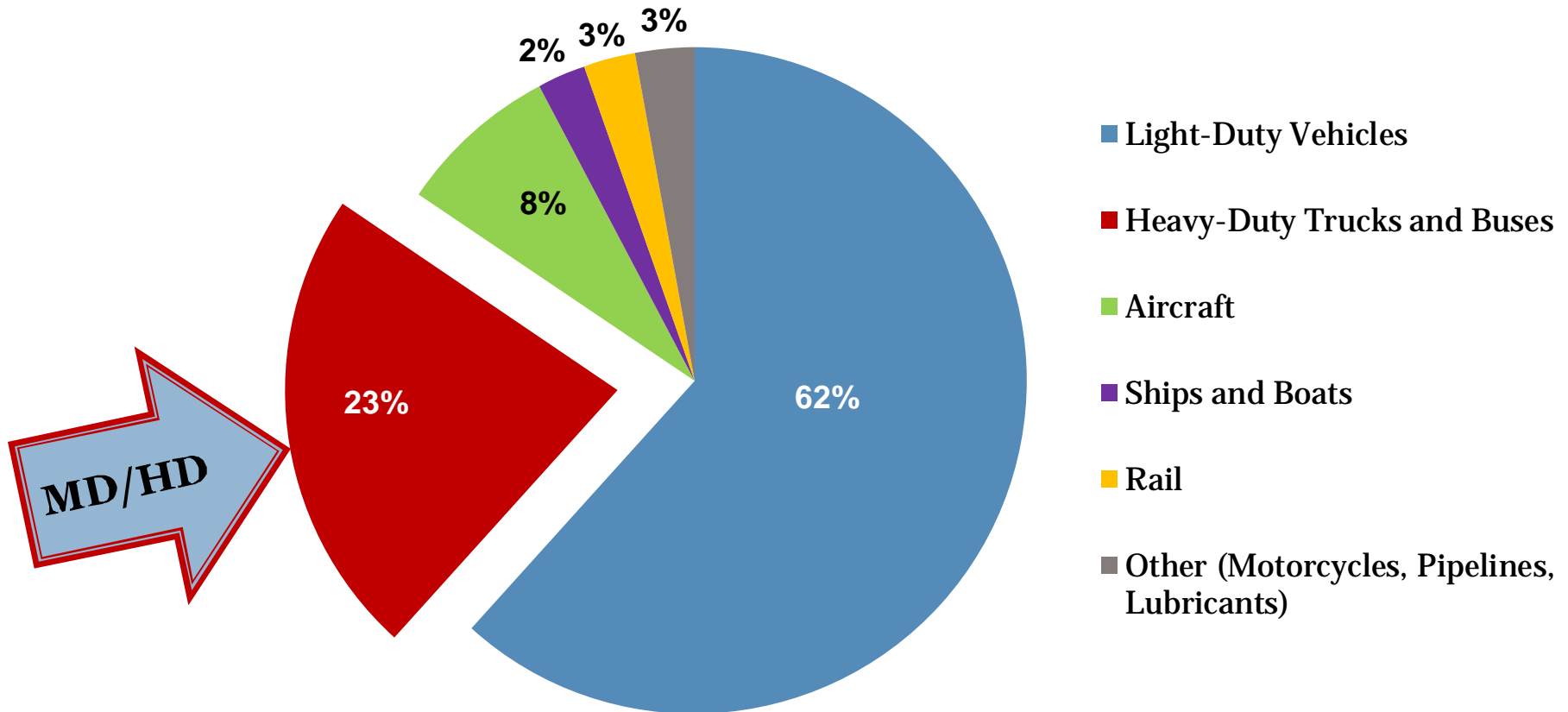
# Medium- and Heavy-Duty Sector Energy Use in 2010



Source: Annual Energy Outlook 2012 (U.S. Energy Information Administration)

# MD/HD Sector Emissions in 2010

Transportation Related Greenhouse Gas Emissions (Tg CO<sub>2</sub>eq) in 2010



Source: U.S. Greenhouse Gas Emissions and Sinks 1990-2010 (EPA 2012)

# Phase 1 – Divides diverse MD/HD vehicle sector into 4 distinct categories



Semi tractors,  
no trailers



Full-size pickup  
trucks & work  
vans

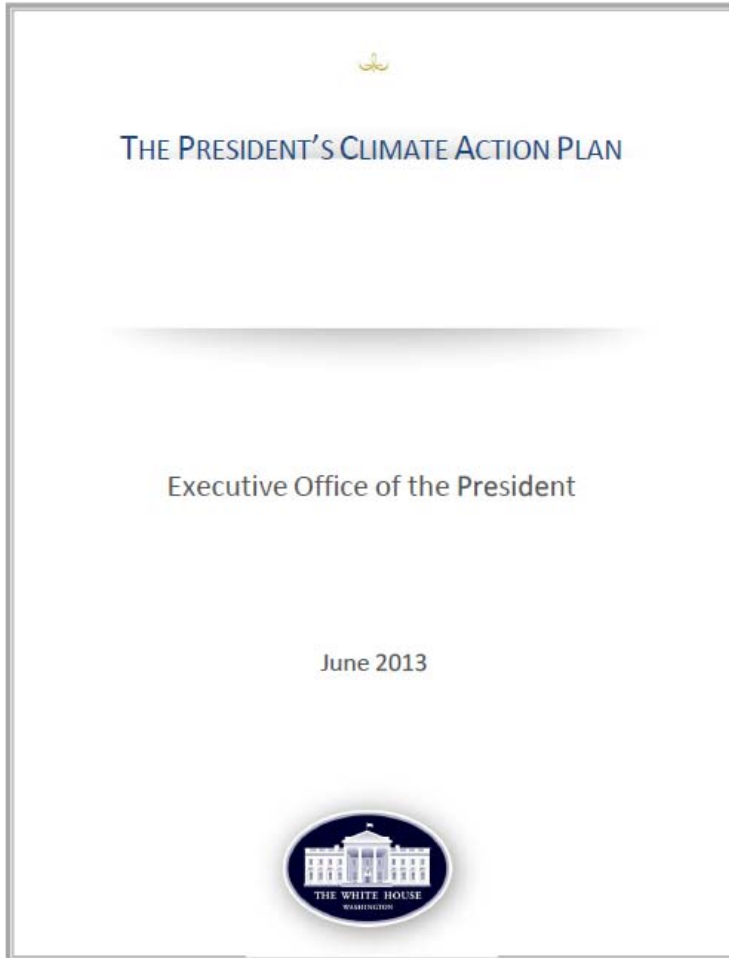


Vocational  
vehicles, regulated  
via the chassis



HD  
Engines

# President Obama's 2013 Climate Action Plan: Commitment to a Phase 2 Regulatory Program for Heavy-duty Vehicles



“During the President’s second term, the Administration will once again partner with industry leaders and other key stakeholders to develop post-2018 fuel economy standards for heavy-duty vehicles .....”

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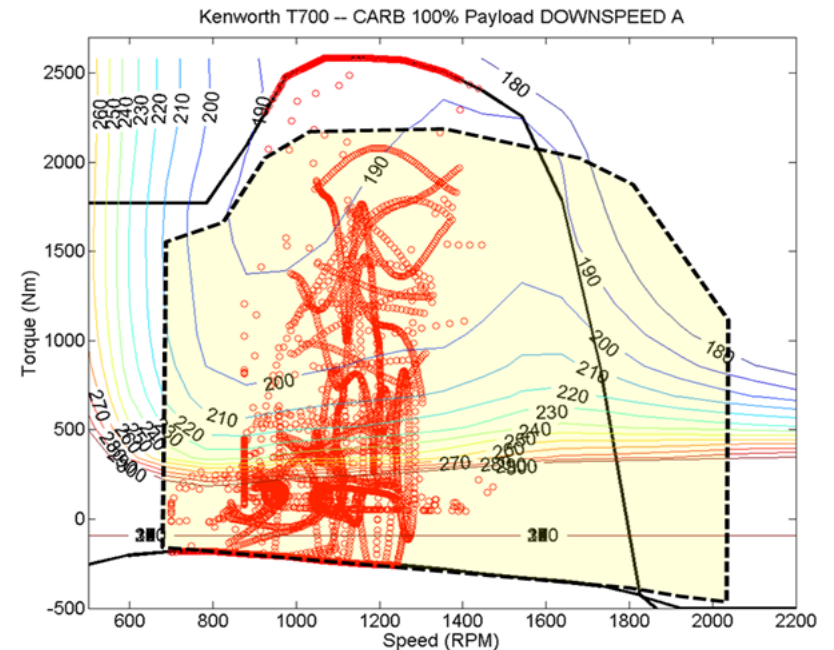
# Phase 2 – Rulemaking Objectives Discussed in Phase 1 Rule

- ▶ Joint NHTSA / EPA rulemaking process consistent with applicable law with notice and opportunity for public review and comment.
- ▶ As discussed in the Phase 1 Final Rule:
  - Consider regulating trailers and vocational vehicle second stage manufacturers
  - Consider refining test procedures and the GEM vehicle simulation compliance model
  - Consider new and advanced technologies, along with more stringent standards and timing
  - Update technology, economic and environmental assessments
  - Consider updating flexibilities



# NHTSA Technology Research

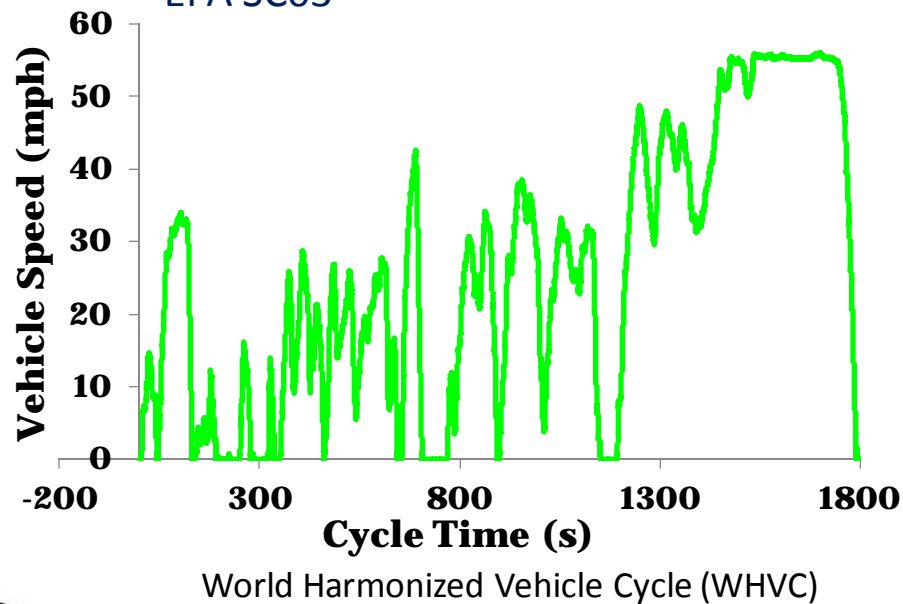
- MD/HD Technology Study with Southwest Research Institute
  - Study of over 50 powertrain and vehicle technologies for effects on fuel consumption and cost
  - Classes 2b-8, including trailers and vocational vehicles
- Potential market research on FE improving technology adoption on current model year 2011 vehicles to augment baseline information



# NHTSA Technology Research: Drive Cycles

## ▶ Class 2b and 3

- Phase 1 Drive Cycles
  - EPA FTP-75 City cycle
  - EPA HWFET Highway cycle
- **Additional Drive Cycles**
  - EPA US06
  - EPA SC03



## ▶ Class 4 – 8

- Phase 1 Drive Cycles
  - GEM ARB Transient
  - GEM 55 MPH cruise
  - GEM 65 MPH cruise
- **Additional Vocational Drive Cycles**
  - Combined International Local and Commuter Cycle (Utility Cycle)
  - Class 6 Parcel Delivery Cycle (Parcel Cycle)
  - World Harmonized Vehicle Cycle (WHVC)
- **Additional Tractor-Trailer Drive Cycles**
  - NESCAUM with grade long haul cycle



# NHTSA Research: Engine Technologies

- ▶ Advanced Bottoming Cycle
- ▶ Air Handling Improvement
- ▶ Coolant Pump
- ▶ Cylinder Deactivation
- ▶ Down-sizing & boosted vs. NA
- ▶ Electric Turbo-compounding
- ▶ Engine Down-sizing
- ▶ Engine Down-speeding (reduced cruise RPM, combined with transmission technology)
- ▶ Engine Friction Reduction
- ▶ Engine Oil Pump Improvement
- ▶ GDI + I EGR
- ▶ Improved Selective Catalytic Reduction (SCR) Conversion, combined with reducing or removing EGR
- ▶ Lean Burn GDI w/ SCR
- ▶ Lower Friction Engine Oil
- ▶ Mechanical Turbo-compounding
- ▶ Natural Gas
- ▶ Reduced After-treatment Backpressure
- ▶ Stoichiometric Gasoline Direct Injection (GDI)
- ▶ Stop / Start
- ▶ Turbo Efficiency Improvement
- ▶ Variable Valve Timing

*Technology application varies by vehicle class, vocation, and engine fuel type*

# NHTSA Research: Vehicle & Trailer Technologies

- ▶ A/C Reduced Reheat
- ▶ Air Compressor Improvements
- ▶ Automated Manual Transmission
- ▶ Automatic Engine Shutdown
- ▶ Automatic Tire Pressure Control
- ▶ Battery Auxiliary Power Unit
- ▶ Cab Insulation to Reduce A/C
- ▶ Chassis Friction Reduction & Improved Lube
- ▶ Diesel Auxiliary Power Unit
- ▶ Driver Coaching Features
- ▶ Driver Management Features
- ▶ Dual Clutch Transmission
- ▶ Fan Power Demand Reduction
- ▶ Fuel Fired Heater
- ▶ Full EV
- ▶ Hybrid Technologies
- ▶ Improved Aerodynamics
- ▶ Improved Transmissions (more gears, higher ratio spread, shift points)
- ▶ Low Rolling Resistance Tires
- ▶ Manual Transmission
- ▶ Shore Power
- ▶ Single Wide Tires
- ▶ Tractor Axle 6X2 or Clutched 6X4
- ▶ Speed limiters
- ▶ Weight Reduction

*Technology application will vary by vehicle class, vocation, and engine fuel type*

# EPA Research

- ▶ Test procedure development
  - Refine and evaluate aerodynamic and powertrain test procedure approaches
  - Attempt to refine GEM to simulate actual powertrain
  - Compare test procedure and GEM results
  - Validate GEM over 120+ vehicle variant tests
  - Assess different Phase 2 combinations of certification testing and simulation
  - EPA developing GEM refinements in-house and with contractor support
    - Main testing contractor: Southwest Research Institute (SwRI)

# Vehicle and Powertrain Tests in Supporting GEM

- ▶ Vehicle chassis and powertrain testing at Southwest Research Institute
  - One Class 6 box delivery truck chassis dyno tests with 7x6 test matrix
  - One Class 6 flat bed vocational truck chassis dyno tests with 7x6 test matrix
  - Kenworth T700 Class 8 tractor-trailer chassis dyno tests with 7x6 test matrix
  - Daimler Cascadia Class 8 truck-trailer chassis dyno tests
  - One transit city bus chassis dyno tests
  - One garbage truck chassis dyno tests
  - MD powertrain test with 7x6 test matrix
- ▶ HD powertrain test at Oak Ridge National Lab is being planned with DOE-EPA interagency agreement
- ▶ Driving cycle refinement with National Renewable Energy Lab is being planned with DOE-EPA interagency agreement
- ▶ Vehicle testing at Environment Canada
  - Class 6 open box truck testing underway
  - Coordinating additional testing opportunities
- ▶ GEM Validations will be done against over 160 vehicle variants

# GEM Development and Enhancement

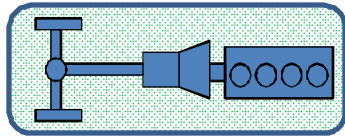
- The Agency formed a strong internal team, working with Southwest Research Institute to develop the next generation of the GEM
- The key technical features of this enhanced GEM include
  - More advanced engine controller
    - Engine fuel cut-off model during braking and deceleration
    - Idle controller
  - Transmission models
    - Automatic transmission
    - Automated manual transmission
  - Enhanced driver model
  - Frictional clutch model
  - GEM Graphic User Interface (GUI)

# Current GEM Status

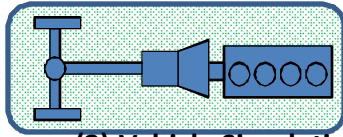
- EPA modeling team is fiercely working with SwRI to conclude modeling development and validations
  - All sub-models have been developed
- The GEM is being validated against three different trucks over a total of 24 vehicle driving cycles
  - Majority of the comparisons between simulations and testing data are under 5% accuracy
- Extensive validations against massive vehicle test data are under way whenever the testing data become available



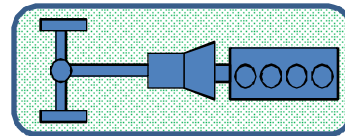
# Certification Options



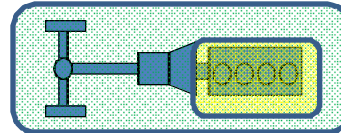
(1) Full Vehicle Simulation



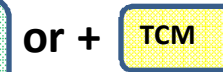
(2) Vehicle Simulation + Engine Standards



(3) Controllers-in-the-loop Simulation

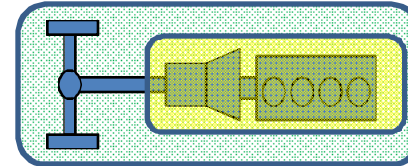


(4) Engine-in-the-loop Simulation (two variations)

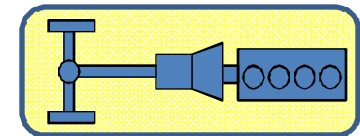


OR +

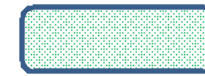
TCM



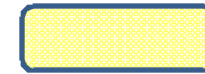
(5) Vehicle Simulation + Powertrain-in-the-loop/ Engine Standard



(6) Full Chassis Dyno Test



Simulation



Hardware

*Model Fidelity and Validation Challenges Increase*

*Test Cost and Capital Investment Increases*

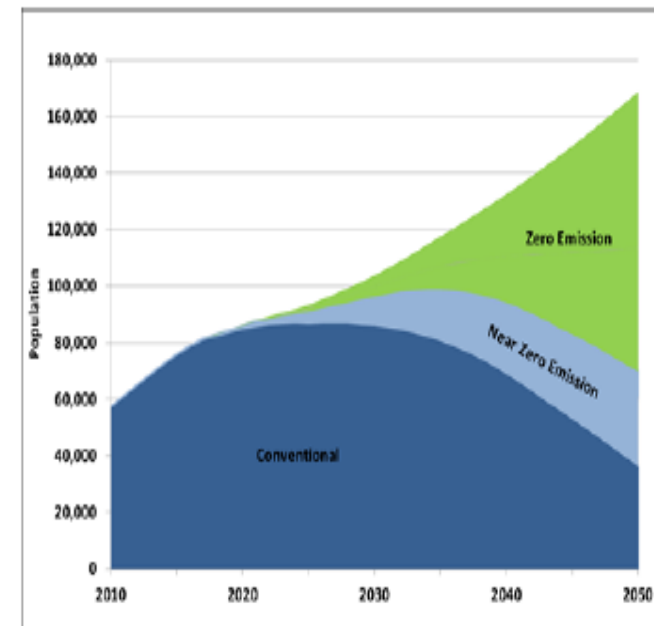
Vehicle simulation is one of the key certification elements regardless which option is selected

# What's Happening in California?

- 2008: ARB adopts mandatory fleet-level requirements for tractors and trailers
  - Based on EPA SmartWay performance
- 2012: ARB Releases 2050 Vision for Clean Air document
  - Calls for significant additional NO<sub>x</sub> and CO<sub>2</sub> reductions from heavy-duty sector
- 2013: Adopting EPA GHG Phase 1 Standards
  - Board hearing in December 2013
  - Similar to ARB's adoption of HD criteria emissions standards
  - Also adopting new voluntary Low NO<sub>x</sub> standards for heavy-duty
  - Signaled intent to move beyond Federal Phase 1
- ARB Participation in Federal Phase 2 Standards Development



South Coast Heavy Duty Truck Population  
(advanced technology scenario)



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# Thank you

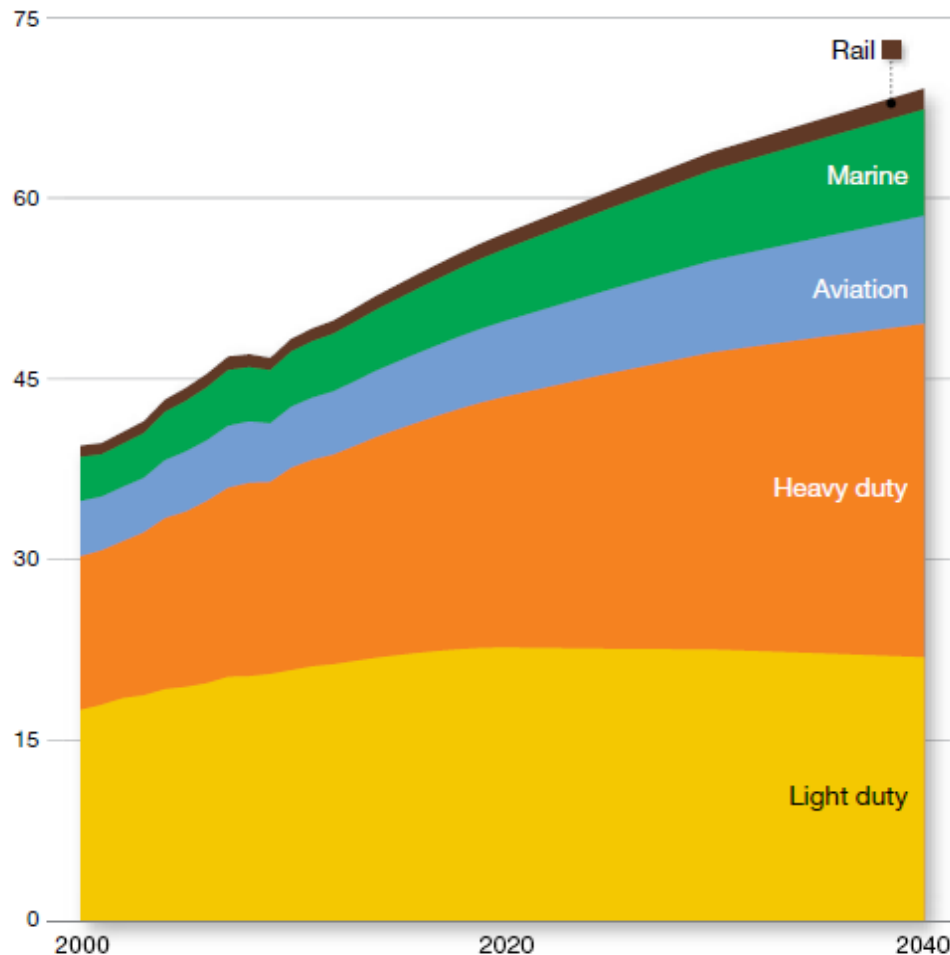


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# World-Wide Transportation Energy Use: HD Vehicle Grows Faster than any Other Transportation Sub-sector

Transportation energy demand by sector

Millions of oil-equivalent barrels per day



➤ World-wide, HD vehicle energy demand estimated **to grow by 65%** over next 30 years

➤ In 2040, HD Vehicles projected to be largest transportation sub-sector use of energy.

➤ **40%** of all transportation energy

# Phase 1 – Pollutants addressed and flexibilities

- EPA regulates CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub> and HFCs.
- NHTSA regulates fuel consumption.
- Both agencies offer manufacturers flexibilities including credit Averaging, Banking and Trading (ABT), among other provisions



GEM\_sim

## Greenhouse Gas Emissions Model (GEM)

**Identification**

Manufacturer Name:  Vehicle Configuration:  Date:   
Vehicle Family:  Vehicle Model Year:

**Regulatory Subcategory**

Class 8 Combination - Sleeper Cab - High Roof  
 Class 8 Combination - Sleeper Cab - Mid Roof  
 Class 8 Combination - Sleeper Cab - Low Roof  
 Class 8 Combination - Day Cab - High Roof  
 Class 8 Combination - Day Cab - Mid Roof  
 Class 8 Combination - Day Cab - Low Roof  
 Class 7 Combination - Day Cab - High Roof  
 Class 7 Combination - Day Cab - Mid Roof  
 Class 7 Combination - Day Cab - Low Roof  
 Heavy Heavy-Duty - Vocational Truck (Class 8)  
 Medium Heavy-Duty - Vocational Truck (Class 6-7)  
 Light Heavy-Duty - Vocational Truck (Class 2b-5)

**Simulation Inputs**

Coefficient of Aerodynamic Drag:   
Steer Tire Rolling Resistance [kg/metric ton]:   
Drive Tire Rolling Resistance [kg/metric ton]:   
Vehicle Speed Limiter [mph]:   
Vehicle Weight Reduction [lbs]:   
Extended Idle Reduction:

**Simulation Type**

Single Configuration  
 Plot Output  
 Multiple Configurations

**RUN**

# Phase 1 – Standards Implementation

NHTSA Fuel Consumption standards are mandatory beginning in MY 2016

- Fuel Consumption based on CO2 only
- Voluntary early compliance MY 2014 & 2015

EPA Greenhouse Gas Emission standards are mandatory beginning in MY 2014

- CO2, N2O, CH4 and HFCs

	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018	MY 2019
EPA	M	M	M	M	M	M
NHTSA	V	V	M	M	M	M



# Phase 1 - Compliance

## **MY 2013 Deadlines:**

- March 31, 2014 – Year end report for ABT manufacturers due
- October 1, 2014 – Final report for ABT manufacturers due
- Reporting template will be provided to manufactures on the EPA website

## **MY 2013 Early Compliance:**

- 3 vocational and tractor manufacturers
- 2 engine manufacturers
- 2 heavy duty pick up truck and van manufacturers
- All manufacturers in EPA program opted into NHTSA program

## **MY 2014 Compliance (partial estimates):**

- Mandatory EPA compliance and optional NHTSA
- 16 vocational and tractor manufacturers
  - 9 have opted into NHTSA program
- 7 engine manufacturers
  - 3 have opted into NHTSA program
- 7 heavy duty pick up truck and van manufactures
  - 6 have opted in NHTSA program

# NHTSA Technology Research Engines

- HD diesel: DD15 14.8L I-6
- LD / MD diesel: ISB 6.7L I-6
- Port injected gasoline: 6.2L V-8
- Turbo GDI gasoline: Ecoboost 3.5L V-6



**Diesel**  
**15 Liter I-6**



**Gasoline**  
**6.2 Liter V-8**



**Gasoline**  
**3.5 Liter V-6**



**Diesel**  
**6.7 Liter I-6**

# Phase 2 – NHTSA FE Technology Research

- **Current MD/HD Fleet Baseline Powertrains:**
  - Build GT model for two gasoline and two diesel engine models to span classes 2b-8 vehicles and validate with engine operating data

- **Gasoline Classes 2b-7**
- Engine: Ford EcoBoost 3.5L V6
- Transmissions: Chrysler 6-spd 68RFE (2b-3), Allison 2000 (4-7)

- **Gasoline Classes 2b-7**
- Engine: Nat. aspirated V8
- Transmission: Chrysler 6-spd 68RFE (2b-3), Allison 2000 (4-7)

- **Diesel Class 2b-8a**
- Engine: Cummins ISB 6.7 L I6
- Transmission: Chrysler 6-spd 68RFE (2b-3), Allison 2000 (4-8a)

- **Diesel Class 8b**
- Engine: Detroit Diesel DD15 14.8 L I6
- Transmission: Eaton 10-speed AMT

Smaller → to Larger

# Phase 2 – NHTSA FE Technology Research

- **Phase 2 MD/HD Fleet Baseline Powertrains:**
  - Modify the two gasoline and two diesel engine models (spanning classes 2b-8 vehicles) to represent potential Phase 2 improvements

- **Gasoline Class 2b - 7**
- Engine: Ford EcoBoost 3.5L V6
- Transmission: ZF 8-spd (2b-3), improved Allison (4-7)

- **Gasoline Classes 2b-7**
- Engine: Nat. aspirated V8
- Transmission: ZF 8-spd (2b-3), improved Allison (4-7)

- **Diesel Class 2b-7**
- Engine: Cummins ISB 6.7 L I6
- Transmission: ZF 8-spd (2b-3), improved Allison (4-7)

- **Diesel Class 8**
- Engine: Detroit Diesel 14.8 L I6
- Transmission: Manual, Dual Clutch

Smaller → to Larger