DAIMLER

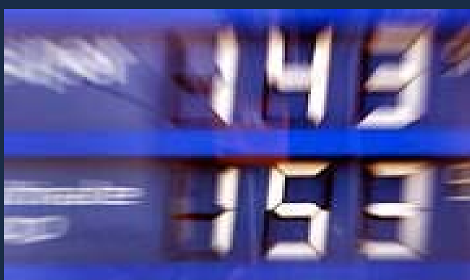
The Electrification of the Automobile

- Technical and economic challenges

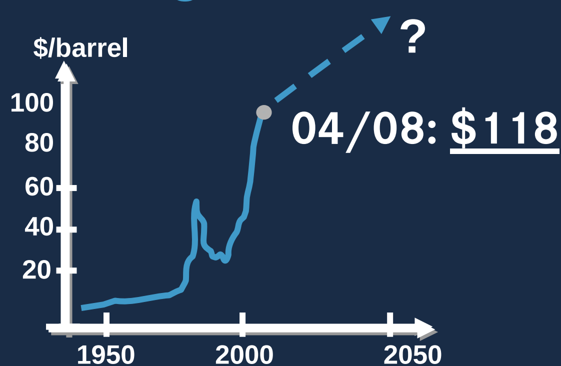
Dr. Christian Mohrdieck
Director
Fuel Cell & Battery Drive Development

Global Trends

Limited Resources



E.g.: Oil Price



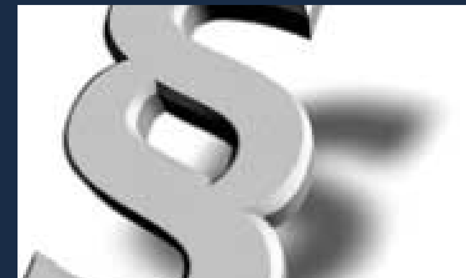
Creeping Mobility

Megacities Top 5 Ranking

1900		2003		2015	
London	6,5	Tokio	35,0	Tokio	36,2
New York	5,5	Mexico City	18,7	Bombay	22,6
Tokio	5,2	New York	18,3	Delhi	20,9
Paris	4,0	Sao Paulo	17,9	Mexico City	20,6
Berlin	2,4	Bombay	17,4	Sao Paulo	20,0

Source: Bronger (1996)

Law / Legislation



City-Maut London

Daily Fee:

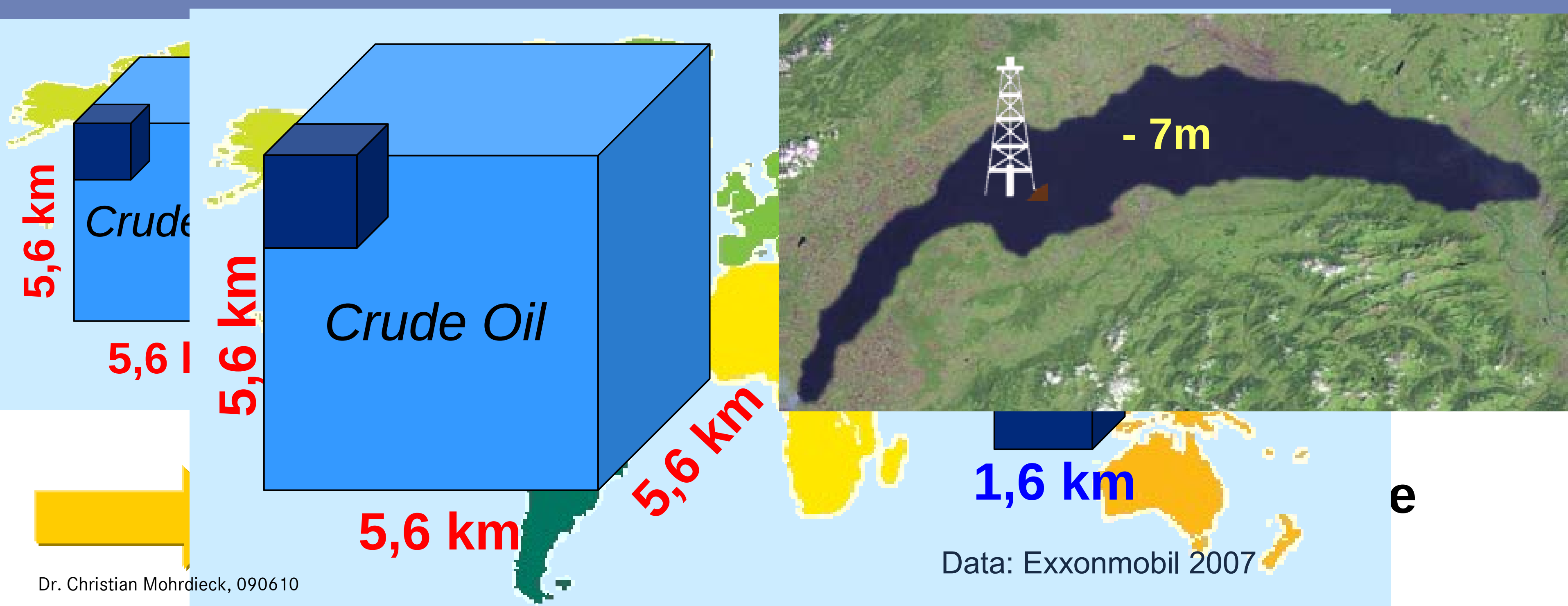
8 £

Limited crude-oil resources: We are aware of our responsibility!

World crude-oil deposits: **179 bn tons** ⇨ a cube with a side length of **5.6 km**

Annual oil consumption: **3,9 bn tons** ⇨ a cube with a side length of **1.6 km**

Average water content of Lake Geneva: **89 bn tons** ⇨ Theoretical annual decrease of water level: **7m**



Worldwide emission regulations necessitate new power train technologies

CV: NOx and Particle

PC: Fuel Consumption CAFE [1]:
→≥ 30 mpg for MY2012

7,8 l/100km

Fuel Consumption CARB [2]:
AB1493 → 205 g CO_2/mi for MY2016 (= 127 g CO_2/km)

~ 5,3 l/100km

Emission: focus NOx reduction!
→ BIN8: 0,14 g/km NOx
→ BIN5: 0,07 g/mi NOx
→ SULEV: 0,02 g/mi NOx

ZEV & AT-PZEV Mandate !

[1] 50 states; [2] 5+ X states

CV: NOx and Particle

PC: Fuel Consumption:
→ 140 g CO_2 /km in 2008
→ 120 g CO_2 /km in 2012

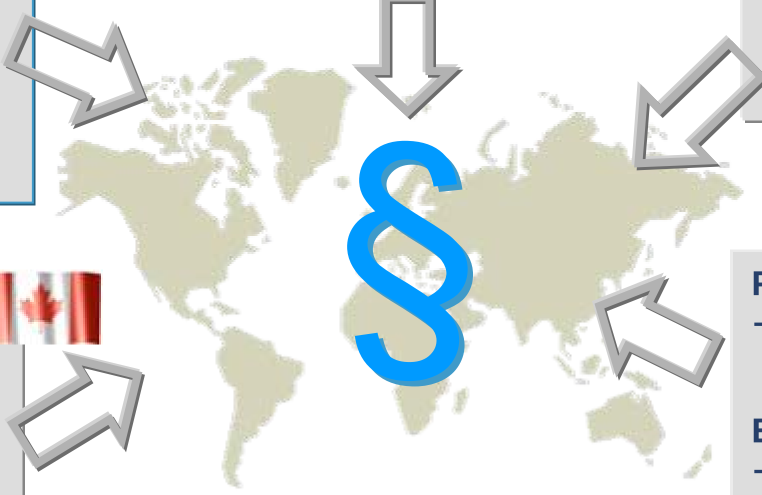
~ 5,0 l/100km

Emission: EU5 in 2009
→ 0,18* g/km NOx
* Final decision pending

CV: NOx and Particle

PC: Fuel Consumption:
→ weight classes in 2010

Emission: Urban NOx Control
→ 0,14 g/km NOx in 2007
→ J-LEV Program



Fuel Consumption:
→ Oriented on CARB

Emission:
→ Oriented on EPA*

Fuel Consumption:
→ 16 weight classes in 2008: from 43 mpg to 21 mpg

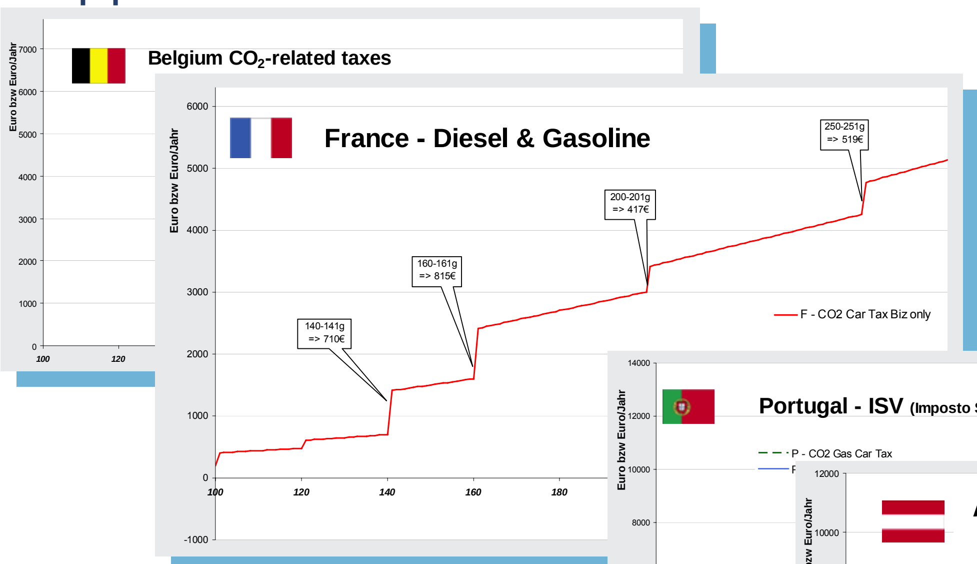
Emission: EU oriented
→ EU4 in 2006

5,5-13,9 l/100km

***Environmental Protection Agency**

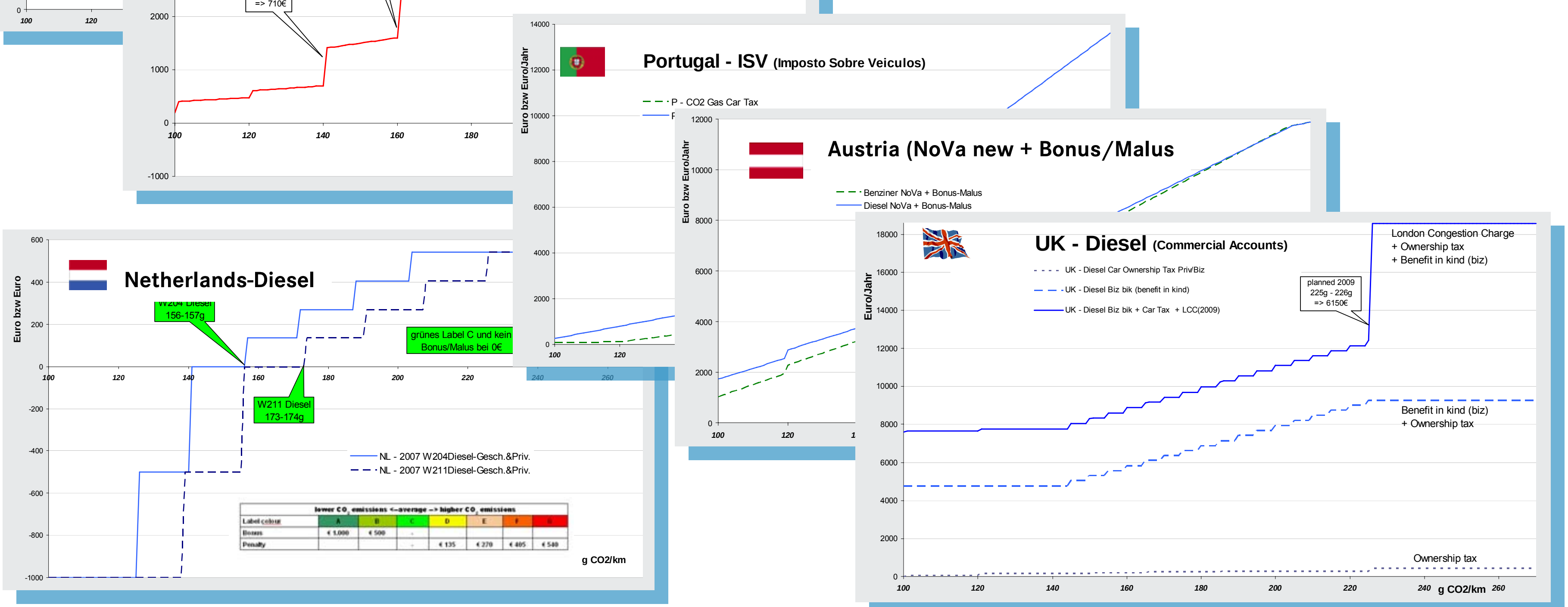
Diverse Individual National Regulations:

Difficult to manage by OEMs. Therefore Daimler pursues and supports the harmonization of standards and regulations!

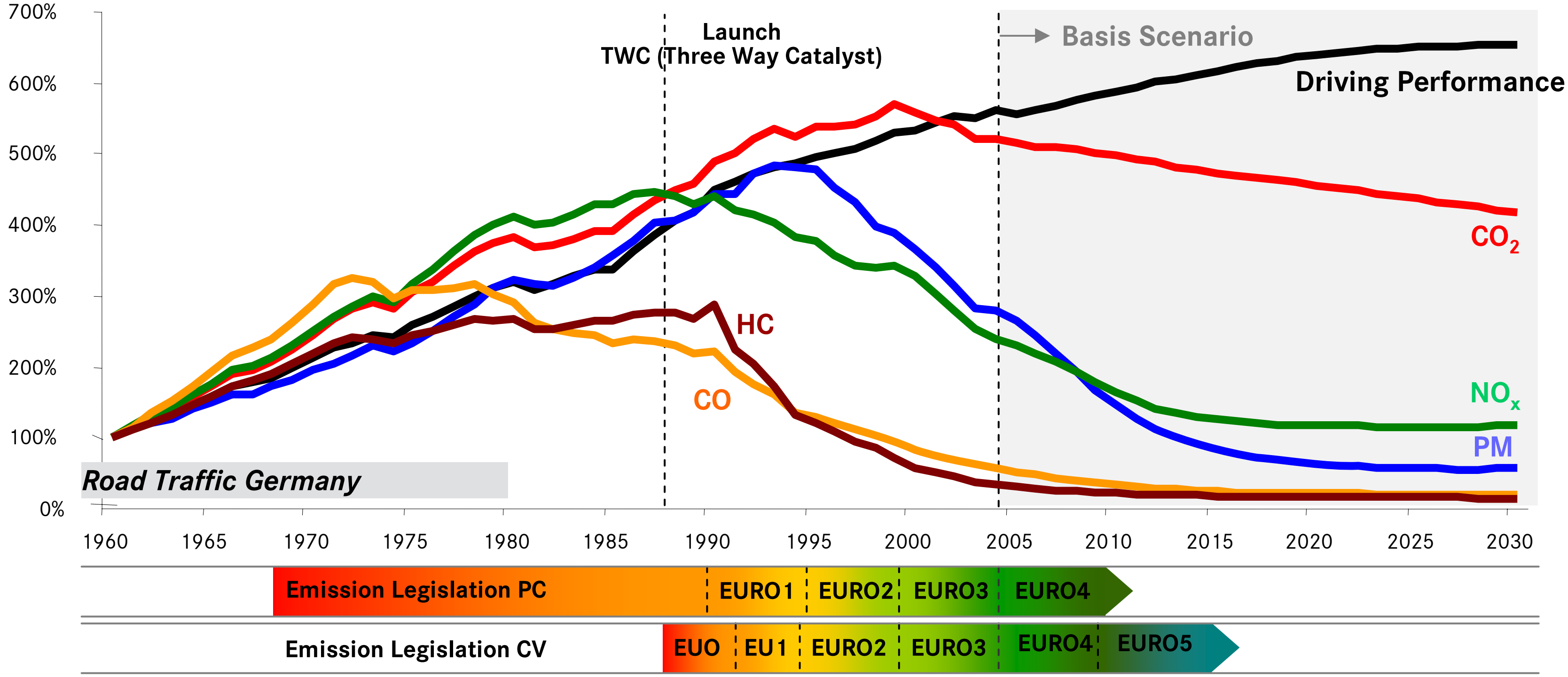


National Levers:

- Tax incentives (e.g. France)
- Extremely high taxation (e.g. UK)
- Labeling (e.g. Netherlands)



Trend Of Driving Performance and Emissions

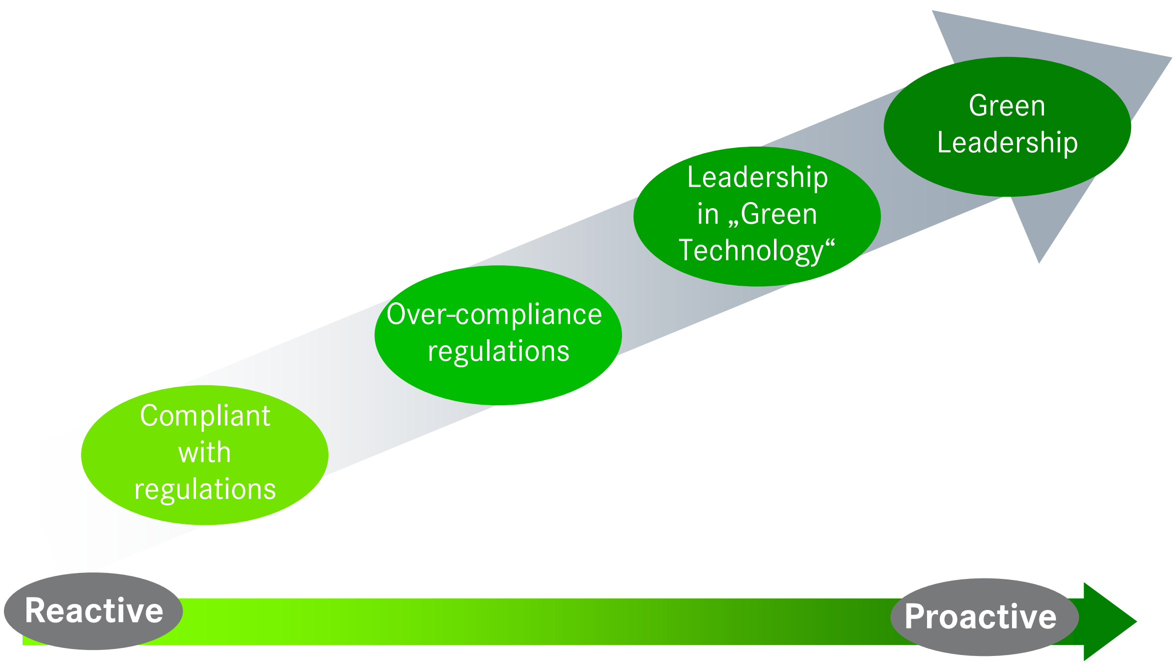


Through several technical improvements, a significant reduction of pollutants has been achieved whilst the driving performance increased. Also a turnaround on CO_2 emission has been achieved. (Source: TREMOD)

Sustainable Mobility

Significant improvements in environmental friendliness are decisive element of our claim to be No. 1

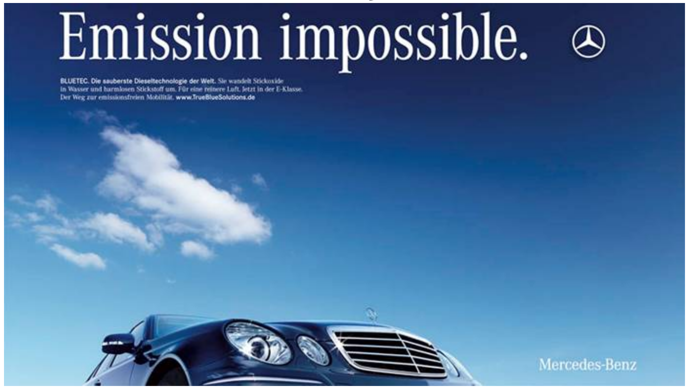
Aspiration: Leadership in "Green Technologies"



Customer advantages

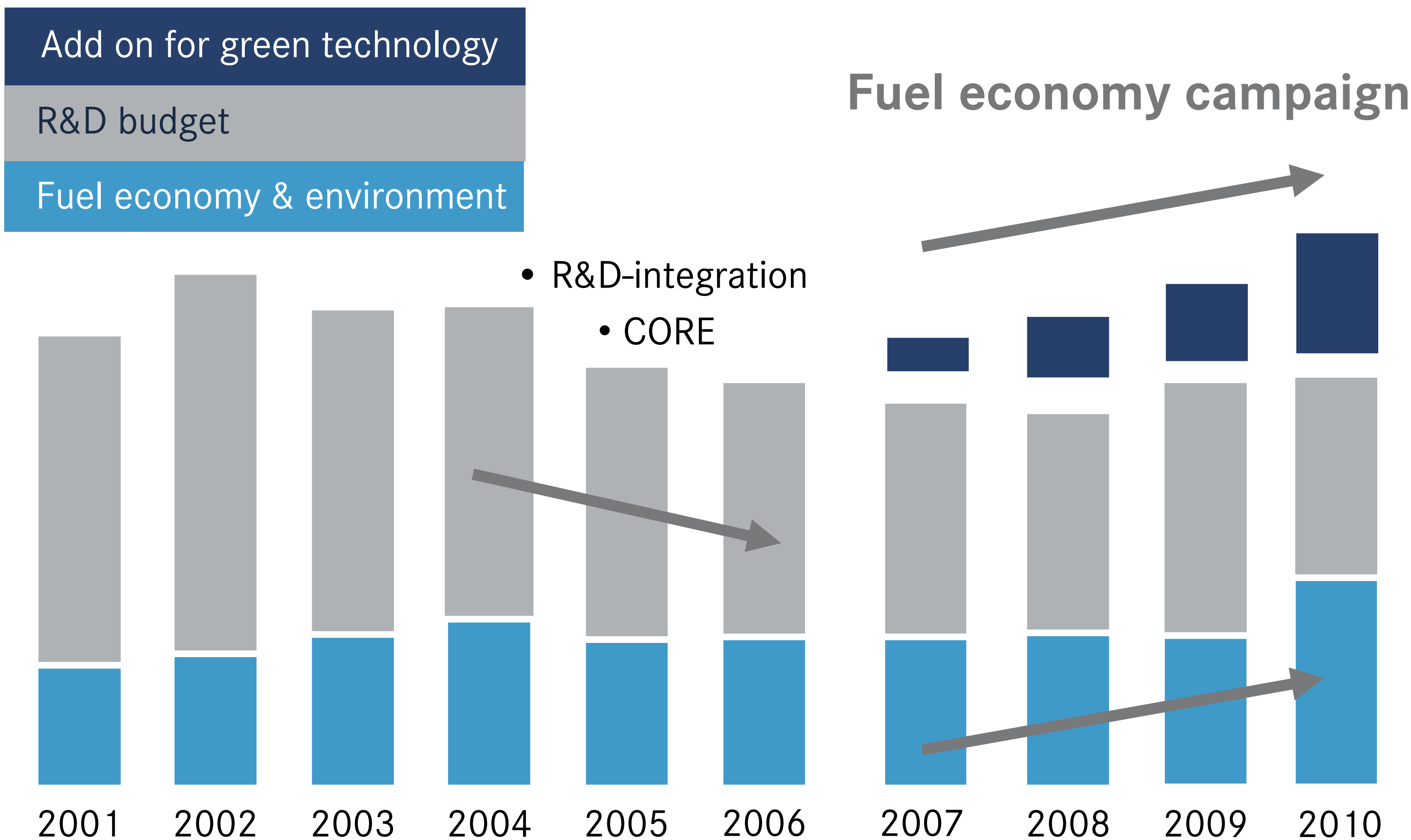
Fuel efficient cars

Eco-friendly brand



In comparison to small car manufacturers our product portfolio allows no absolute „Green Leadership“

Sustainable Mobility
Research & Development budget



Sustainable Mobility
Mercedes-Benz Roadmap

Optimization of our vehicles with high-tech combustion engines	Hybridization for further increase in efficiency	Emission-free driving with fuel-cell/ battery electric vehicles
BlueEFFICIENCY CGI, BlueTEC DIESOTTO	**HYBRID Range Extender Plug-In**	**Fuel cell Battery-/E-Drive**





Energy sources for the mobility of the future

Clean fuels for combustion engines

Emission-free driving

Daimler's Roadmap to Sustainable Mobility

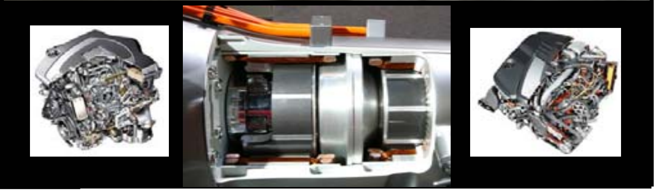
today → **future**

Zero-emission vehicles with fuel cell/battery drive

Improved & alternative fuels

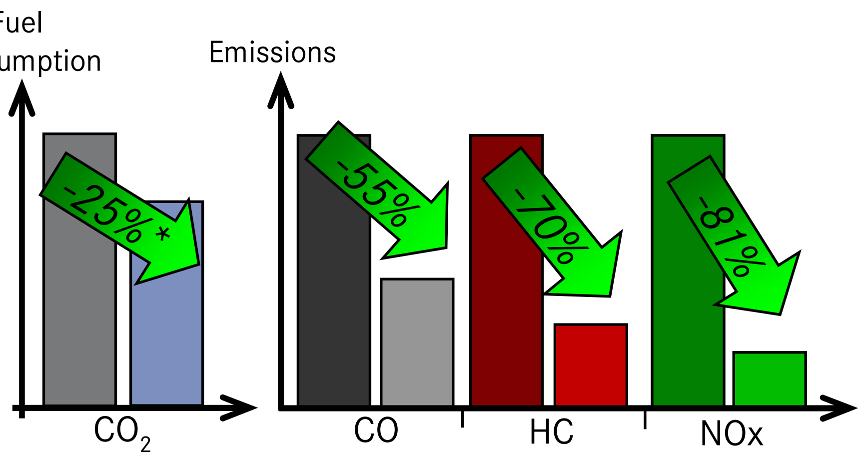
Efficient cars

with efficient *power trains* with or without *hybrid modules*

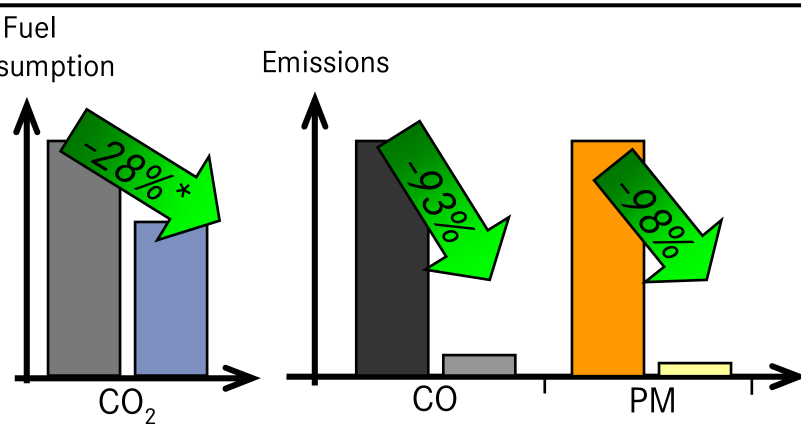


Compared to 1990, Mercedes-Benz portfolio has reduced CO_2–emissions by 30%.

Gasoline



Diesel



Today 11 models between 4,9 (115 g/km) and 6,5 l/100 km (150 g/km)

Sales volume EU: 20% around 5 l/100km, 38% under 6,5 l/100km

CO_2 –World Champion and most-sold 3-liter car

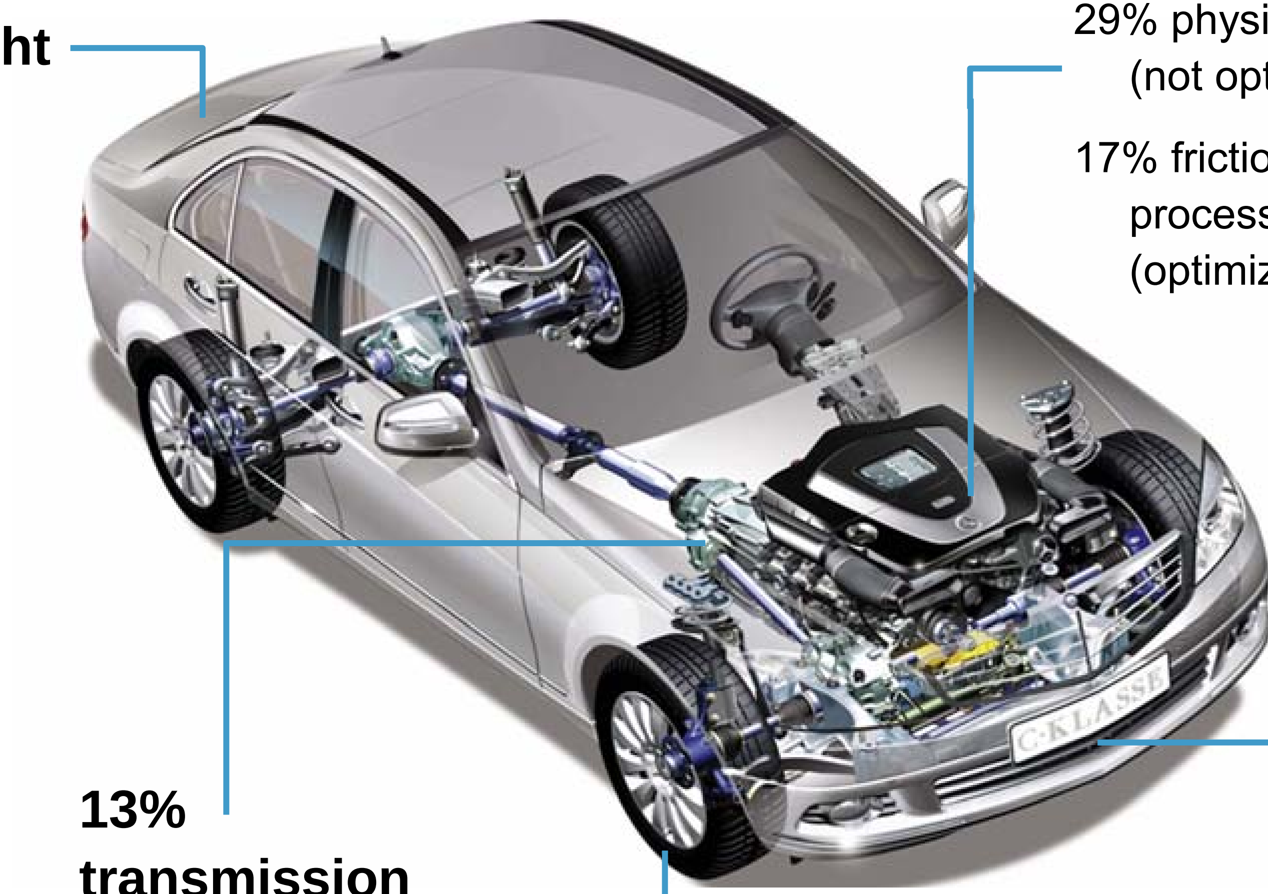
Origins of CO2 in a Passenger Vehicle

46% Engine

29% physical efficiency (not optimizable)

17% friction / combustion process etc. (optimizable)

10% Weight



8% other:

Climate Control, Electrics, Steering,

11% air resistance

13% transmission

12% roll resistance

***) data applies for mid class segment**
(3-Litre gasoline engine | RWD | NEFZ)

Continuous improvement in combustion engines: Potentials for diesel and gasoline engines

Diesel engine

Characteristics

☺ Consumption

☹ Emissions

Key technologies:

- Injection system
- Combustion process
- Homogenization
- Turbocharger
- Exhaust gas after-treatment

Gasoline engine

Characteristics

☺ Emissions

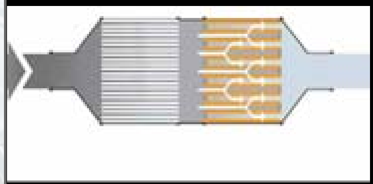
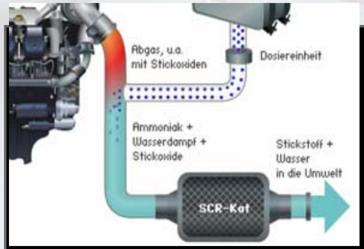
☹ Consumption

Key technologies:

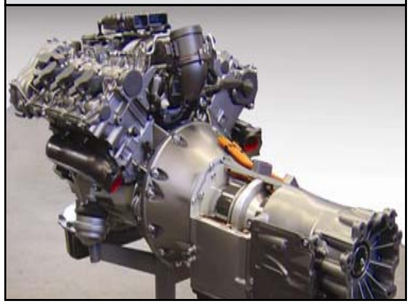
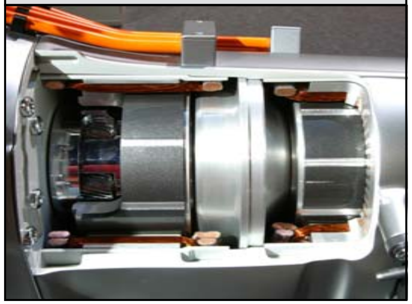
- De-throttling
- Direct Injection
- Charging
- Reduction of friction
- Engine cooling management

Target → **Gasoline cars as efficient as diesels; Diesel cars as clean as gasoline cars**

Three steps towards the cleanest diesel in the world: Reduction of NO_x levels up to 80 percent

Optimization of the engines and combustion processes, clean fuels		**Minimize untreated emissions**
Oxidizing catalytic converter, particulate filter		**Minimize emissions of carbon monoxide, unburned hydrocarbons and particulate matter**
BLUETEC technology		**Reduces nitrogen oxide levels up to 80 percent**

Modular Hybrid Technologies

Powertrain- Integration	Energy Storage	High-power electronics	Hybrid transmission
			

Bundling of Know-how and Resources

Increased efficiency by Hybridization

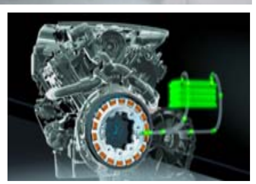
			
S 400 HYBRID with Lithium-Ion Battery	**ML 450 HYBRID** Two Mode	**Citaro G BlueTec Hybrid** City bus	**Hybrid Commercial Vehicle**

The Potential of Hybridization

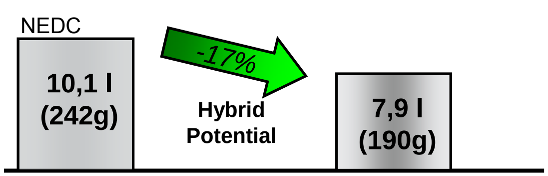
Mobility Scenario Hybrid Vehicles:

Mainly in Interurban & Urban Traffic

S 400 BlueHYBRID



Fuel Economy



Basis S 350

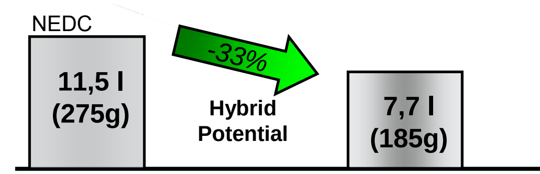
S 400 BlueHYBRID with Lithium-Ion Battery

Key benefits

- Comfortable Start-stop Technology
- Better Performance
- Recuperation of Braking Energy
- Better Energy Management
- Improved Fuel Efficiency

ML 450 BlueHYBRID

Fuel Economy



Basis ML 350

ML 450 BlueHYBRID with Two Mode

500 Daimler Hybrid buses for New York

The largest order for hybrid buses in history

1600 Daimler Hybrid buses in North America

Advantages for people and environment:

Urban driving: Compared to standard diesel propulsion, the hybrid units will provide

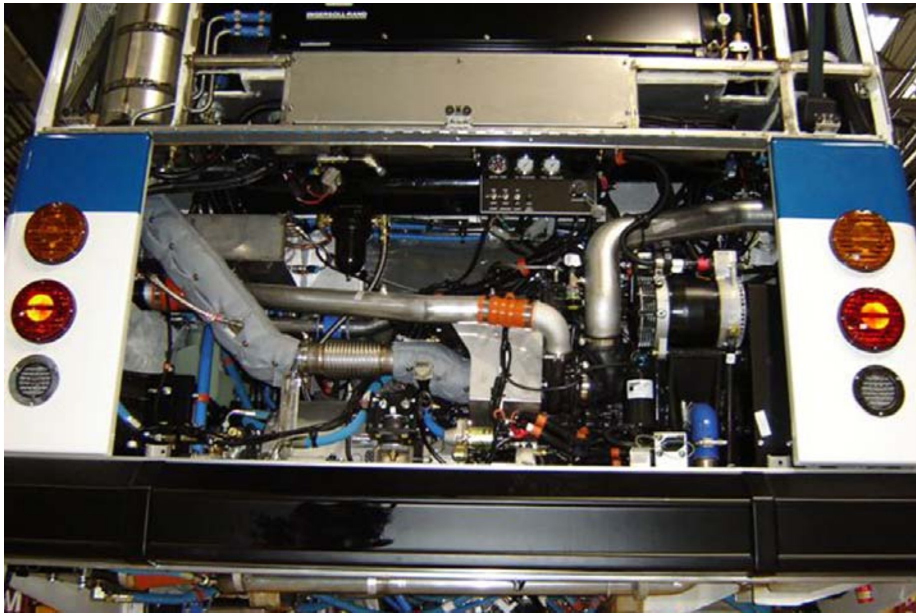
...significantly better fuel economy (25 - 30 % less),

...greatly reduced emissions

90% less particulate matter
40% less NOx
30% fewer greenhouse gases

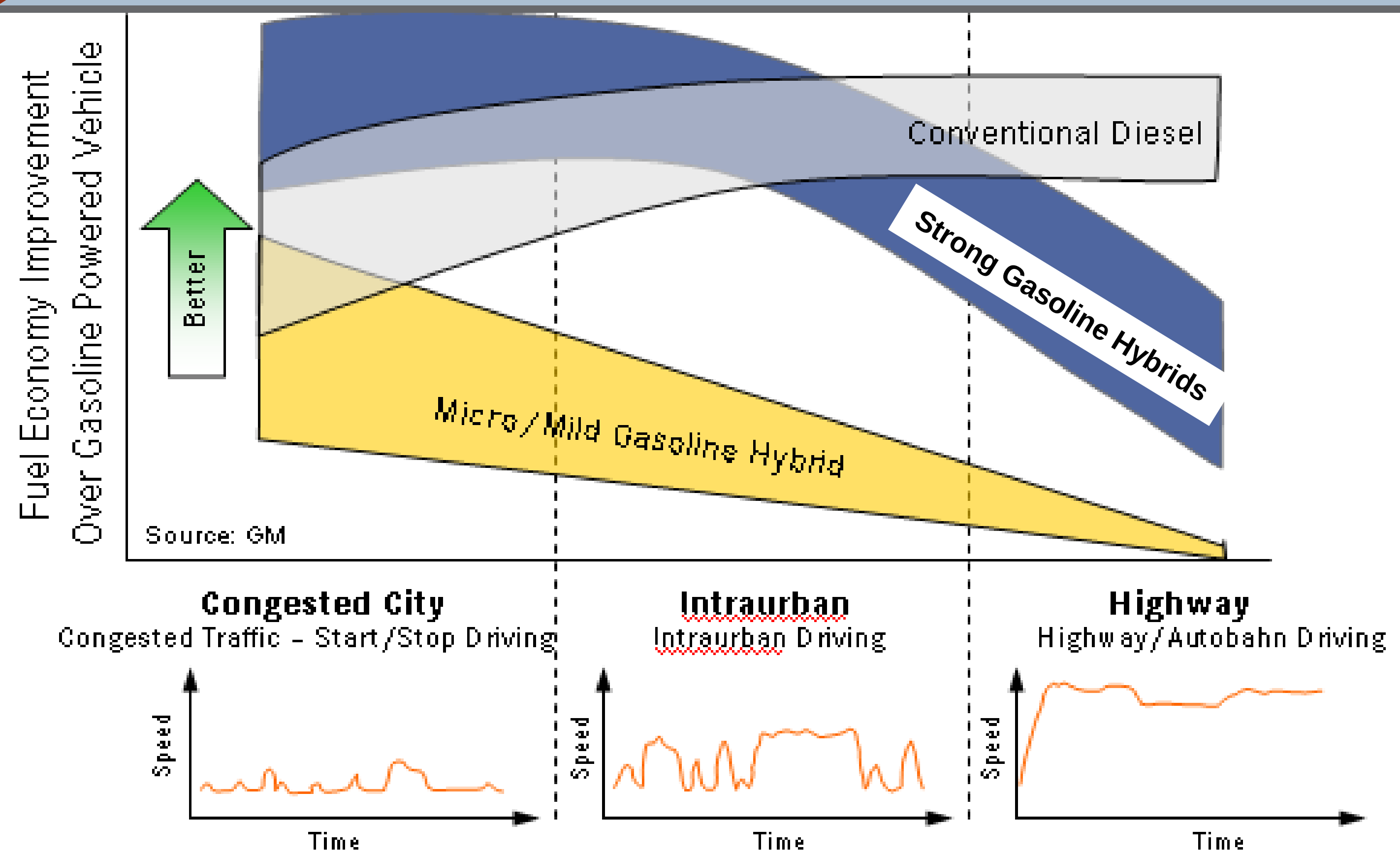
...offers faster acceleration

...enables quieter, smoother ride without the frequent transmission shifts encountered in conventional buses.



Fuel Efficiency of different powertrain concepts

Hybrid powertrains are beneficial under city driving conditions



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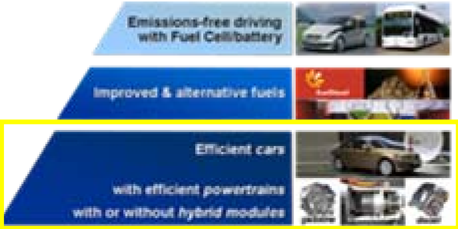
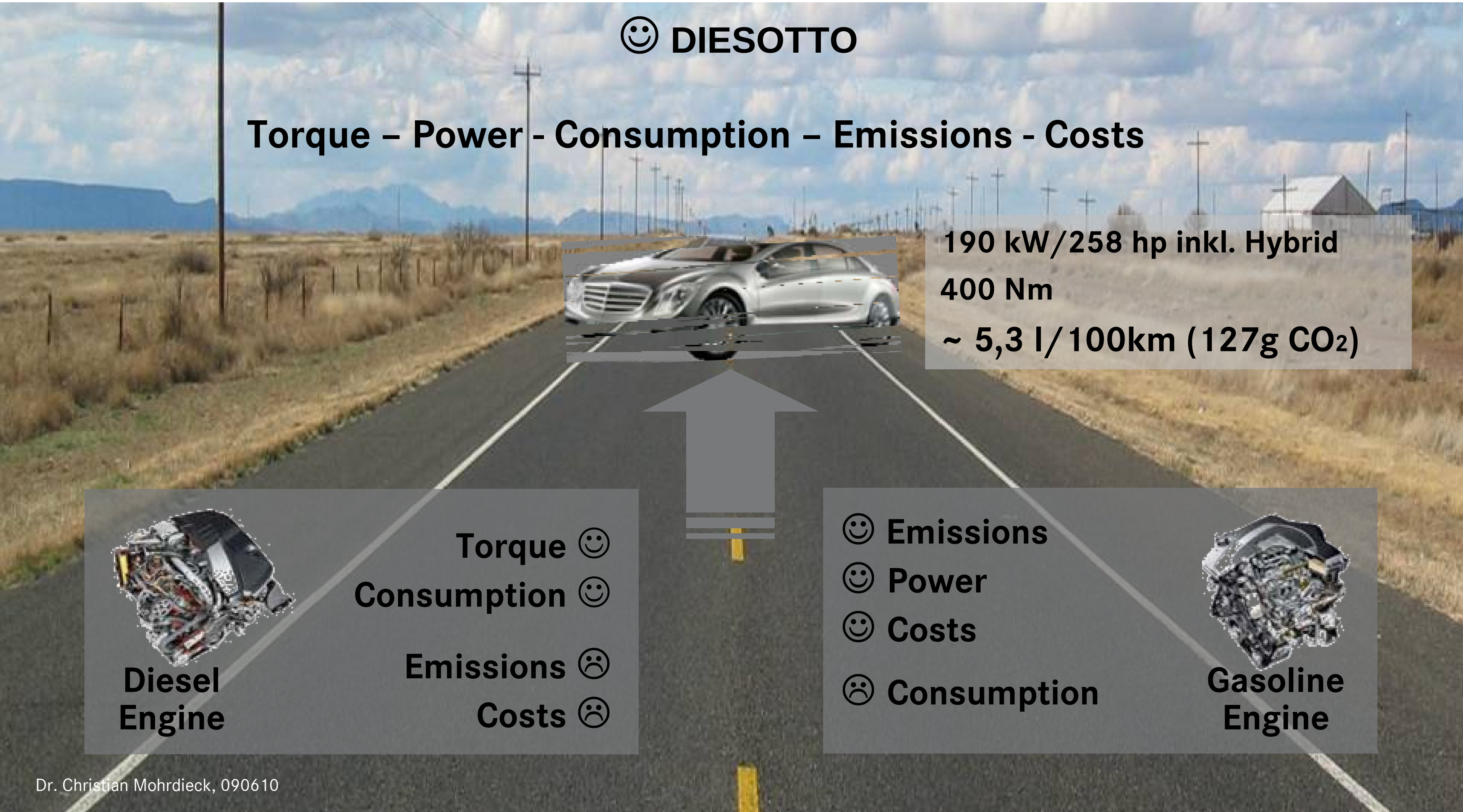
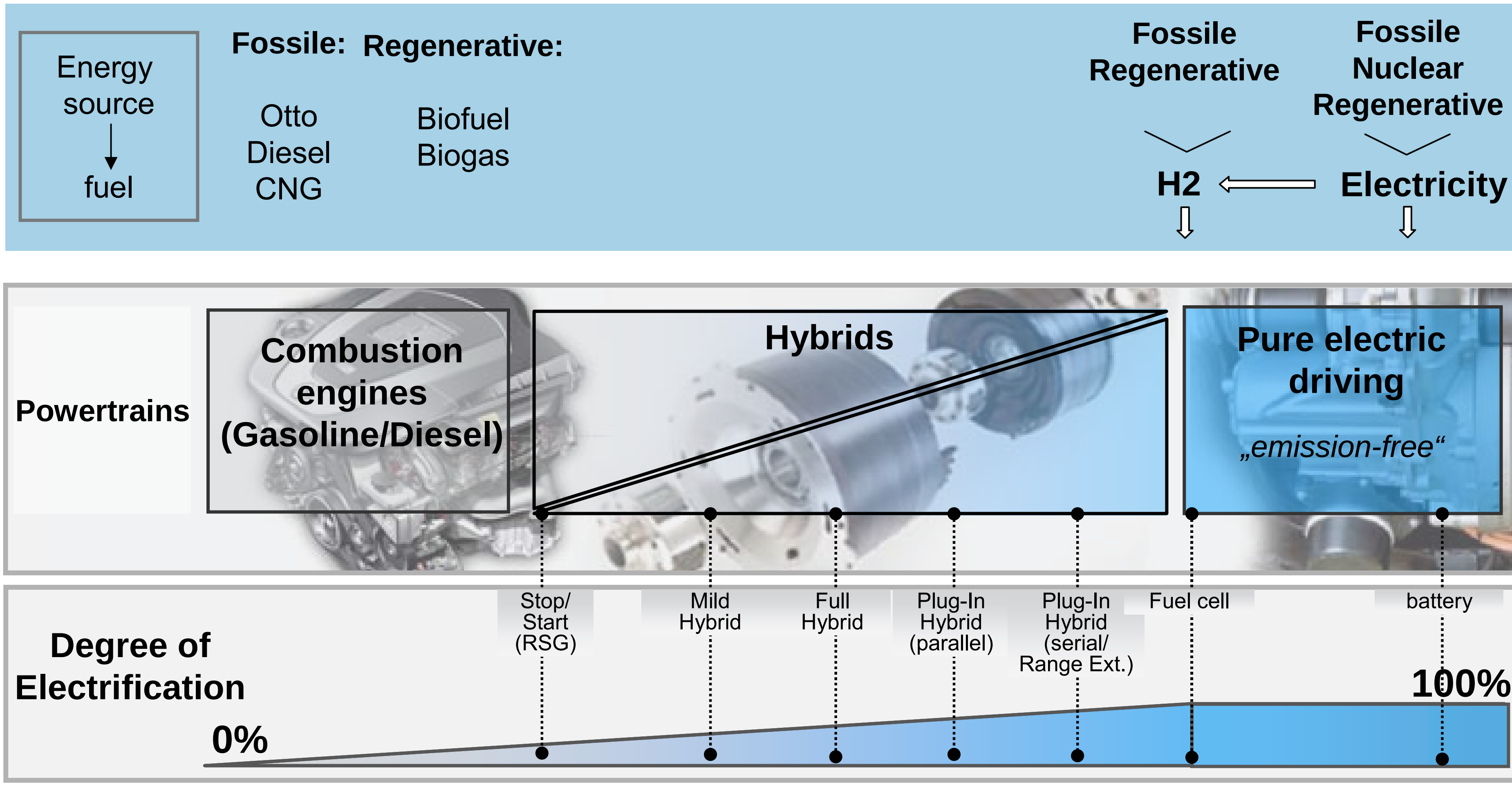
The future of the combustion engine:

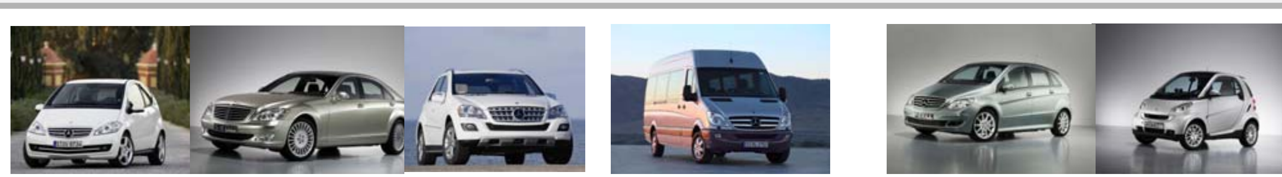
DIESOTTO combines the advantages of both Gasoline and Diesel engine!





The Range of Alternative Powertrains





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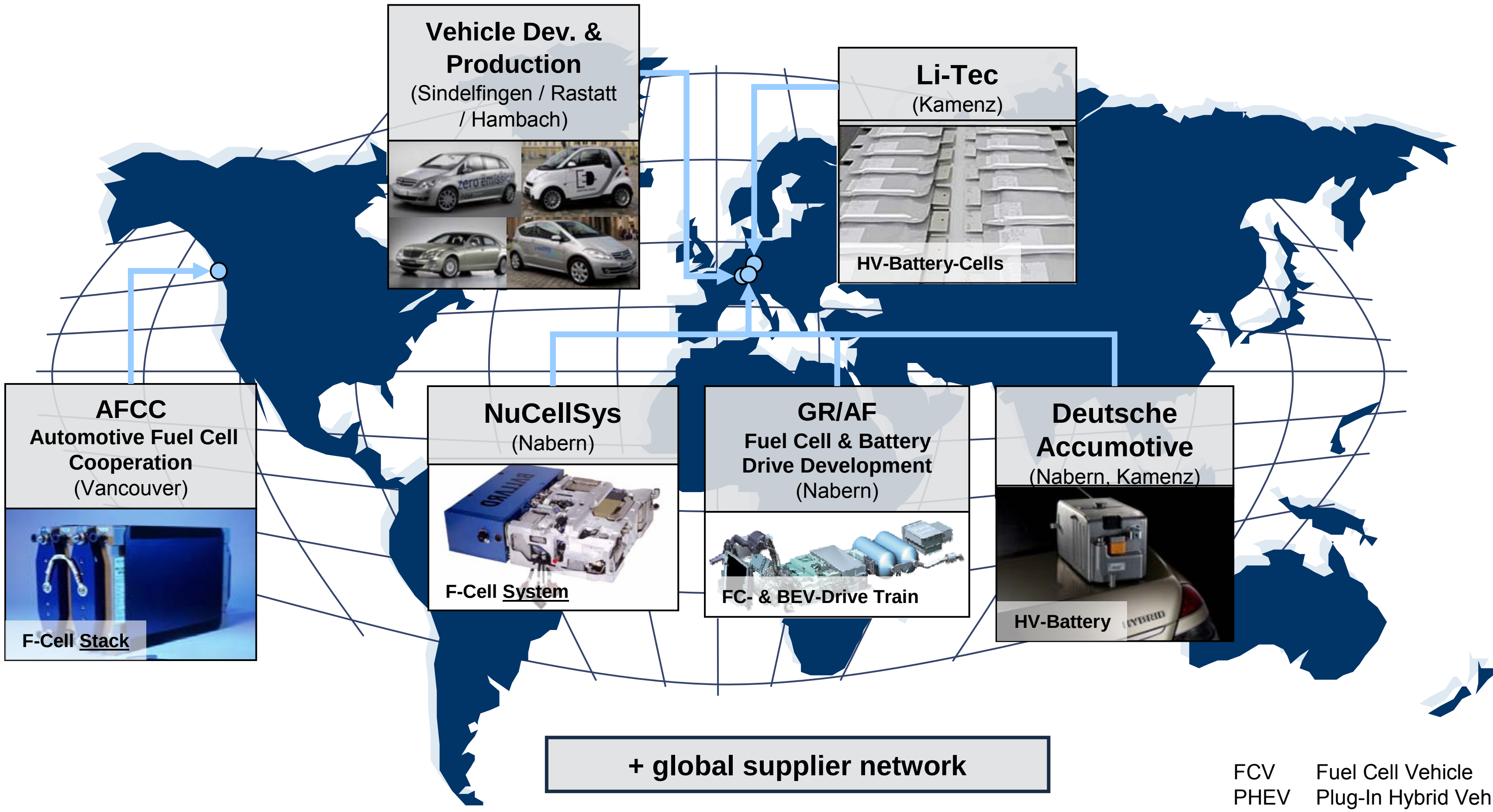
Global Competence Network: Fuel Cell- and Battery Electric Vehicles



FCV	Fuel Cell Vehicle
PHEV	Plug-In Hybrid Vehicle
BEV	Battery Electric Vehicle
HV	High Voltage

Shareholder structure LiTec and Deutsche Accumotive

Li-Tec

Battery cells

1

DAIMLER 49,9%

EVONIK INDUSTRIES 50,1%

li-Tec endless power.

Supply/Contribution:
Electrodes, Separators

LITARION

Deutsche Accumotive

Battery systems

2

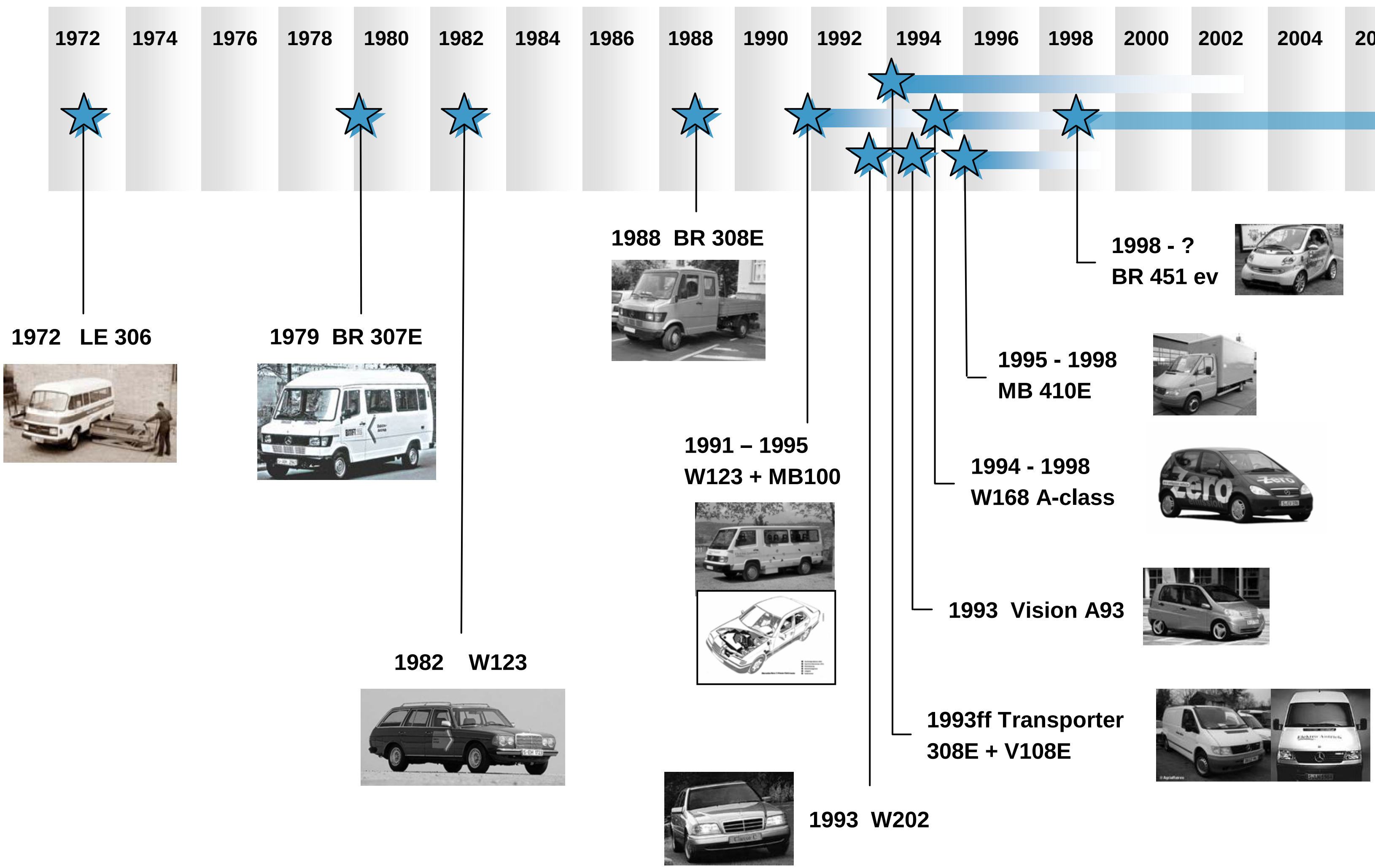
DAIMLER 90%

EVONIK INDUSTRIES 10%

Deutsche Accumotive

Cooperation with
Tier1 on E/E

Daimler‘ history on Battery Electric Vehicle



smart Electric Drive London Project

- **Demo fleet of 100 smart electric drive** on the basis of smart fortwo predecessor model

- **Electric drive**:
  - 30 kW Permanent Magnet-Motor
  - Zebra-Battery 15 kWh (NaNiCl)
  - Range: ~100 km in EUDC
  - max. speed 100 km/h

„ the car is fabulous – couldn‘t be better!“

Customer‘s voice in London

- **Customers:**
  - Fleet customers preferably in **city area of London** as a 4 year lease model in co-operation with MB UK
  - smart ev is **exempt from London congestion charge!**
  - **70 vehicles delivered** with very positive feedback from customers
  - End of production July 2008

- **Forecast**:
  - Investigation of other possible pilot projects on basis of the new smart fortwo for European cities

Technical Data of next generation Smart electric drive

Technical Data	
Vehicle Type	Smart fortwo (BR451)
Engine	Electric engine Output (Continuous / Peak): 35 kW / 50 kW Max. Torque : 130 Nm
Consumption	~ 13 kWh / 100km
Range	150 km (100 miles)
Top speed	125 km/h (78 mph)
Acceleration	11,5 s (0-100 km/h)
Battery	Li-Io-Battery, Output (Continuous / Peak): 35 kW / 55 kW; Capacity: 17.6 kWh

Challenges for the Battery Technology

Technology

- Power Density
- Energy Density
- Lifetime
  (Calendar & Cycle)
- Fast charge capab.
- Low temp. power

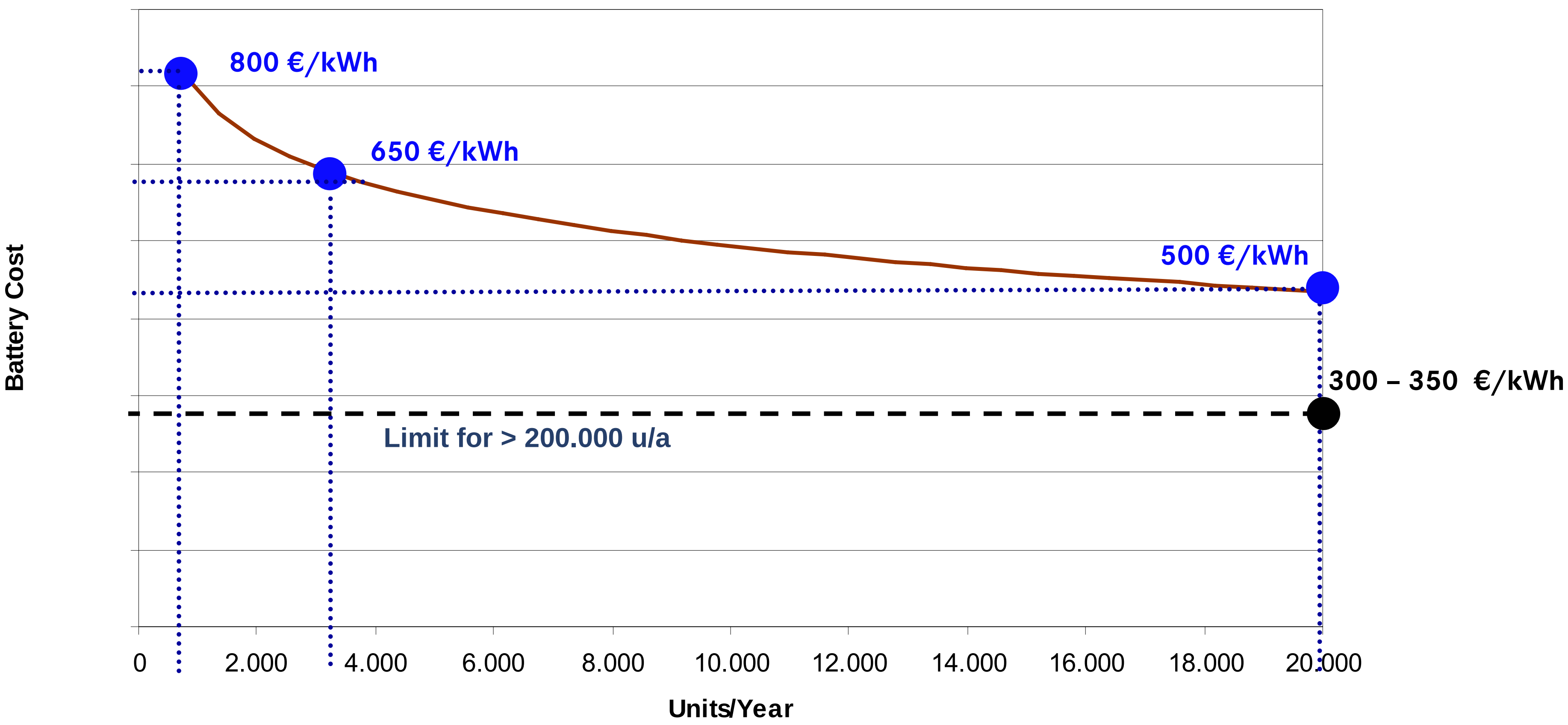
Cost

- Materials
- Electric Drive
- (Power) Electronics
- Infrastructure
- Cooling

Infrastructure

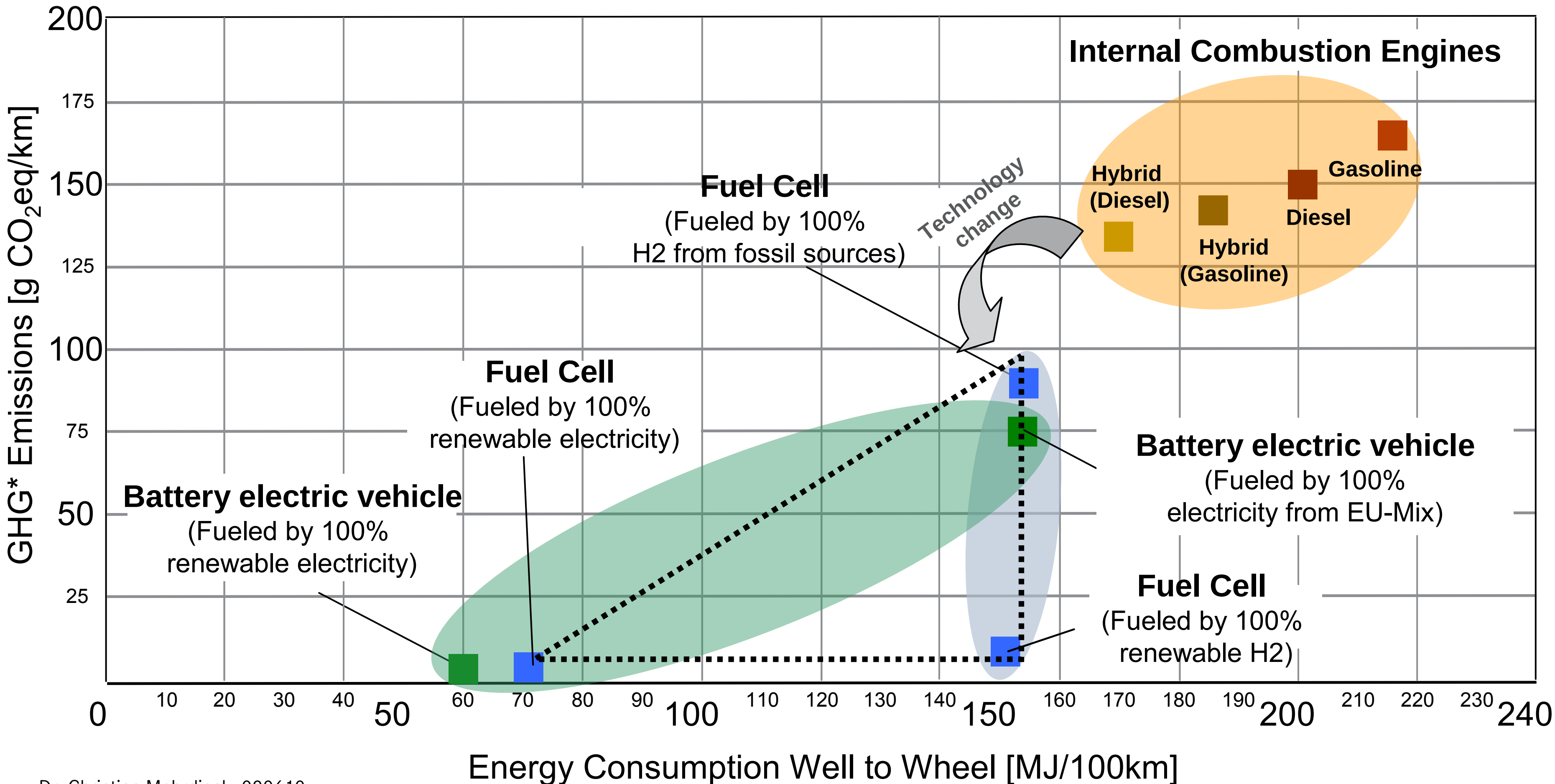
- Reliable technology
- Production at Competitive Cost
- In-time Availability
- Sufficient Coverage

Battery (System) Cost for Electric Vehicle at 20.000 units/a



Total Energy Balance – Well-to-Wheel Classification

Fuel Cell: long range (>400km), short refueling time (3 min), cars/vans/trucks
Battery: ideal in small cars for city traffic (100-150km), overnight recharging



Dr. Christian Mohrdieck, 090610

Source: EUCAR/CONCAWE "Well-to-Wheels Report 2004"; Optiresource, 2006 Reference vehicle class: VW Golf

*GHG: Green House Gas

Emission-Free Driving: Fuel-Cell- and Battery-Vehicles

Emission-fees | Congested urban areas | Zero-emission regions | Megacities

Fuel Cell Vehicles

~100 F-CELL vehicles in customer hands

Enablers

- <u>Technology/components</u>:
  - Battery (esp. Li-Ion)
  - Fuel-cell stacks
  - Hydrogen storage
  - Electric engines
  - Power electronics
- <u>IP-Rights</u>
- <u>Partnerships</u>

Battery-electric veh.

~100 smart ev - test fleet in London

Development Process Fuel Cell

Stack → **System** → **Drive System** → **Vehicle**

specs ← specs ← specs

old:	**AFCC**	**NuCellSys** 50/50 DAI/Ford	**Daimler Ford**	**Daimler Ford**
new:	**AFCC** 50,1 / 30 / 19,9 DAI / F / BPS	**NuCellSys** 100% DAI	**Daimler**	**Daimler**

Experiences with Daimler Fuel Cell Vehicles

60 F-Cell vehicles in Customers' hands (since 2004)

~ 2.000.000 km*

37 Buses (Citaro) Europe, Australia, China

~ 2.120.000 km*

3 Light Duty vehicles at UPS Europe, USA

~ 64.000 km*

*Data May 2009

Daimler is pioneer of Fuel Cell Vehicle (FCV), long experience with FCV's (first FCV in 1994)

Daily operation of more than 100 FCV's all over the world

Big variety of FCV's: Passenger cars, buses, vans

Operation of FCV's at customers in different climate zones with varying ambient temperatures

In 2007, A-class F-Cell achieved 100,000 miles, 2,500 operating hours without stack failure

F-Cell in Sweden

Challenges for the Fuel Cell Technology

Technology

- Power Density
- Cooling (FC Power)
- H_2-Storage (Range)
- Robustness
- Durability
- Cold Start, Freezability

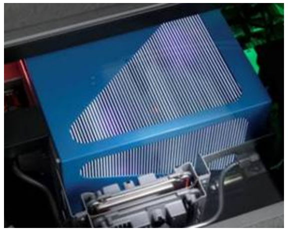
Cost

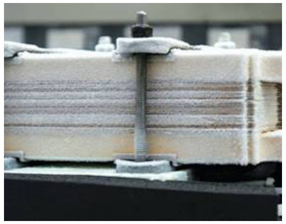
- Fuel Cell System & Stack
- Electric Drive
- H_2-Tank
- Infrastructure
- Cost of H_2

Infrastructure

- Reliable technology
- Production at Competitive Cost
- In-time Availability
- Sufficient Coverage

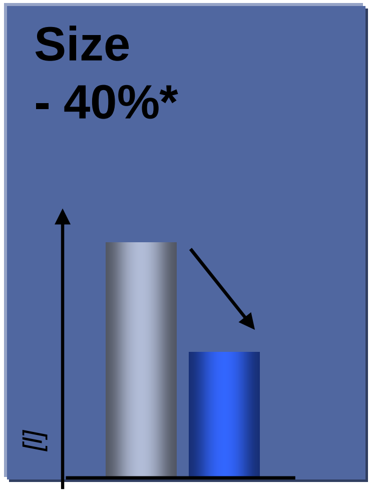
Fuel cell drive: Sustainable mobility of the future

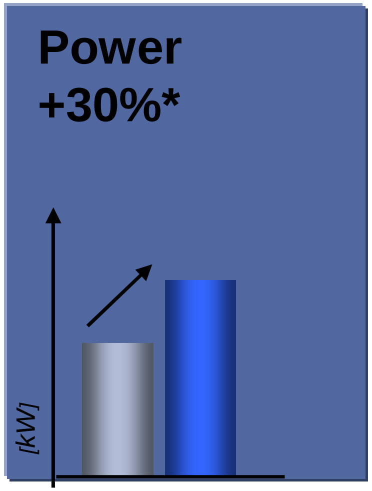


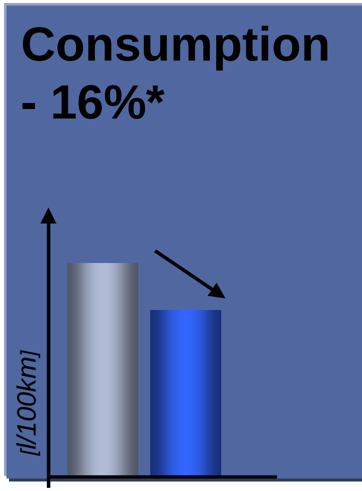


Next generation fuel cell drive:

- Power: 85 kW / 350 Nm
- Lithium-Ion battery
- Range: 400 km
- Freeze start down to - 15°C







*Compared to A-Class F-Cell

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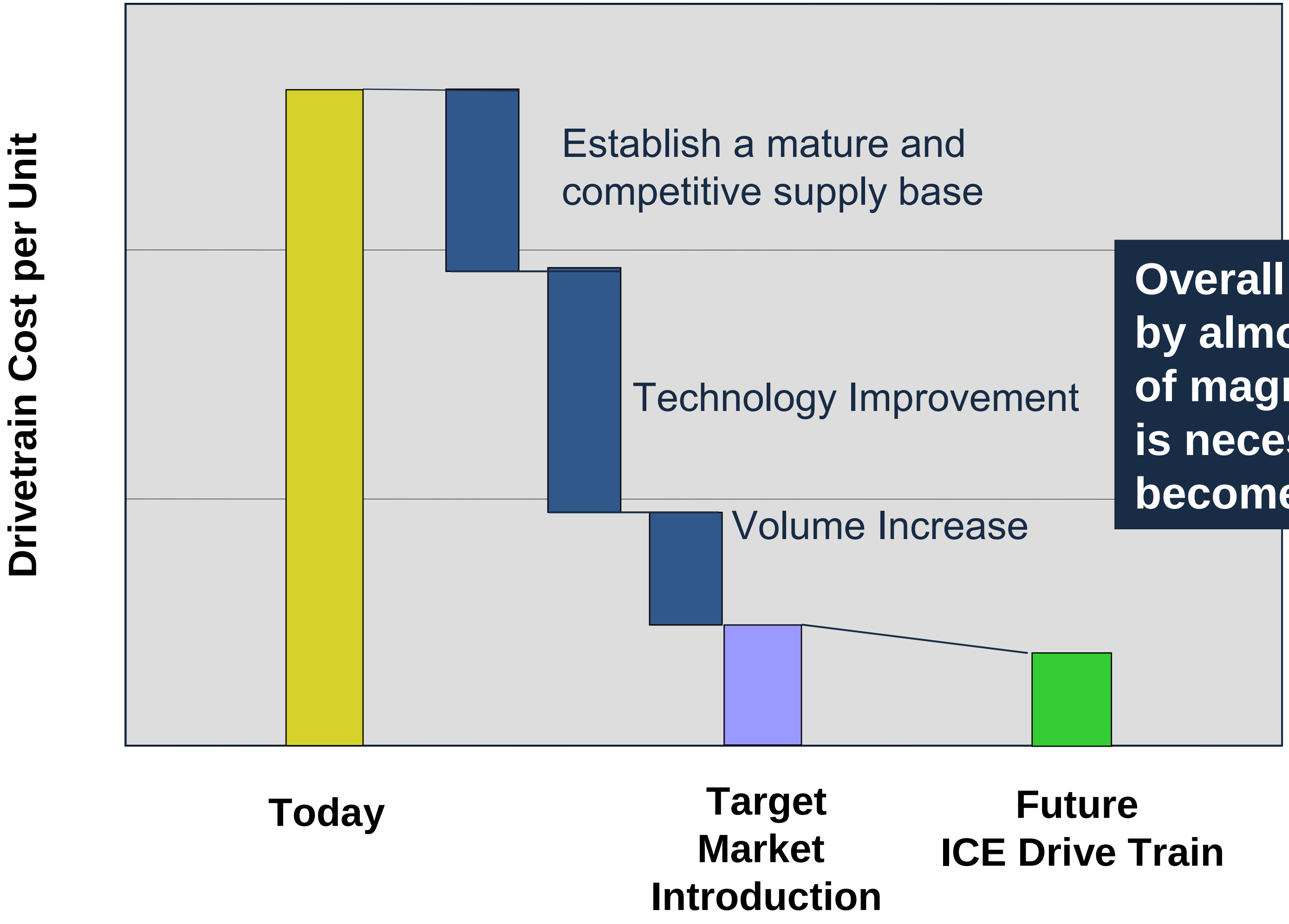
Significant Cost Reductions of Fuel Cell Powertrains



Overall cost reduction by almost two orders of magnitude is necessary to become competitive!

Daimler's Fuel Cell Technology Roadmap

Bus

Generation 1
Technology Demonstration

Generation 2
Customer Acceptance

Future Generations

Passenger Cars
Lead Application

2004 – **Generation 1**
Technology Demonstration
F-Cell

2010 – **Generation 2**
Customer Acceptance
B-Class F-Cell

2013 – **Generation 3**
Cost Reduction I

201x – **Generation 4**
Market Introduction
Cost Reduction II

202y – **Generation 5**
Mass Production

Sprinter

Generation 1
Technology Demonstration

Generation 2
Customer Acceptance

Future Generations

Daimler is dedicated to commercialize Fuel Cell Vehicles

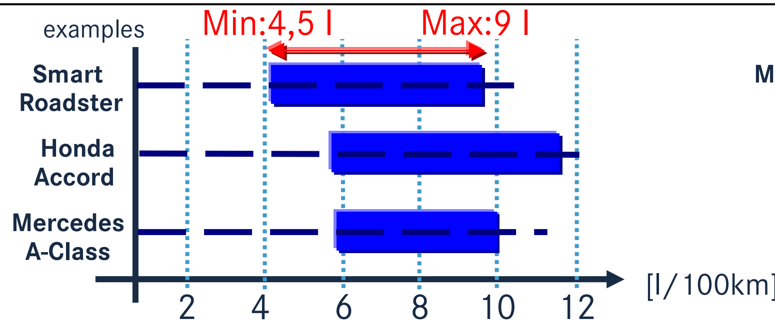
Emission-Free Driving: Engagement of all Stakeholder is necessary!

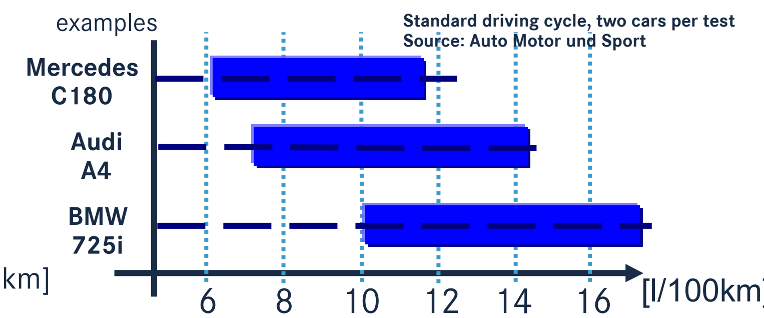
Daimler together with partners supports the build-up of a world wide infrastructure for H2 and electricity

- **Renewable power generation**
- **Public charging infrastructure**
- **Production and distribution of hydrogen for fuel cell vehicles**

Driver behavior, traffic management and infrastructure: Key elements for fuel efficiency and emissions reduction

Driver Behavior

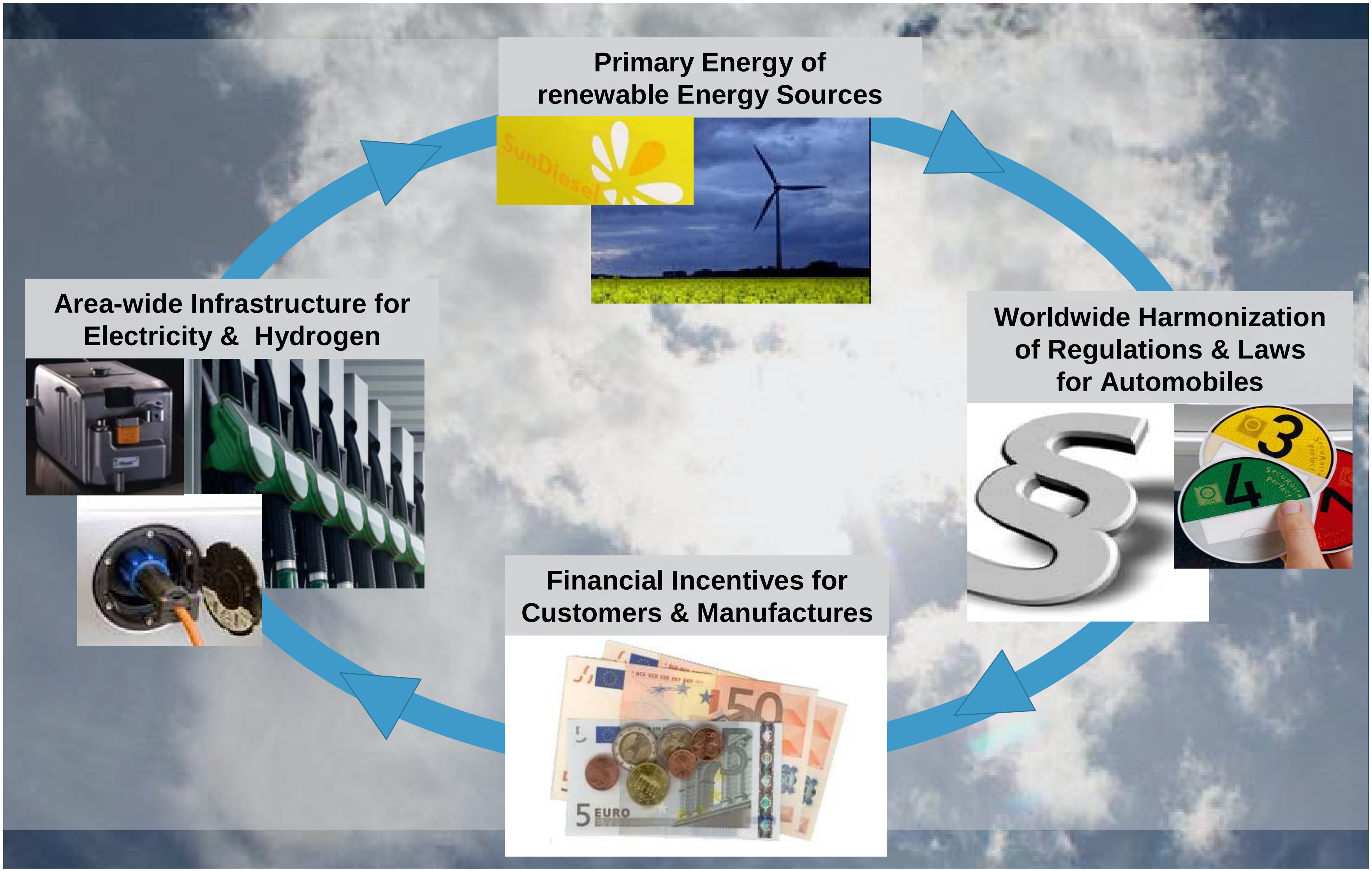




Fuel consumption (min/max): driver influence causes up to 100% deviation

Infrastructure & Traffic Management

Preconditions for Sustainable Mobility




Thank you for your attention!

Disclaimer

This document contains forward-looking statements that reflect our current views about future events. The words "anticipate," "assume," "believe," "estimate," "expect," "intend," "may," "plan," "project," "should" and similar expressions are used to identify forward-looking statements. These statements are subject to many risks and uncertainties, including an economic downturn or slow economic growth in important economic regions, especially in Europe or North America; the effects of the subprime crisis which could result in a weaker demand for our products particularly in the U.S. but as well in the European market; changes in currency exchange rates and interest rates; the introduction of competing products and the possible lack of acceptance of our products or services; price increases in fuel, raw materials, and precious metals; disruption of production due to shortages of materials, labor strikes or supplier insolvencies; a decline in resale prices of used vehicles; the business outlook for Daimler Trucks, which may be affected if the U.S. and Japanese commercial vehicle markets experience a sustained weakness in demand for a longer period than expected; the effective implementation of cost reduction and efficiency optimization programs; the business outlook of Chrysler, in which we hold an equity interest, including its ability to successfully implement its restructuring plans; the business outlook of EADS, in which we hold an equity interest, including the financial effects of delays in and potentially lower volumes of future aircraft deliveries; changes in laws, regulations and government policies, particularly those relating to vehicle emissions, fuel economy and safety, the resolution of pending governmental investigations and the outcome of pending or threatened future legal proceedings; and other risks and uncertainties, some of which we describe under the heading "Risk Report" in Daimler's most recent Annual Report and under the headings "Risk Factors" and "Legal Proceedings" in Daimler's most recent Annual Report on Form 20-F filed with the Securities and Exchange Commission. If any of these risks and uncertainties materialize, or if the assumptions underlying any of our forward-looking statements prove incorrect, then our actual results may be materially different from those we express or imply by such statements. We do not intend or assume any obligation to update these forward-looking statements. Any forward-looking statement speaks only as of the date on which it is made.