European development of a certification method to quantify the FC and CO$_2$ emissions of complete heavy-duty vehicles

Tony Greszler
VP, Government and Industry Relations
Volvo Powertrain
Summary EU Activities

- EU Commission to present a strategy targeting fuel consumption and CO$_2$ emissions from heavy duty vehicles - Q1 2013
  - Will include a certification method to quantify FC and CO$_2$ emissions of complete HDV
  - The method will most likely be based on a simulation tool with verification of model parameters via measurement

Usage of CO$_2$ test results not decided. Options are:
- Pilot phase or mandatory testing from 2013 on?
- Collect experiences $\rightarrow$ eventually adaptations of test procedure
- Collect and analyse test results
  - Labeling and information for customers to decide which model fits best to his demands. Further options are target values and limits (e.g. g CO$_2$/ton-km)
Three Commission projects

Lot 1: Assess the amount and reduction potential of GHG emissions from Heavy Duty Vehicles. Final report ready

Lot 2: Propose a method to quantify such emissions for whole vehicles as well as for vehicle components. Planned to be ready end of 2011

Lot 3: New extension of Lot 2
Draft Legislation
Lot 3 is expected to be completed during 2012
Summary of Lot 1
- Results

- A number of instruments have potential to reduce CO₂ emissions from HDVs
  - Performance requirements, best practices, speed reduction, dimensions, driver training, fuel taxes, road user charges, labeling, incentives etc.
  - No prioritization has been done by Lot 1

- Most meaningful metric of FC/GHG performance will be in relation to the work performed

- Any possible standards would also best take into account specific duty cycles for different applications or classes of HDV
**Shares in energy consumption**

Example: EURO V semitrailer with total 28 t, highway driving

- **Air resistance**: 53.8%
- **Rolling resistance**: 25.2%
- **Engine brake**: 2.4%
- **Sum service brakes**: 7.5%
- **Drivetrain losses**: 6.5%
- **Auxiliaries**: 5%
- **Engine cooling fan**: 0.5%
- **Alternator**: 0.9%
- **Air compressor**: 2.3%
- **Steering pump**: 0.7%
- **A/C compressor**: 0.2%

**Must be included:**
- ***Air resistance***
- ***Rolling resistance***
- ***Engine efficiency*** → +transmission ratios

**Shall be included:**
- **Transmission losses**

**May be included:**
- *Auxiliaries*
- *Power consumers* (Auxiliaries are more important for buses!)

---

Stefan Hausberger
VDA Technischer Kongress, 24.03.2011
HDV CO₂ test procedure
Summary of Lot 2
- Preliminary results

- Simulation based test method which should fulfill the following demands:
  - Incentive to apply efficient technologies
  - Repeatable and reproducible
  - High sensitivity to fuel saving measures
  - Realistic results
    - Categorize HDVs into different vehicle classes and mission profiles
  - Reasonable costs and efforts to run and examine the procedure
  - Applicable to (almost) all HDV categories and technologies
  - Simple and robust
Summary of Lot 2
- Preliminary results

- The simulation tool calculates engine power demand and speed based on a defined vehicle driving cycle
  - Fuel consumption will be interpolated from a steady state engine map

- Input data
  - Engine map for fuel consumption, measured during engine type approval
  - Basic vehicle data such as mass, number of axles, rolling resistance, air resistance, transmission
  - Driving cycles for different vehicle categories and mission profiles
Basic approach for planned CO₂ certification

\[ P_e = P_{roll.} + P_{air} + P_{acc} + P_{grad} + P_{tr.} + P_{aux} + P_{cons.} \]
\[ n = \left( \frac{v \times 60 \times I_{axis} \times I_{gear}}{d \times \pi} \right) \]

Fuel consumption map:
- a) steady state + WHTC correction factors
- b) transient engine maps

Driving resistances, options:
- a) constant speed (Pe from FC or Ecu-Pe)
- b) coast down
  General: method for body builders

Influence from different tire models
\( \Delta \) of resistance values from EC No 1222/2009

Transmission ratios, transmission losses:
- a) default value (optional OEM specific map)

Power demand from engine from
- a) default \( P_e \) for different technologies
- b) detailed simulation

Component testing:
- Gear box, axis: transmission, \( \eta = F(...) \)
- Auxiliaries duty cycle, \( \eta = F(...) \)
Test cycles as input for simulation tool

Driving conditions very different between vehicle categories and mission profiles. Options:

a) One representative cycle per vehicle category (and mission profile) eventually including target speed phases and road gradients + one short standard cycle verifiable with PEMS or on chassis dyno

![Graph showing velocity over time with different speed profiles]

approx. 8 different cycles necessary

b) WHVC with different weighting factors for urban, road, motorway

Disadvantages: no target speed phases, no road gradients → may be unfair for several future technologies

Advantages: simpler, compatible with engine test approach
Summary of Lot 2
- Preliminary results

- Determination of driving resistance values
  - Constant velocity (preferred) and/or Coast down (variability concerns)
  - Both options will be further investigated in the project

- Determination of the Fuel Consumption Engine Map
  - The Euro VI test cycles, WHSC and WHTC, can not be used, don’t fully cover all relevant engine operation conditions
  - Most promising proposal is to measure 50 to 80 steady state points in addition to the type approval
    - Interpolation of the fuel consumption for the WHTC engine load course from the steady state engine map
    - Measured fuel consumption in WHTC
    - Calculate a ”WHTC correction factor”
Summary of Lot 2
- Preliminary results

- Practicable approaches have been found for main elements of the certification procedure for FC and CO₂ emissions of heavy duty vehicles
  - Detailed description of the procedure and of the formulas for evaluation can be expected for many parts in 2011

- To include gear box and auxiliaries in the certification test would give incentives to further improve the energy efficiency of these components
  - Need to figure out which to include and which to replace by a simplified approach

- Fully representative test cycles should include road gradients and target speed phases
Summary of Lot 3
- Planned deliverables

- Development of a simulation tool, definition of test cycles, type approval procedure etc.
- Draft Legislation with the indicated objective to cover 95% of EU HDVs
- Lot 3 is expected to be completed during 2012
Industry input to the Commission

- Fuel efficiency for HDV is market driven

Industry supports

- Integrated approach to CO₂ emissions
  - Procedure for fuel efficiency calculation of complete vehicles
- Cost-effective policy measures
- Globally harmonized policies
- Study inclusion of transport into an international, non-sector specific, emission trading scheme
ACEA pre-study on fuel efficiency simulation

- Vehicle classes and missions
- Efficiency metrics
- Demonstrate simulation methodology
- Validation
Identified vehicle classes and transport mission profiles > 7.5 GVW

Vehicle classes and mission

- Long Haul
- One day trip
- Regional delivery/collection
- Urban delivery/collection
- Municipal utility
- Light off road
- Heavy off road
One drive cycle for each vehicle class and mission.

**Route**

**Definition of route**

**Vehicle performance**

**Driver model**

![Graph showing speed (km/h) vs. Distance (km)](image)

**Vehicle performance**

- One drive cycle for each vehicle class and mission.

**Driver model**

- Graph showing speed vs. distance.
Choice of drive cycle is important

- Main target is realistic fuel consumption values
- Fuel consumption is heavily influenced by the cycle
Accuracy of simulation depends on accurate data input

- Aerodynamics
- Rolling resistance
- Engine
- Weight
- Transmission
- Torque converter
- Axles
- Auxiliaries
- Vehicle control strategies
ACEA input to EU Commission

- Any legal requirement shall result in the intended effects on road
- Compliance should be verifiable by standardized and accurate procedures