DAIMLER

CO2/FE regulatory developments around the world

Results from vehicle simulation study

EC/ICCT Workshop on CO2 emissions from Heavy Duty Vehicles
Brussels, November 10th, 2011

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Agenda

1 Introduction

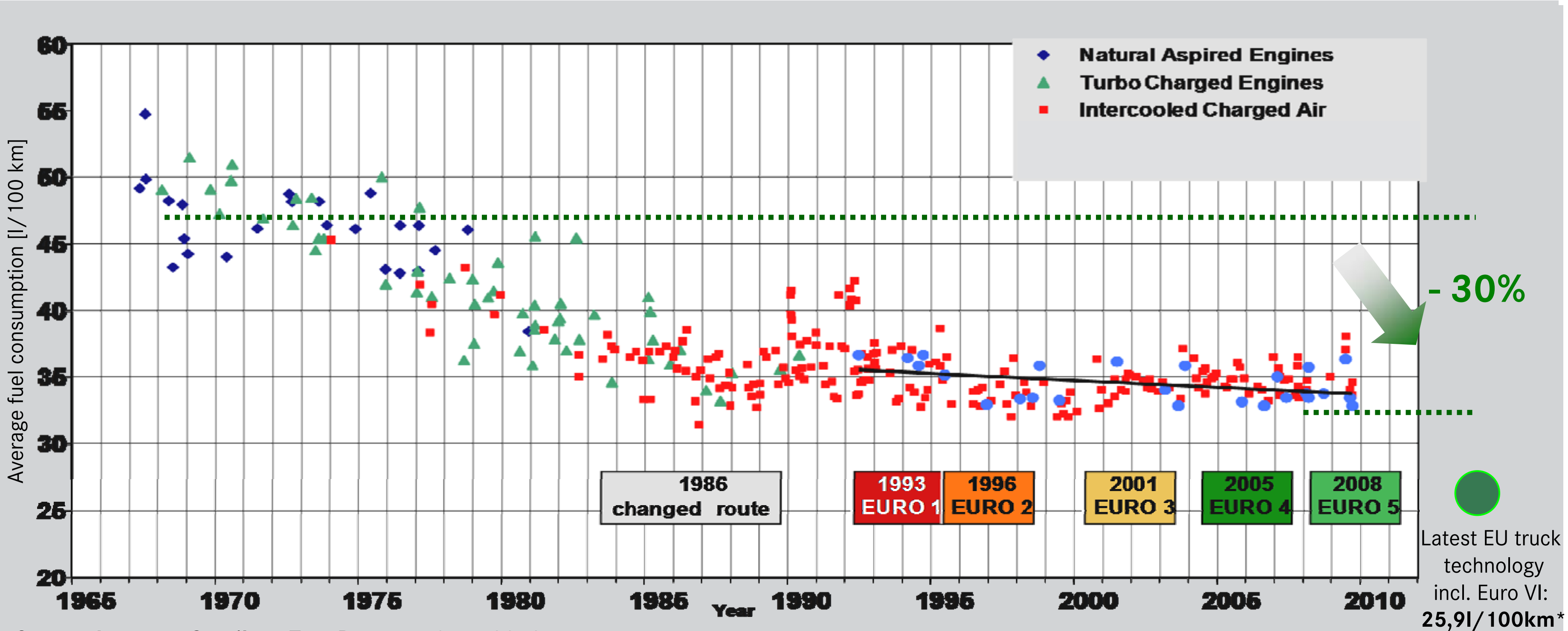
2 GHG initiatives for HDV in major regions

3 Elements of a GHG reduction approach for HDV reflecting simulation results

4 Conclusion

History: big wins in fuel economy of HDV

–30% reduction in fuel consumption

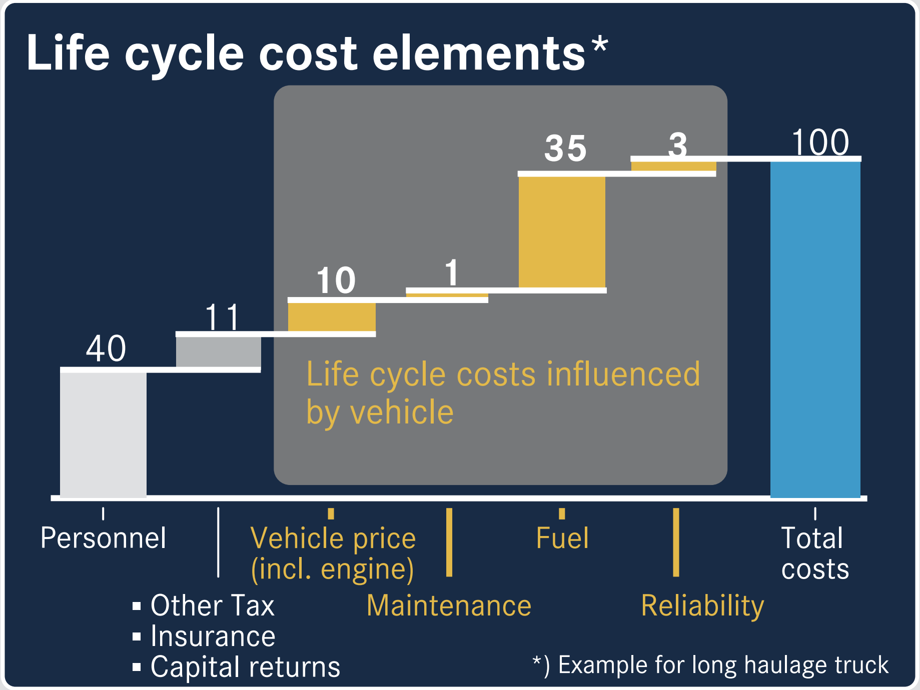


Source: Lastauto Omnibus, Test Reports 1967 - 2010

* Test cycle not fully comparable to Lastauto Omibus

- Reduction of fuel consumption is one of the most important customer purchase criteria.
- Competition driven drastic reduction of fuel consumption of HDV observable.
- Strong emission reduction measures restrict further fuel economy improvements.

Fuel economy has always been the competitive lever in the truck & bus business



Comparison of 4 leading Long Haul Tractors in Europe

km/h	79,60	78,31	80,16	81,46
L/100 km	37,25	36,97	38,90	38,22
km/h	80,02	78,67	79,64	81,27
L/100 km	36,79	36,08	38,90	38,13
km/h	80,13	79,16	80,67	81,05
L/100 km	37,03	35,76	37,13	38,02
km/h	79,53	79,37	80,39	81,24
L/100 km	37,01	36,39	36,57	37,61
km/h	79,82	78,88	80,21	81,26
L/100 km	37,02	36,30	37,87	38,00
mit Adblue 2)	38,08	37,14	37,87	38,84

Source: Lastauto-Omnibus Feb. 2009, Germany

- **Competition works: Only a difference of 4,5% in fuel consumption between the best and the worst on a distance of 620km !**

HDV industry calls for the integrated approach:

- Comparison on the Route Stuttgart – Milano and back
- Reduced Operation Time combined with higher Payload

Model Year 1965

Driving Time: 20:08 hrs

Average Speed: 58 km/h

Payload: 16 t

Model Year 2009

Driving Time: 15:26 hrs

Average Speed: 76 km/h

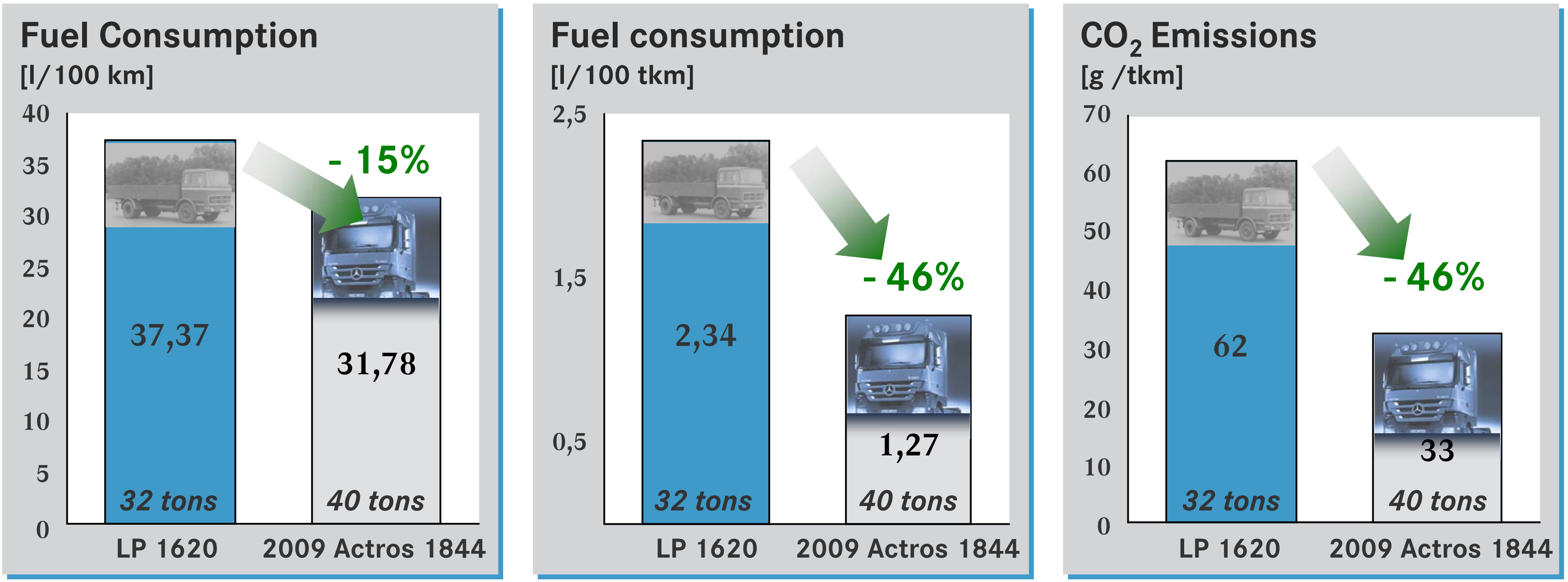
Payload: 25 t

Transalp Trucking 2010 - 50 Years of Continuous Progress – Daimler AG

- **Almost 25% less driving time and 64 l diesel savings on the route Stuttgart – Milano and return**

HDV industry calls for the integrated approach:

- Higher payload together with less fuel consumption and CO_2-emissions per ton and kilometer*.



* measured on 1,159.6 km Transalp Test Drive

- **Fuel consumption and CO2 emissions per tkm almost halved.**

Regulatory activities on CO_2 for HDV in major regions

2011
2012
2013
2014
2015
2016
2017
2018
2019

USA

- Aug.: Rule Signed
- Initial Engine & Vehicle Standards in force
- Tightened Engine & Vehicle Standards in force

China

- Industrial FC Standard in place
- National GB standard in place
- National GB standard in place entire HD-fleet first Phase

Japan

- FE regulation defined since 2006)
- Tightened Standards in discussion
- FE standards In force

Europe

Industry:

- Recommended approach: CO2 declaration procedure HDV

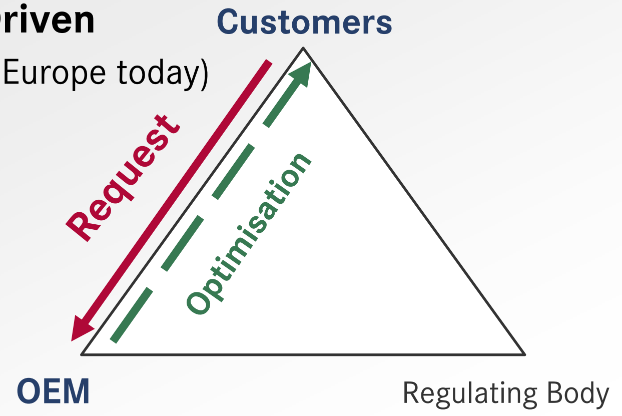
European Commission:

- CO2 measurement procedure
- Impact Assessment on Policy Instruments for GHG Reductions.

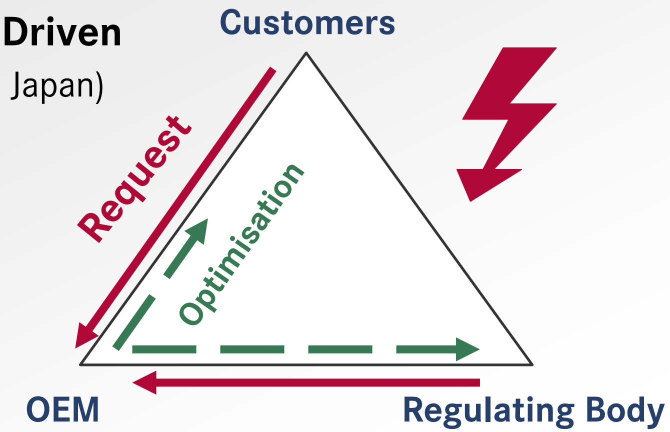
- GHG reduction standards/performance requirements in all key markets in place or under development apart from Europe.
- What is the most effective approach for Europe
  - Performance requirements vs. CO2 declaration ?
  - Regulatory approach vs. market oriented approach ?

Customer demand vs. regulatory requirements

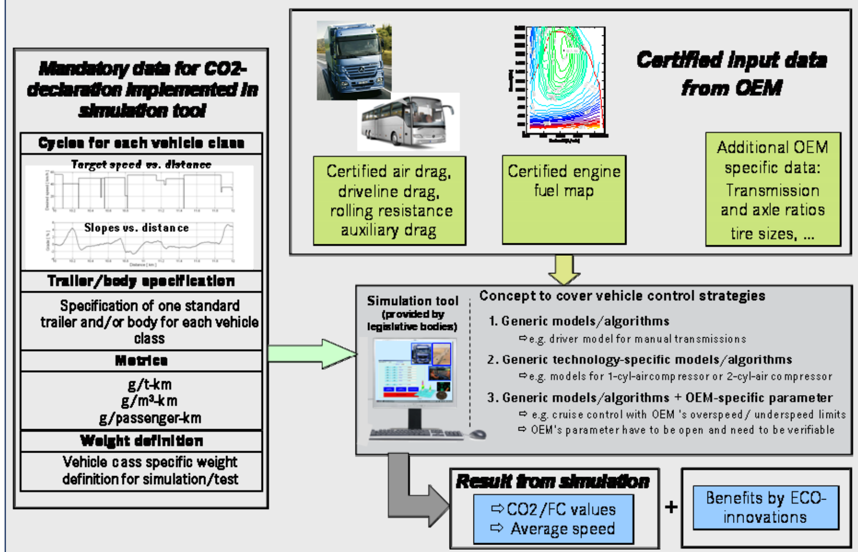
Customer Driven
(e.g. Situation Europe today)



Regulation Driven
(e.g. Situation Japan)



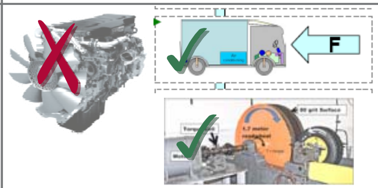
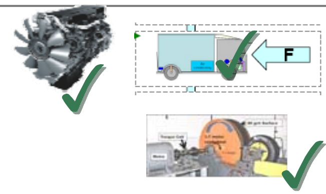
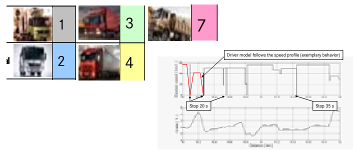
Key requirements for a CO2 declaration



Source: ACEA

- **Regulation should not result in suboptimal solutions for fuel economy compared to market driven optima but regulation should maximally reinforce the strong market driven approch.**
- **CO2 declaration therefore should expose the specific use conditions and configurations in the heavy truck market (instead of limit values for non integrated vehicle designs)**

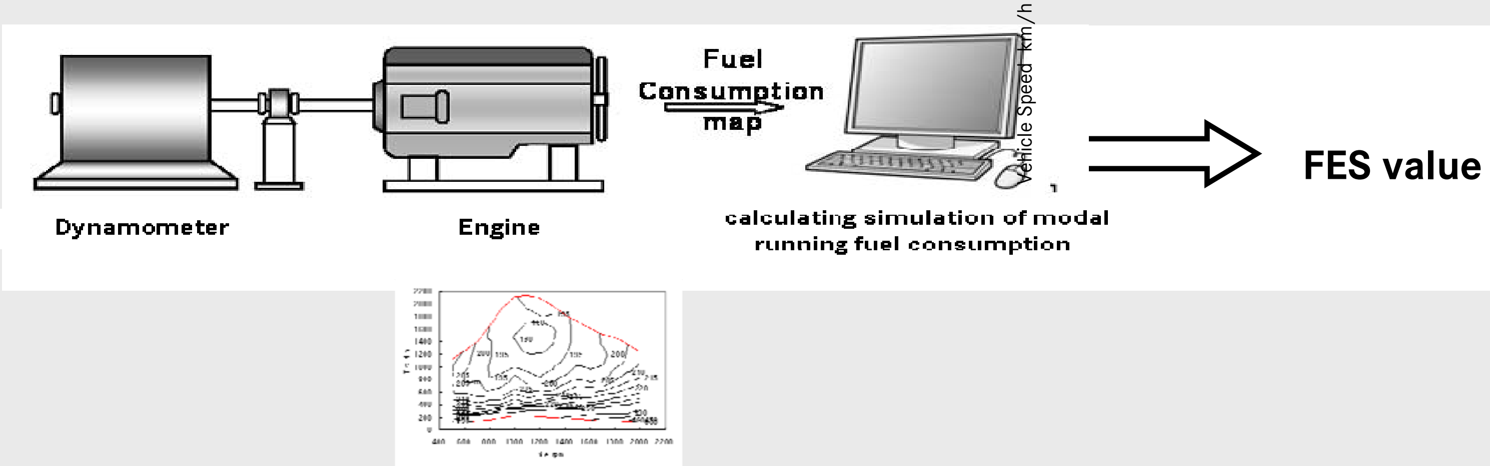
Overview on measurement methods of regulations

				 **Recommended Approach**
Measurement Principle	 Separate engine (test bench) and vehicle standard (simulation)	 Chassis dyno test for key type vehicles. Simulation used for variants.	 Vehicle Simulation with OEM specific measured input data	 Vehicle Simulation with OEM specific measured input data
Metrics	g/ton-mile, gCO_2/BHP-HR	g/vkm	g/vkm	g/tkm
Simulation Input Data				
Segmentation / Cycles	Weight oriented (GVW) segment approach	• Most likely GVW based (>3,5t) • Cycles: based on C-WHVC (Chinese version).	Weight oriented (GVW) segment approach	Mission specific vehicle segmentation, Mission Based Cycles: desired speed over distance, grade over distance, defined stops 

- **Current situation characterized by**
  - **regional markets, variety of products and therefore**
  - **major differences in methodological approaches**

Elements of Japanese HD-Regulation

Method



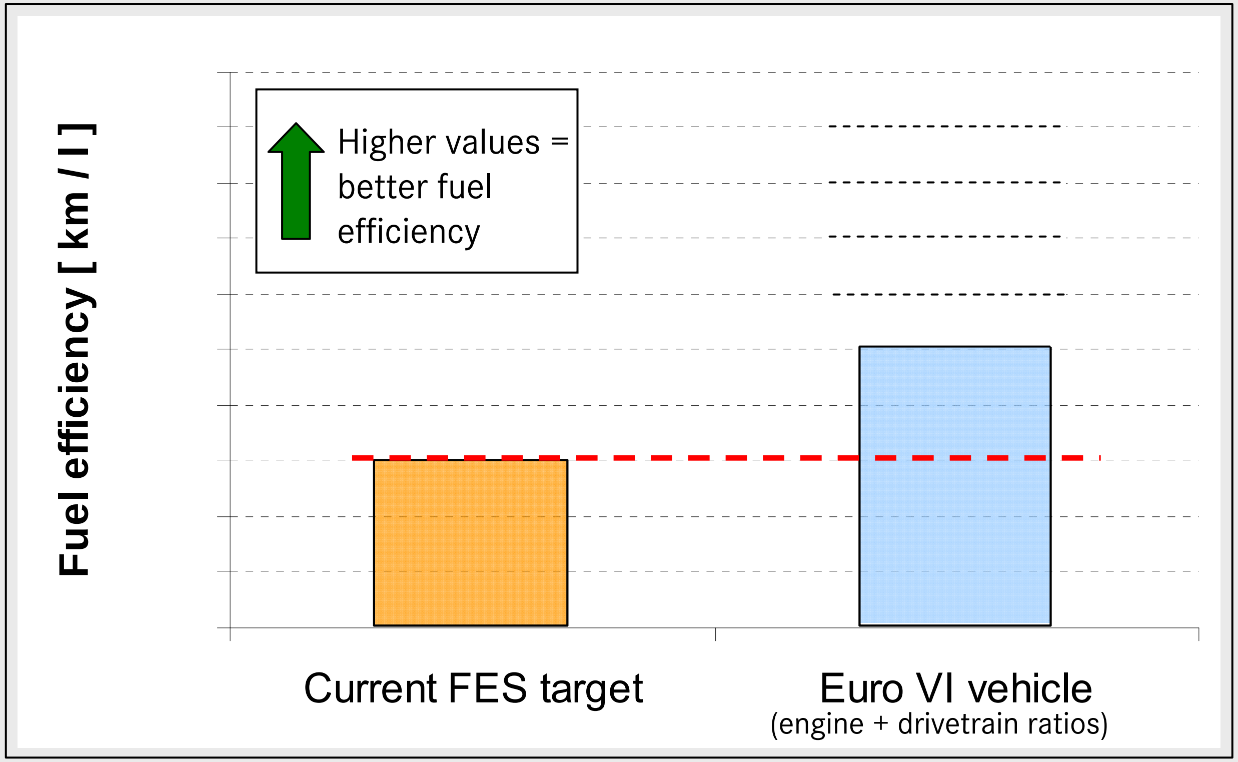
Input Data

Max Engine torque
Idling engine speed
Max engine speed
Rated engine speed
T/M gear ratio
final gear ratio
Tire radius

Limits

Category				Target value of Fuel Efficiency km/L
Truck	T1	3.5< GVW ≦7.5	Pay Load≦1.5t	10.83
	T2		1.5<Pay Load≦2t	10.35
	T3		2< Pay Load≦3t	9.51
	T4		3< Pay Load	8.12
	T5	7.5< GVW ≦8t		7.24
	T6	8< GVW ≦10t		6.52
	T7	10< GVW ≦12t		6.00
	T8	12< GVW ≦14t		5.69
	T9	14< GVW ≦16t		4.97
	T10	16< GVW ≦20t		4.15
	T11	20< GVW		4.04
Tractor	TT1	GVW ≦20t		3.09
	TT2	20t< GVW		2.01

Japan (fuel efficiency standard)



- Official **vehicle classification** number T11 **(70 % City, 30 % Highway)**
- Standard **vehicle configuration** (25 t, 6X2)
- Official **simulation tool**: (F)ExecutionProgram.exe (TRIAS 5-8-2007)
- **Driving resistances** For air-drag and rolling resistance fixed values are used in simulation tool
- **FC in idling mode** is entered separately (not derived from FC map)

Notes:

- boundary conditions for FC map measurements are not exactly as defined in FES rules (consideration of auxiliaries);
- no optimization of fuel map data for FES → Resulting chances and risks are about neutral in total

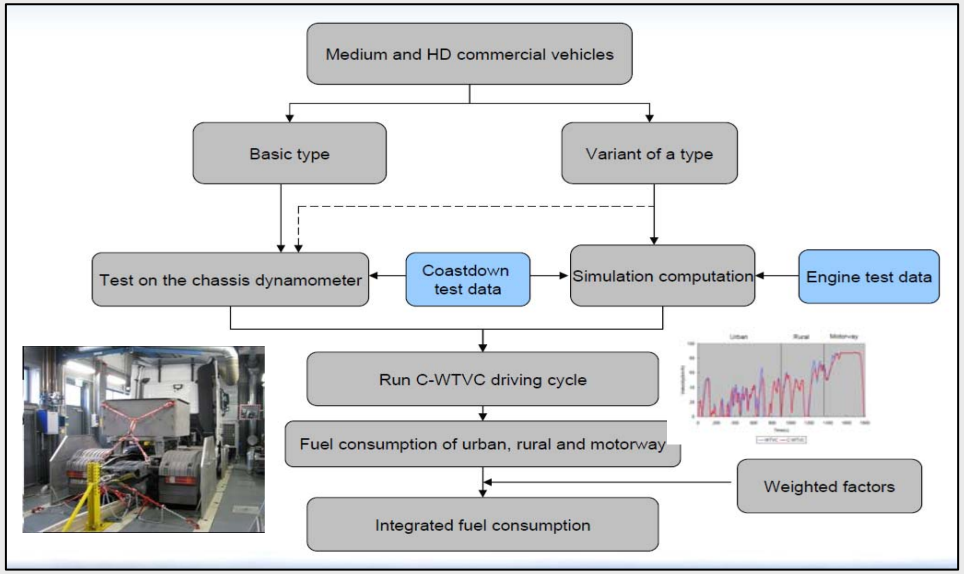
Vehicle classification and specifications (T11):

Fuel consumption classification No.	Classification		Standard vehicle specifications					Intercity running ratio (%)
	Range of gross vehicle weight (t)	Range of maximum loading capacity (t)	Vehicle weight (kg)	Maximum loading capacity (kg)	Passenger capacity (persons)	Overall height (m)	Overall width (m)	
T11	20 <	–	8,765	15,530	2	2.934	2.490	30

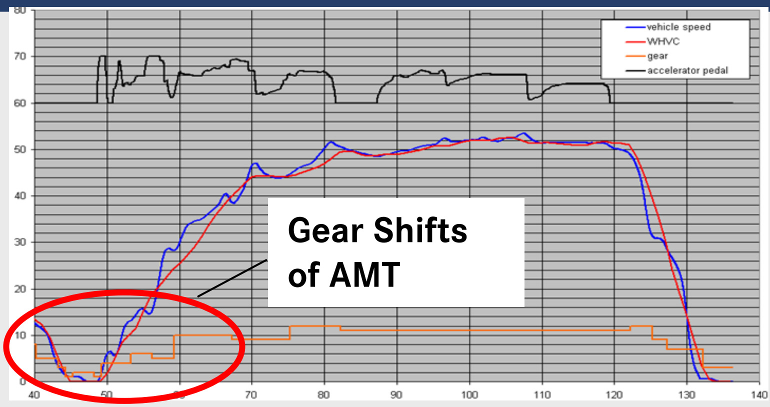
- **An efficient Euro VI engine and drivetrain would meet the FES target 2015 for T11 class. (high sales volume, 6x2, 25 t, 4.04 km/l)**

Elements of Chinese HD-regulation

Method: Standard Framework



Specifics Chinese WHVC



Fuel Consumption Limits

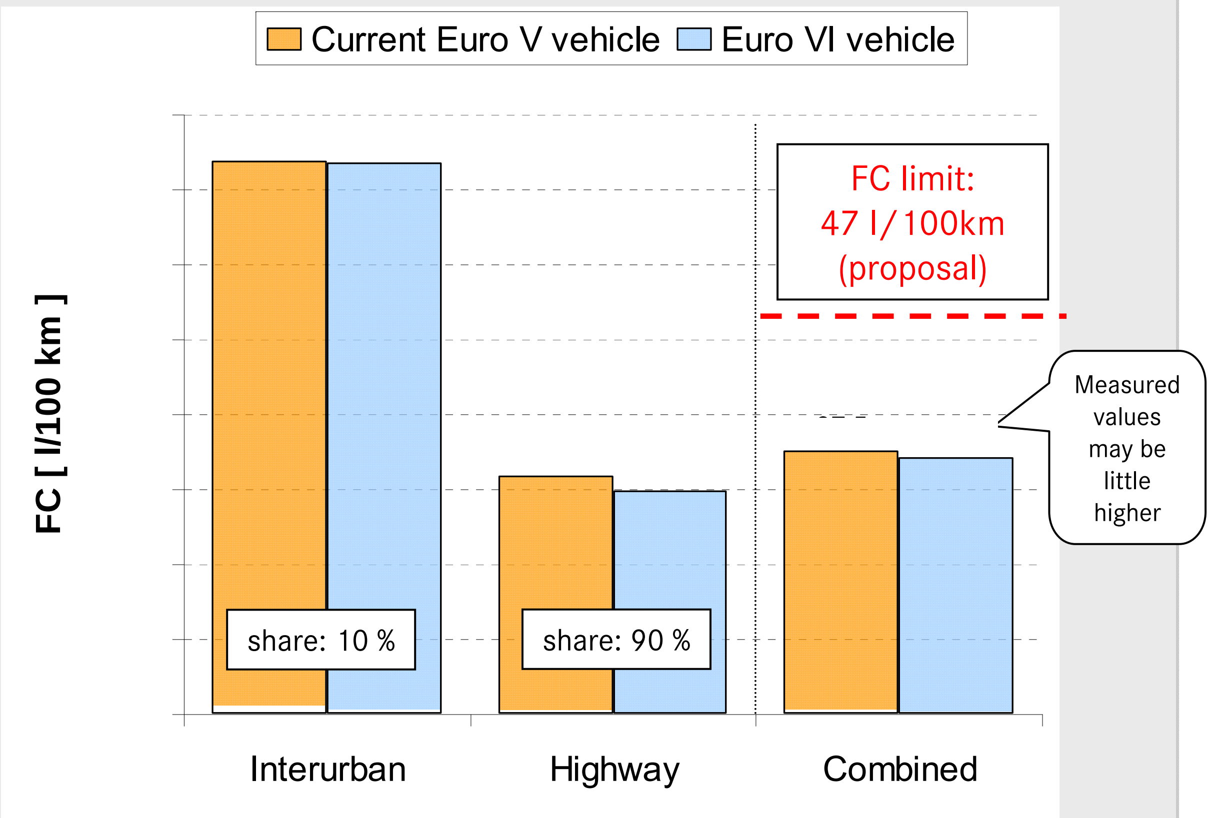
- 3 categories:
    - FC of Rigid Truck (NOT incl. Tipper)
    - FC of Semi-Trailer Truck Tractor
    - FC of Bus (NOT incl. City-Bus)
- Metric: L/100km

Excerpt: Tentative Proposal of FC Limits of Semi-Trailer Truck Tractor

GCW kg	L/100km
GCW ≤ 18000	–
18000 < GCW ≤ 27000	–
27000 < GCW ≤ 35000	45.0
35000 < GCW ≤ 40000	47.0
40000 < GCW ≤ 43000	49.0
43000 < GCW ≤ 46000	51.5
46000 < GCW ≤ 49000	53.9
49000 < GCW	–

China - comparison Euro V / Euro VI vehicle
(CATARC FC tool)

- Engine power 315 kW Euro VI and 320 kW Euro V
- Torque 2100 Nm
- Mass: 40.000 kg
- Coast-down curve generated artificially
- Same rolling resistance
- Aerodynamic improvements for Euro VI vehicle
- Same gearbox data
- Standard final gear ratio for each vehicle



Notes:
- Just simulated values, no chassis dynamometer tests
- CATARC FC tool version 1.0.0.20110225

- **Both Euro V and Euro VI vehicles would meet the proposed Chinese FC limit.**

Elements of CO_2 classification class 8 sleeper cab

Aerodynamics CdA

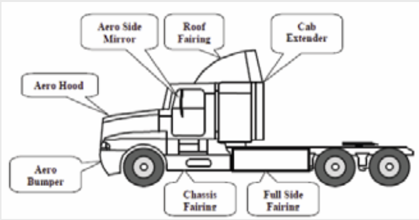
BIN I (CdA >= 7.6): classic tractor with features increase drag

BIN II (CdA: 6.7-7.5): conventional tractor general aero shape, avoids classic features

BIN III: (CdA: 5.8-6.6): EPA SmartWay, adds components to reduce drag

BIN IV: (CdA: 5.2-5.7): additional aerodynamic refinements available today

BIN V: (CdA: <= 5.1): additional aerodynamic refinements expected available in future



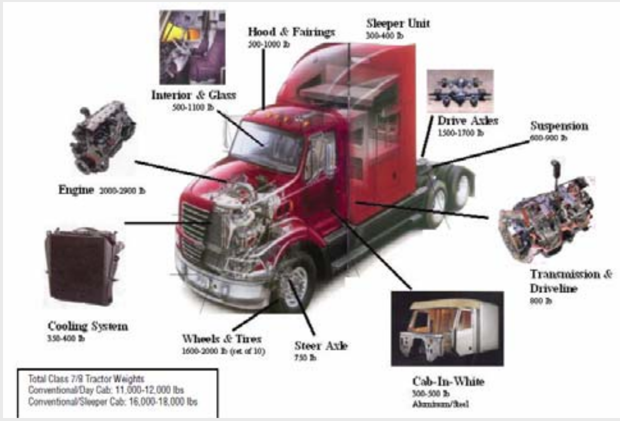
Tires

Baseline: Crr: Steer = 7.8; Drive = 8.2

BIN I: Crr: Steer <= 6.6; Drive <= 7.0: SmartWay low resistance tires

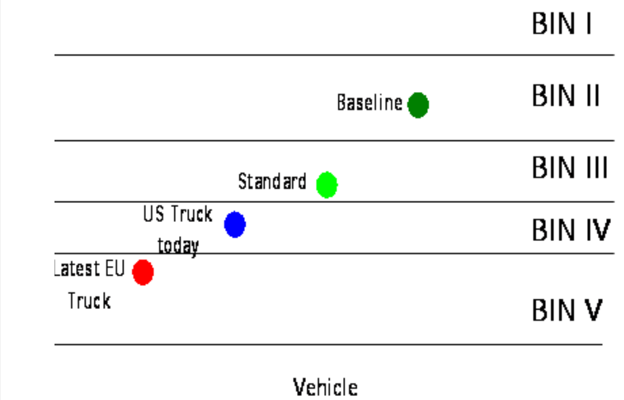
BIN II: Crr: Steer = 5.7; Drive = 6.0

Weight Reduction



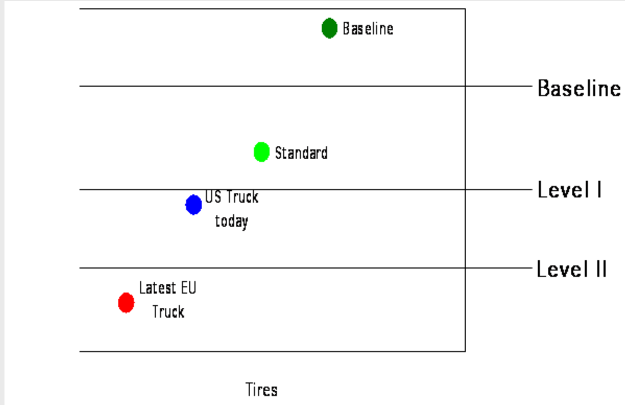
Elements of CO_2 classification Class 8 Sleeper Cab

Aerodynamics C_dA



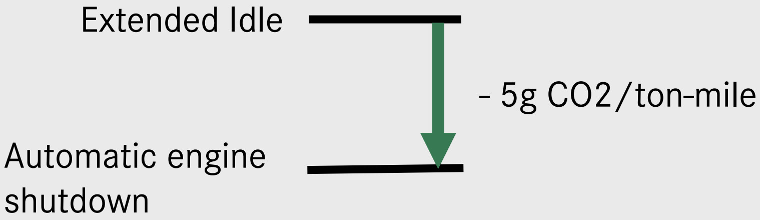
Aerodynamics of latest European truck outperforms future US trucks (trailer gap)

Drive & Steer Tires (C_{rr})



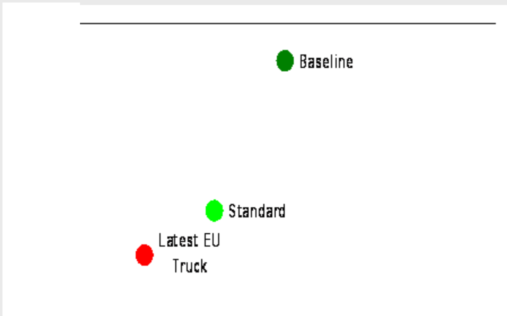
Highest contribution to rolling resistance: (Drive Tire: 42.5%, Steer Tire 12,5%)

Idle Reduction



Credit of 5g CO2/ton-mile through automatic engine shutdown

Weight Reduction

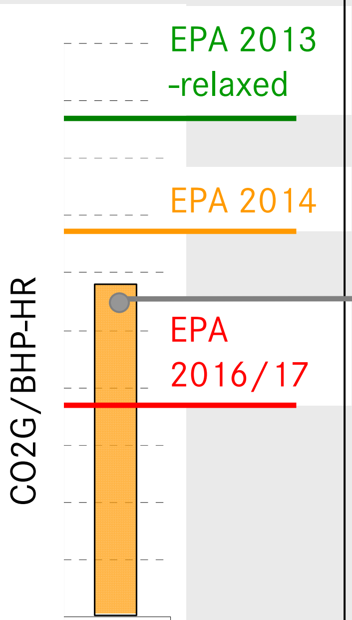


EU comparable to US standard

USA – fuel map comparison

- Euro VI engine compared to NAFTA-engine fulfilling the EPA2014 CO2 limit

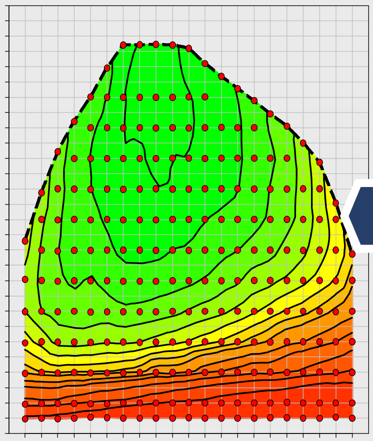
US-engine CO2-limits



Most advanced engines available on US market today

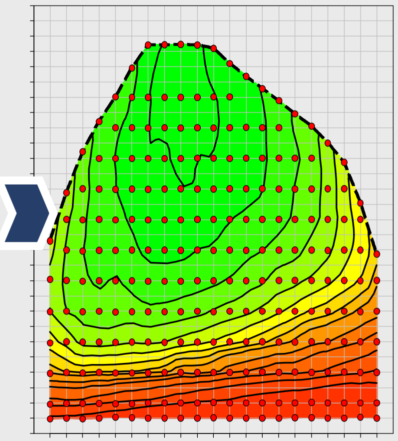
Fuel map comparison as <u>indication</u> of <u>general efficiency levels in vehicle</u>

EPA 10 Fuel Map



Analysis shows that EPA 10 map is better in some areas, while Euro VI is better in some other areas of the fuel map. All in all the efficiency ratios are very similar

Euro VI Fuel Map

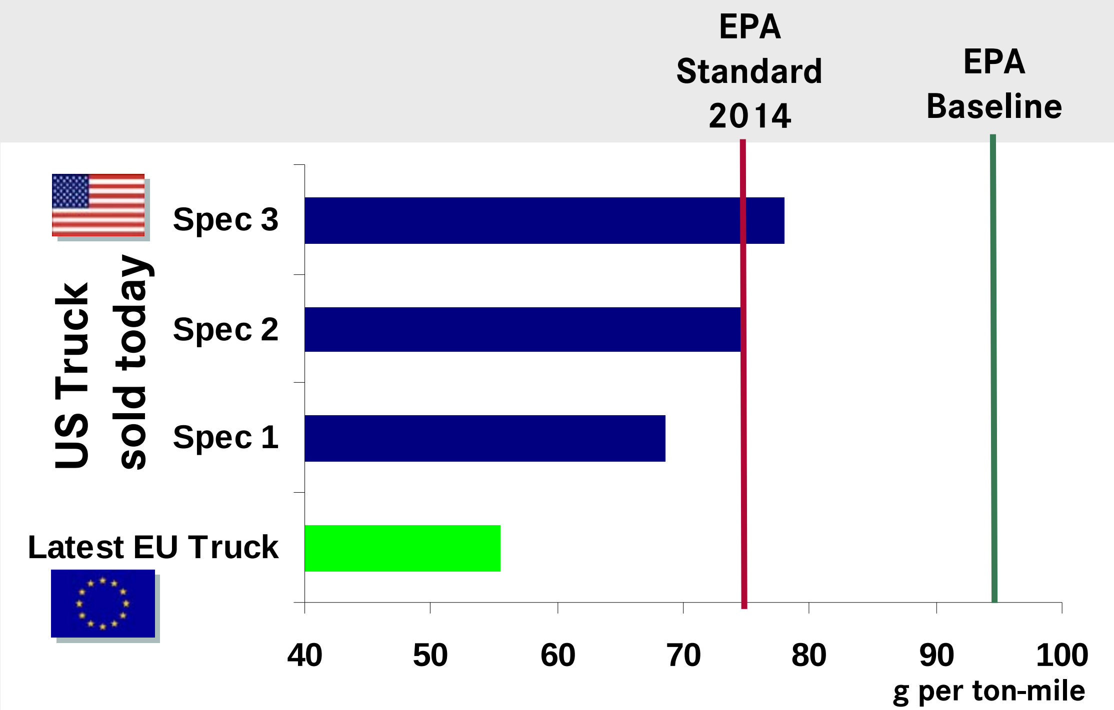


<u>Remark:</u>
Test cycles, tailpipe NOx and vehicle operational profiles different in Europe and US !!

- **Euro VI engine with comparable or even better fuel efficiency in nearly all operating points**

Vehicle simulation based on the US GEM 2.0 model

- Class 8 High Roof Sleeper Cab



- GEM input data for regulation relevant items, have been selected as illustrated previous slide.
- **Speed limit reduction for EU truck have been considered:** 55mph instead of 65

Facts

- For US truck today typical* specifications of fleet customers are selected.
- For Europe specification of latest EU truck technology is selected.
- All trucks specification have been modeled employing official GEM model provided by EPA, using standard engine 2014.

*) not statistically representative

- **US market: most advanced trucks meeting 2014 standards.**
- **Based on the GEM Model and its limitations performance of latest European trucks significantly better – in reality the difference is smaller**

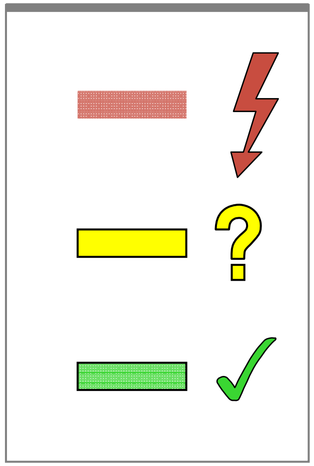
Evaluation of Feasibility of technologies proposed in LOT-1

Long Haul – Cost Effective Scenario

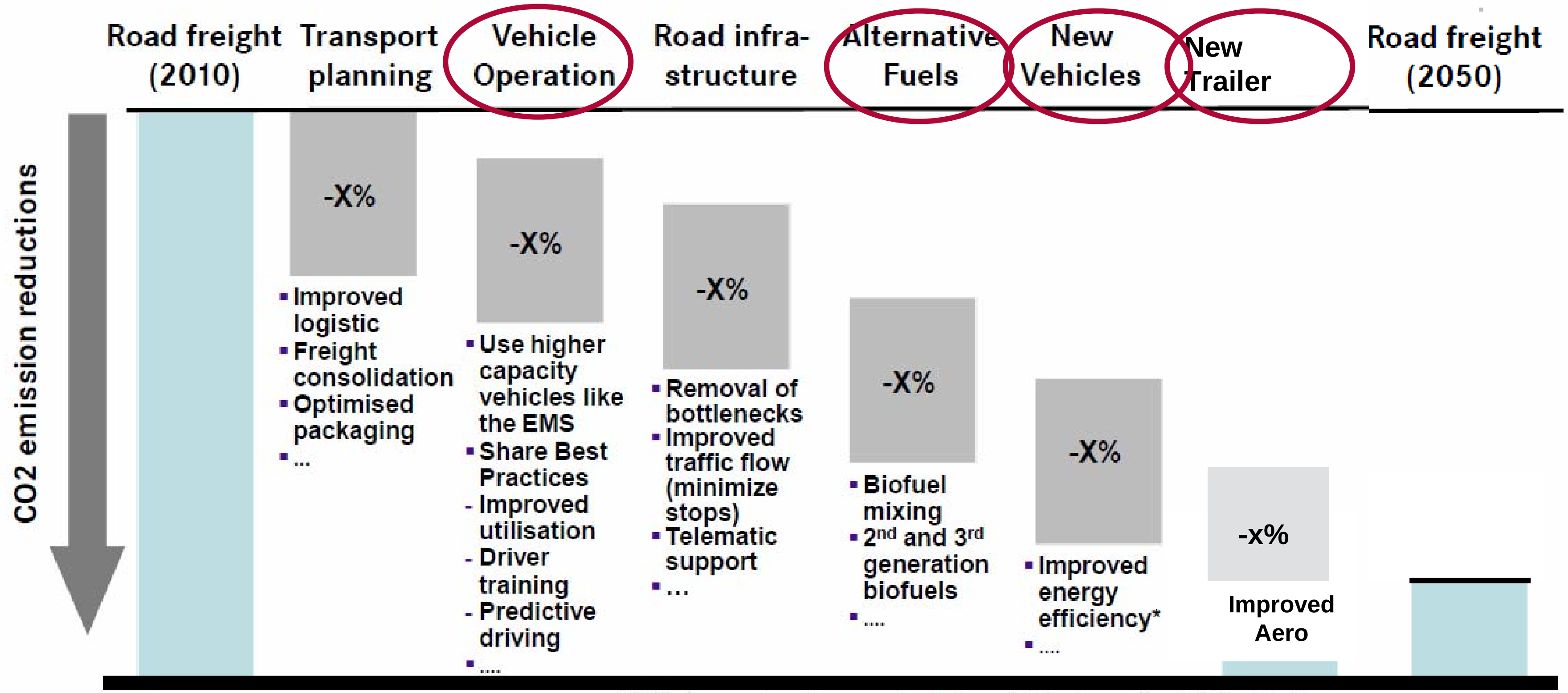
Technology	Evaluation	Comments
Electric Vehicle		Long Haul not applicable
Alternative Fuelled Bodies		e.g. solar
Full Hybrid		Not cost effective
Stop/Start System		No fuel reduction impact in Long haul
Dual Fuel (CNG/Diesel)		CO2 reduction vs. energy efficiency
Pneumatic Booster		Not cost-effective according to Daimler evaluation
Controllable Air Compressor		
Automated Manual Transmission		
Aerodynamic Trailers/Bodies		Known to have high reduction potential
Aerodynamic Fairings (Tractor)		
Spray Reduction Mud Flaps		
Predictive Cruise Control		Early field tests
Automat. Tire Pressure Monitoring		In series
Low Rolling Resistance Tires		Already available in EU; further development activities of tire manufacturer
Single Wide Tires		Already available in EU

EU Trucks

Latest Technology



Integrated approach



* Will also require changes of existing vehicle size and weight legislation

- Tight resources require the consideration of entire vehicle including trailer for identifying most cost effective GHG reduction measures.
- Soft measures such as driver training can result in 5-15% fuel consumption reduction
- Biofuel has high potential to reduce GHG emission over the entire vehicle fleet.

Recommended Principles for a CO2 declaration approach

1. **CO2/FE values have to be "realistic" for all to be declared vehicle variants and CO2 reduction in real world can be determined accurately**
   - ⇨ full vehicle approach needed including engine fuel consumption in vehicle
   - ⇨ avoid split in engineering activities for declaration versus customer use
   - ⇨ "realistic" means an representative value for the specific vehicle applications, despite the fact that the spread of FE at the customer is often huge
   - ⇨ Assist customers in purchase decisions

2. **As much as possible CO2 reduction measures should be covered, but declaration procedure need to be repeatable, robust and practicable**
   - ⇨ nearly all reduction potentials should occur in test/simulation procedures

3. **Effort/resources for CO2- declaration reasonable for OEM's**
   - ⇨ it will be more effort, but test burden should be reasonable/acceptable

- **Only a full vehicle approach is able to fulfill declaration principles**

Key requirements for harmonization of test procedures vs. current status

Key Requirements	USA	China	Japan	ACEA
Standard for vehicle incl. engine				
Simulation based				
Measured OEM-specific engine data				
Measured OEM-specific vehicle data				
Metrics: gCO_2/tkm (ton-mile)				
Mission Specific Vehicle Simulation				
Market Specific Cycles incl. slope				

+ ***Chances***

- \+ Structure and Key Components similar.
- \+ Phase 2 of US regulation offers opportunities to improve US standard
- \+ World wide initiatives justifies UN-ECE work on measuring methods/test procedures

- ***Risks***

- Fulfillment of requirements with regional variability.
- Industry: High costs due to variety of measurement methods/test procedures.
- Customer: real world fuel consumption may not match values derived from regulation.
- Society: Inefficient use of tight resources resulting in lower real world reductions.

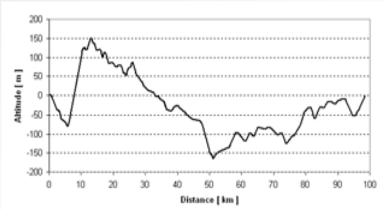
- **Adjusting existing measurement principles essential to achieve harmonization on reasonable level.**

World harmonization essentially required but regional approaches with rising variation in crucial details

International harmonization of cycles, methods and simulation tool

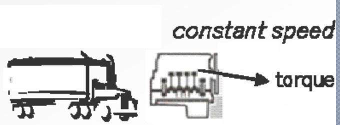
Cycle Definition

- Slope
- Load



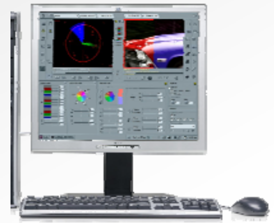
Measuring Methods / Test Procedures

UN-ECE:
- Aerodynamic
- Tires
- Fuel Maps



Simulation Tool

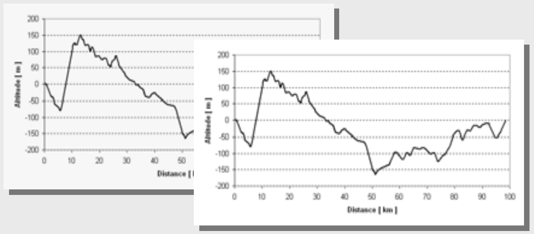
Simulation tool
(provided by legislative bodies)



Application of internationally harmonized standards as basis for specifically required characteristics

Cycles, depending on use-cases (missions)

- Regional
- National



Segmentation:

- with regional/ national differences

City delivery	
Delivery / communal	
Heavy delivery	
Long haul	
One Overnight	
On-road construction	
Heavy construction	

- **World-wide standards for measurement of HDV fuel consumption need to be developed.**
- **Regional aspects (world-wide simulation/regional test cycles/vehicles/...) need to be taken into account.**

Conclusion

European manufacturers & customers have given fuel efficiency high attention, all "low hanging fruits" are already harvested.

The ACEA approach of a certified declaration of fuel efficiency offers customer guidance in terms of real life results, further encouraging competition

The integrated approach offers additional and cost effective potentials for the improvement of fuel efficiency and CO2 performance.

Thank you for your attention