Business from technology

Photo: VW

Vehicle energy efficiencies

IEA EGRD Workshop
“Mobility: Technology Priorities and Strategic Urban Planning
Nils-Olof Nylund
VTT Technical Research Centre of Finland

Outline

- General introduction
- Ways to reduce fuel consumption
  - engine technology
  - reduced need for power
  - electrification
- Trends for
  - passenger cars
  - buses
  - heavy-duty trucks
- ICE vs. EV
- Summary

Elements determining the environmental impacts of traffic

Community structure

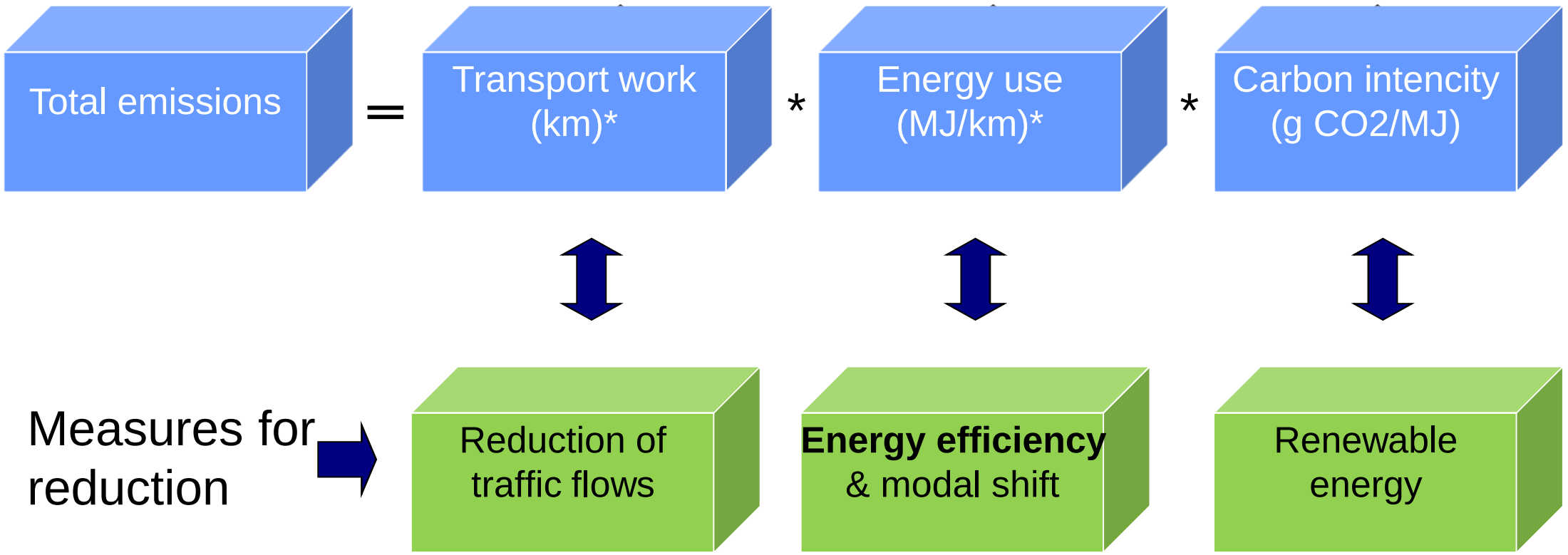
Traffic volumes & choice of transport mode

Energy for transport

Vehicles and user behaviour

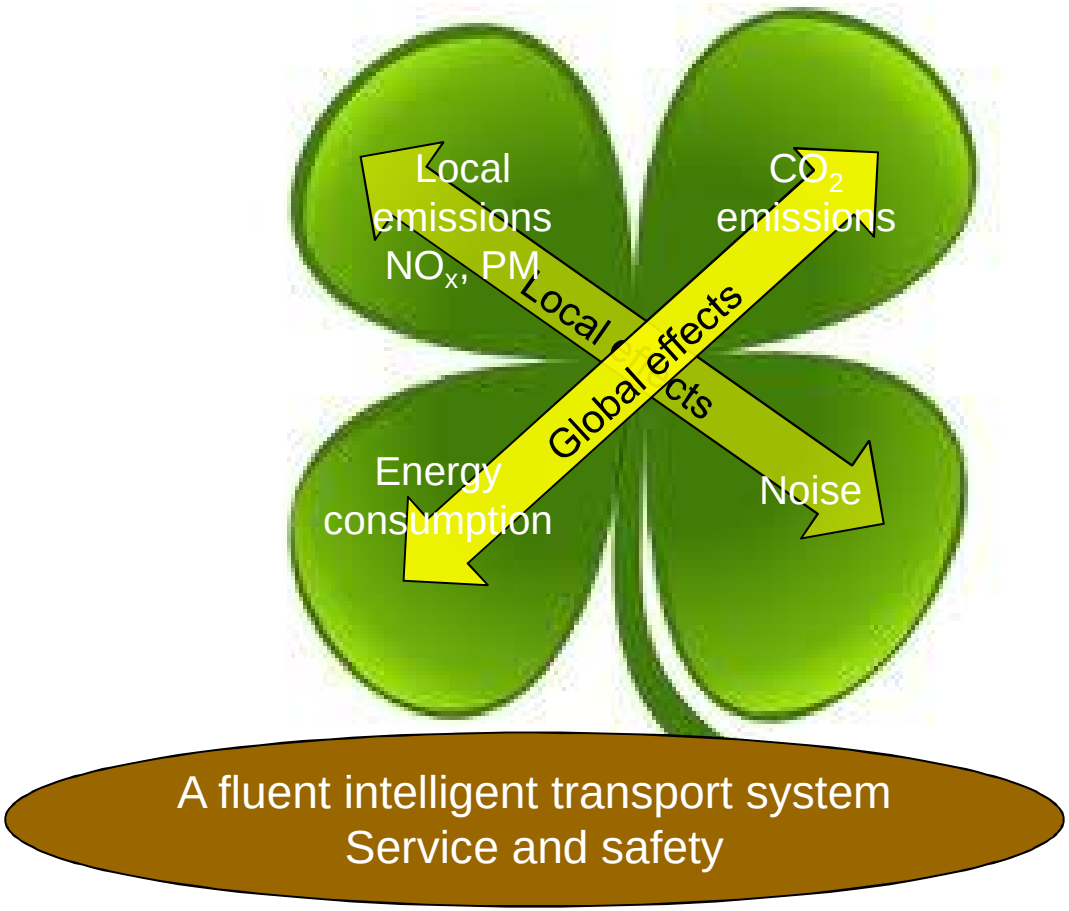
Policy orientation ⟷ Technology orientation

Formation and control of CO_2 emissions



*passenger/tonkilometre

Environmental friendliness
Multi-dimensional contemplation



Current status of vehicles

- The current passenger car is:
  - reliable
  - comfortable
  - relatively safe
  - environmentally friendly regarding regulated emissions
  - in most cases a ”high-performance” vehicle
- What should be improved?
  - fuel efficiency
  - the ability to use renewable or CO_2-neutral energy
  - rational use of cars
- Traditionally heavy-duty vehicles have been fuel efficient but dirty, but with the JPN 2009, US2010 and Euro VI emission regulations the situation will change

Factors affecting energy consumption/CO_2 emissions

Vehicle use

Load

Environmental conditions

Mileage

Fuel/energy carbon intensity

Traffic fluidity

Driving res.
- weight
- aerodynamic drag
- rolling res.

Information system

Driveline characteristics
- manual/automatic
- hybrid

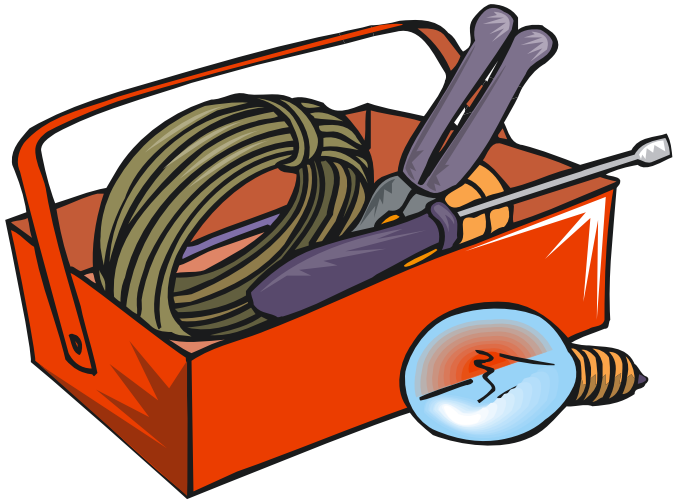
Technology

Driving behaviour

Powerplant characteristics

Technical tool box for a cleaner future

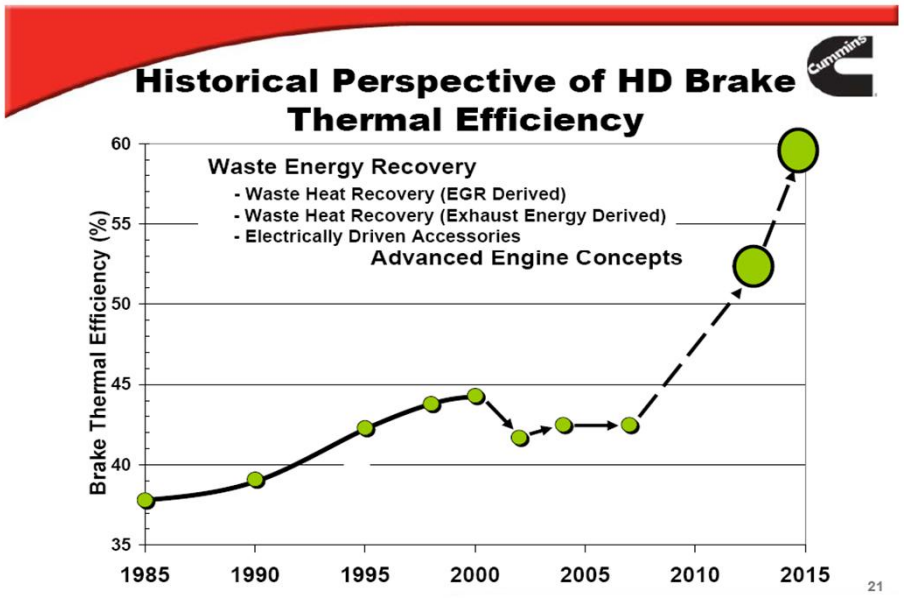
- Improved engine technologies
  - Combustion, AMT
- Reduced need for power
  - AMT
- Hybridisation
  - HEV
- Electrification
  - HEV, AFC
- Fuel cell technology
  - AFC, HEV, Hydrogen
- Alternative fuels
  - AMF, Bioenergy, Combustion, Hydrogen



iea Energy Technology Network

Improving engine efficiency

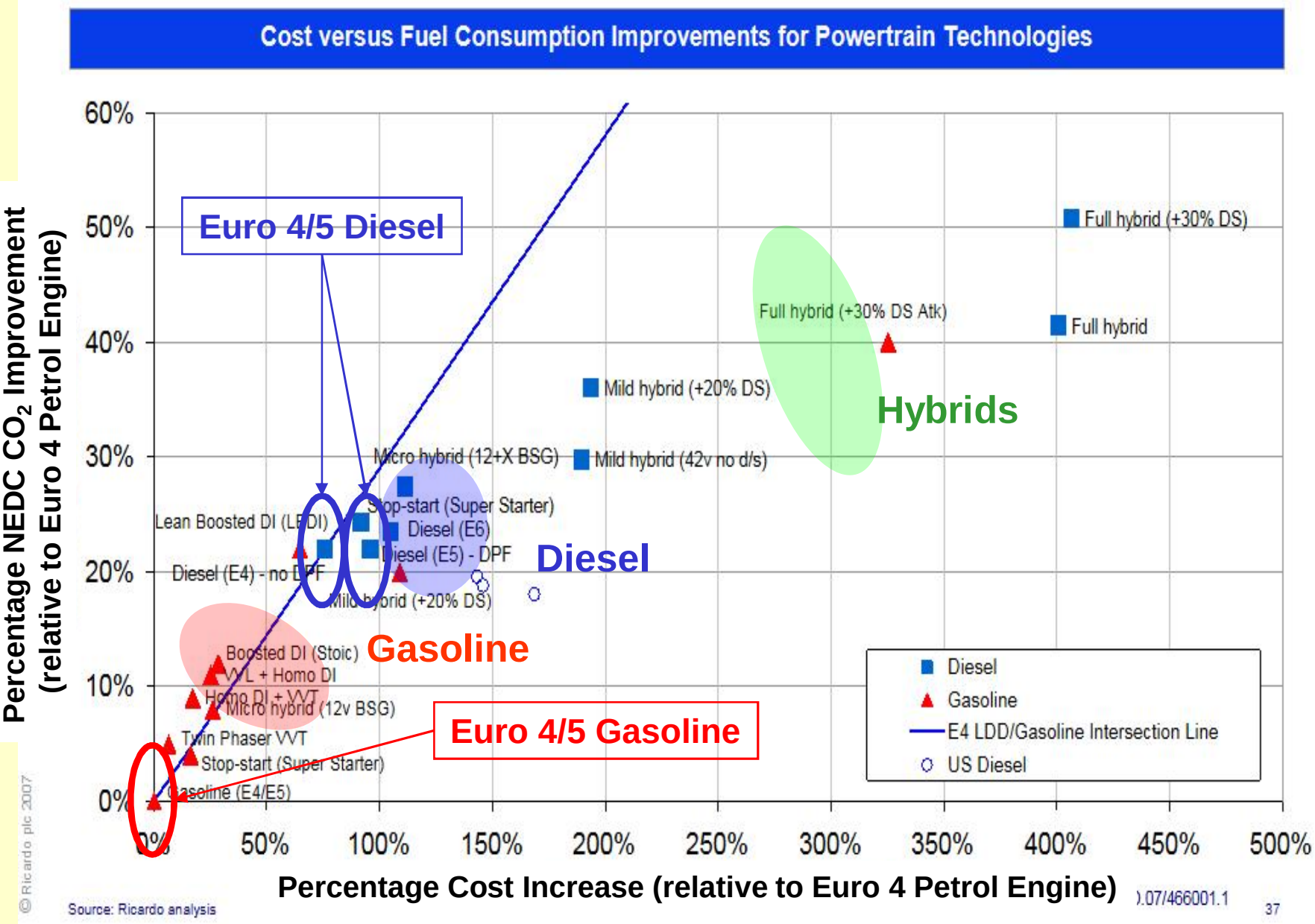
- For all ICE types the pathway into the future includes :
  - reducing the physical size of the engine and increasing relative load (”downsizing”)
  - improving boosting technologies
  - implementation of direct fuel injection
  - reduction of friction
  - increase in control parameters
  - powerful control systems
  - electrification of auxiliaries



- The main challenge
  - simultaneous reduction of fuel consumption and regulated exhaust emissions

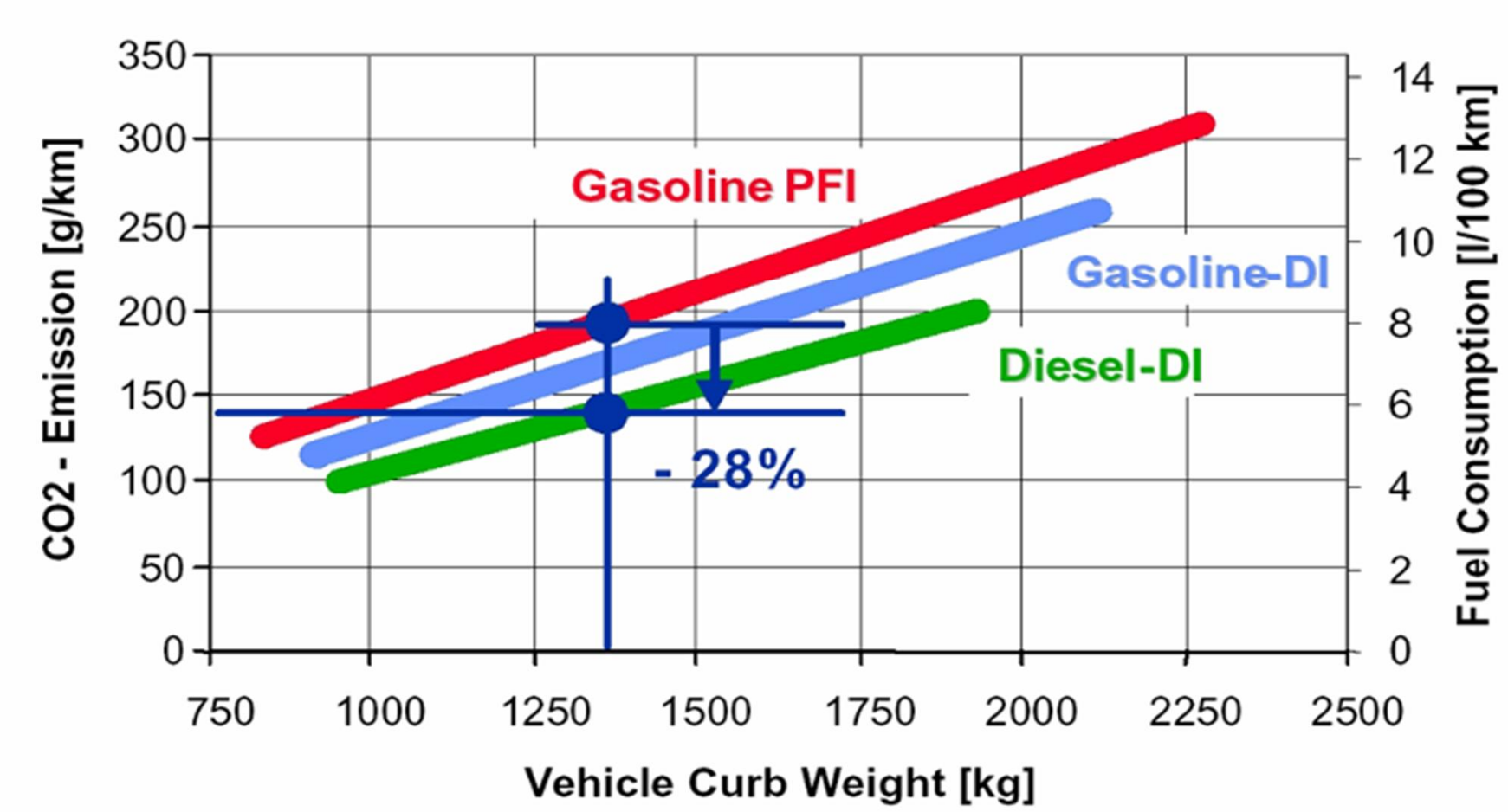
- Future possibilities
  - combining the best features of Diesel and Otto (spark-ignited) engines
  - waste heat recovery
    (with a focus on heavy-duty engines)

Reducing CO_2 Adds Cost to Vehicle Powertrain



Source: Ricardo analysis communicated to CONCAWE (2008)

Effect of engine type and curb weight on passenger car fuel consumption



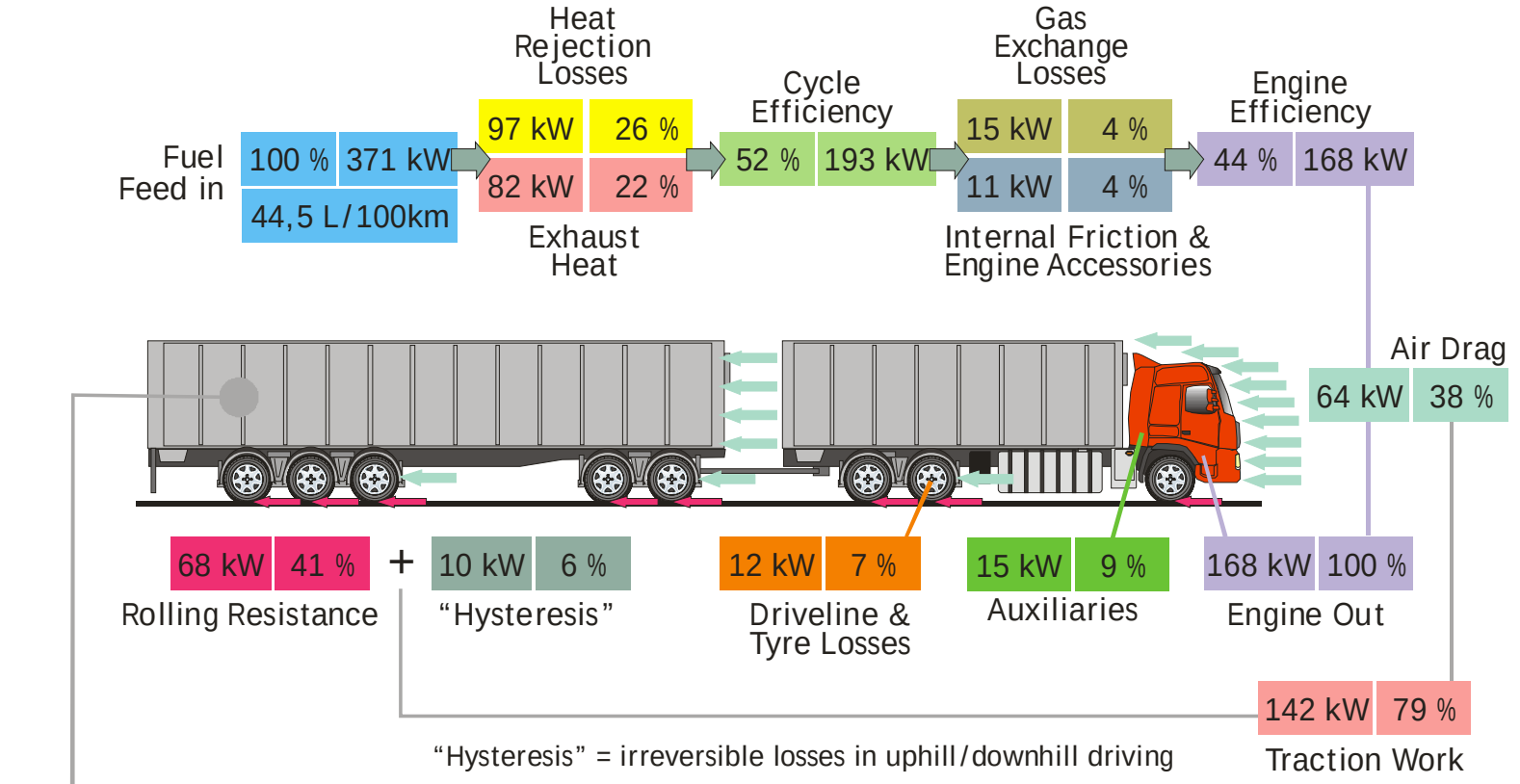
Reducing the need for power

- We should reduce curb weight, rolling resistance and aerodynamic drag
- Weight reduction can be acheved through reduction of size (passenger cars) and by utilizing lighter materials (all types of vehicles):
  - high-strength steels
  - aluminium and aluminium alloys
  - magnesium and magnesium alloys
  - titanium and titanium alloys
  - carbon fiber composites
  - nanocomposites

- The effect of weight:
  - For passenger cars a weight reduction of 10 % reduces fuel consumption some 6 – 7 %.
  - For buses 1,000 kg of added weight as curb weight or passengers increases fuel consumption some 2.5 l/100 km (6 %) in city driving (e.g. Helsinki)
- Aerodynamic drag becomes significant at higher speeds

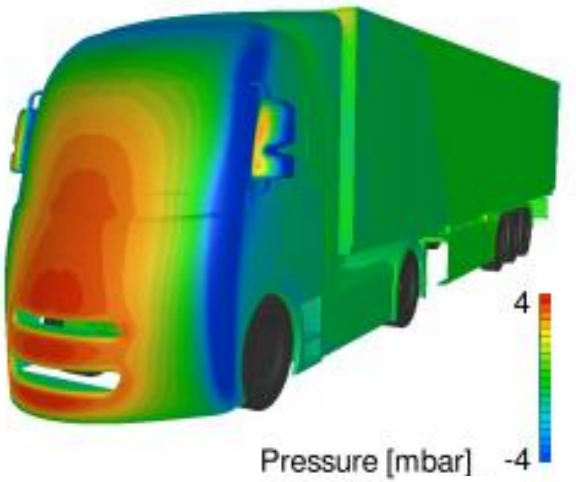
More small cars needed?

60 ton Tractor & Trailer, Full Payload, Freeway at 80 km/h



Combined Total Mass	Fuel-feed	Engine Losses	Engine Out	Auxili-aries	Diveline Losses	Traction Work	"Hyste-resis"	Rolling Resistances	Air Drag	
	371	204	168	15	12	108	10	68	64	kW
	100 %	55 %	44 %	4 %	3 %	35 %	3 %	18 %	17 %	
60 000 kg			100 %	9 %	7 %	77 %	6 %	41 %	38 %	

Improving aerodynaomics of HD vehicles



30 % smaller drag: fuel savings10 – 15 %

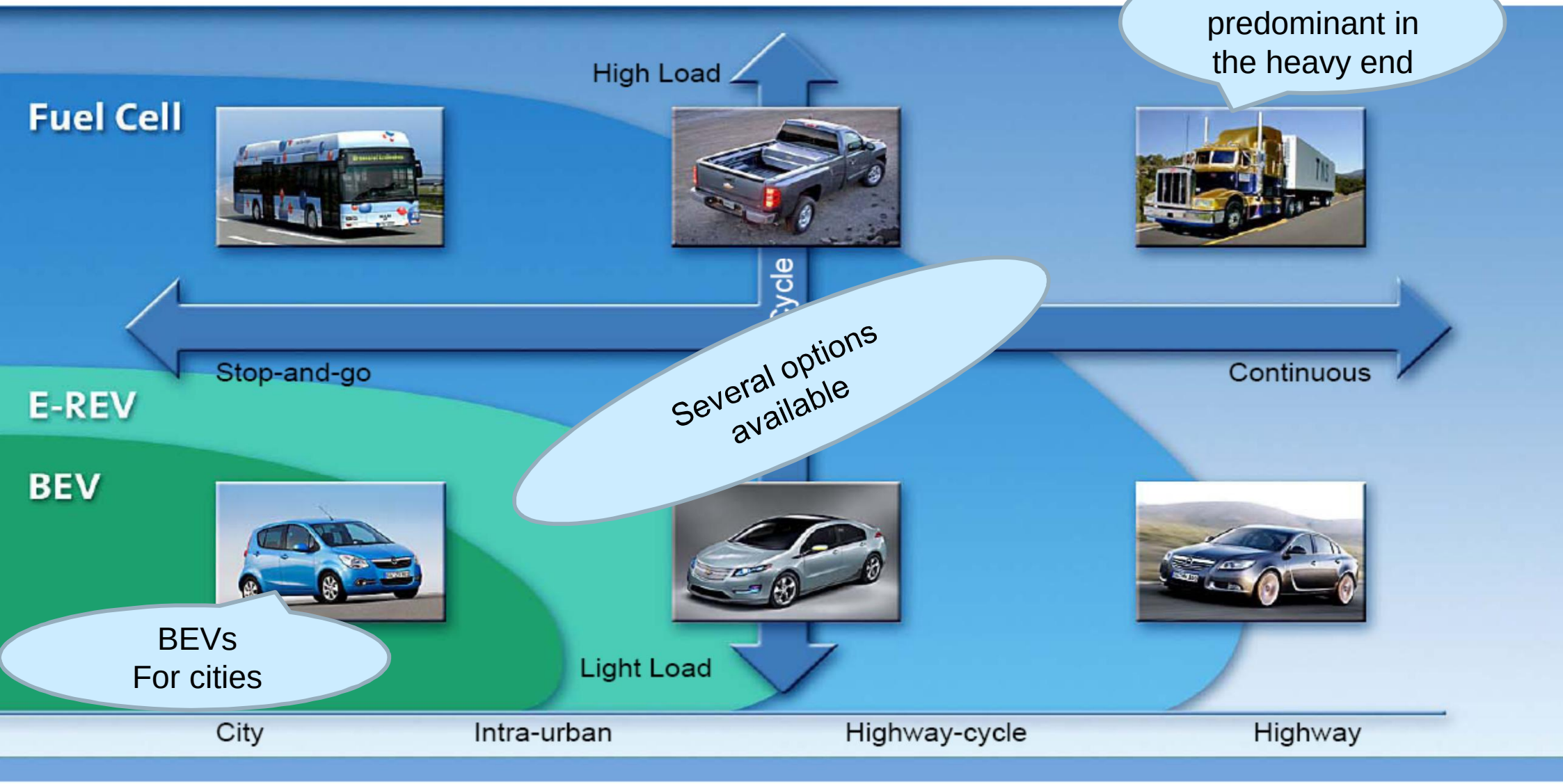
Steps in Electrification

Internal combustion engine	Mild Hybrid	Full Hybrid	Plug-In Hybrid	Electric vehicle	Fuel Cell
 1,2 l 77 kW TSI®	 Start-Stop system recuperation	 Touareg Hybrid®	 Golf twinDRIVE®	 E-Up!	 Tiguan Hymotion®

The share of electricity increases

Steiner/VW 2010

Application Map for Electric Vehicle Technologies



No Silver Bullet !!!

Source: GM

Key technical measures to promote energy efficiency for various vehicle classes

Passenger cars:

- smaller and lighter vehicles
- reduced performance
- hybridization, electrification

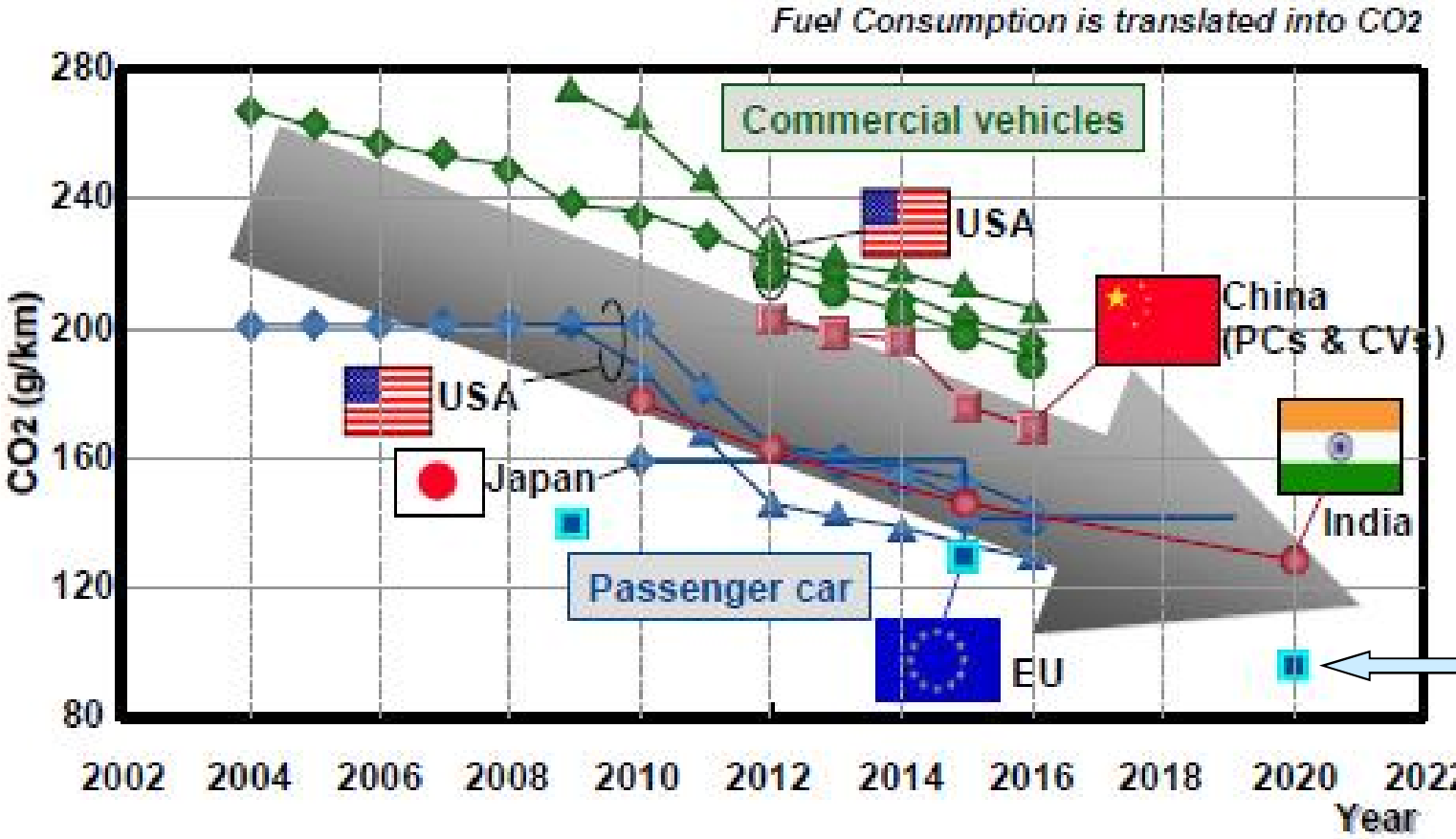
Energia-merkinnän päästöluokka	Raja-arvot CO2-päästöille g/km	CO2-päästöä vast. polttoaineenkulutus (pyöristettynä 0,1 l/100 km tarkkuuteen) Bensiini (l/100 km)	Diesel (l/100 km)
A	max. 100	max. 4,3	max. 3,8
B	101 - 120	4,3 - 5,1	3,8 - 4,5
C	121 - 130	5,1 - 5,5	4,5 - 4,9
D	131 - 150	5,6 - 6,4	4,9 - 5,6
E	151 - 175	6,4 - 7,4	5,7 - 6,6
F	176 - 200	7,4 - 8,5	6,6 - 7,5
G	201 -	8,6 -	7,6 -

City buses:

- reduced weight
- hybridization, electrification

- HD trucks for highway use
  - improved aerodynamics

Development of CO_2 limit values for passenger cars

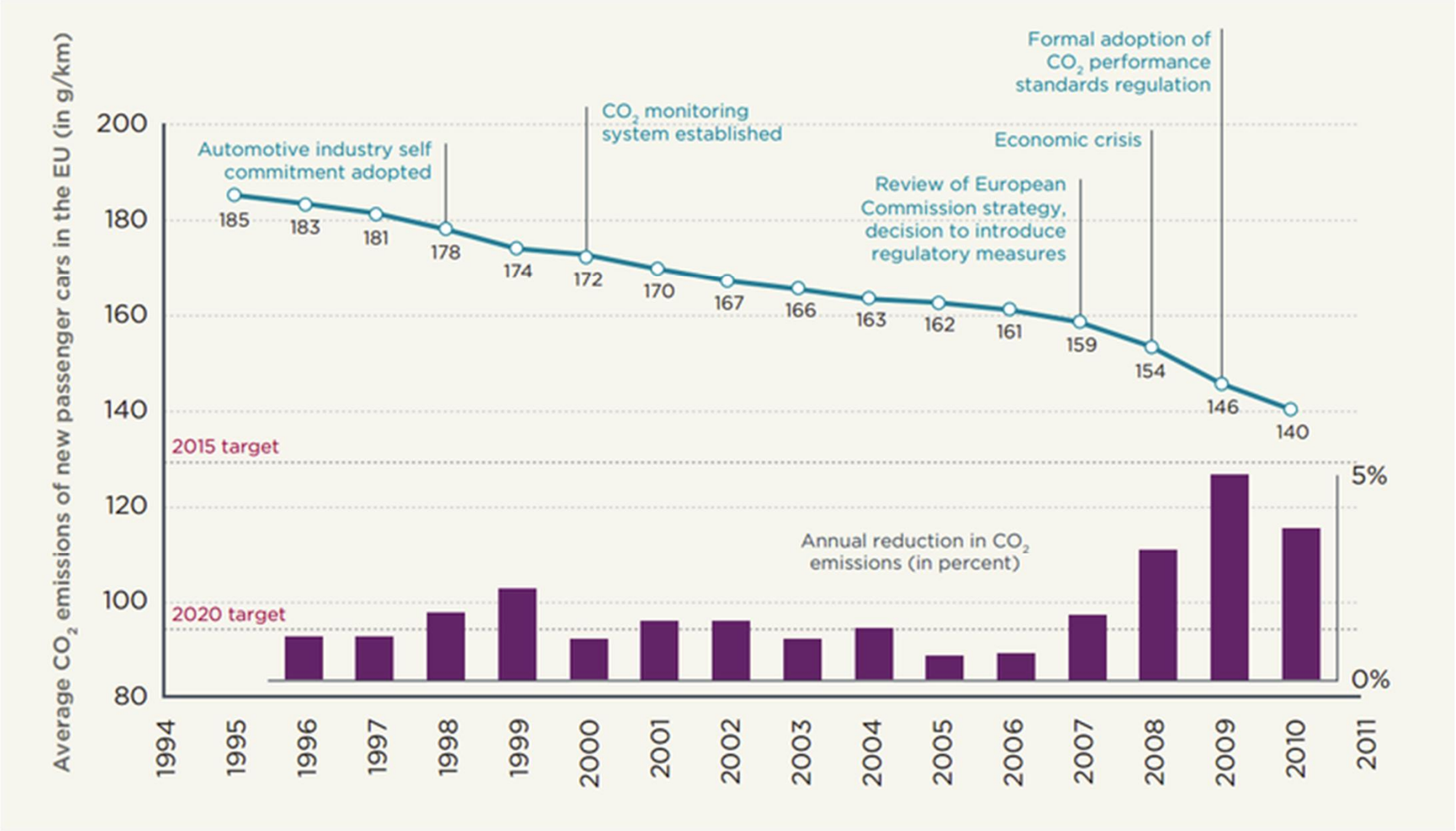


95 g/km
(~4.0 l petrol
/100 km)

Both developed and emerging countries have similar tendencies to enhance CO_2 regulations.

Source: Tanaka/Toyota 2011

Development of passenger car CO_2 emissions in Europe



185 g CO_2 ~ 7.9 l petrol/100 km
140 g CO_2 ~ 6.0 l petrol/100 km

Vägverket

Pick the low-hanging fruit first!

What is the fuel consumption of a Volvo V40 ?

It depends!.....

Volvo V40 T5 automatic
8,1 l/100 km

185 g CO2/km

Volvo V40 D2
3,6 l/100 km

94 g CO2/km

I.e. a reduction of 49 %!

Photo: Volvo Cars

O. Hådell 2008, mod. 2012

Technical progress

	VW Golf VII diesel 2013		VW Golf I diesel 1976		Audi A6 Avant 2013
					
Displacement (l)	1.6		1.5		3.0 twin-turbo
Max output (kW)	77		37		230
Torque (Nm)	250		84		650
Max speed (km/h)	192		144		250 (limited)
Acceleration 0 – 100 km/h (s)	10.7		18		5.3
Curb weight	1295		780		1930
Fuel consumption (EU comb. l/100 km)	3.8		6.4		6.4
CO_2 emission (g/km)	99	⟷	169	⟷	169
Particulate filter	yes		no		yes

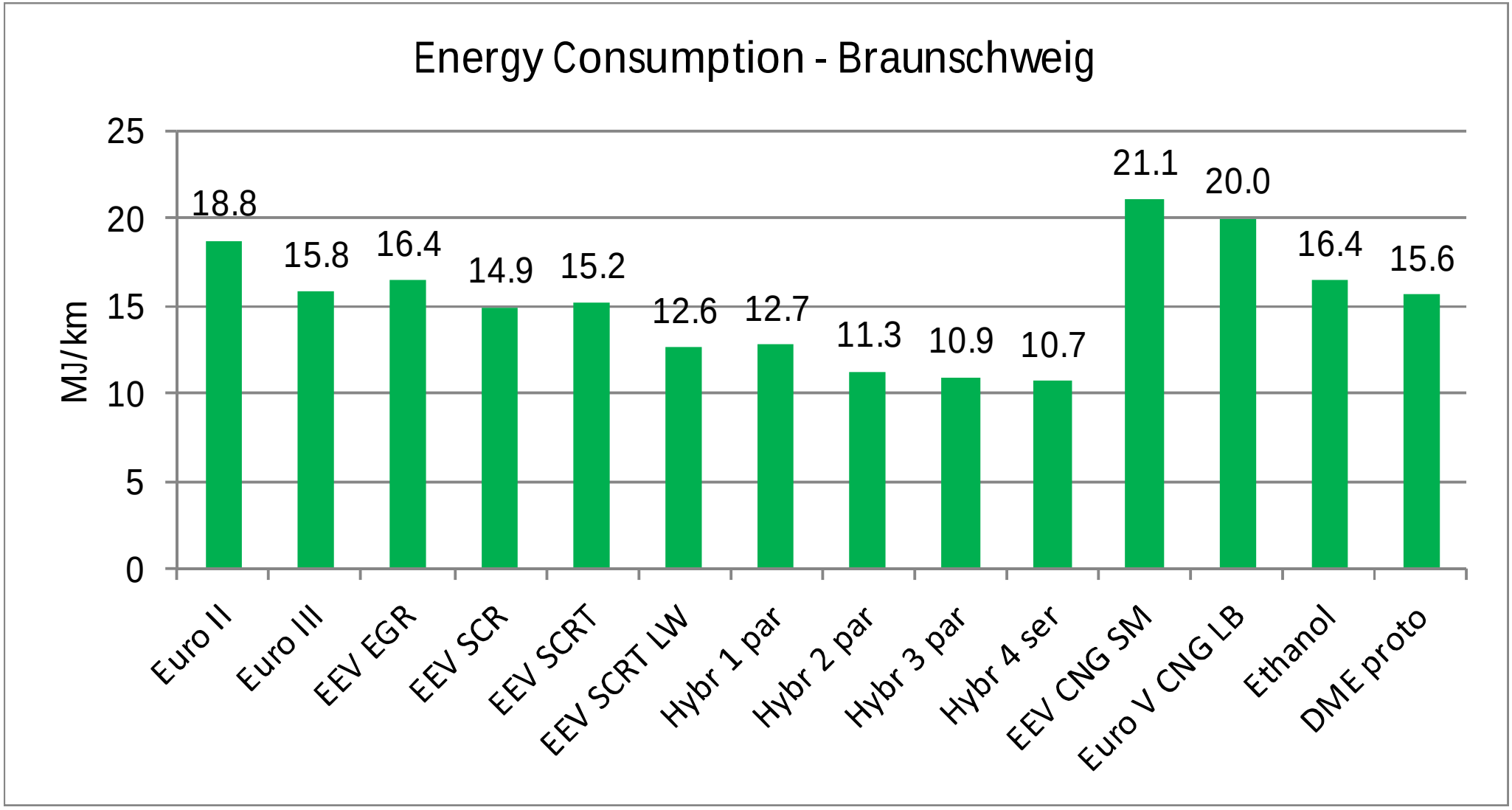
What would have happened if the technical potential would have been used for fuel efficiency only (keeping performance and weight constant)?

IEA Technology Network Cooperation: Fuel and Technology Alternatives for Buses Overall energy efficiency and emission performance

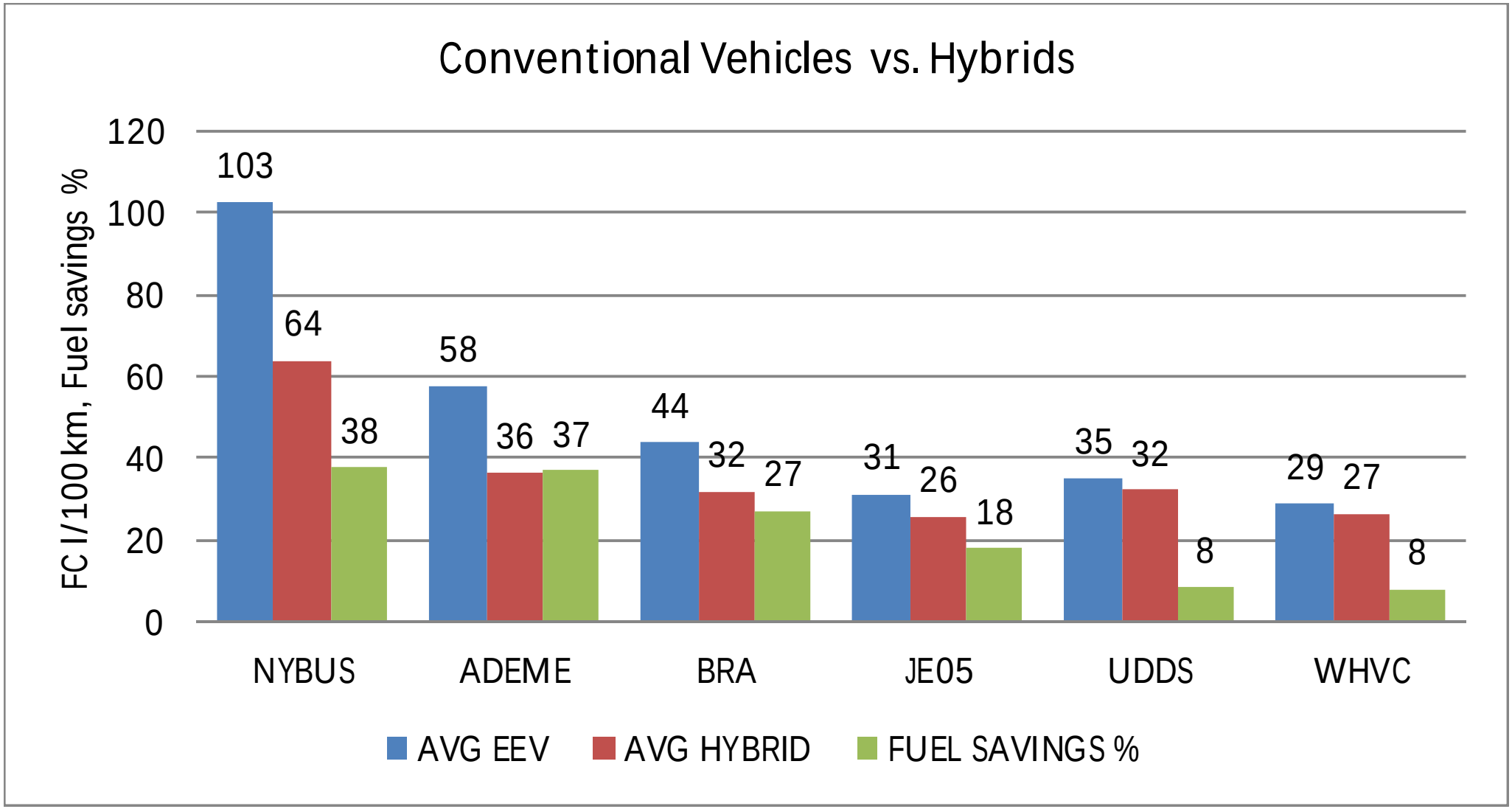
SAE 2012 Commercial Vehicle Engineering Congress
October 2-3, 2012
Rosemont, Illinois USA
Kati Koponen & Nils-Olof Nylund
VTT Technical Research Centre of Finland

SAE 2012-01-1981

Energy consumption of European vehicles Braunschweig cycle

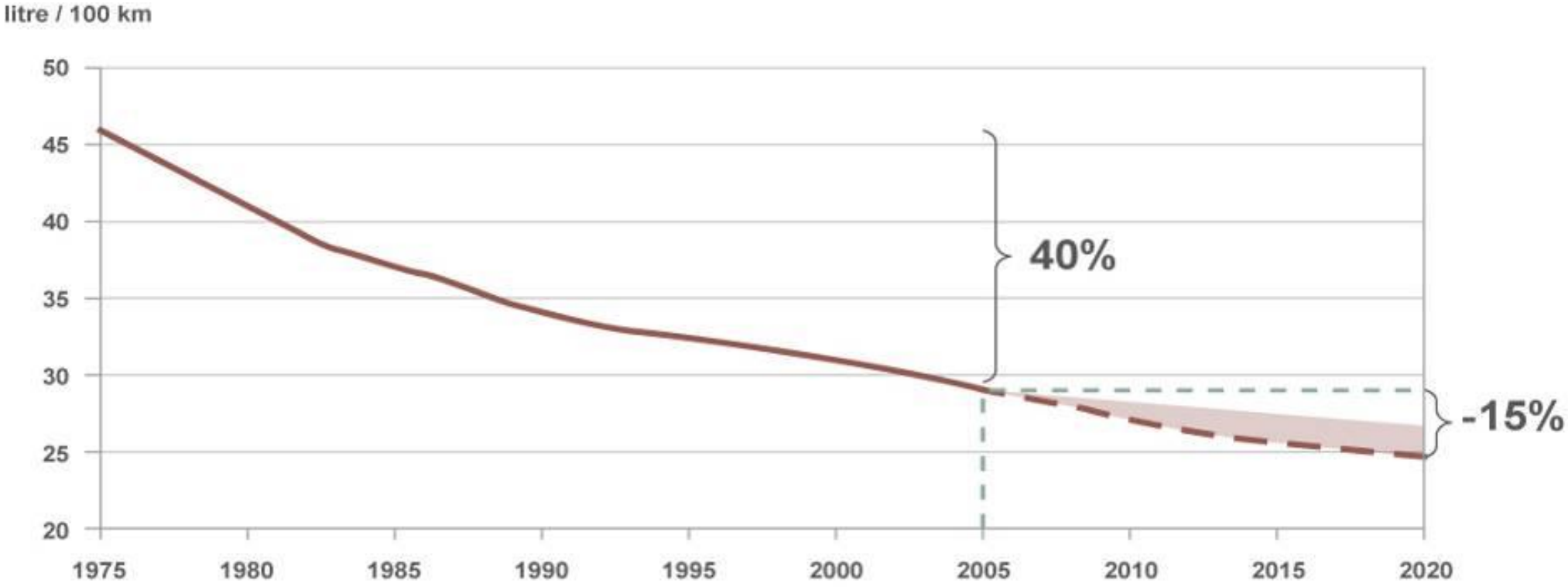


Fuel savings through hybridization
European vehicles

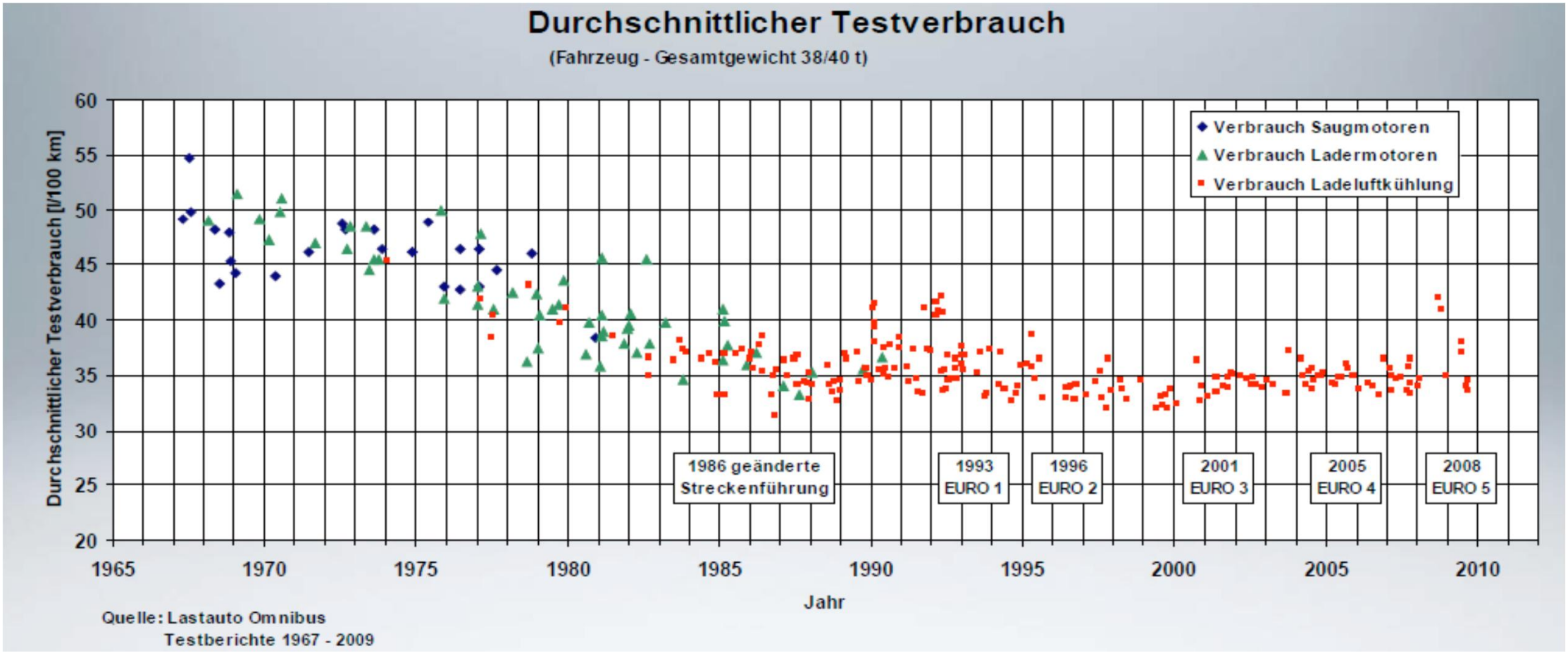


Reduced fuel consumption

Volvo FH12, 40 ton in traffic

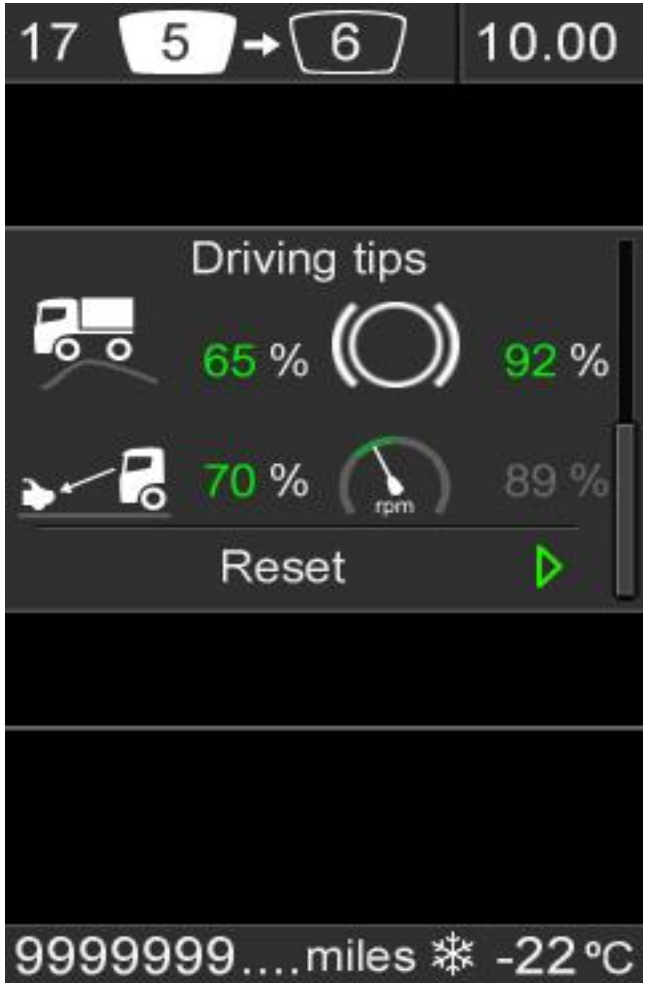


Tested fuel consumption of 38/40 t truck combinations

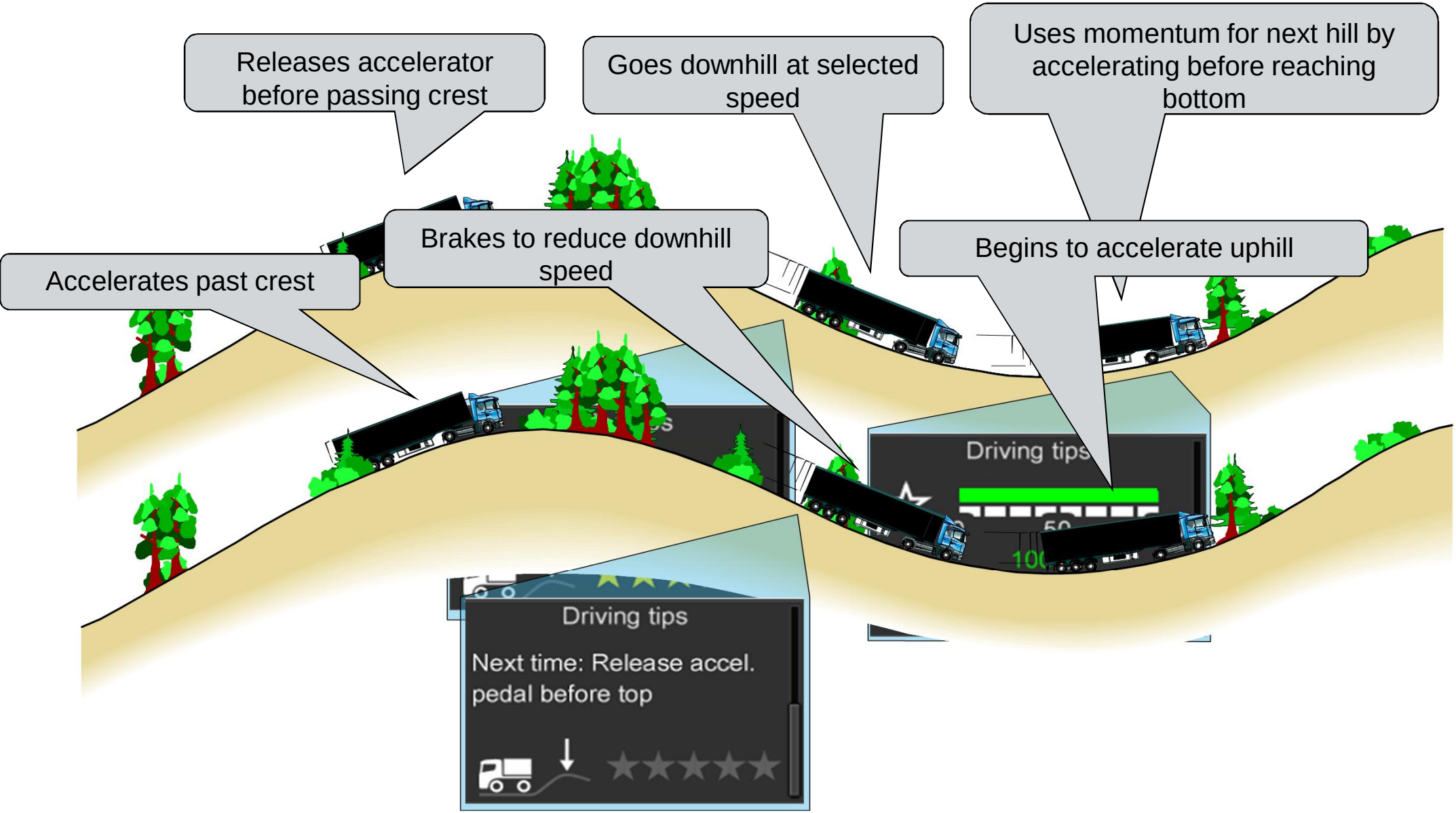


Summary mode

- **Instant feed-back on driving behaviour in the instrument cluster**
- **Tips given when good and bad events have been detected**
- **Evaluated situations**
  - **Hill-driving**
  - **Brake use**
  - **Anticipation**
  - **Gear selection**



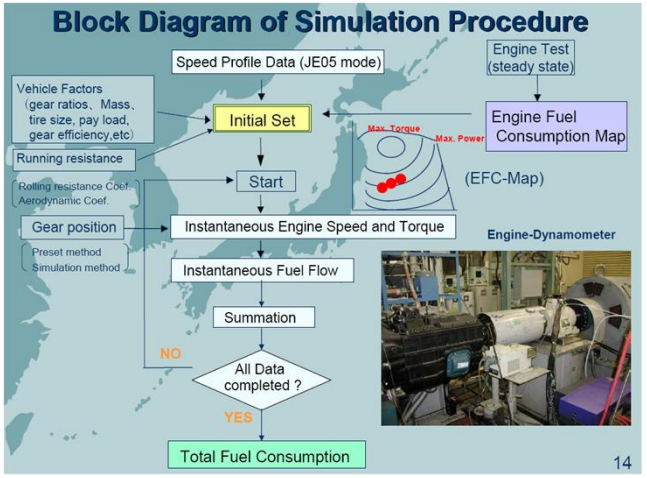
Source: Göran Lingström/Scania



Source: Göran Lingström/Scania

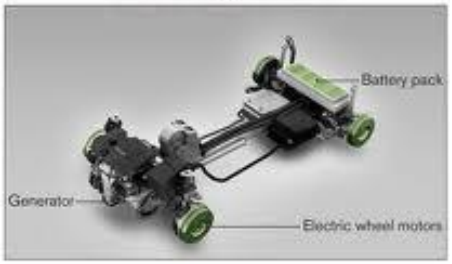
Energy efficiency/CO_2 regulations for HD vehicles

- Japan has been the forerunner
  - fuel efficiency standards for heavy vehicles above 3.5 t as of 2006
- USA
  - the first US GHG emission and fuel consumption standards for heavy- and medium-duty vehicles were adopted on August 9, 2011
- EU
  - methodology and regulations under development



Wani 2007

Business from technology



PERFORMANCE EVALUATION OF PASSENGER CAR, FUEL AND POWERPLANT OPTIONS

IEA AMF Annex XLIII

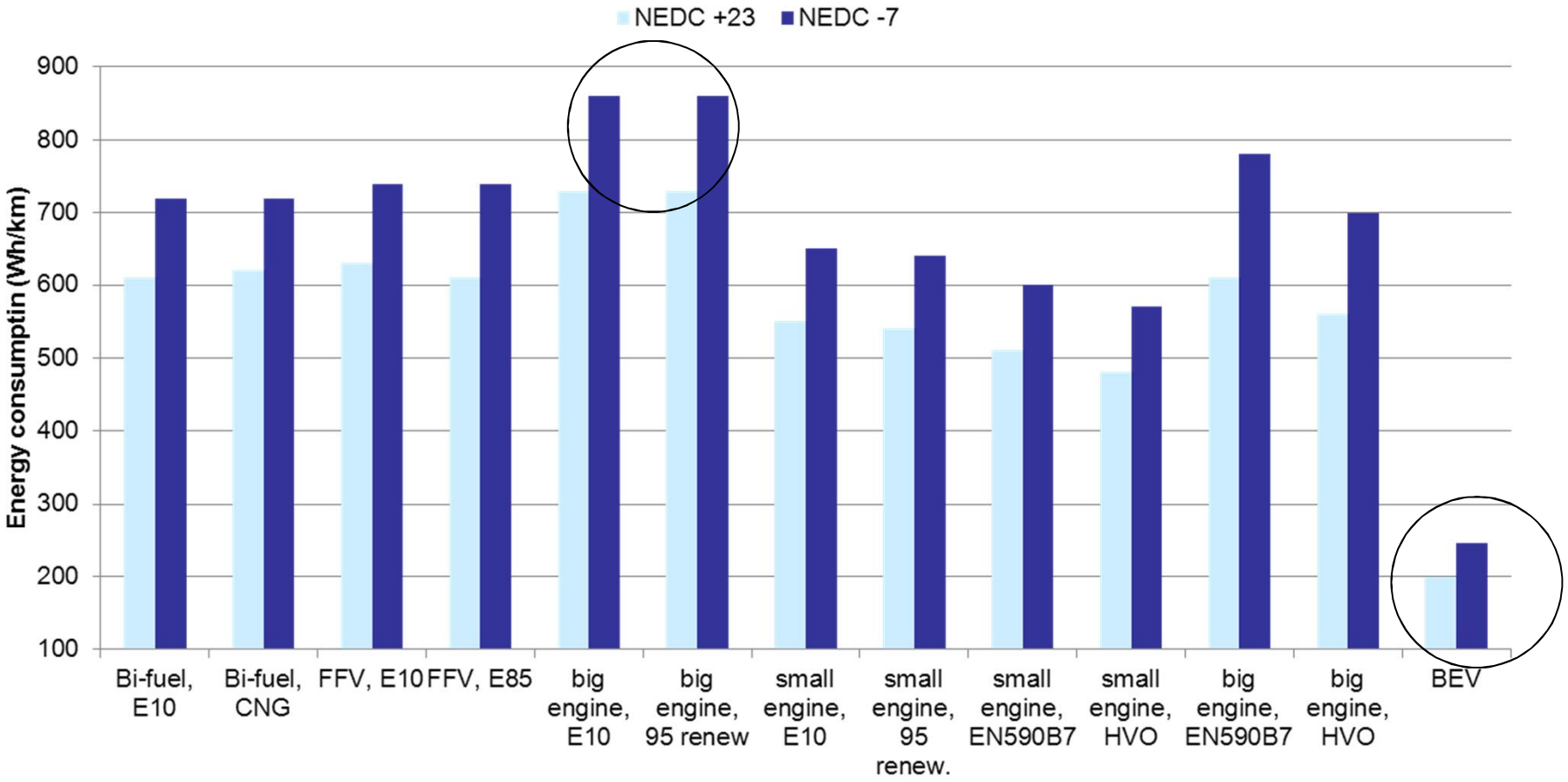
IEA ExCo 44

Jukka Nuottimäki
VTT Technical Research Centre of Finland

Annex 43: Content of the project

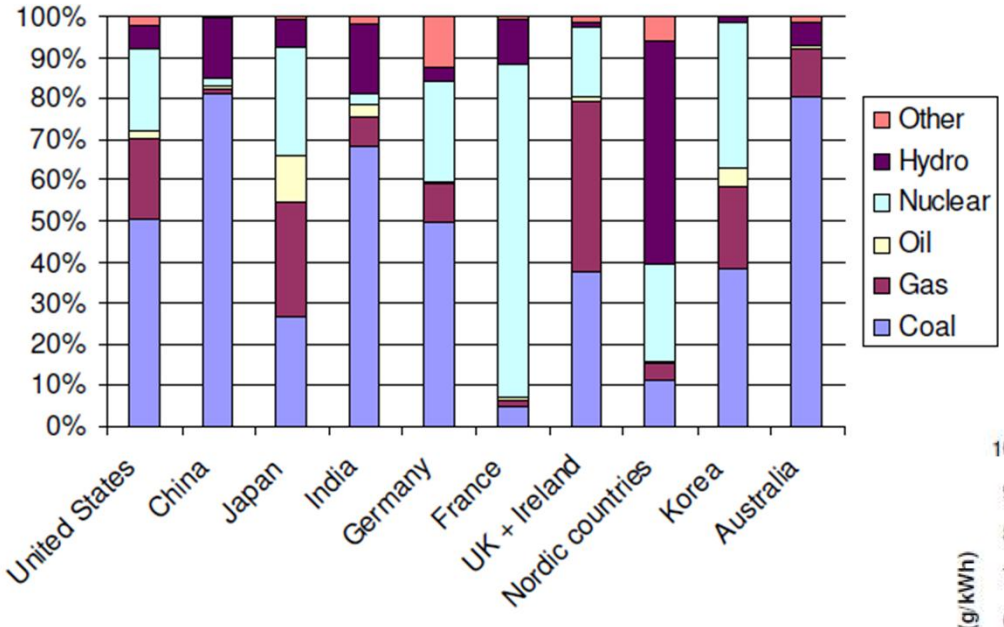
- The core of the comparison consists of benchmarking a set of passenger cars of such make & model that offer multiple choices for engine, i.e. gasoline, flex-fuel, diesel, CNG/LPG and perhaps also some hybrid and EV variations
- The project will also demonstrate the differences in efficiency arising from the engine type and size
- The test matrix will allow some modulation of duty-cycle and ambient temperature in order to give more application/environment specific data
- Making this kind of back-to-back comparison can ”neutralize” the vehicle itself from the equation, thus highlighting the role of the propulsion system
- Combined to the results of the upstream fuel-cycle research conducted within the IEA Bus Project, this project can be enlarged to a comprehensive, full fuel-cycle evaluation

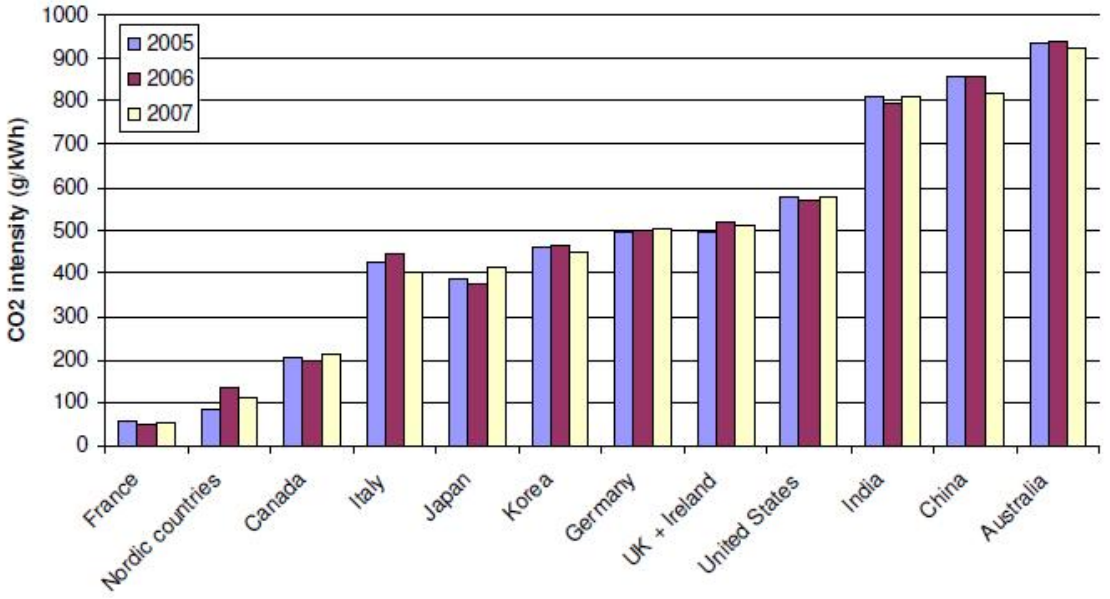
Finnish Results:
Energy consumption of a medium sized vehicle on NEDC



Max 860 Wh/km (big gasoline engine), minimun 198 Wh/km (BEV)

Power generation profiles





Source: Ecofys 2010

Energy consumption EV vs. ICE

- Electric vehicle Nissan Leaf
  - energy consumption 0.21 kWh/km (motoring magazine TM 2012)
  - transmission losses 5 %
  - total energy consumption 0.22 kWh/km (well-to-wheel WTW, renewable electricity)
  - total energy consumption 0.55 kWh/km (well-to-wheel WTW, gas turbine power plant)

- Diesel car VW Golf 1.6 D Blue Motion Technology
  - factual fuel consumption 5.0 l/100 km (own experience)
  - energy consumption 1.80 MJ/km (0,50 kWh)
  - total energy consumption 0.60 kWh/km (WTW)

Sources: Ecofys 2010, Climate Counter 2012

Summary

- Independent of the energy source, energy efficiency must be prioritized
- Several technical measures are available for reducing energy consumption
- Emphasis of measures varies from one vehicle category to another
- Light-duty vehicles show greater potential for reduction of energy consumption than heavy-duty commercial vehicles
- Driving behaviour has a major impact on energy consumption and emissions

VTT creates business from technology