Integrated Virtual Lab in Supporting Heavy Duty Engine and Vehicle Emission Rulemaking

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October 6, 2011

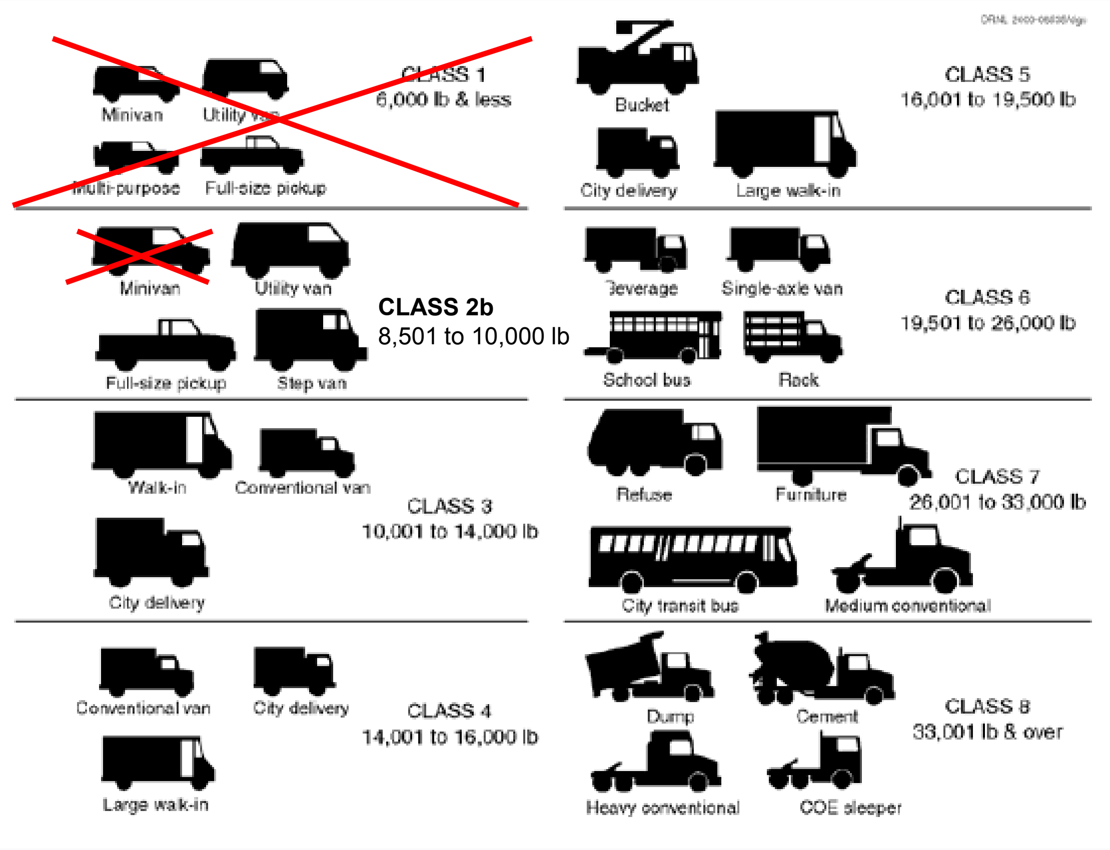
U.S. DEPARTMENT OF ENERGY
DEER 2011
DETROIT
DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE

Outline

- Greenhouse Gas Emission Regulation
- Agencies' Greenhouse Gas Emission Model (GEM)
- Integrated Virtual Lab
- Next Generation of GEM

Medium & Heavy Duty Fuel Efficiency & GHG Rule

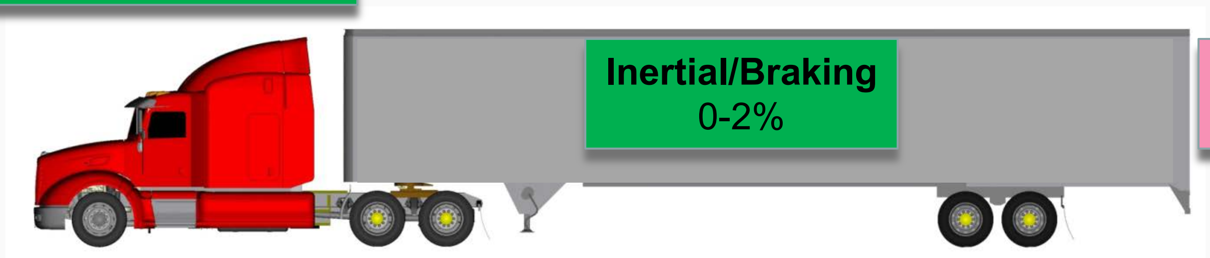
- ☑ First ever Medium- & Heavy-Duty Standards
- ☑ Allows manufacturers to produce a single fleet of vehicles to meet requirement
- ☑ Certifications for all vehicles except pickup and van will be conducted by the EPA simulation tool - GEM



Greenhouse Gas Emission Model (GEM)

Energy Loss for 2010 Class 8 Trucks at 65 mph and 80,000 lb GVW

Total Engine Loss
57-59%



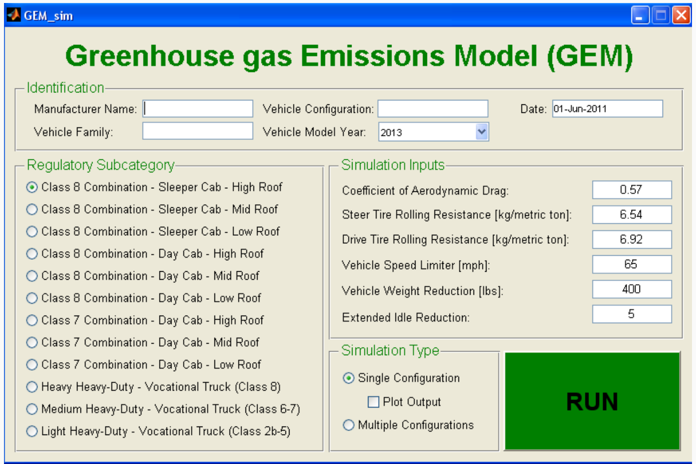
Inertial/Braking
0-2%

Aerodynamic Loss
15-22%

Vehicle Auxiliary Loads
1-4%

Drivetrain
2-4%

Rolling Resistance
13-16%



EPA pre-specified (green)

Allowed user inputs (pink)

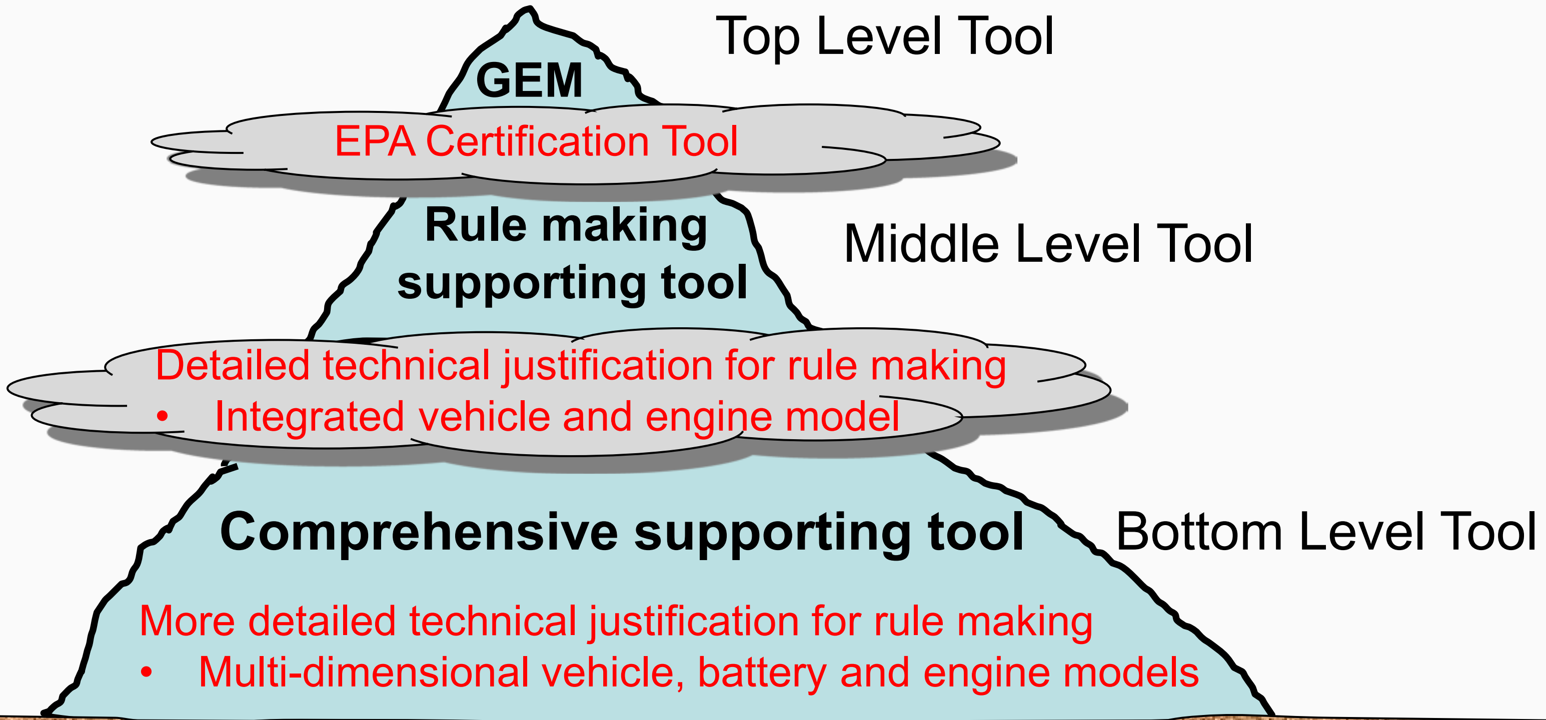
http://www.epa.gov/otaq/climate/gem.htm

Methodology and Motivation

- Certification tool must be capable of capturing all of the elements that are identified as important through chassis or engine dyno tests

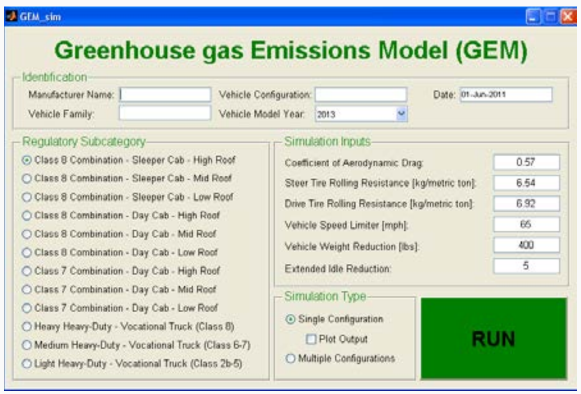
- Systematic analytical tool box must be developed to serve the following goals
  - Identify and justify technology road maps
  - Provide reliable input parameters required by certification tool

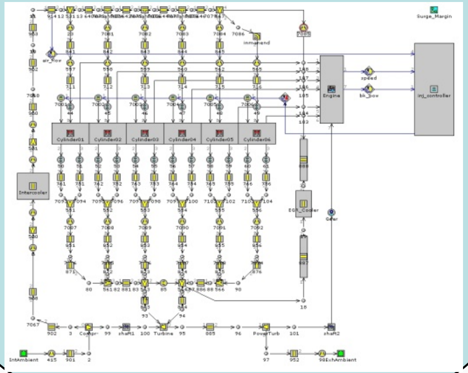
EPA Analytical Tool Box



- **Abundant testing data are available**
  - **EPA steady and transient tests**
  - **Contractor chassis dyno tests and on-road vehicle tests**
  - **Various channels for data collection from industry**

Integrated Engine and Vehicle Model





Aero Drag Coeff

Engine fuel maps
Technology justifications
Technology road maps

Model Fidelity, Computational Requirement

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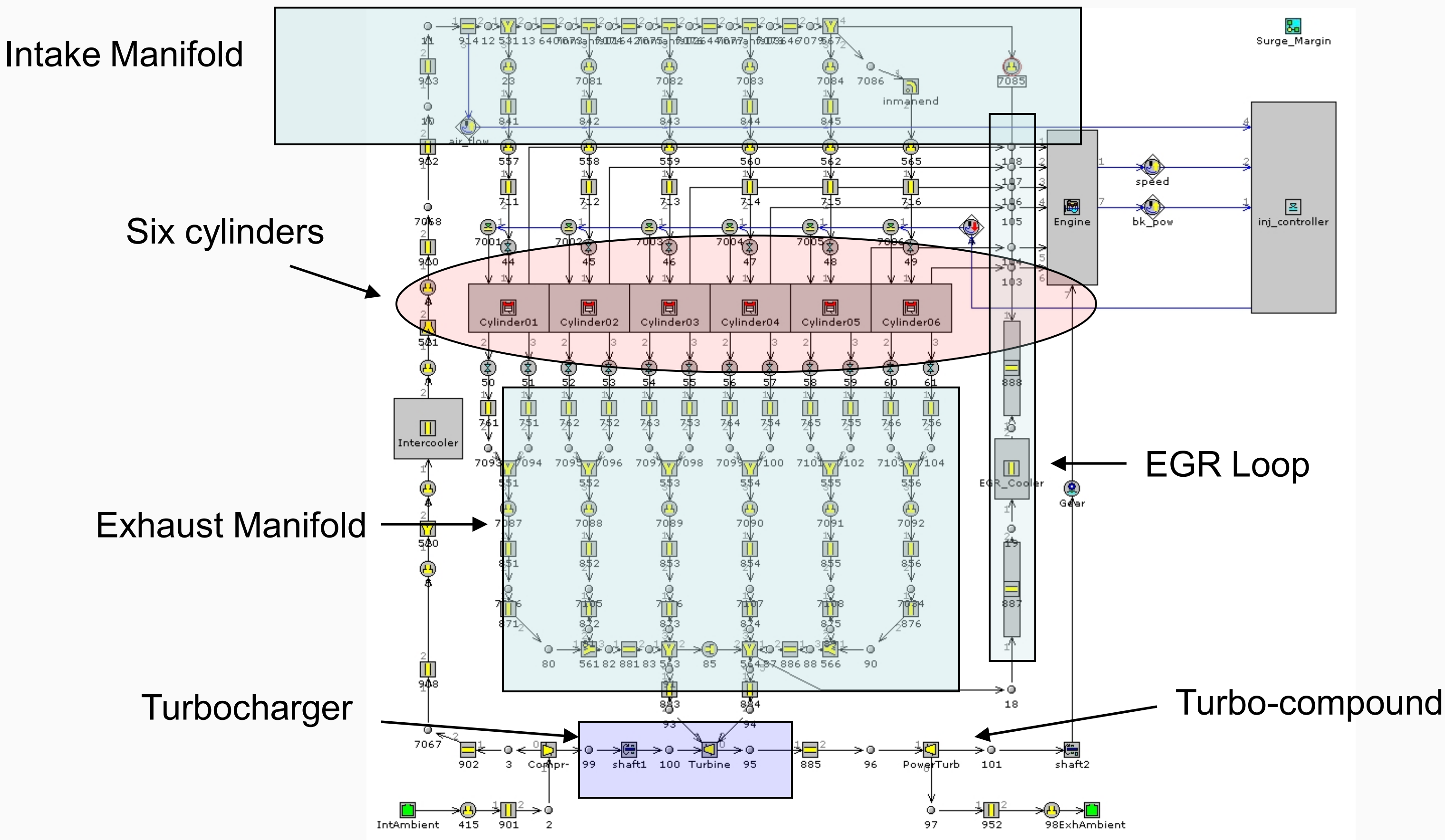
Case Study - Engine cycle simulations
for Illustration Purpose

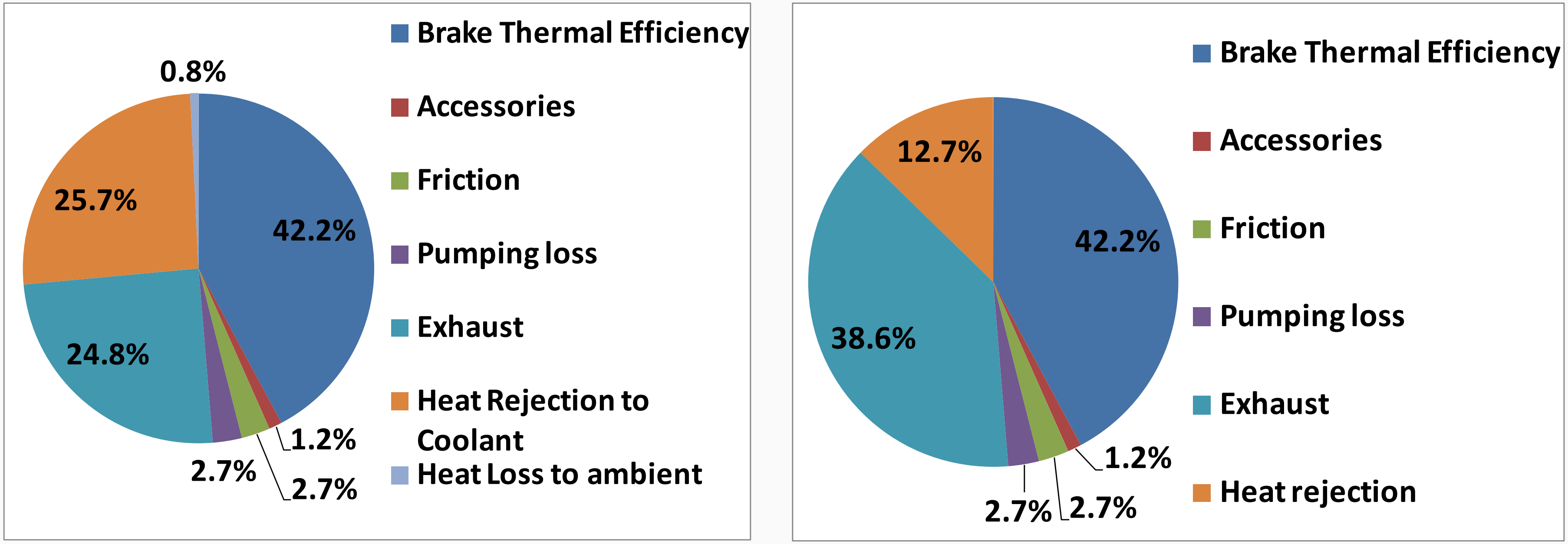


Energy Balance in Different Methods

15L HD baseline engine: RPM =1515 and BMEP = 17.3 bar

Control volume – entire engine

Control volume – cylinders



- Distribution of exhaust energy and heat rejection are quite different
- Difference in these losses signifies the importance of waste energy recovery
- It also shows strong interaction between heat rejection and exhaust energy
  - Improvement of heat rejection could translate increase of exhaust energy and pumping loss

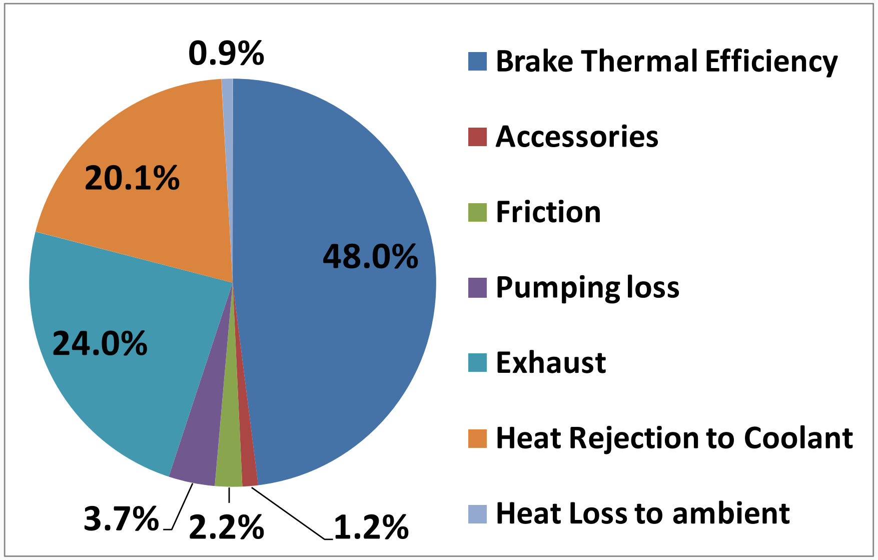
Technology Identification for Improvement

- Potential technologies in 2020 time frame
  - Waste heat recovery (WHR)
    - Turbo compound or/and Rankine Cycle
  - Combustion optimization with more advanced fuel injection system and combustion concepts
  - Mild EGR rate
  - Back pressure reduction with more advanced aftertreatment system
  - Better insulation of cylinders and exhaust system
  - Higher turbocharger efficiency
  - Low parasitic loss and friction
  - Variable breathing system
- Synergy effects must be taken into consideration, since all technologies are not additive

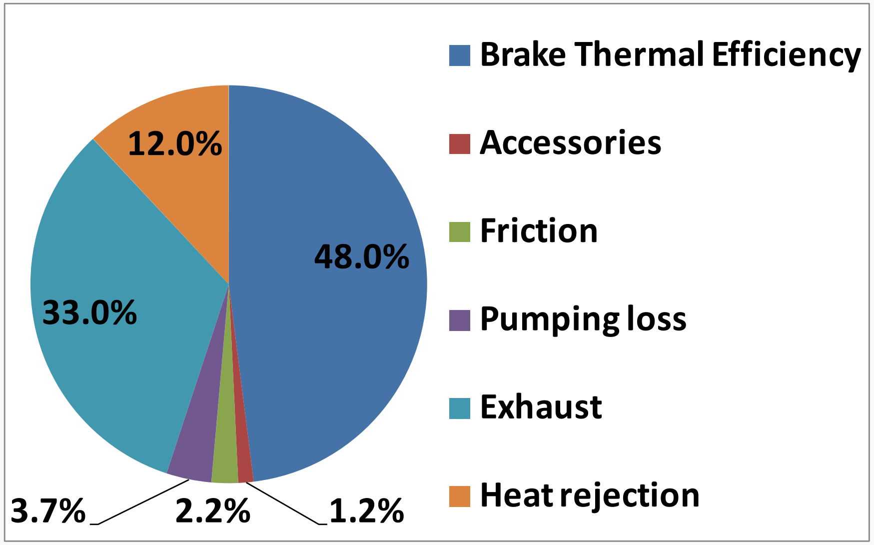
Technology Identification and Justification

- Engine cycle simulations play critical roles in identifying the technology path with taking synergy effect into consideration
  - 15L HD baseline engine: RPM =1515 and BMEP = 17.3 bar
  - Engine only with turbo-compound

Control volume – entire engine



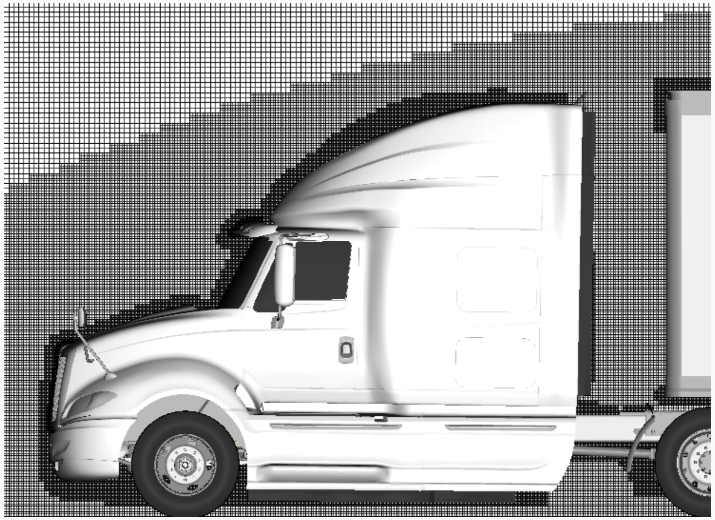
Control volume – cylinders

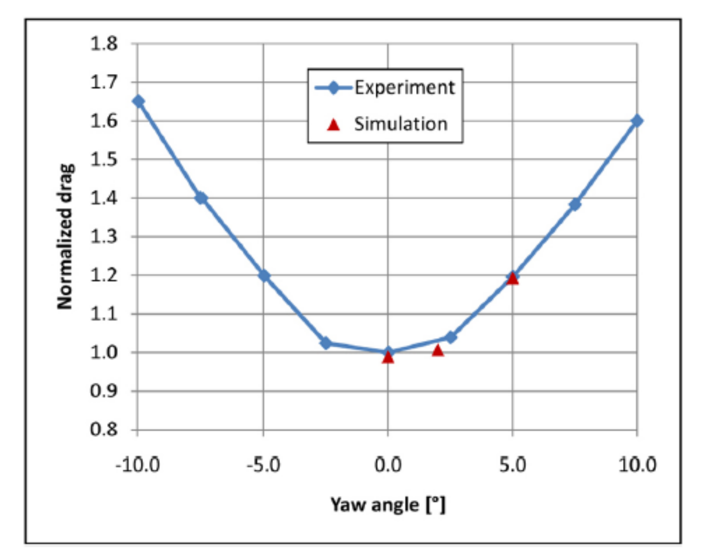


- Difference in heat rejection and exhaust energy between two approaches is significantly reduced, showing much lower heat rejection with more waste energy utilization
- Exhaust energy is still high, and other WHR must be used in order to approach 50% efficiency

More Comprehensive Supporting Tools

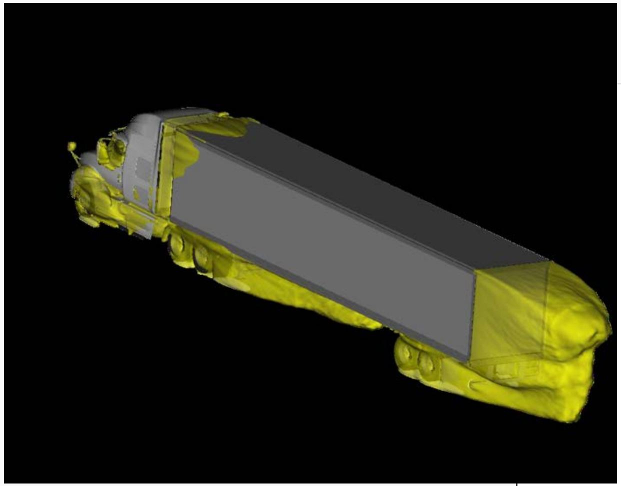
- Certification tool GEM requires aerodynamic drag coefficient (Cd) as input
- 3D CFD is complementary to EPA specified testing approach, thus providing a powerful alternative to obtain Cd
- The agency is actively evaluating different CFD approaches

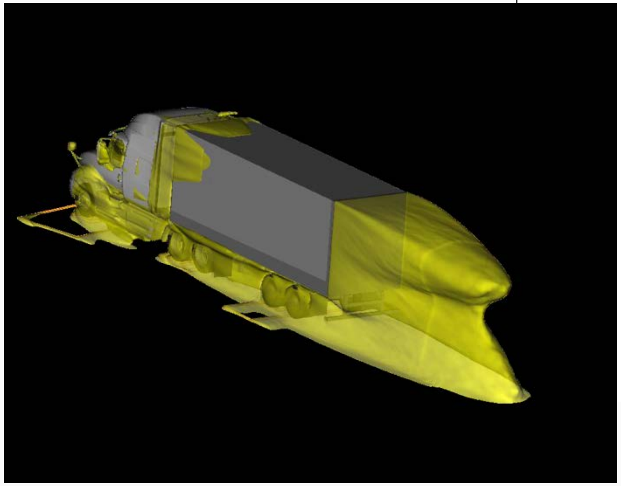


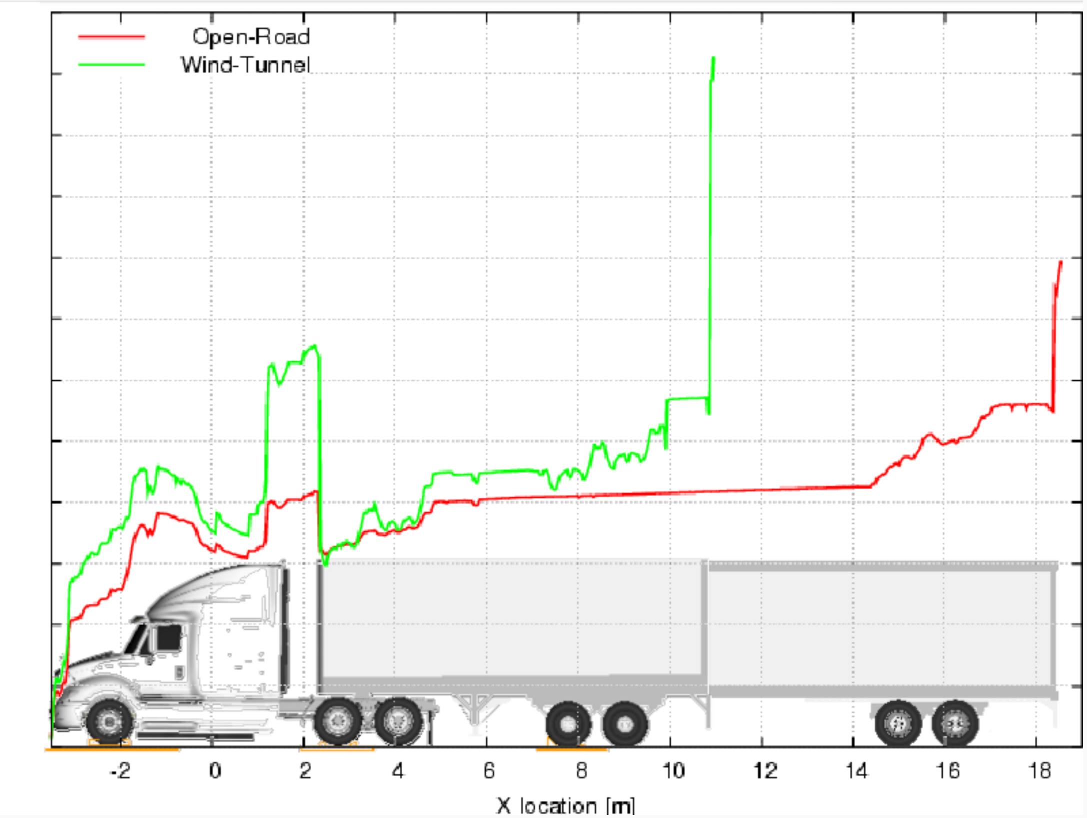


Wind Avg. Drag Coefficient

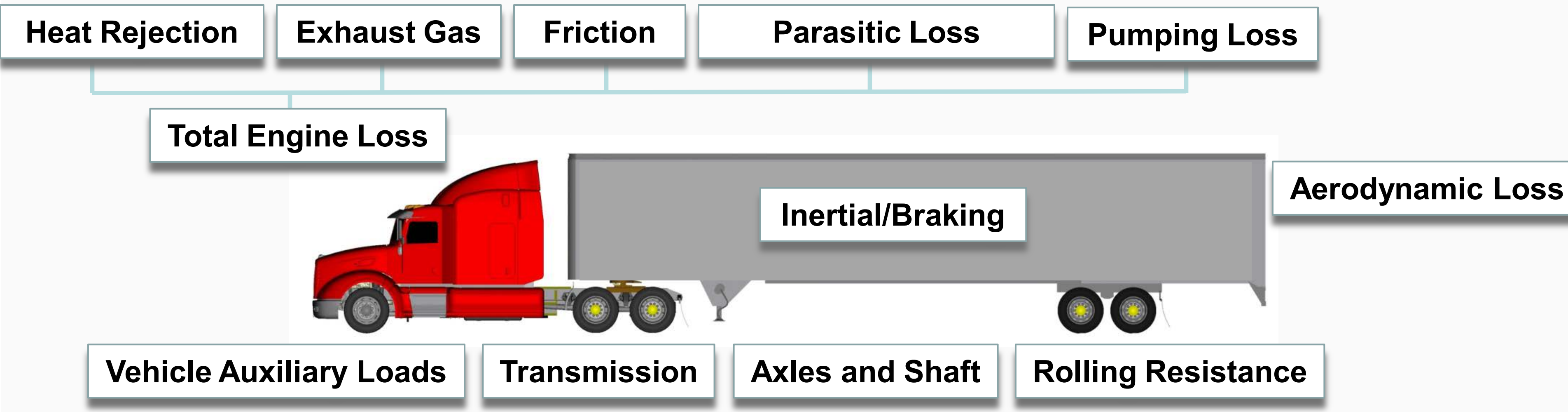
Trailer Impacts on Aerodynamic Drag







Next Generation GEM

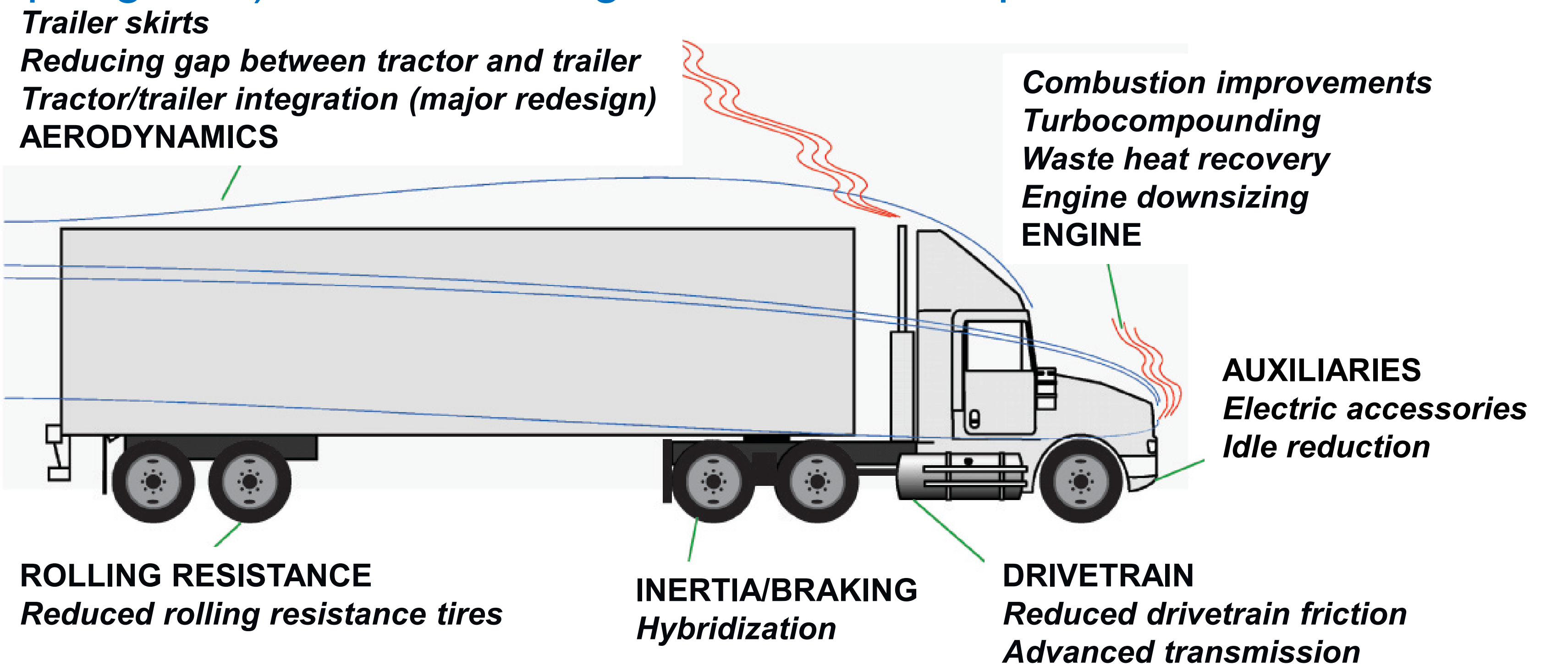


- Certification will consider all possible means that can be realized in a chassis dyno cell in order to improve engine and vehicle efficiency
- GEM will continue evolving and improving, taking all losses or technologies into consideration that are identified as important
- The agency's integrated virtual lab provides the supporting base to accomplish the agency certification needs

SuperTruck

A Systems Level Technology Development, Integration, and Demonstration for Efficient Class 8 Trucks

Goal: By 2015, a 50 percent improvement in freight efficiency (ton-miles per gallon) of Class 8 long-haul trucks compared to current models



SuperTruck program lays out a foundation for next phase rulemaking