Global Harmonization of GHG Regulation

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GHG Workshop
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Why Harmonize?

- GHG emissions anywhere has the same global impact.
- Technology differentiation should be driven by market requirements, not regulatory divergence.
  - Limited resources for development should be applied as broadly as possible.
  - Increasing sales volume of efficiency technology will lower the cost and increase utilization.
  - Global market for technology increases competition, innovation, and reduces cost.
  - Minimize cost of testing and compliance verification.
- HD GHG regulations are complex and regulators also have limited resources.
  - Adopting harmonized processes can draw on collective resources to improve simulations, testing, and overall process.
  - Broaden the scope of technologies that can be included.
Existing CO2 certification procedures are very different, but all use simulation to be able to handle vehicle configuration and operation variation.
Premises to select approach for a CO2 certification HDV

1. CO2/FE values have to be “realistic” for all vehicle variants and CO2 reduction in real world must be determined with sufficient accuracy.
   ⇒ Avoid engineering for certification rather than customer application
   ⇒ “Realistic” means a representative value for the specific vehicle applications
   ⇒ Relative accuracy is more important than absolute accuracy
   ⇒ Guide customers in purchase decisions

2. Should cover as many CO2 reduction technologies as possible, but measurement procedure needs to be repeatable, robust and practicable
   ⇒ A reasonable combination of simulations and tests is needed

3. Effort/resources for CO2- determination must be reasonable for OEM’s
   ⇒ Need to provide a CO2 value for each vehicle variant in an appropriate duty cycle
   ⇒ Only by simulation can the number of vehicle variants and operations be managed
   ⇒ A balance between number of vehicle variants considered and effort is crucial

4. Should incentivize the most cost-effective efficiency technologies to promote customer acceptance

Only a simulation based full vehicle approach is able to fulfill the premises.

Adapted from ACEA Workgroup CO2-HDV
Process to develop a harmonized approach

Agree on major premises
There are 2 premises which are fundamental to developing a new regulation:

1. Full vehicle approach versus engine separately
2. Simulation based approach versus chassis dyno

Take existing concepts/methods

Tire labeling system
Fuel map test procedure
Cycle definition concept
Segmentation concept
Air drag test procedures
Bin concept
Simulation tools/models

Define needed method enhancements (examples)
- Include vehicle drag
- More cycles needed
- Include drivetrain impact
- More accurate/comparable air drag test procedure

Goal: global harmonized CO2 regulation concept with appropriate region specifics
Parts within a HDV CO2 certification procedure

0 General approach
1 Simulation tool
2 Vehicle segmentation
3 Body and trailer
4 Cycles
5 Fuel map
6 Total vehicle drag
7 Auxiliaries
8 Controls
9 Weight definition
10 Metrics
11 Hybrids

Each topic requires careful evaluation and inputs. But we must first agree on the fundamental process.
Volvo Harmonization View

• **Globally Harmonize**
  – Vehicle simulation model
  – Input formats (duty cycle, components)
  – Component characterization (e.g., engine map, accessories, tires)
  – Complete vehicle only. No component requirements.
  – Metrics
  – ECO feature process
  – Validation testing
  – Default value process

• **Do not Harmonize**
  – Stringency (target values)
  – Duty cycle (speeds, loads, grades)
  – Labeling of FE & GHG
  – Default values

• **To be Determined**
  – Vehicle categories
  – Driver model
  – Vocational Vehicle approach
  – Aero measurement and simulation
  – Trailer configurations

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**Concern:**
EPA typically requires much more documentation and verification of certification inputs. Need to balance accuracy with regulatory burden.

**Multiple application profiles for a single vehicle is ok for FE declaration but problematic for regulation.**
Vehicle Model Approach

• Complete vehicle model must include
  – Major vehicle characteristics
    • Aerodynamics
    • Rolling resistance
    • Appropriate accessory loads
    • Idle control technology
    • Speed control
  – Major drivetrain components
    • Engine efficiency map
    • Transmission gearing, efficiency, shift control (or controller in loop)
    • Axle ratio, driven/non-driven axles, efficiency
    • Energy recovery utilization
• Optional at discretion of regulators and/or manufacturers (could be in base model or handled under innovative technology approach)
  – Accessory controls
  – Driver management
  – Innovative technology
Major elements of a “Simulation based approach”

**Mandatory data for GHG/FE simulation implemented in simulation tool**

- **Cycles for each vehicle class**
  - Target speed vs. distance
  - Slopes vs. distance

- **Trailer/body specification**
  - Specification of one standard trailer and/or body for each vehicle class

- **Vehicle class & weight definition**
  - Vehicle class specific weight definition for simulation/test

- **Metrics**
  - g/t-km or mile
  - g/m³-km or mile
  - g/passenger-km or mile

**Certified input data from OEMs**

- **Certified air drag, driveline drag, rolling resistance auxiliary drag**

- **Certified engine fuel map**

- **Additional OEM specific data:**
  - Transmission and axle ratios, tire sizes, ...

**Simulation tool** (provided by legislative bodies)

- **Concept to cover vehicle control strategies**
  1. Generic models/algorithms
     - e.g. driver model for manual transmissions
  2. Generic technology-specific models/algorithms
     - e.g. models for standard accessories
  3. Generic models/algorithms + OEM-specific parameter
     - e.g. speed control
     - OEM’s parameter need to be verifiable

**Result from simulation**

- CO2/FC values
- Average speed
Vehicle Simulation Model

• One vehicle simulation model should be suitable to work everywhere.
  – Minimize the cost of model development and maintenance.
  – Provide clarity and consistency to vehicle developers.
  – Inputs can vary by locality, vehicle type, and application

• Concern over regulatory control requirements
  – Need to freeze model under each regulatory jurisdiction
  – Establish global process for maintenance and updates with implementation flexibility
  – Allow for flexibility on which inputs are required or optional
Duty Cycle & Component Inputs

- To facilitate a common model, inputs need common formats, even if inputs are locally unique
  - Duty Cycles
    - Include load, grade, speed
    - Distance based with step changes in speed profile
  - Components (engine, transmission, axles, accessories, etc)
    - Common input allows for the same test results to be applied everywhere
    - Tires: adopt global test procedure
      - Provide mechanisms for supplier indemnification (e.g. EPA tire rolling resistance)
Tire rolling resistance
A harmonised method of measuring tire rolling resistance based on ISO 28580 should be established.

The values from the tire labelling system for rolling resistances should be taken to determine the rolling resistance of the vehicle/vehicle combination.
Aero Measurement and Simulation

• Harmonized aero approach between US and EU is less important since tractors are unique.
  – Common test procedure
    • Coast-down, constant speed, wind tunnel?
    • Yaw corrections
    • Measurements
    • Test facility requirements
  – Common accepted input methods for variations
    • CFD, scale tests, interpolations
    • Binning method
  – Common procedure to correct between certified test and individual vehicle inputs
Typical Drag Variation with Yaw Angle

★ Significantly higher yaw impact on commercial trucks

![Graph showing drag variation with yaw angle for different vehicle types.](image)
Trailer Integration

- Tractors must be designed for aerodynamic match to trailers.
- Tractor aero features do not all work well with both aero and non-aero trailers.
- It is essential that tractor designs are forward looking, not backward.
- Regulators should specify the best current or even future trailers for evaluating combination drag.
Fuel Mapping Proposal for Modern Engines with Complex Control Strategies
Complex modern controls do not limit the utility of engine mapping for vehicle simulation.

• All truck OEM’s use vehicle simulations to target engine calibration and to predict fuel consumption in customer applications.
• Very accurate for comparing incremental differences in fuel economy from engine and vehicle improvements.
• Correction factors based on typical on-road engine duty cycles can be applied to Steady state maps to account for transient behavior.
• A panel of experts has been chartered by ACEA, JAMA, and EMA to propose best engine mapping methods.
Proposed Phase II Engine Mapping Approach

• Historically, manufacturers have used steady state fuel maps to characterize fuel rate during vehicle cycle simulations to predict customer real world fuel economy.

• A Phase 2 simulation methodology
  • Use actual fuel maps (not one map for all manufacturers and all applications)
  • Critical step towards achieving realistic simulation results.
  • Results in more representative characterization of CO2 emissions over vehicle drive cycles vs. using certification cycles which are designed to restrict criteria emissions over the entire range of engine operation.
Correction factor process for fuel map

A steady-state fuel map does not consider transient engine behavior and the consistency between WHTC- test and a steady-state-fuel-map-test has to be secured. A correction factor process is therefore proposed.

**Illustration of correction factor process**

Measured steady-state fuel map

Correction factor or factors for transient effects. (compare fuel consumption of WHTC test with calculated fuel consumption based on WHTC measured WHTC load/speed spectra and steady-state fuel map)

FC simulation with a corrected steady-state fuel map gives good correlation with reality and consistency to NOx/PM certification.
Verification of Mapping Accuracy from EU Study
## EU Vehicle Segmentation and Duty Cycle Proposal

<table>
<thead>
<tr>
<th>Identification vehicle configuration</th>
<th>Class</th>
<th>Vehicle Class</th>
<th>Cycle allocation</th>
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<tbody>
<tr>
<td><strong>Axle configuration</strong></td>
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<tr>
<td><strong>Chassis configuration</strong></td>
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<tr>
<td><strong>weight</strong></td>
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<tr>
<td></td>
<td>1</td>
<td>Long haul</td>
<td>R/W</td>
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<tr>
<td></td>
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<td>Regional delivery</td>
<td>R/W</td>
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<td>4</td>
<td>Municipal utility</td>
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<tr>
<td>2 axles</td>
<td>4x2</td>
<td>Rigid + (Tractor)</td>
<td>1.5/10</td>
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<td>Rigid + (Tractor)</td>
<td>1.5/16</td>
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<td></td>
<td>Rigid</td>
<td>&gt; 16t</td>
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<td></td>
<td>Tractor</td>
<td>&gt; 16t</td>
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<td>4x4</td>
<td>Rigid</td>
<td>1.5/16</td>
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<td>Excluding all-wheel drive vehicles 4x4 (sales volume &lt; 1%)</td>
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<td>3 axles</td>
<td>Rigid</td>
<td>1.5/16</td>
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<td></td>
<td>Excluding all-wheel drive vehicles 4x4 (sales volume &lt; 1%)</td>
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<tr>
<td></td>
<td>Tractor</td>
<td>&gt; 16t</td>
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<tr>
<td></td>
<td>6x2/2-4</td>
<td>Rigid</td>
<td>all</td>
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<tr>
<td></td>
<td>Tractor</td>
<td>all</td>
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<td></td>
<td>6x4</td>
<td>Rigid</td>
<td>all</td>
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<td>Tractor</td>
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<td>6x6</td>
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<td>Tractor</td>
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<td></td>
<td>4 axles</td>
<td>Rigid</td>
<td>all</td>
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<td></td>
<td>Excluding 8x2 (very low sales volume &lt; 1%)</td>
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Need to add trailer configurations and targets for tractors. Adds complexity. Current US regulatory vehicle segments may be adequate.
GHG/FE Regulation Metrics

- Measurement must account for vehicle freight capacity (or people for buses and coaches).
- Ton-miles is the current GHG/FE metric
  - Tons are fixed for a vehicle segment
  - No allowance is made for extra tons by reducing vehicle weight (but only 20-30% of loads are grossed out)
- Volume (cube-miles) is applicable to the majority of long-haul van applications
  - Since volume is in the trailer, a volume based metric might make sense for trailers
- Metric changes should be considered as new regulation evolves.
ECO Feature Evaluation

• Any technology not included in base model should qualify.
  – Even if well-established, credit should be given for application to any specific truck.

• Evaluation process should be harmonized
  – Avoid multiple testing unless warranted by duty-cycle differences
  – Maximize the global applications
  – Use standardized tests methods (SAE type tests) when applicable.
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Thank You