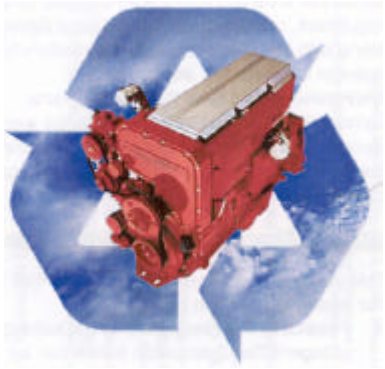
7 th Diesel Engine Emissions Reduction Workshop

August 5-9, 2001

Portsmouth, Virginia



The future of the Diesel engine in passenger cars

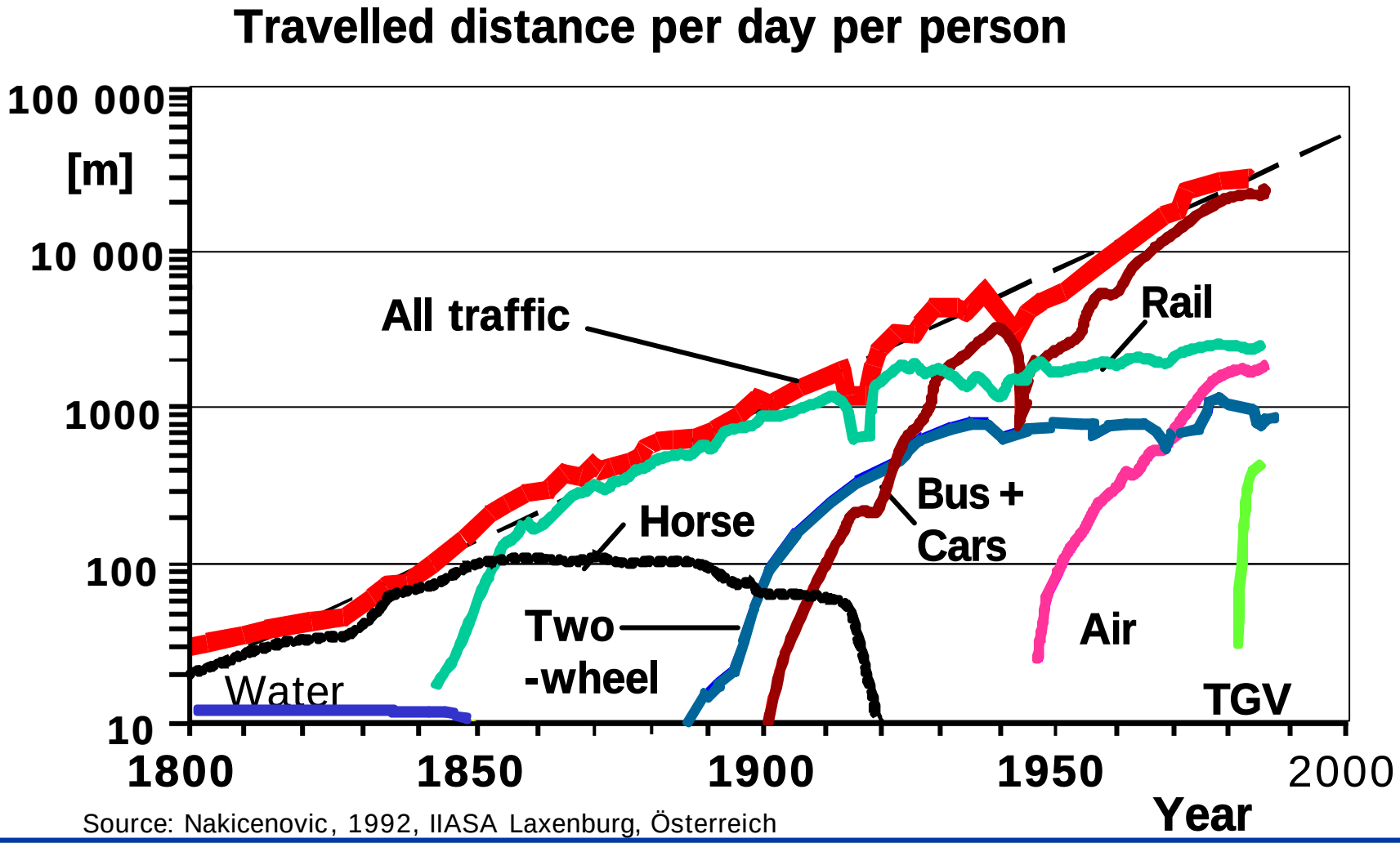
Klaus-Peter Schindler

Volkswagen AG, Wolfsburg, Germany

Content

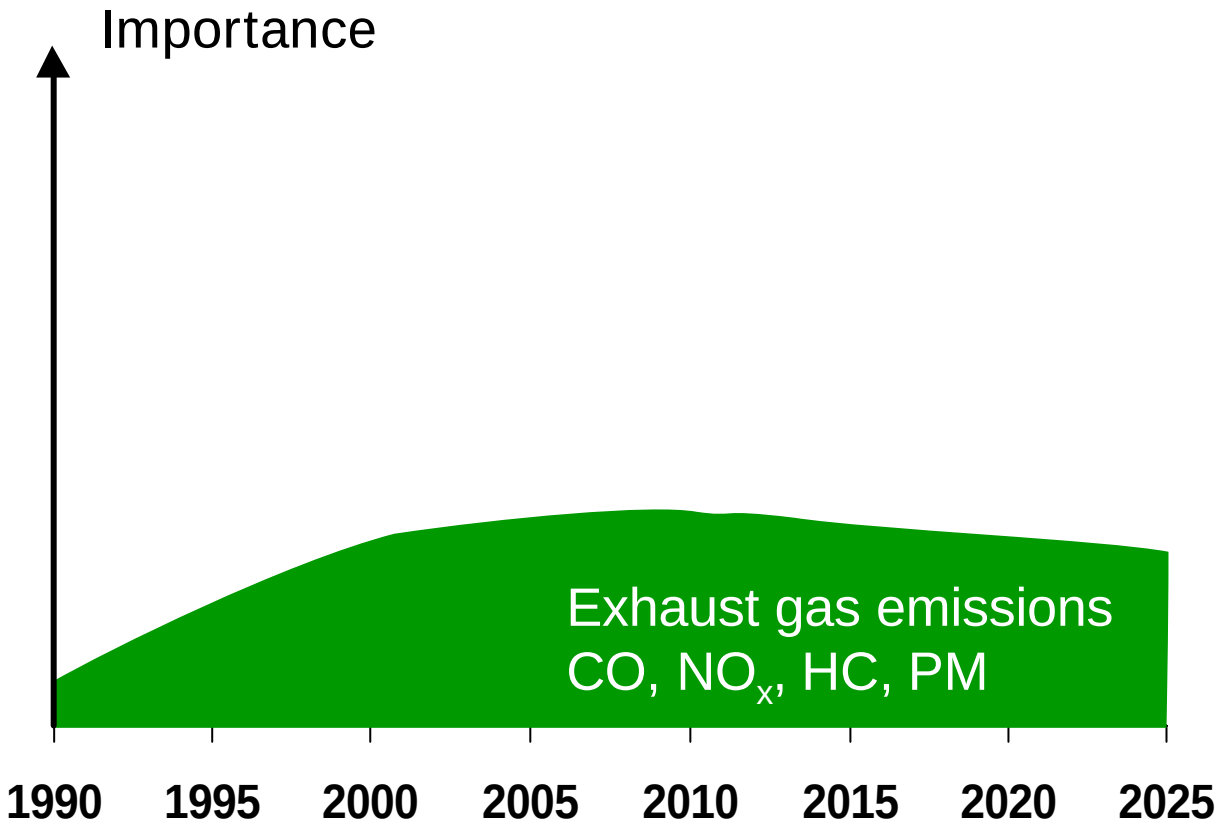
1. Mobility - today and tomorrow
2. Innovative vehicle design
3. Powertrain concepts
4. Outlook and conclusions

Mobility growth

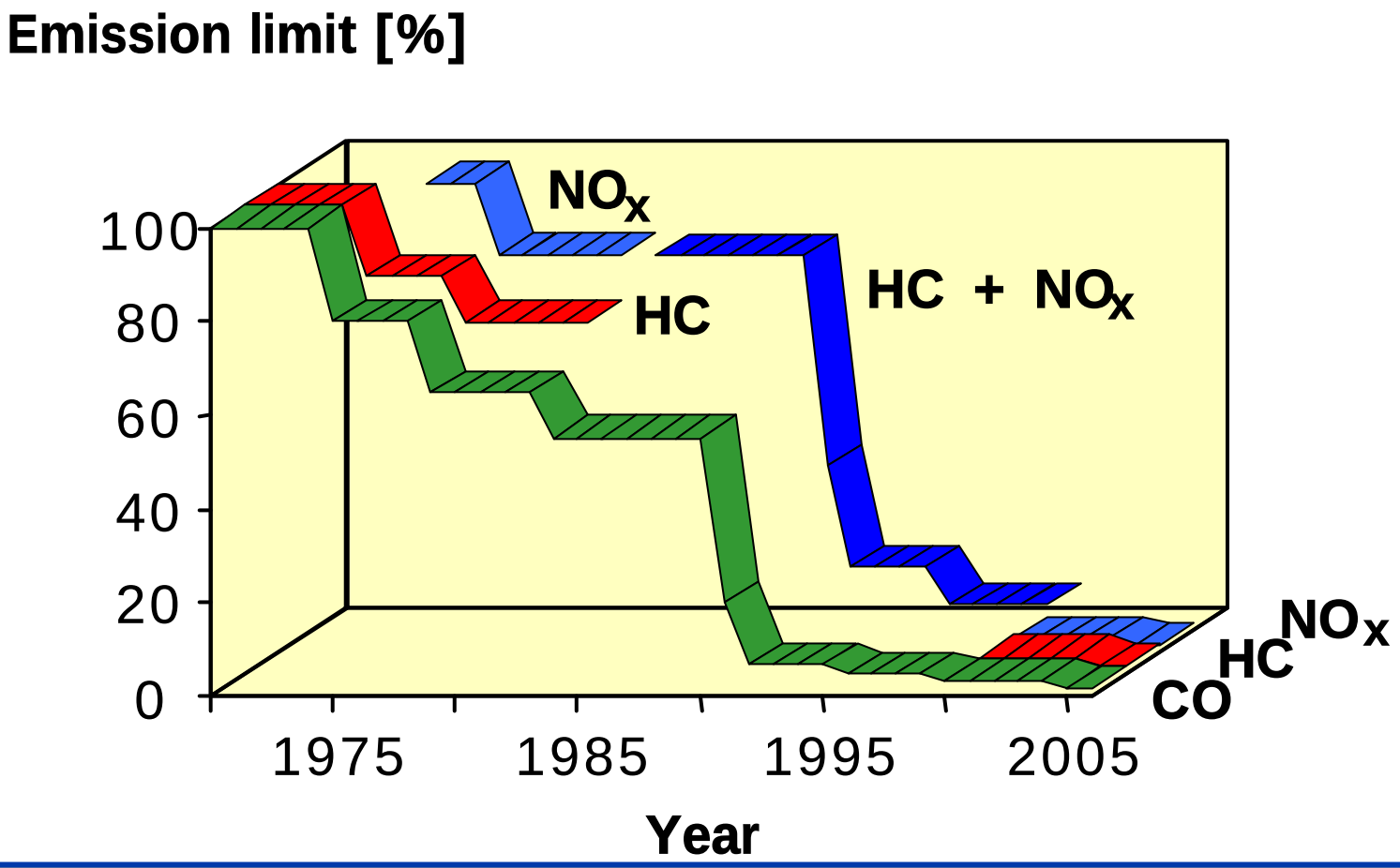


Source: Nakicenovic, 1992, IIASA Laxenburg, Österreich

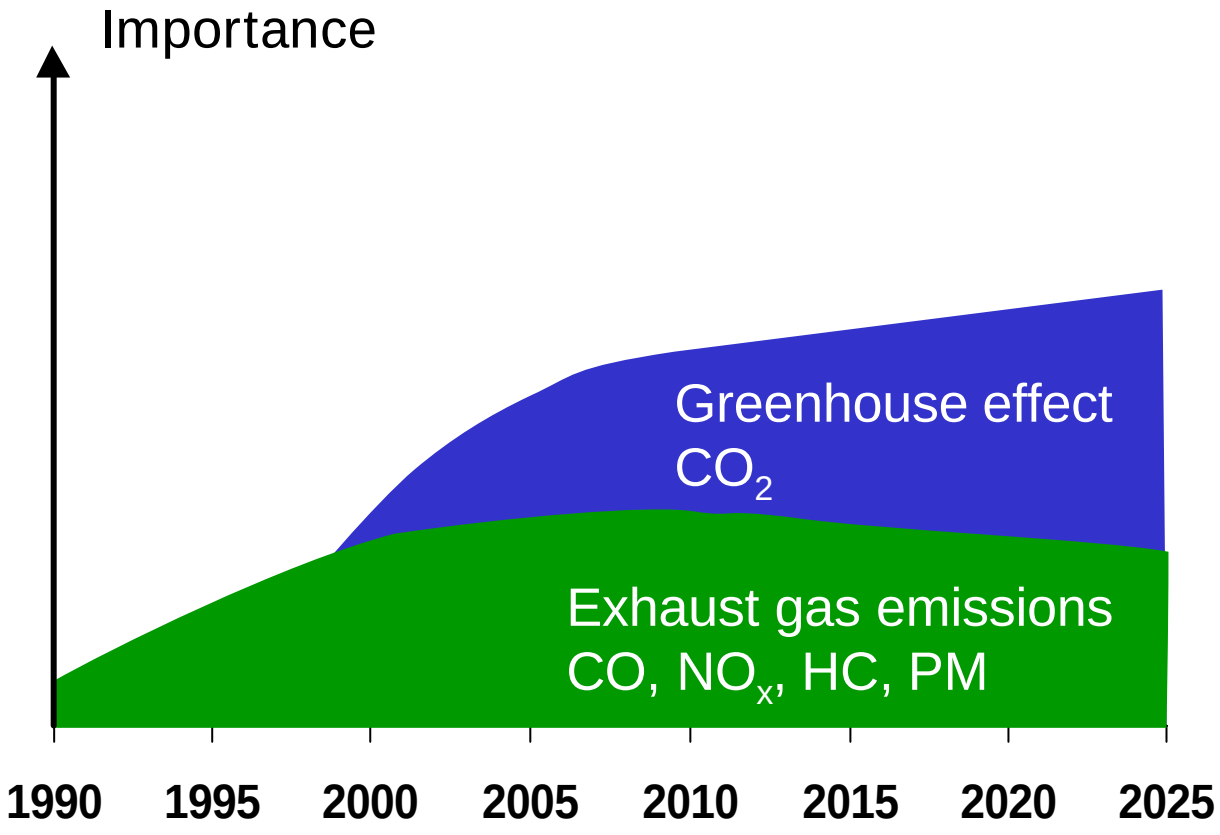
Environmental relevant driving forces of vehicle development



Development of emission standards in Europe

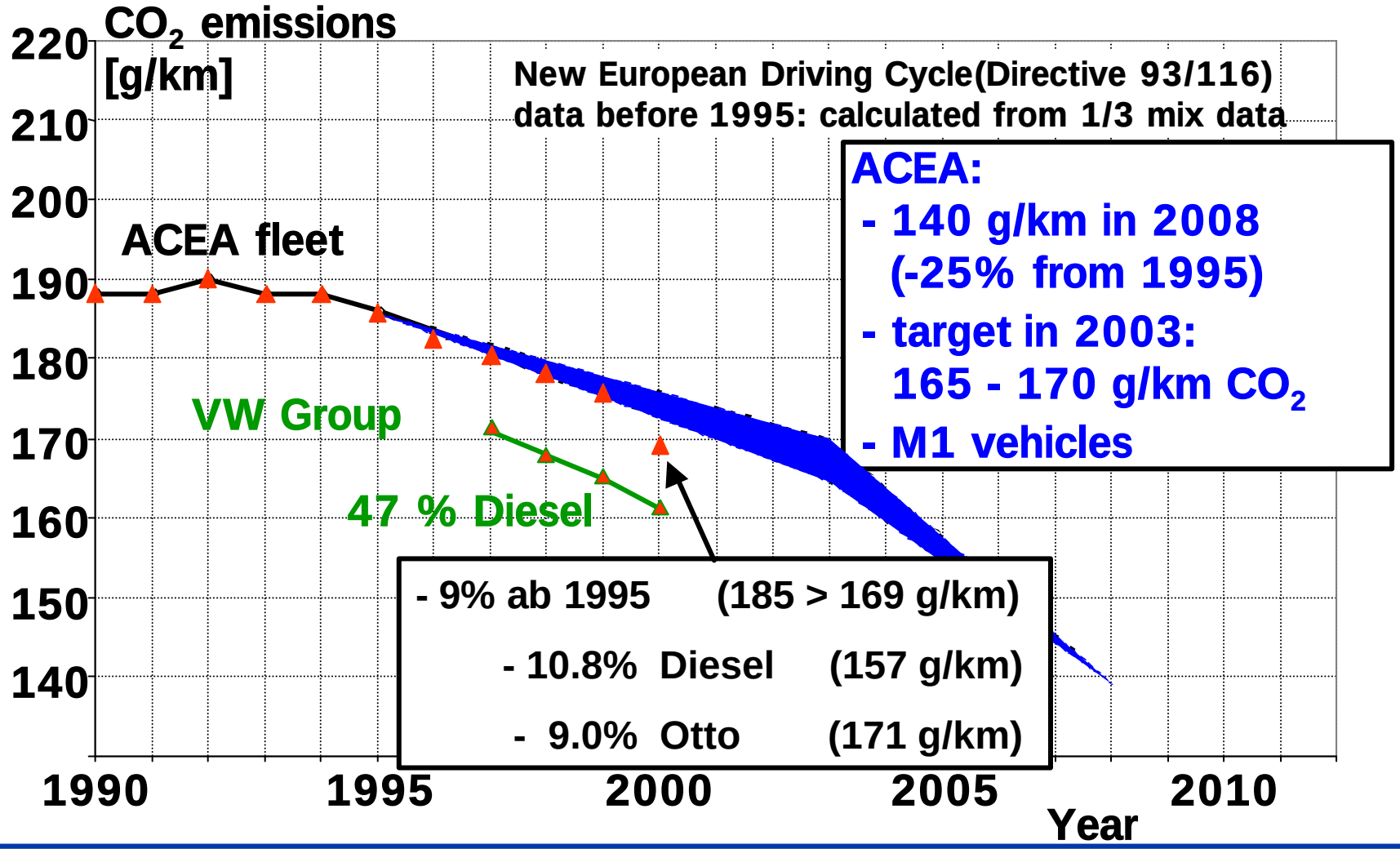


Environmental relevant driving forces of vehicle development

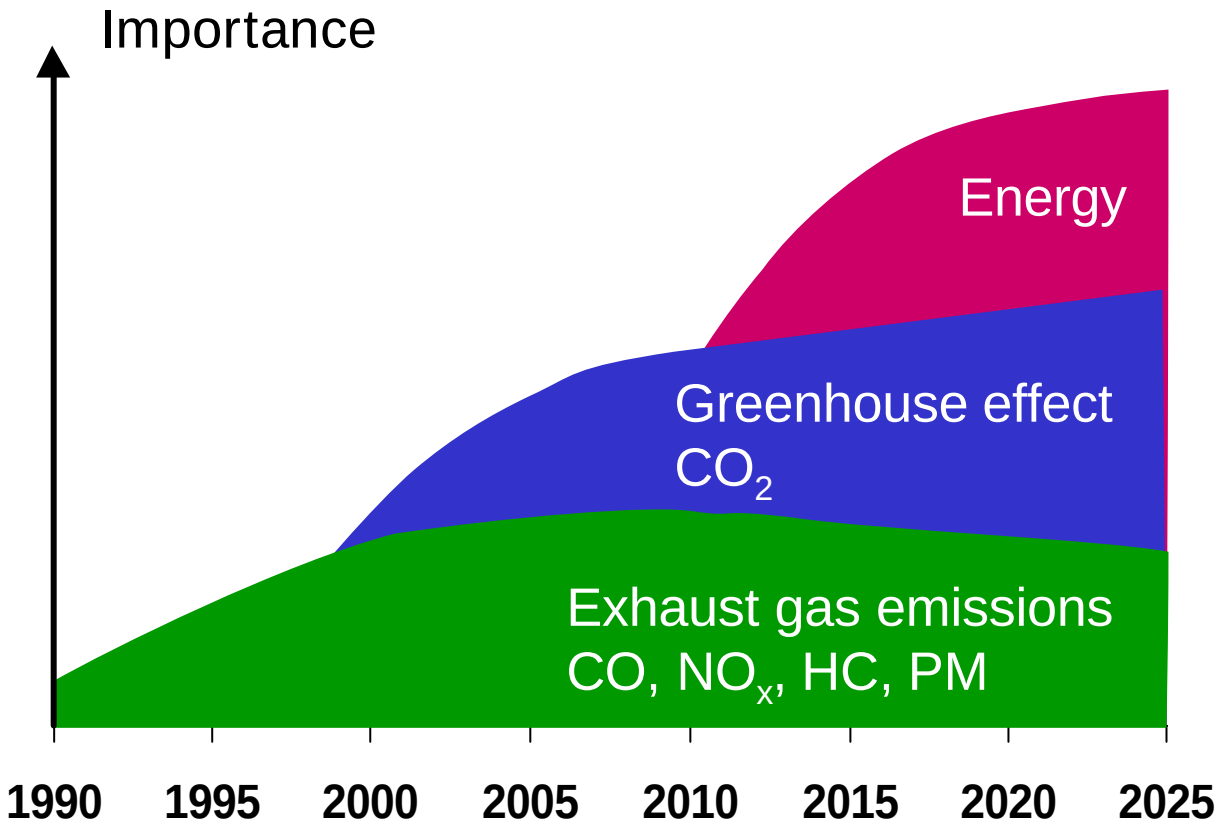


CO_2 Reduction in Europe

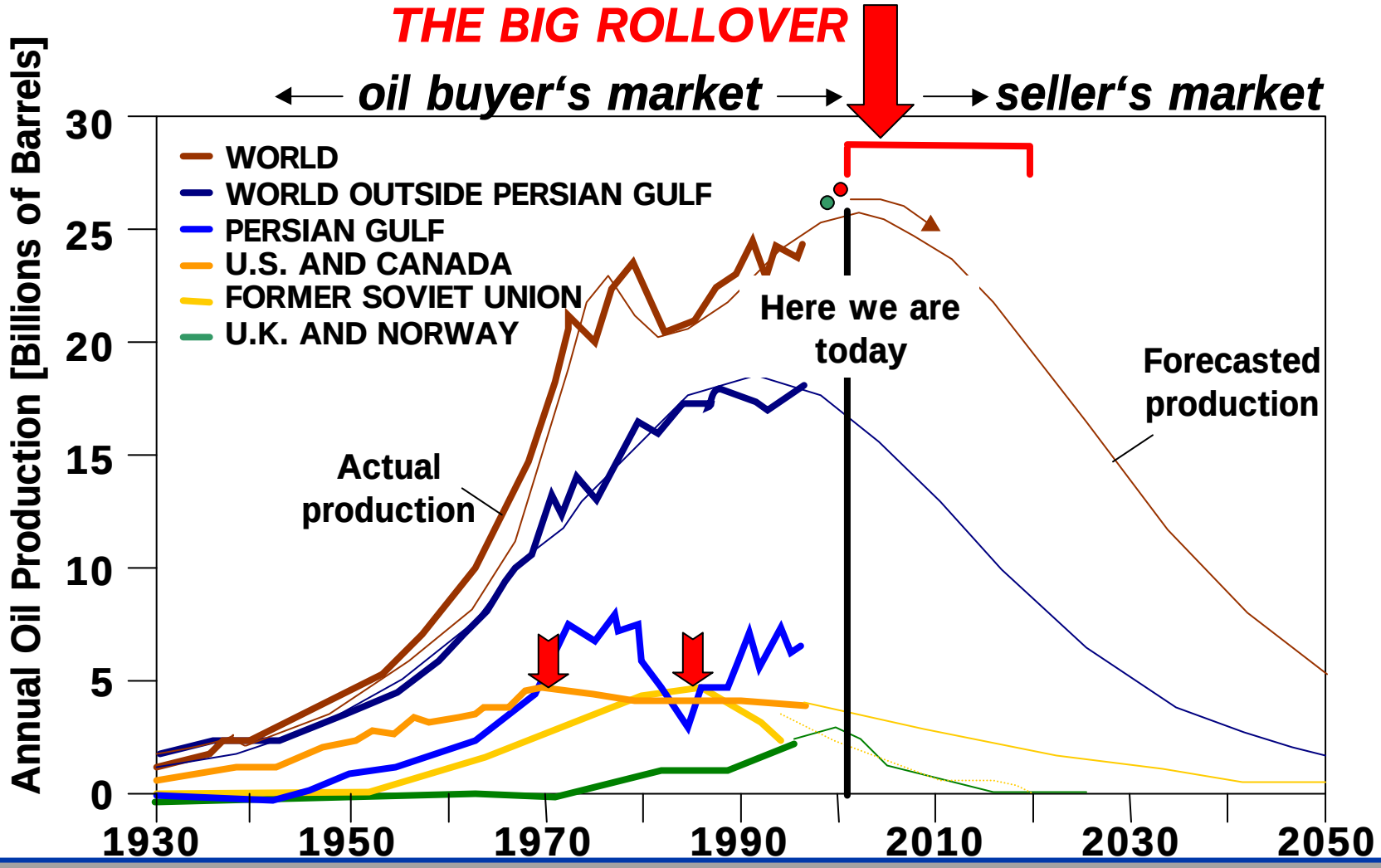
Commitment between ACEA and EU Commission



Environmental relevant driving forces of vehicle development



Are we running out of oil?

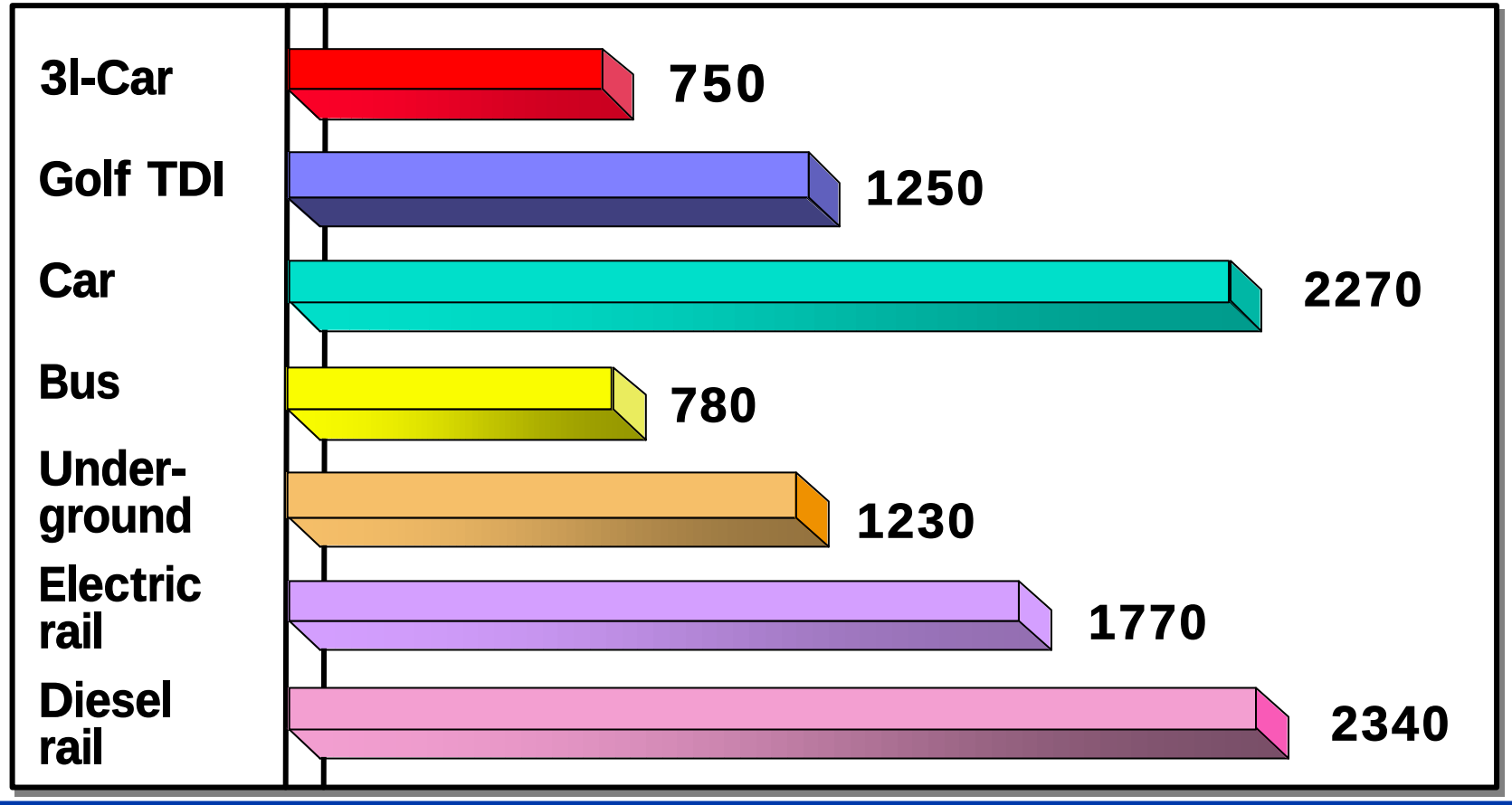


Primary energy requirements [kJ / Pkm]

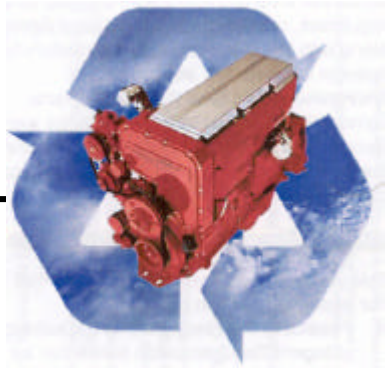
Comparison of various transport means

Urban traffic under 75 km

(taking into account average rate of occupation for each transport form)



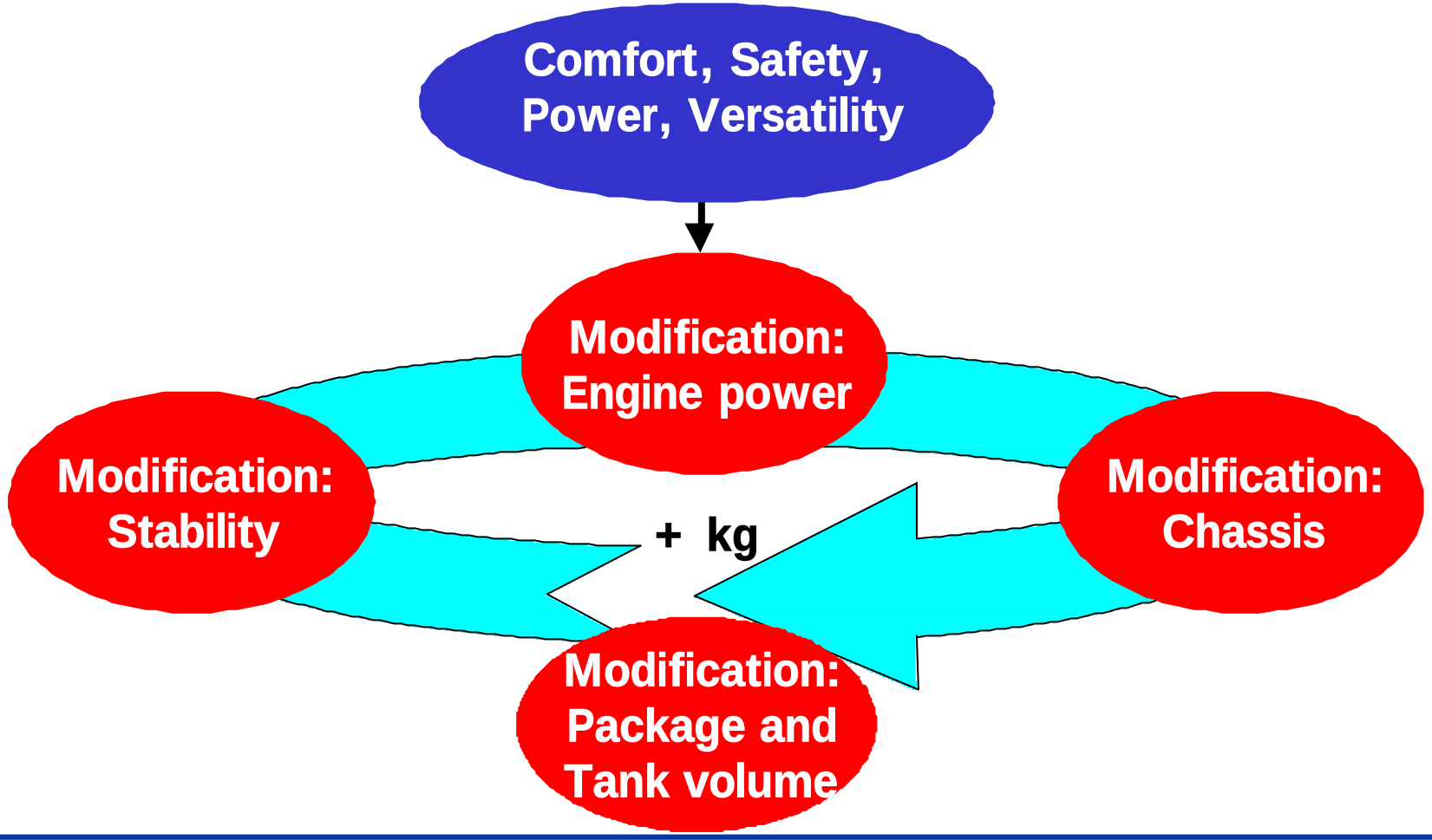
Content



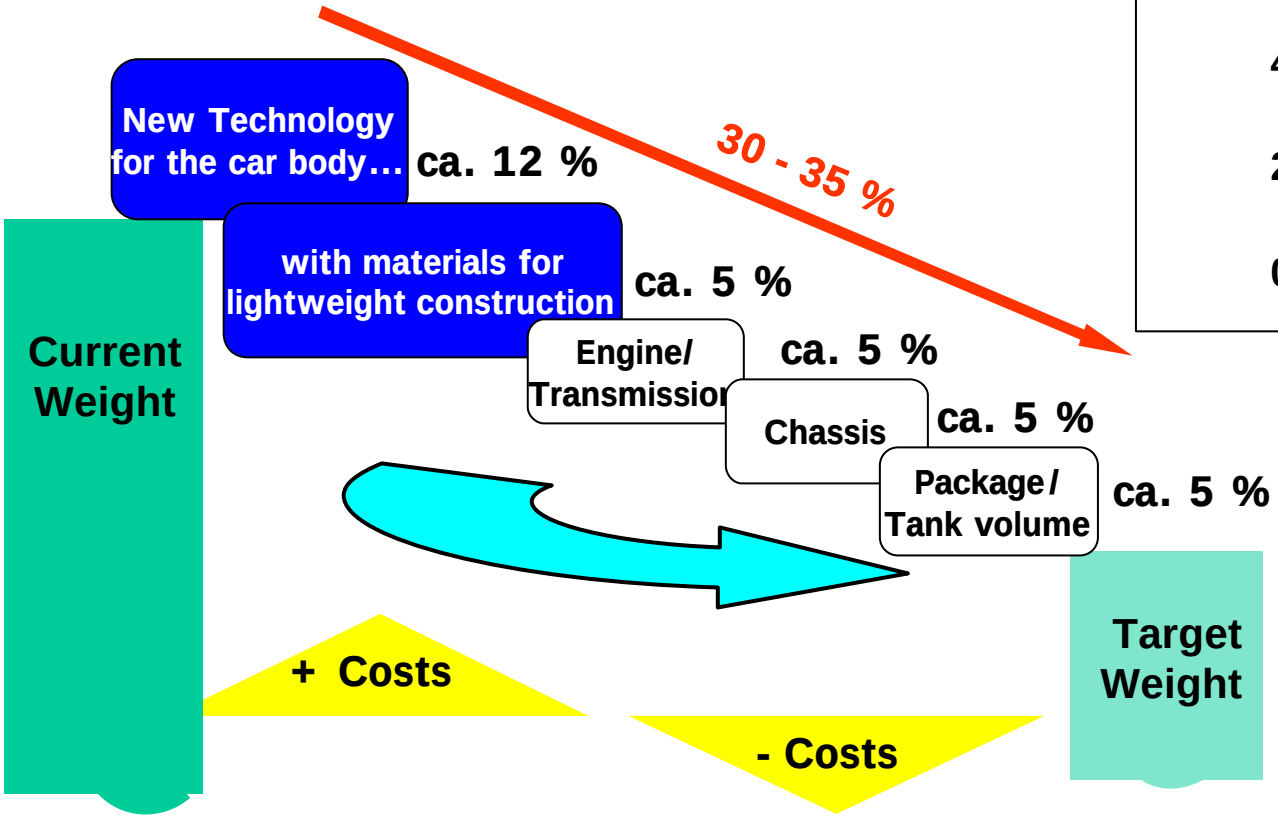
1. Mobility- today and tomorrow

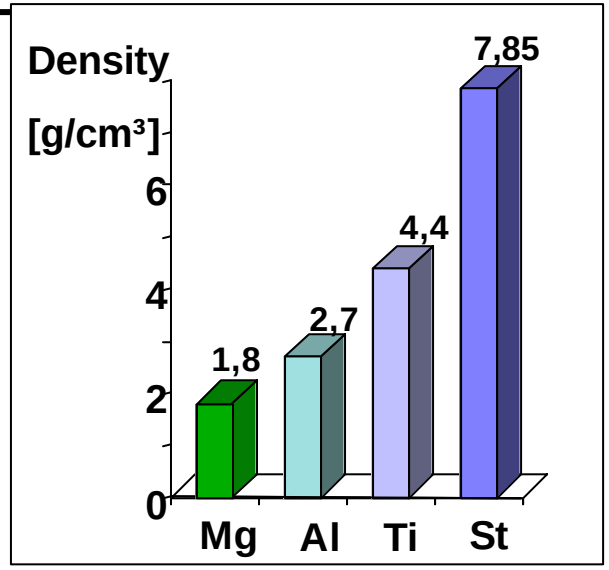
2. Innovative vehicle design

The Challenge: Weight spiral



The reversal of the weight spiral





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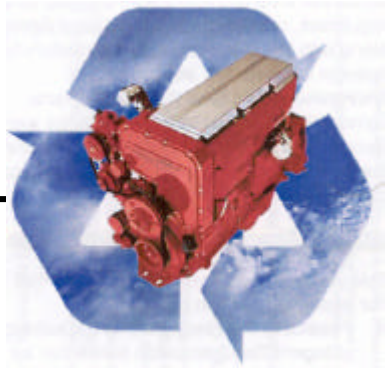
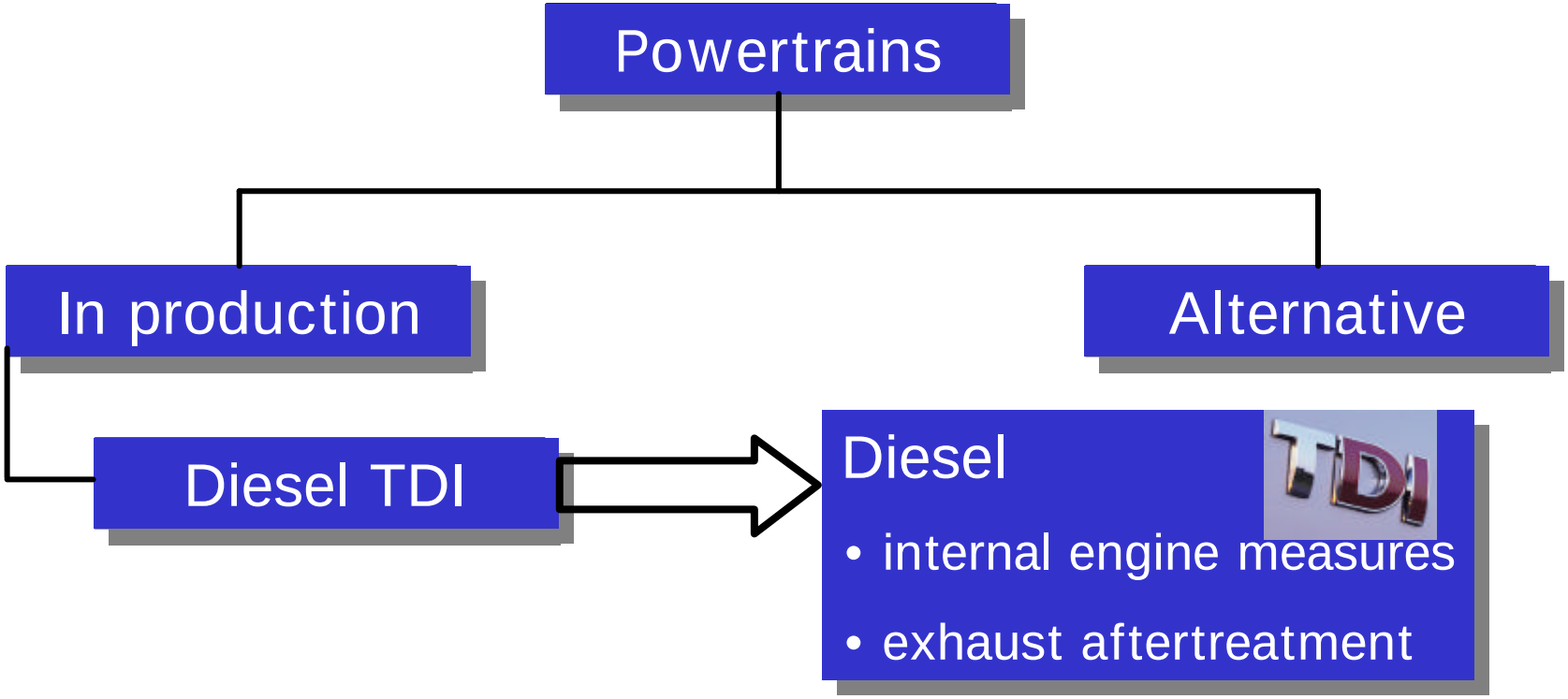


1. Mobility- today and tomorrow

2. Innovative vehicle design

3. Powertrain concepts

Approaches to maintain individual mobility

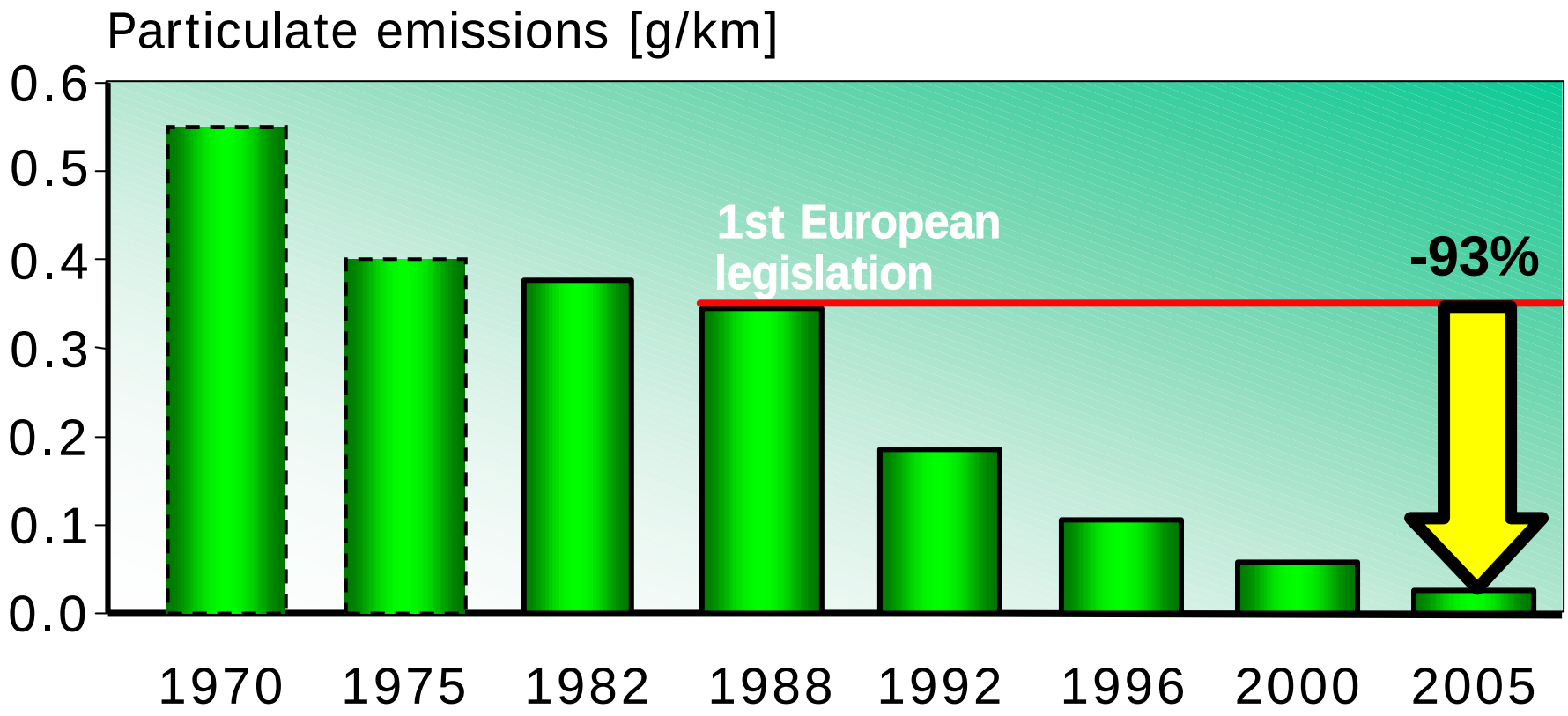


Why do we need the diesel?

The modern diesel engine is …

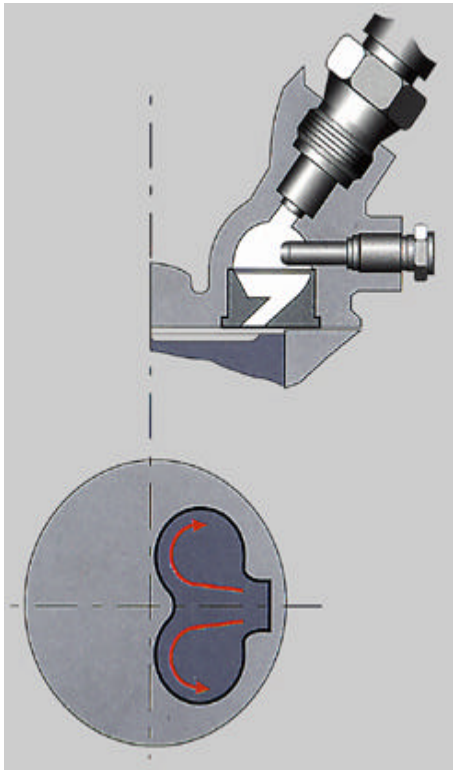
- powerful
- economical
- ecological
- future oriented

Development of particulate legislation

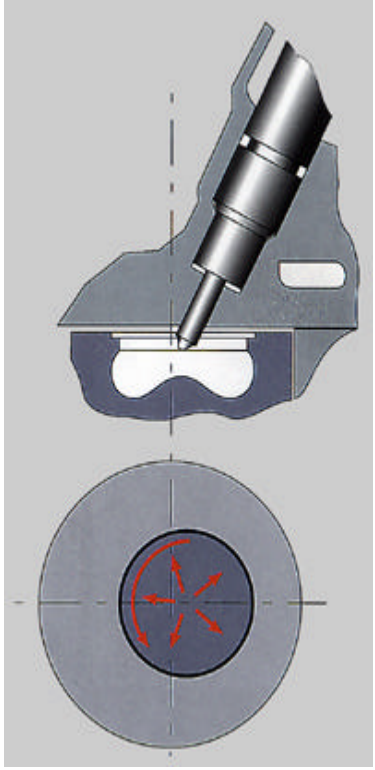


Diesel technologies

Swirl chamber

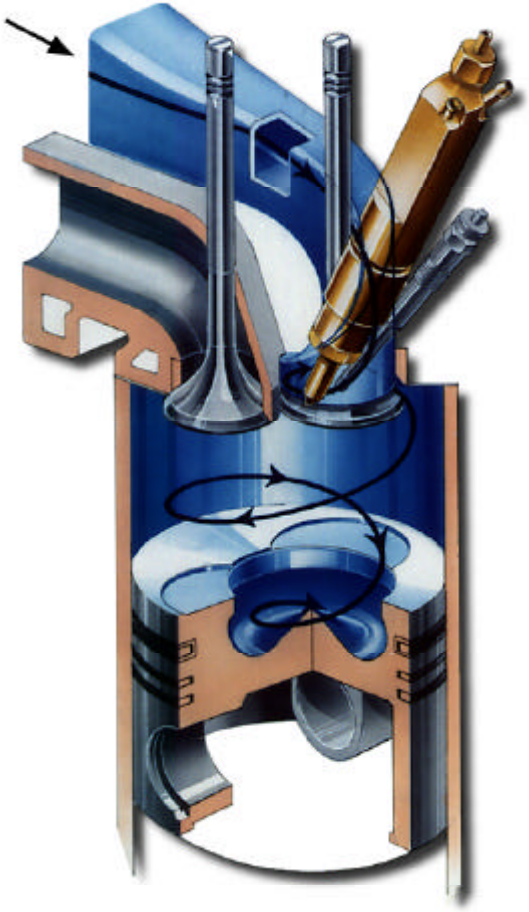


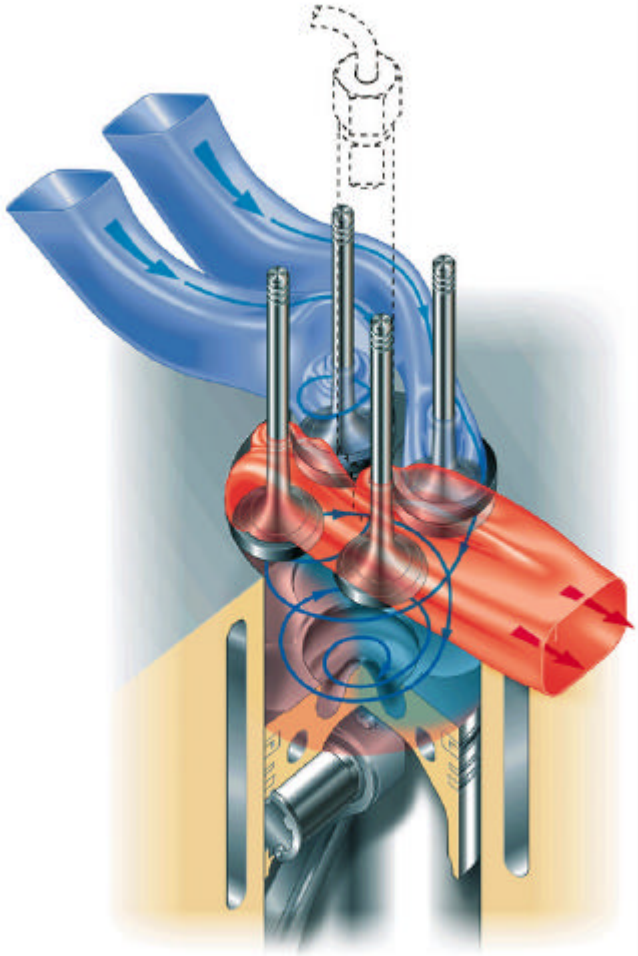
Direct injection



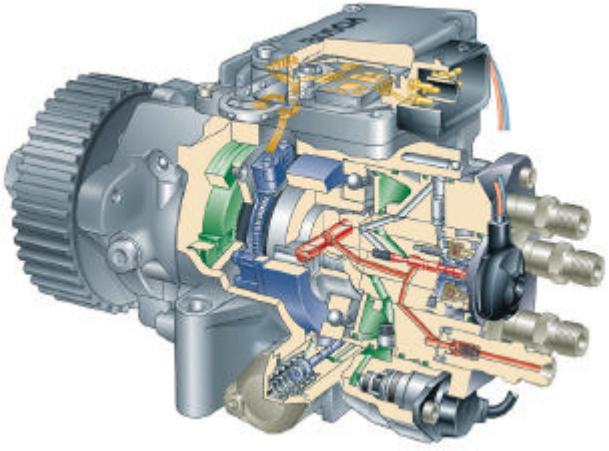
Development potentials of diesel engines

Today‘s direct injection engines characteristics

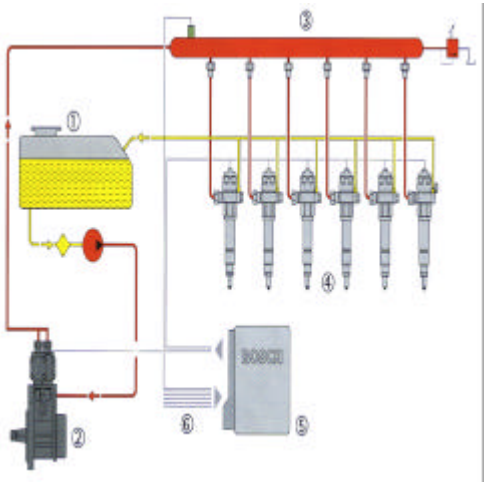




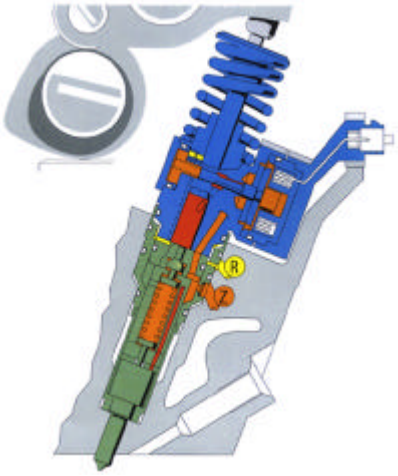
High pressure injection systems



Distributor Injection Pump



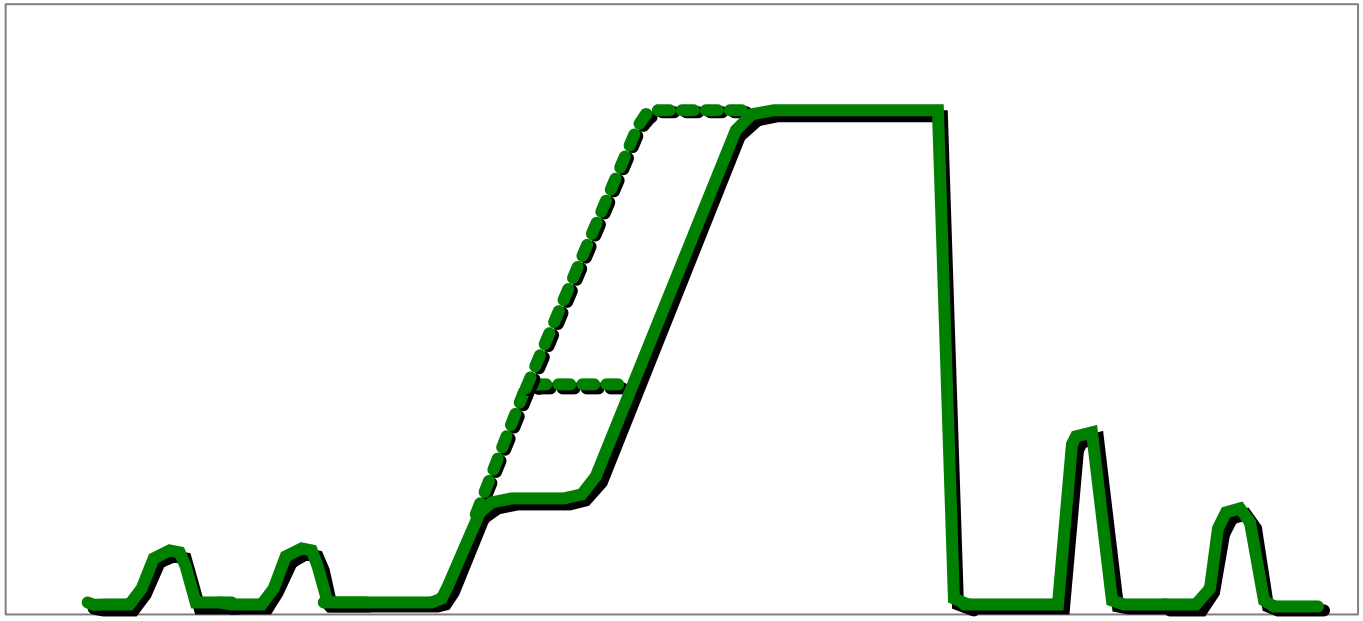
Common-Rail System



Unit-Injector

Future high pressure injection systems
Injection history

Injected mass per time

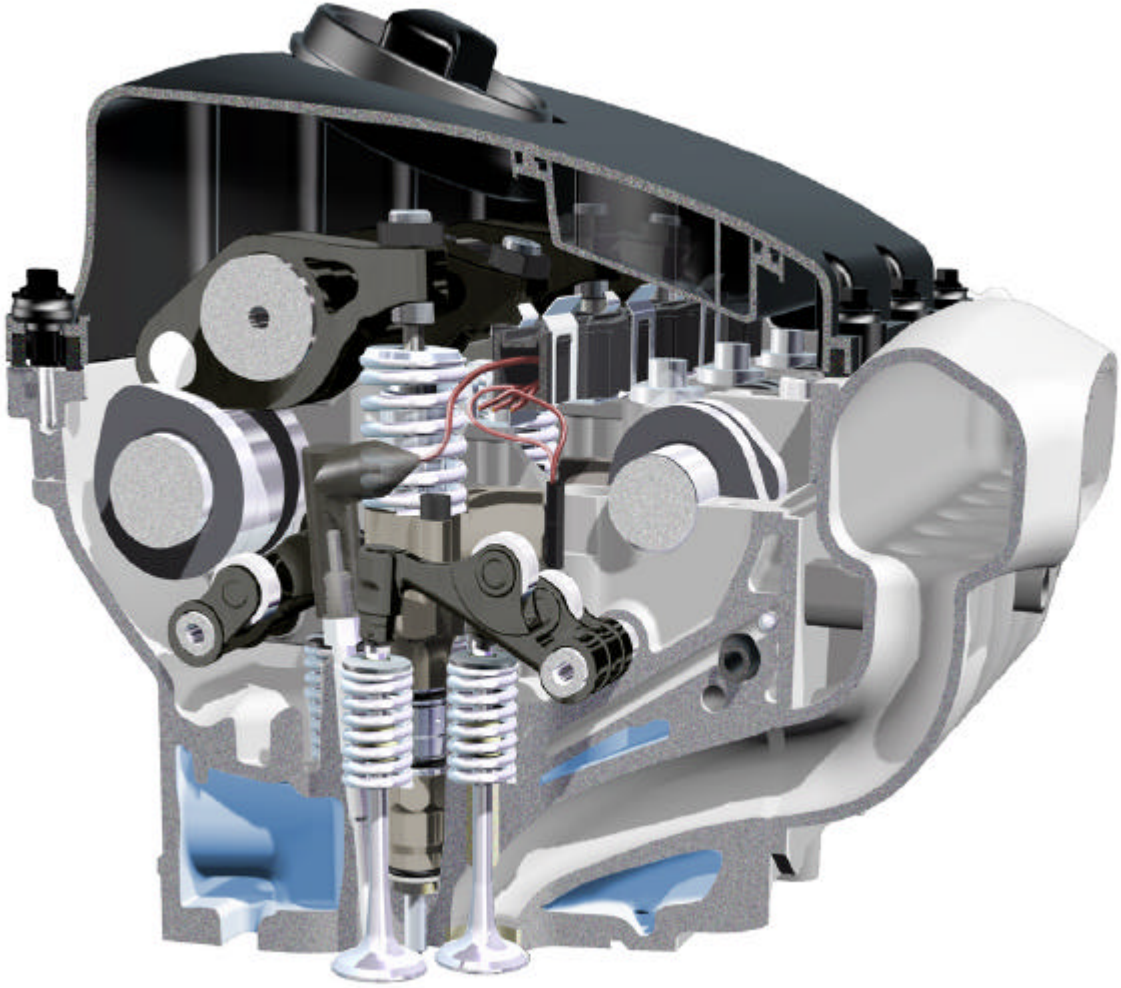


time

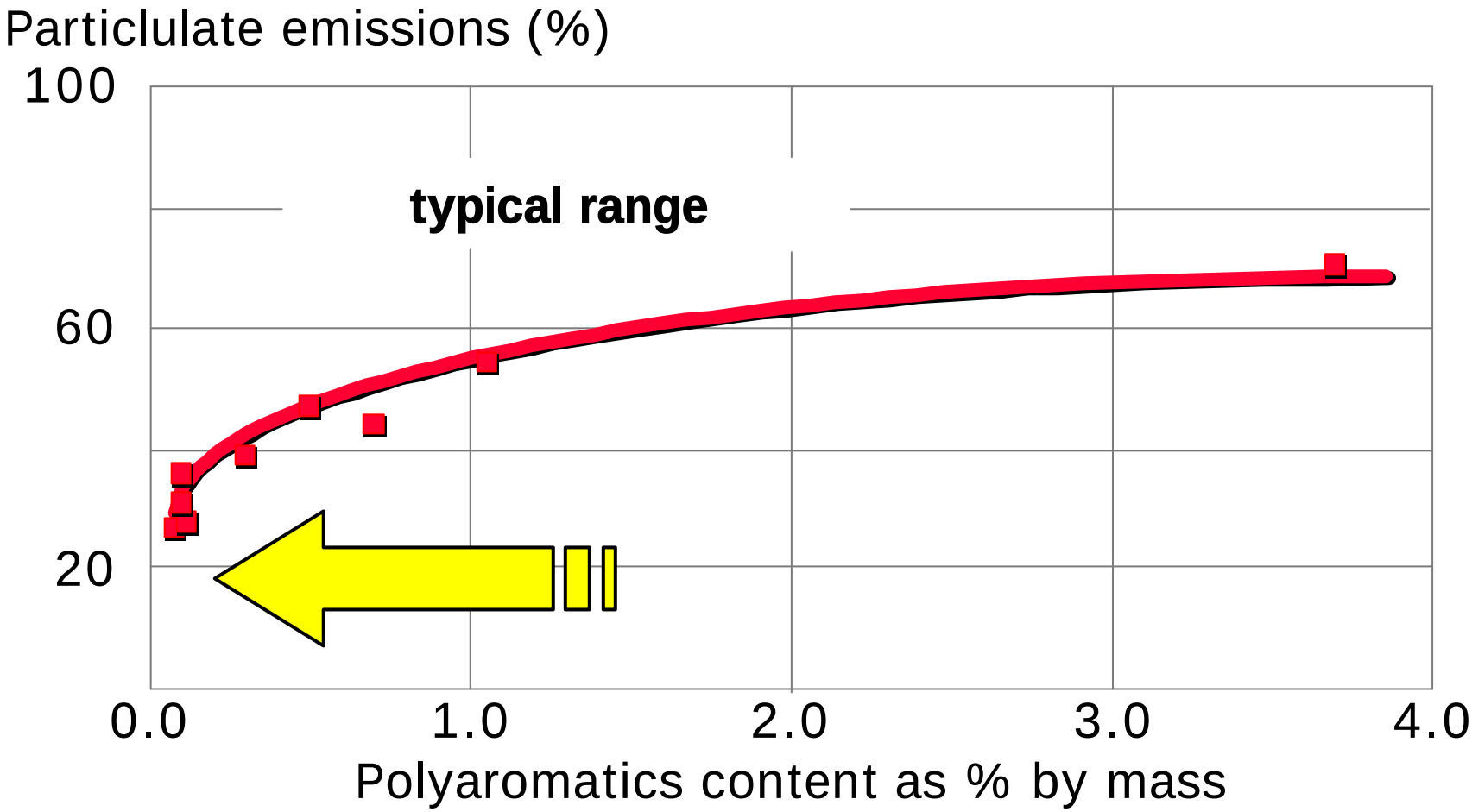
4V Cylinder head with Unit Injector

Environmental related advantages

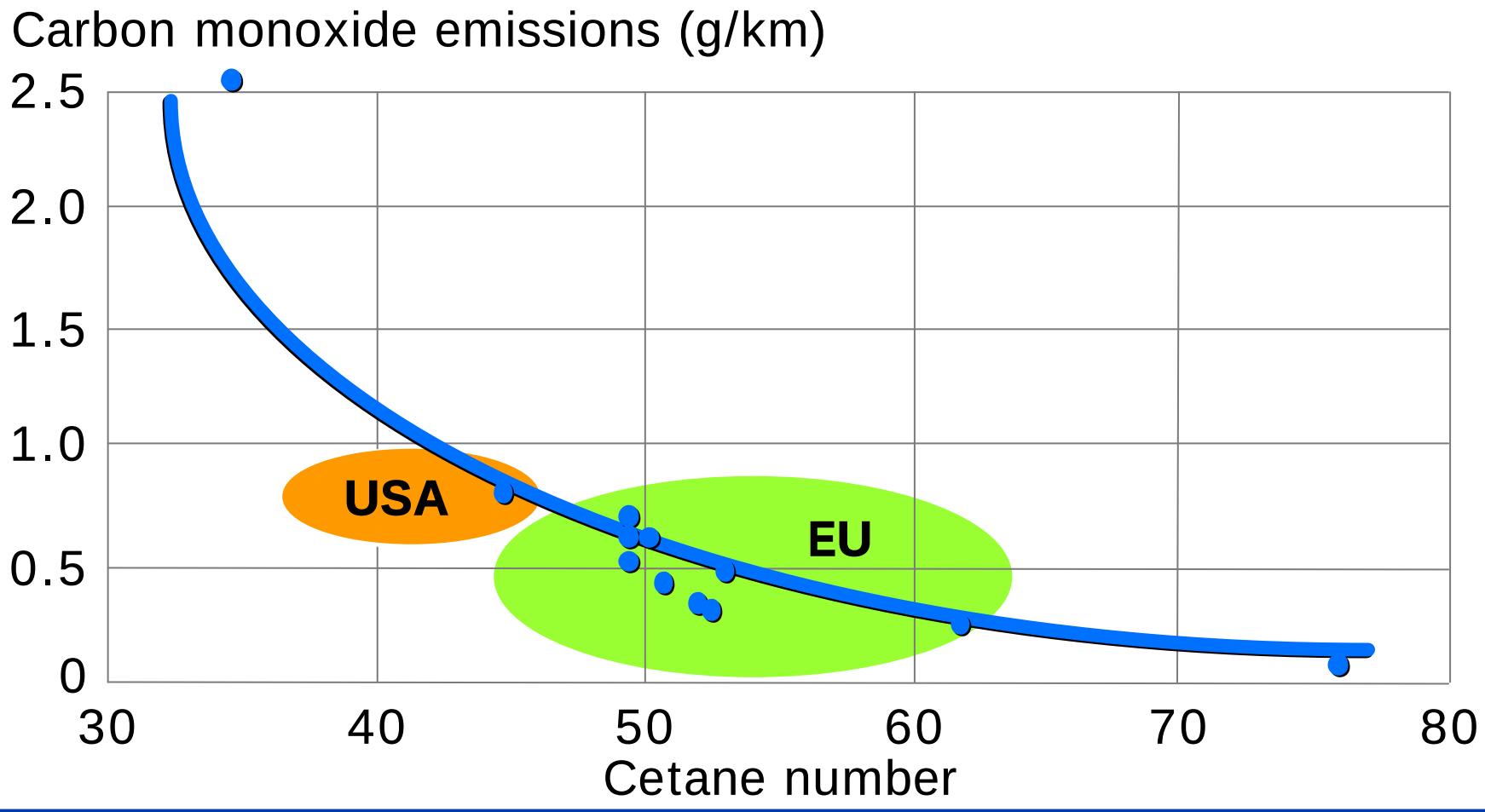
- Low combustion noise
- Low fuel consumption
- Low exhaust gas emissions



Improved fuel quality
Influence of polyaromatics content

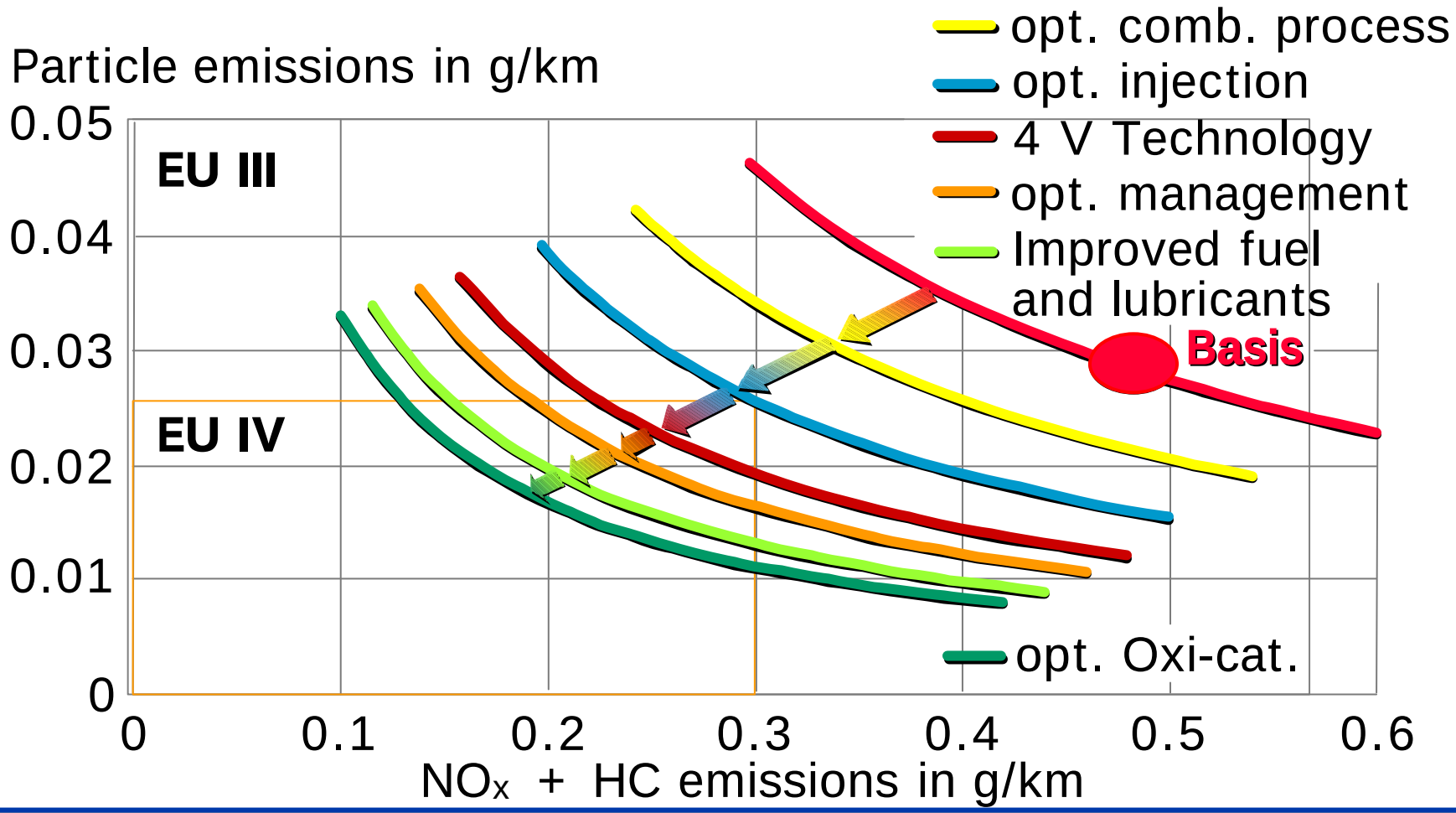


Improved fuel quality
Influence of cetane number

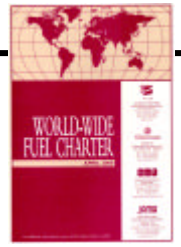


Estimate of potential

85 kW vehicle, Golf category, NEDC



Fuel specifications
EU legislation (2005) and WWFC



	2005 legislation		
• Sulphur content	max. 50	max. 10	ppm
• Aromatics content		max. 15	% wt.
Polyaromatics (di⁺tri⁺)	max. 11	max. 2	% wt.
• Cetane number	min. 51	min. 55	
• Density	max. 845	820 – 840	kg/m^3
• T90		320	°C
T95	360	340	°C
Final boiling point		350	°C

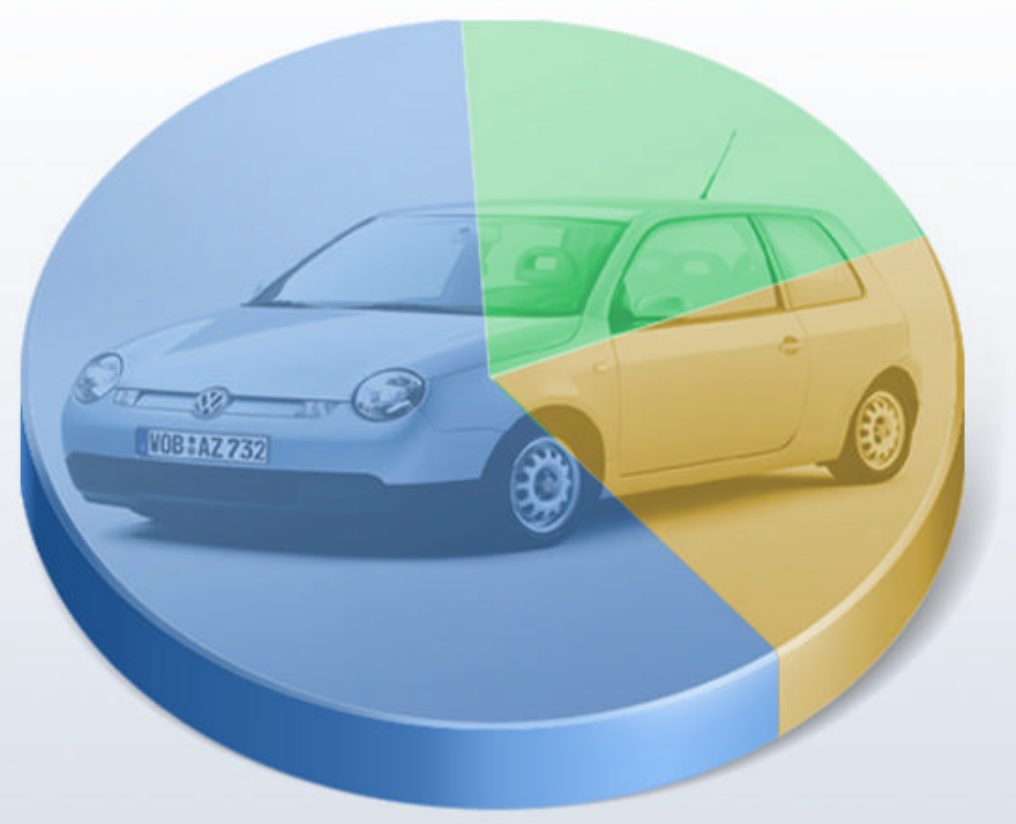
The first 3L vehicle in production

VW Lupo 3L TDI

- 1.2 l TDI engine with unit injection
- 45 kW (61 PS)
- 2,99 l/100 km
- Euro 4 limits

The route to a of 2,99 l/100 km

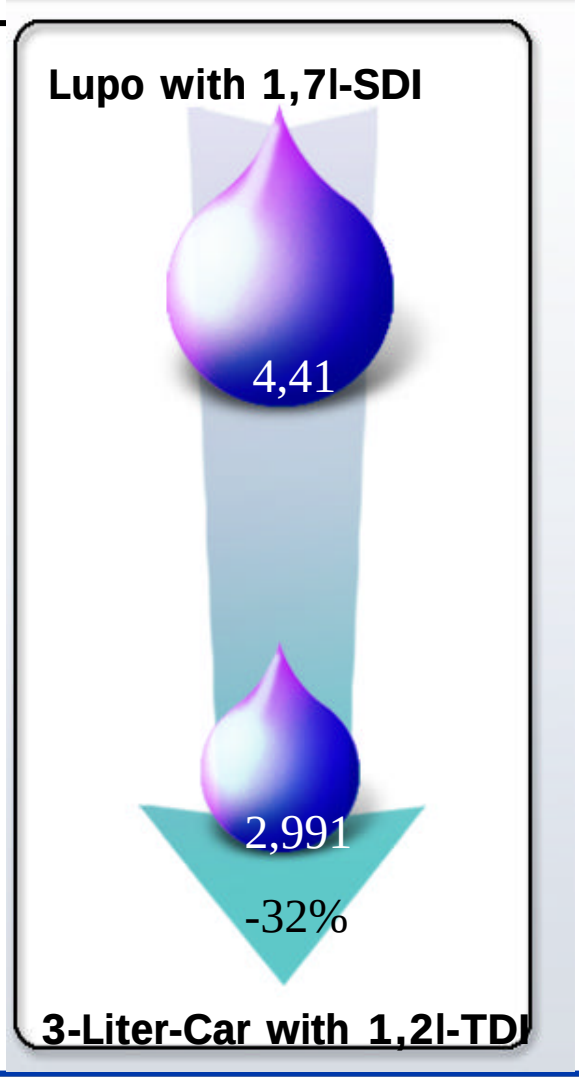
Share of all measures undertaken



Powertrain-concept

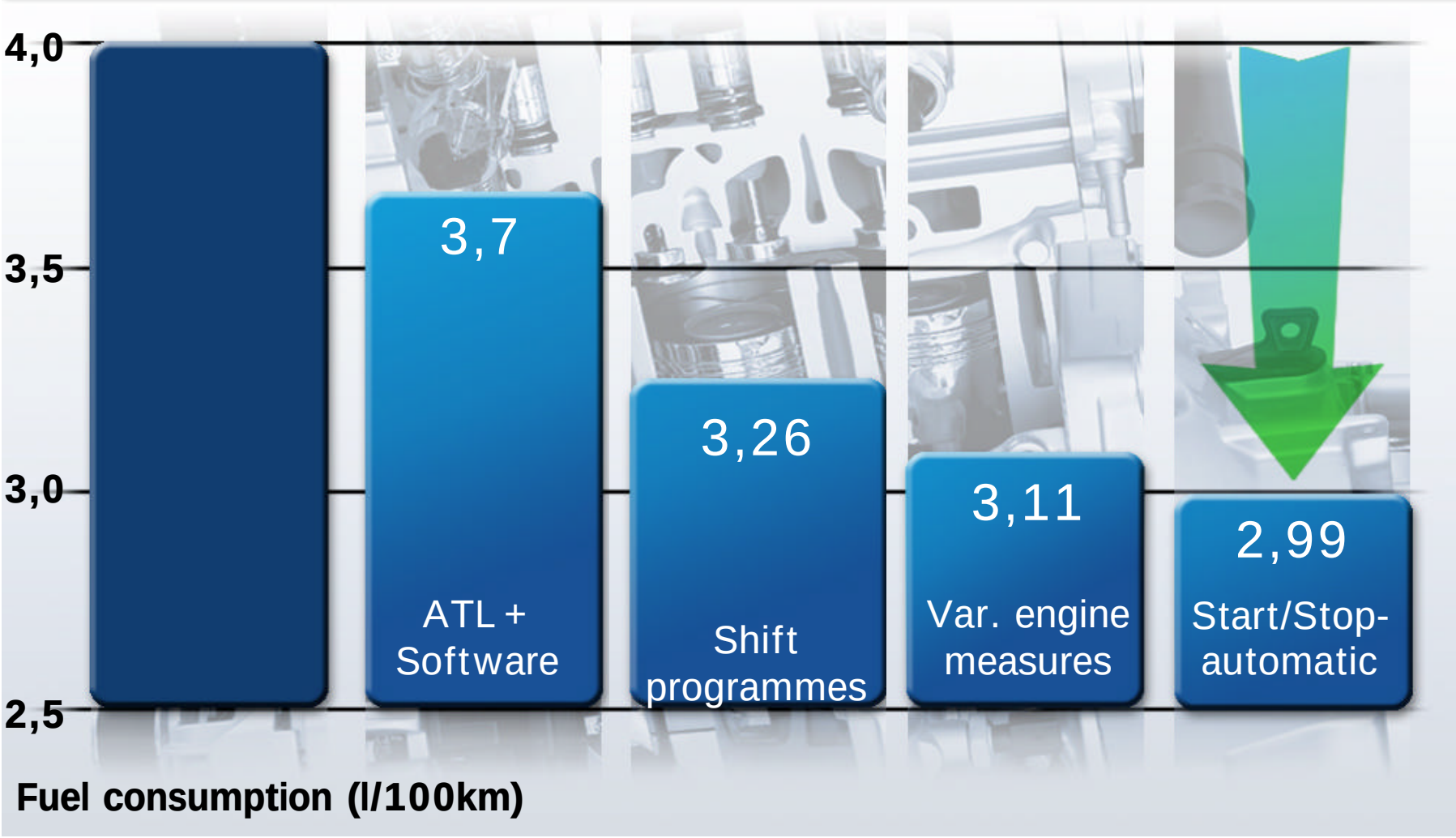
Reduction of drag and driving resistance

Inertia weight reduction

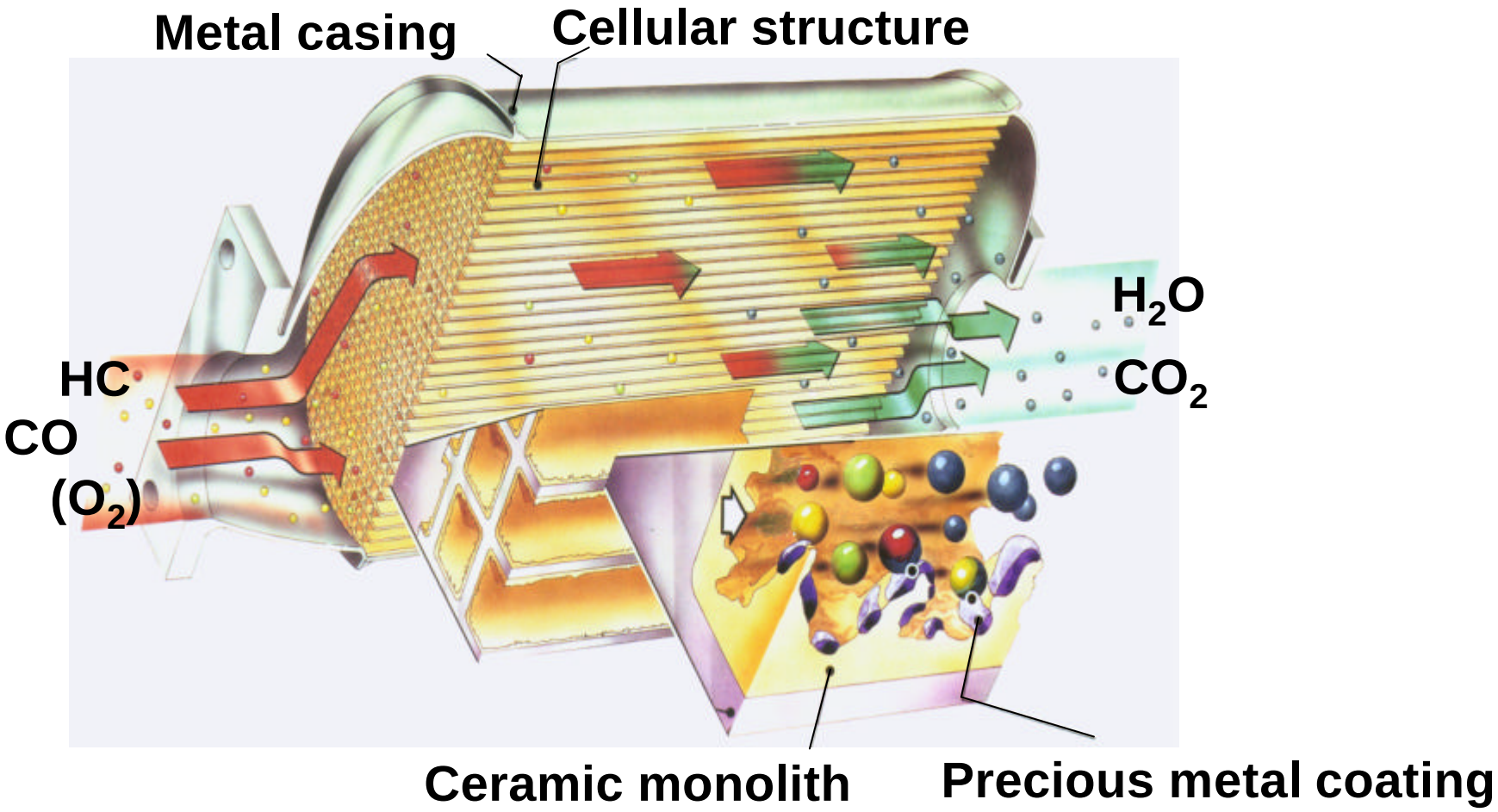


The Volkswagen 3L-Lupo

Reduction of inertial weight

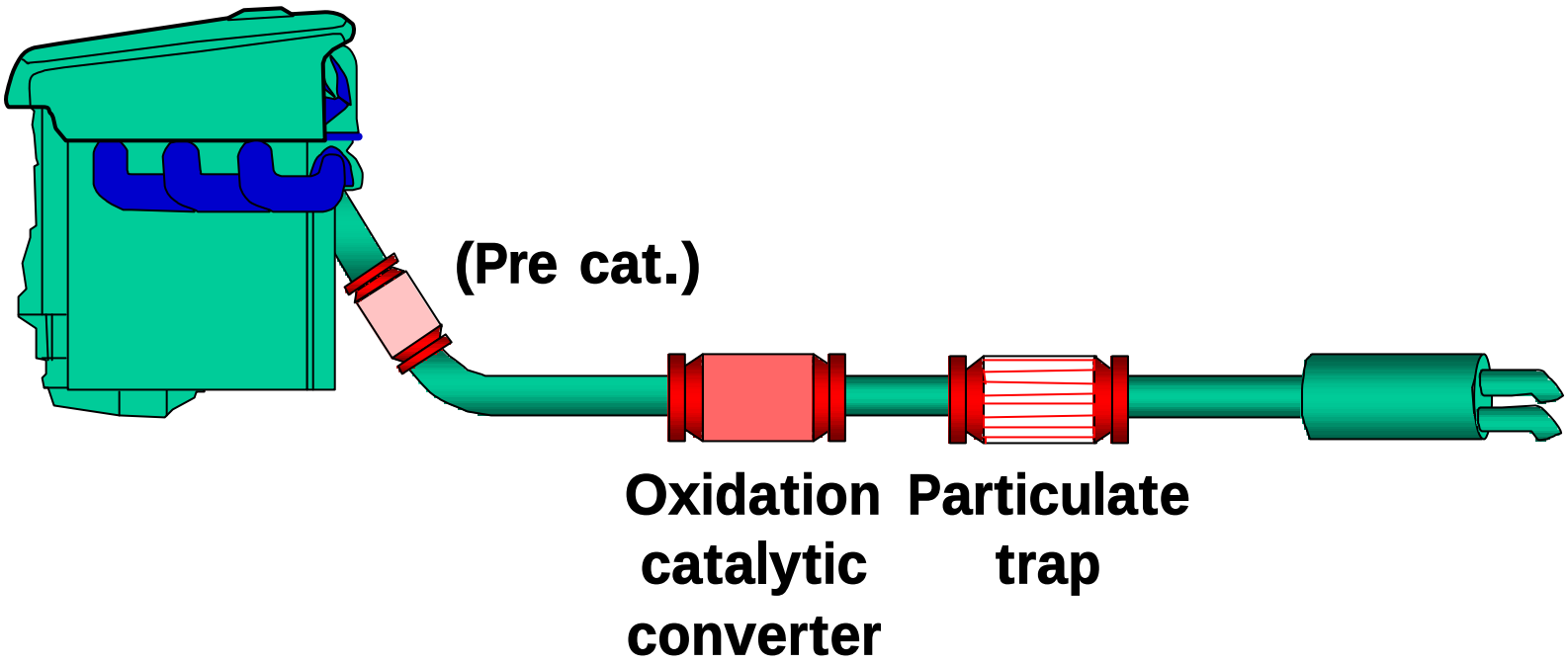


Oxidating catalytic converter principle

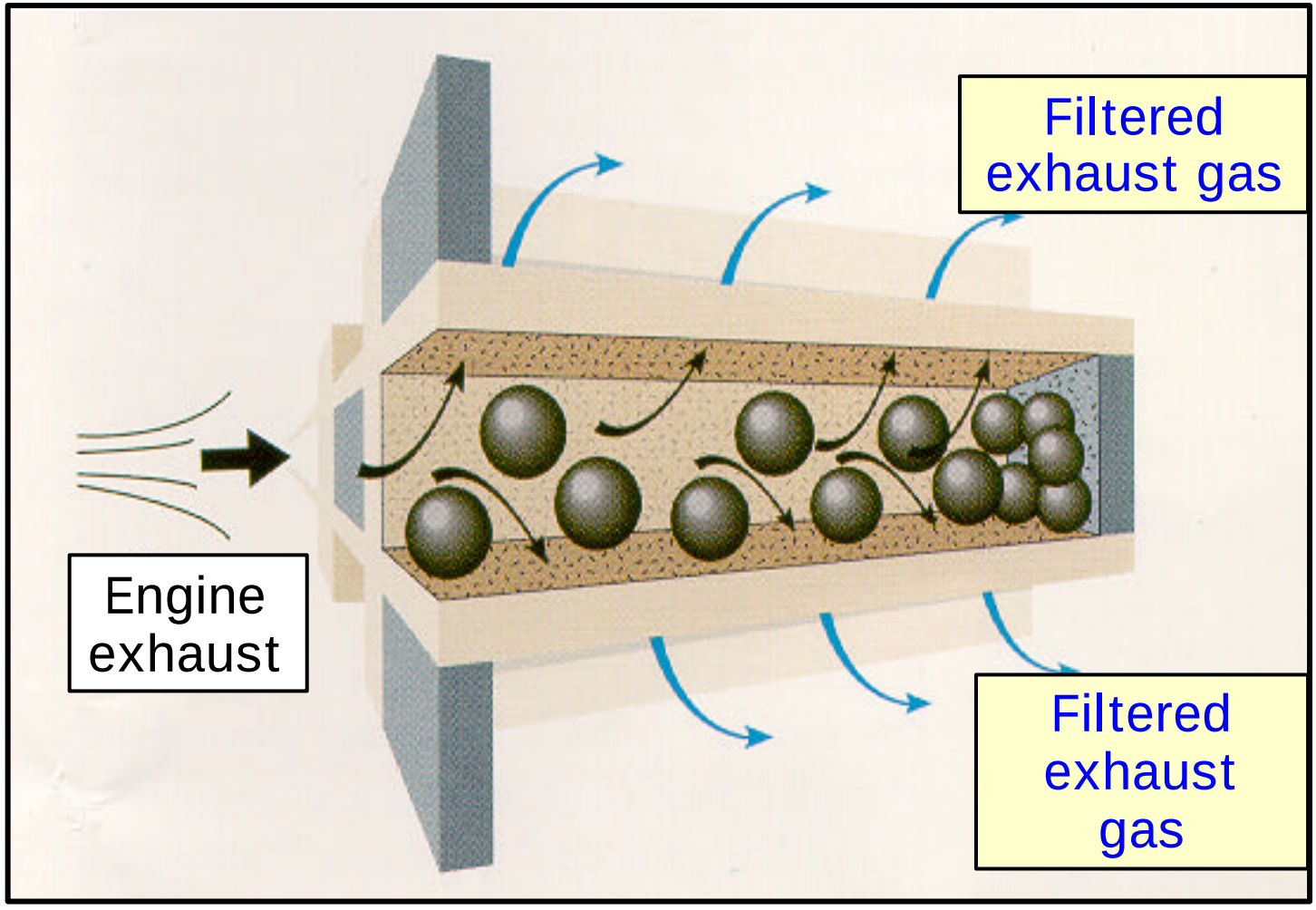


Exhaust gas aftertreatment for particulates

- Discontinuous systems
- Continuous systems



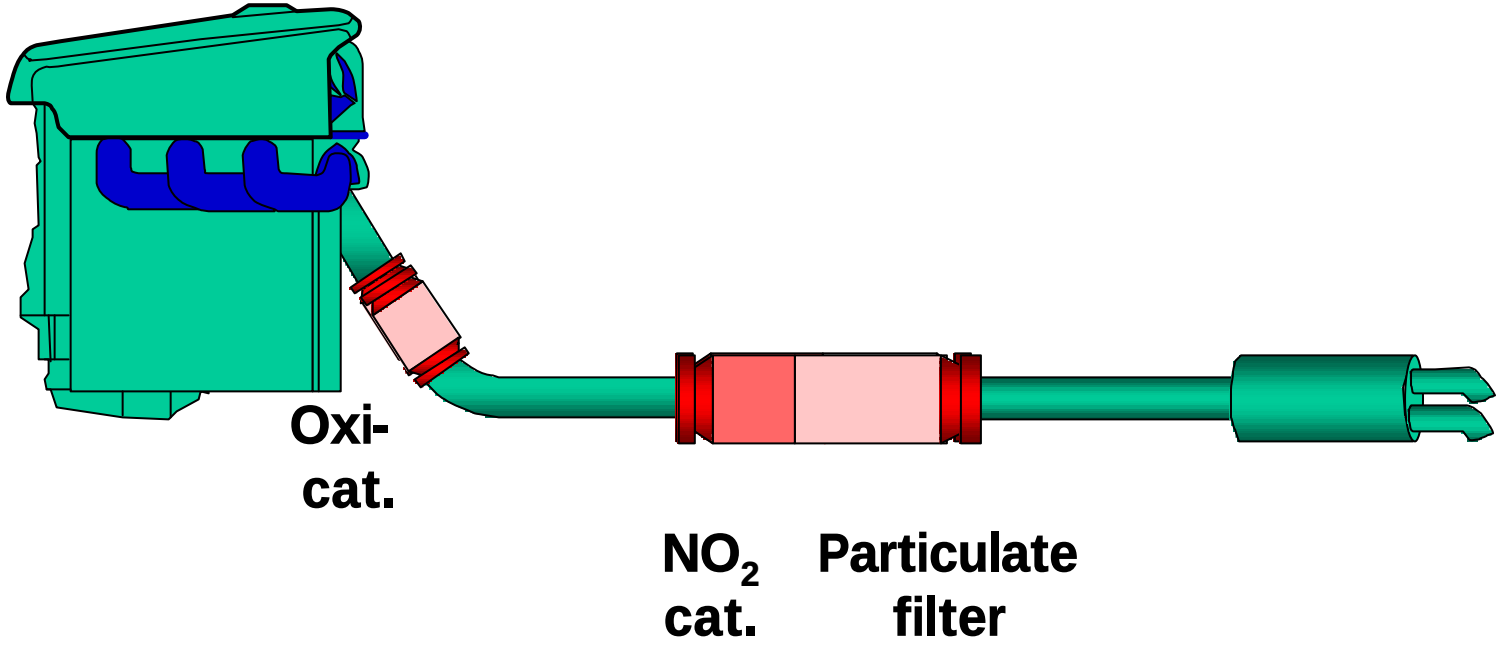
Ceramic particulate trap



CRT-System (Continuous Regeneration Trap)

Oxi cat: $2\ NO + O_2 \rightarrow NO_2$

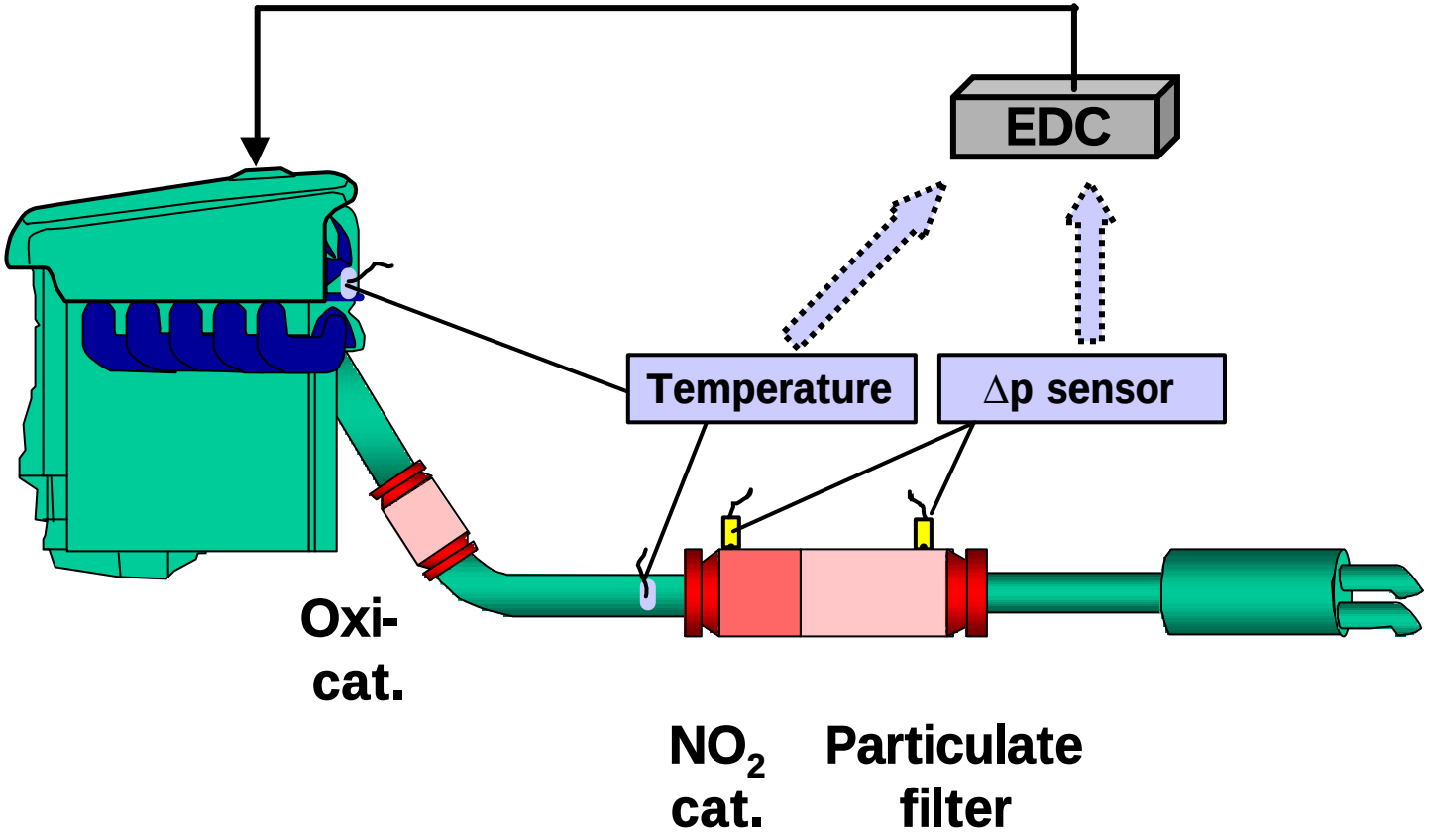
Trap: $2\ NO_2 + C \rightarrow 2\ NO + CO_2$



$\Rightarrow$ sampling and oxidation in parallel

VW exhaust aftertreatment systems

VW particle filter system

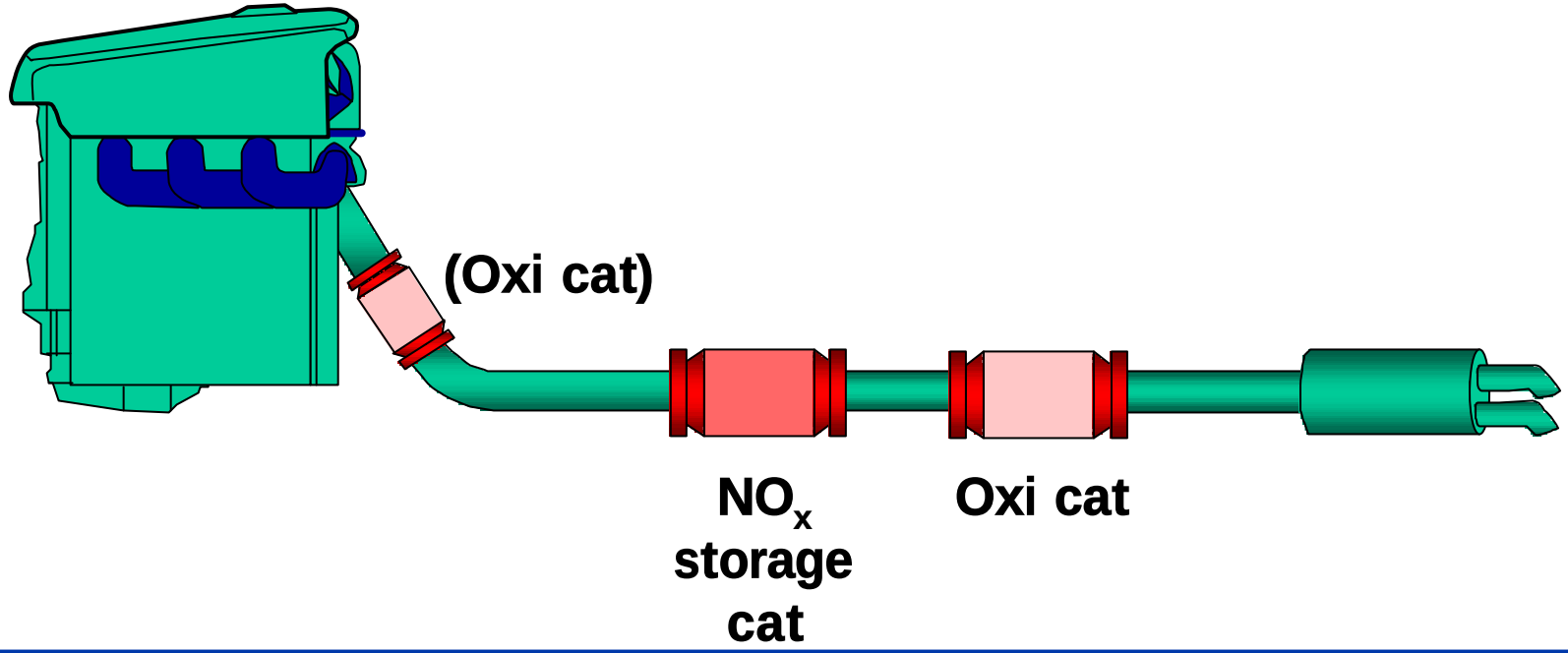


NOx storage catalytic converter

Oxi cat: $NO + 0{,}5\ O_2 \rightarrow NO_2$

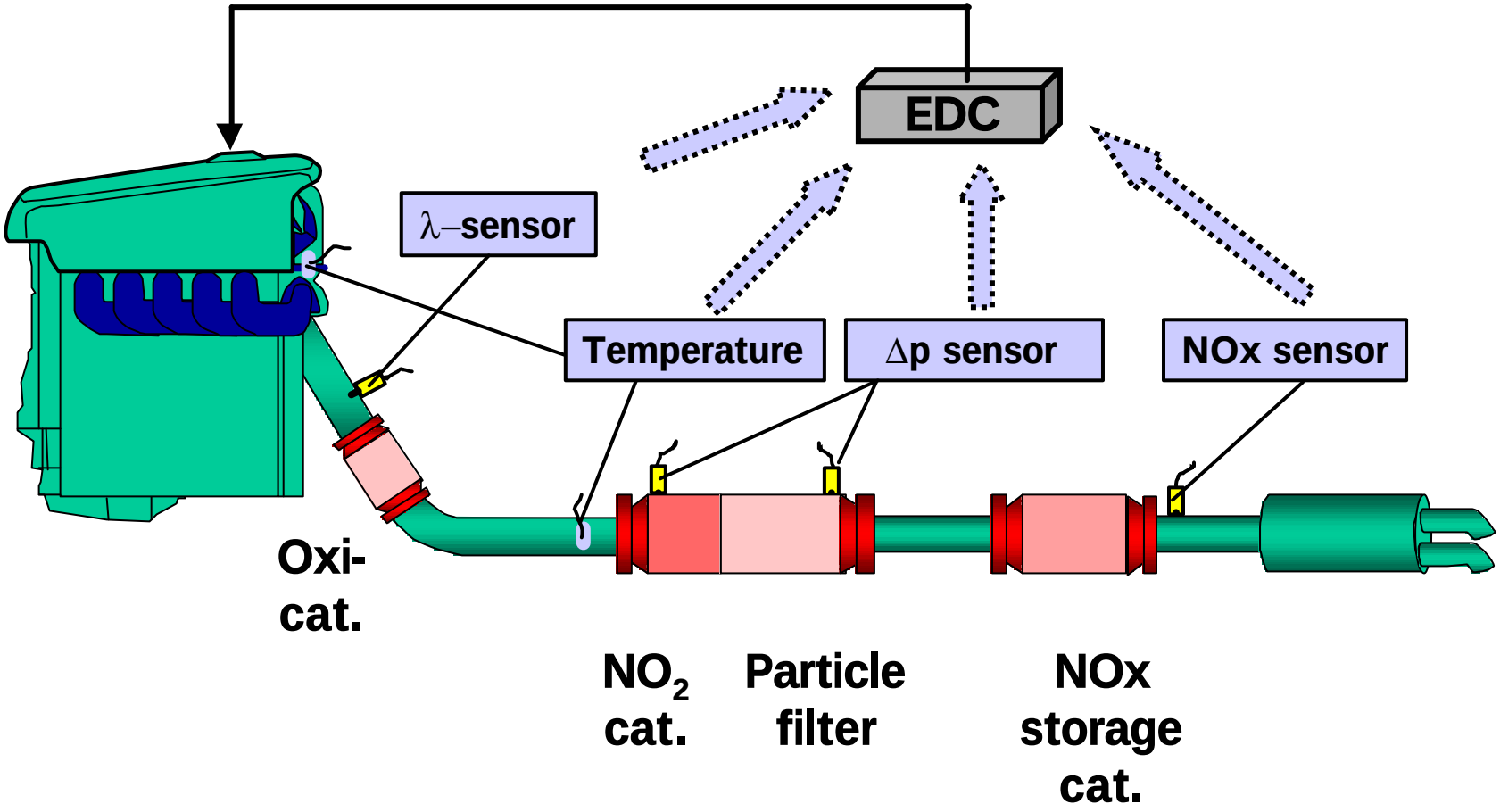
NO_x cat: $NO_2 + 0{,}5\ O_2 + BaCO_3 \rightarrow Ba(NO_3)_2 + CO_2$

Regeneration: $Ba(NO_3)_2 + 5\ CO \rightarrow BaCO_3 + N_2 + 4\ CO_2$



VW exhaust aftertreatment systems

VW particle filter system & NOx storage catalytic converter

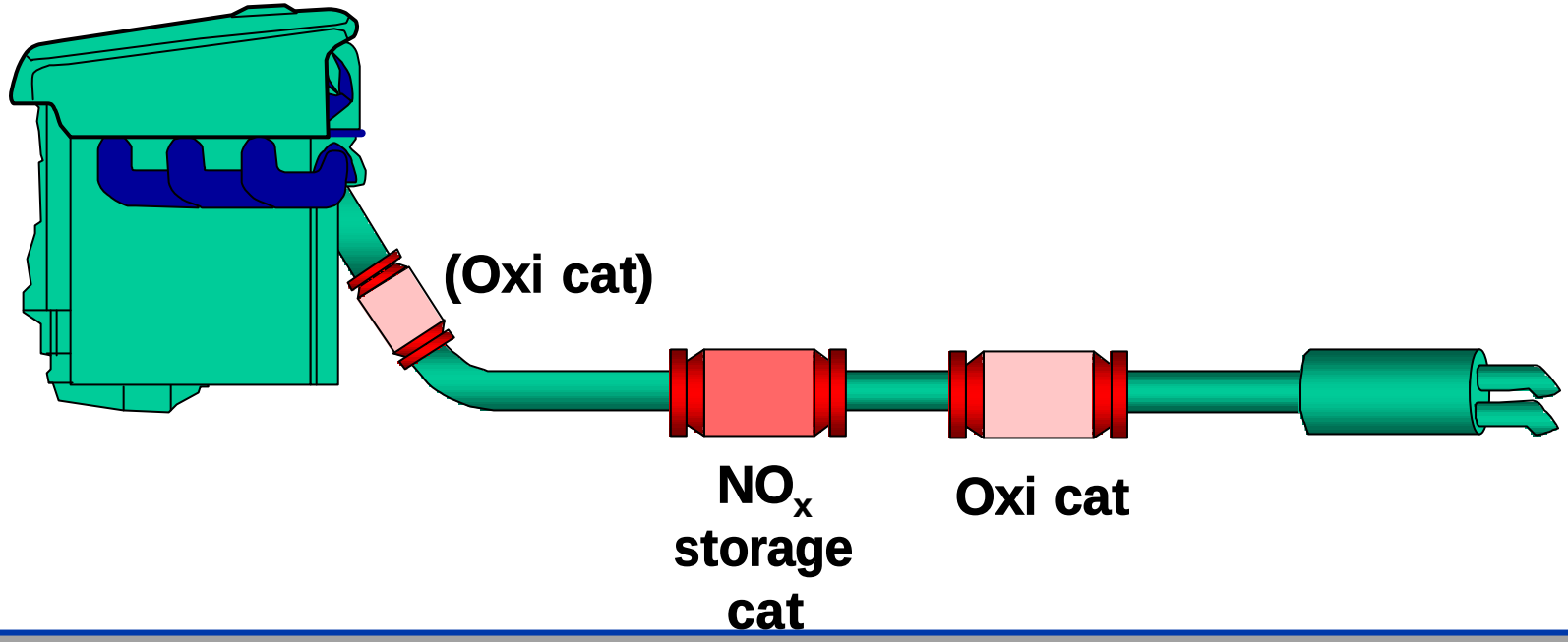


NOx storage catalytic converter

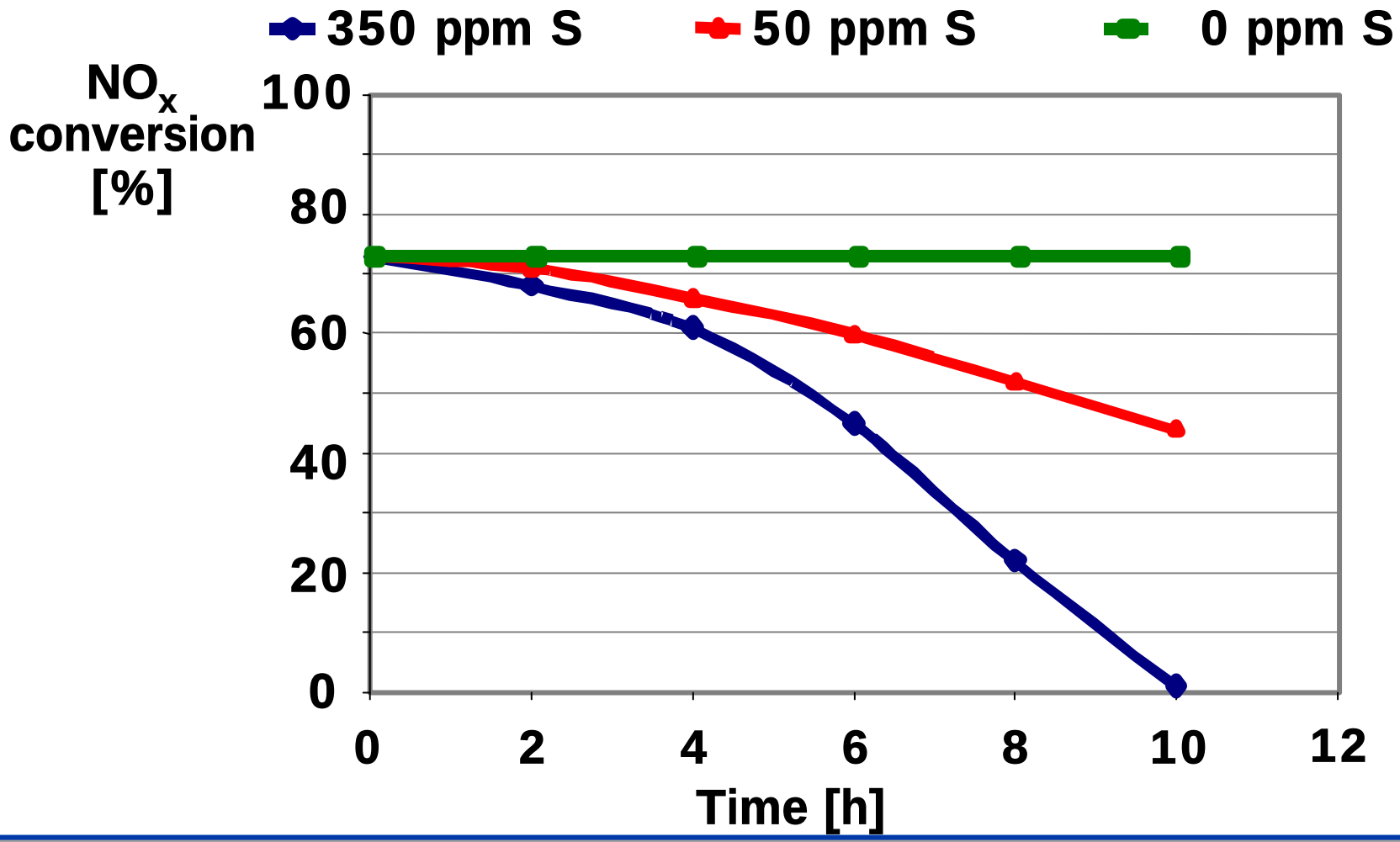
Oxi cat: $NO + 0{,}5\ O_2 \rightarrow NO_2$

NO_x cat: $SO_3 - 0{,}5\ O_2 + BaCO_3 \rightarrow BaSO_4 \quad {}_2 + CO_2$

Regeneration: $Ba(NO_3)_2 + 5\ CO \rightarrow BaCO_3 + N_2 + 4\ CO_2$

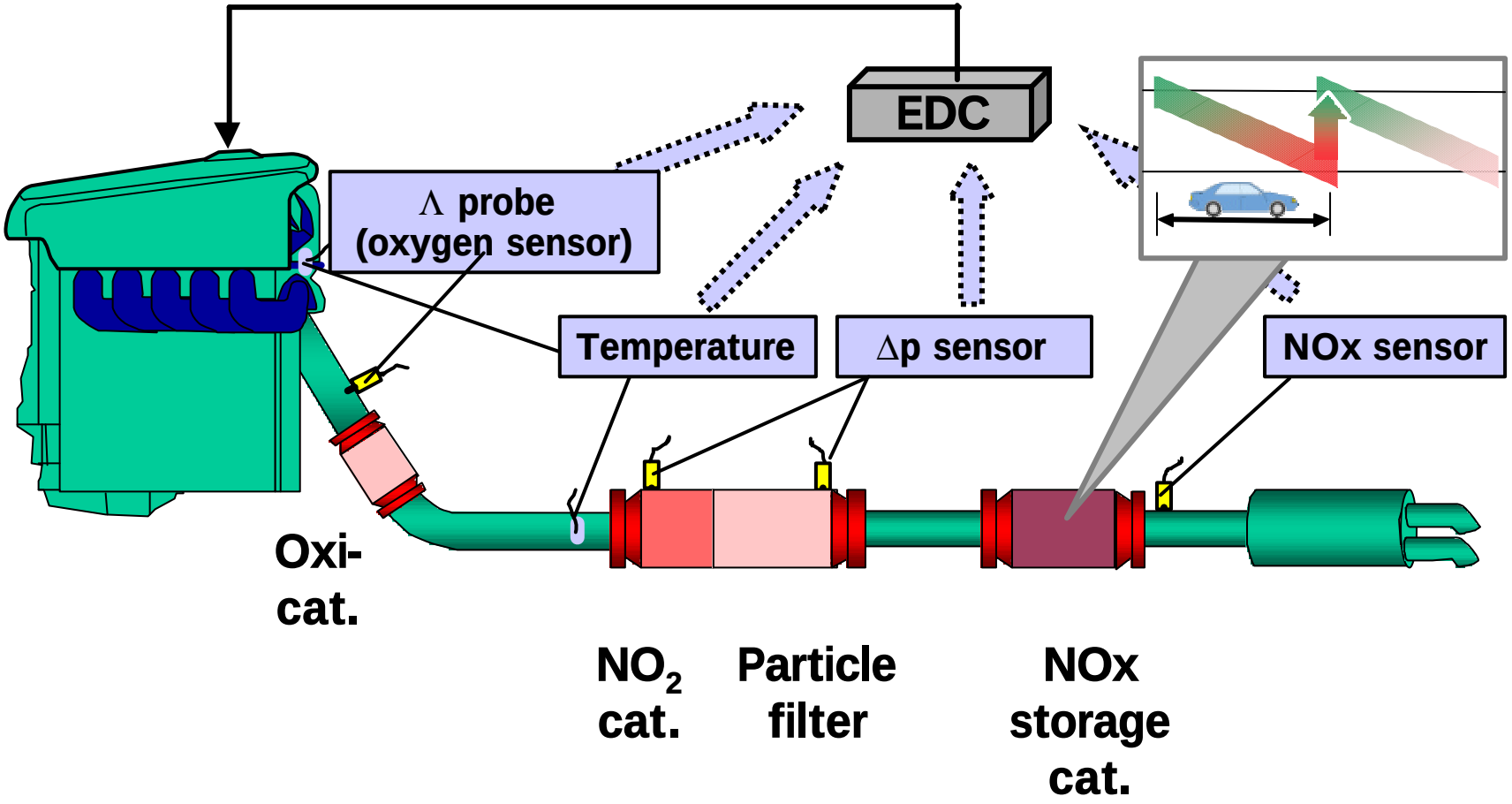


NOx storage cat. – pollution with sulphur

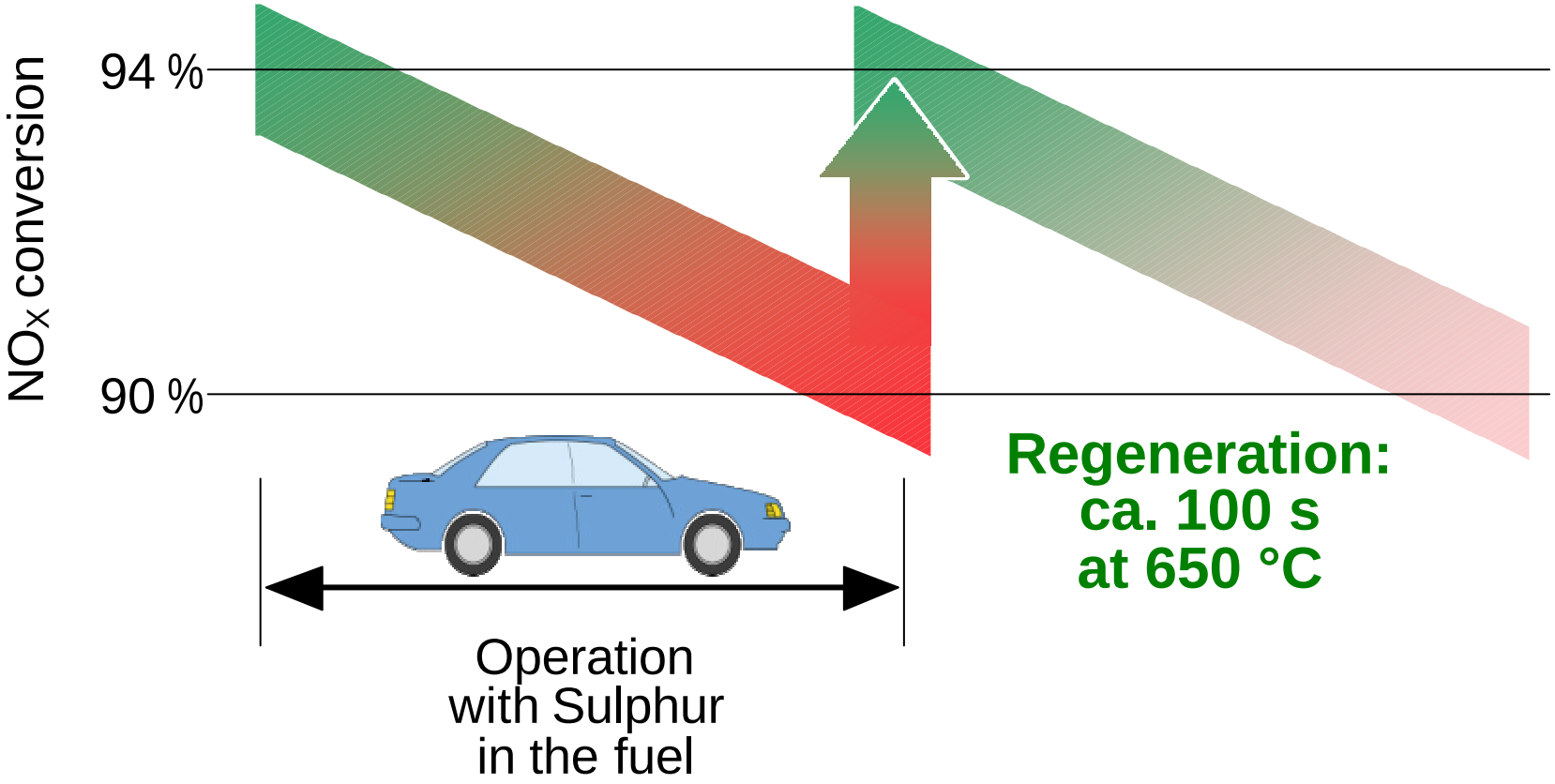


VW exhaust aftertreatment systems

VW particle filter system & NOx storage catalytic converter



Sulphur regeneration: NO_X cat



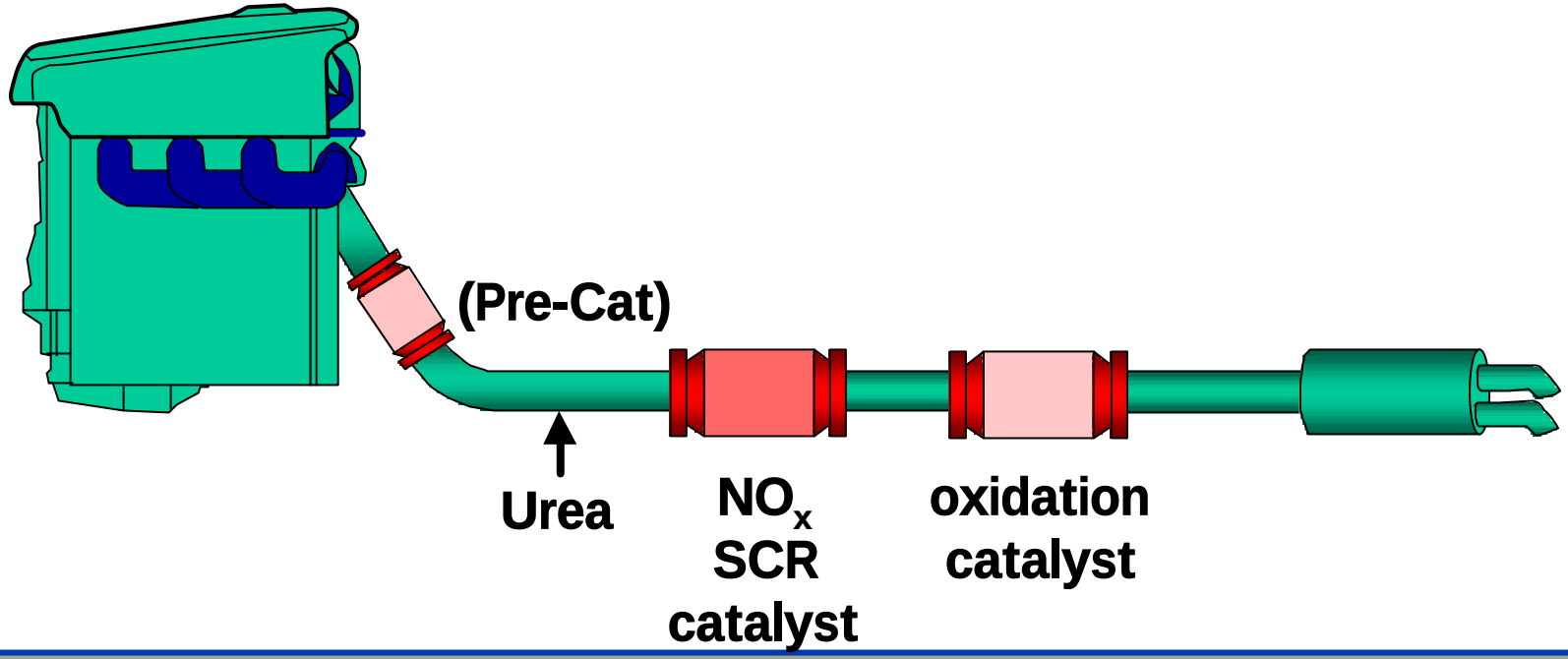
Development potentials of diesel engines

NO_x selective catalytic reduction (SCR)

Hydrolysis: $NH_2COH_2N + H_2O \rightarrow NH_3 + CO_2$

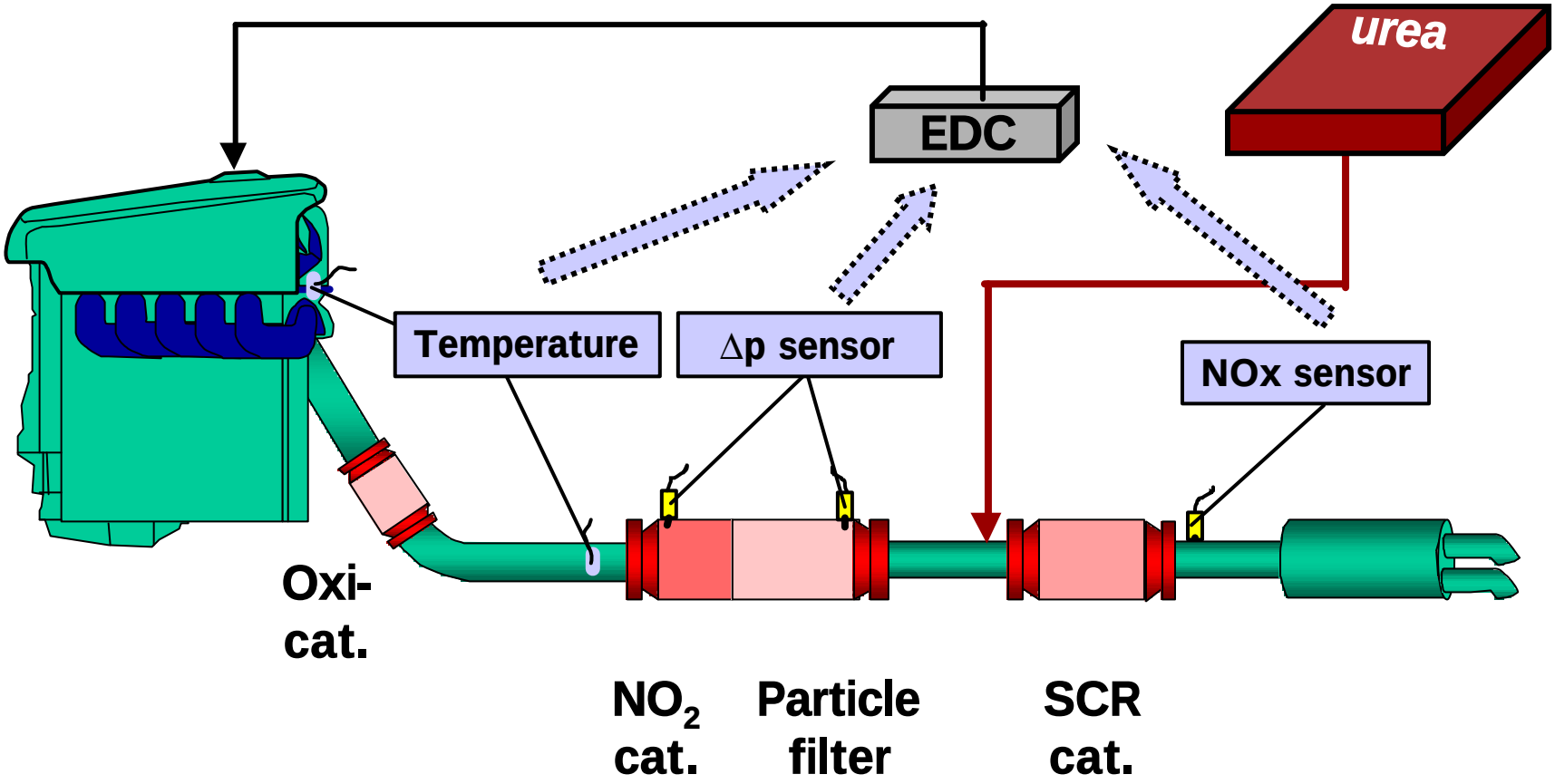
Reduction: $4NH_3 + 4NO + O_2 \rightarrow N_2 + H_2O$

$2NH_3 + NO + NO_2 \rightarrow 2N_2 + 3H_2O$



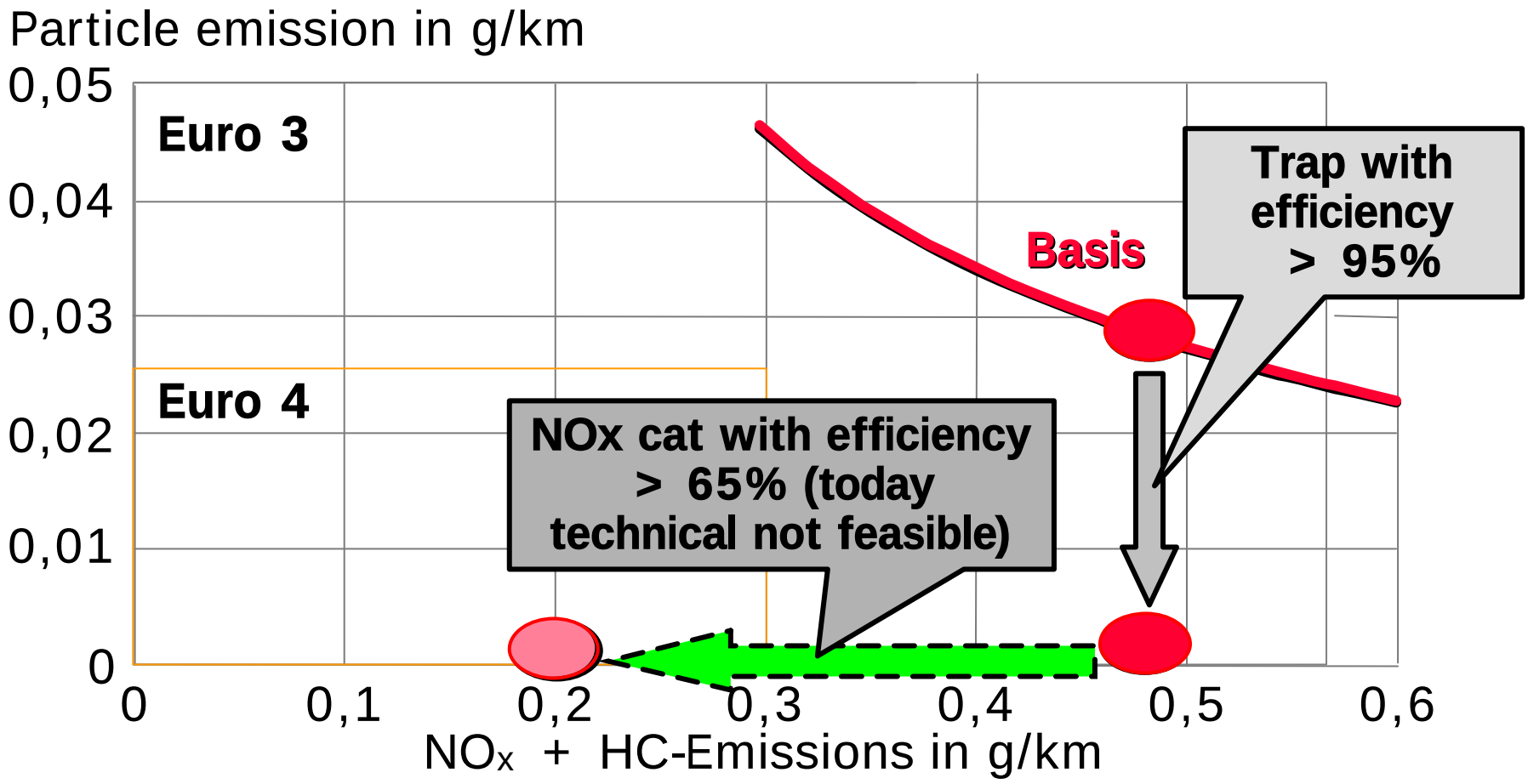
VW exhaust aftertreatment systems

VW particle filter system and SCR system



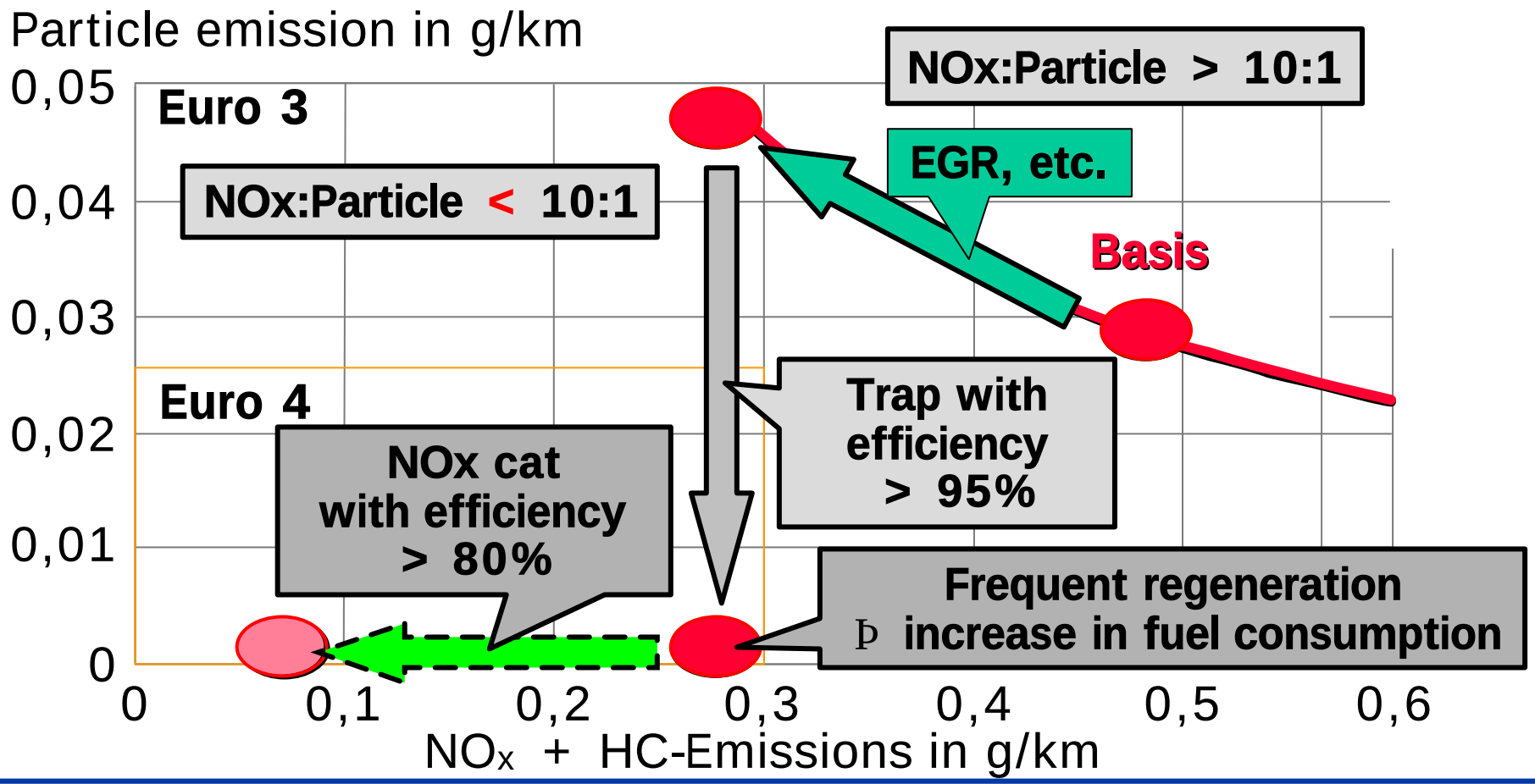
Strategies for future diesel development

Version 1



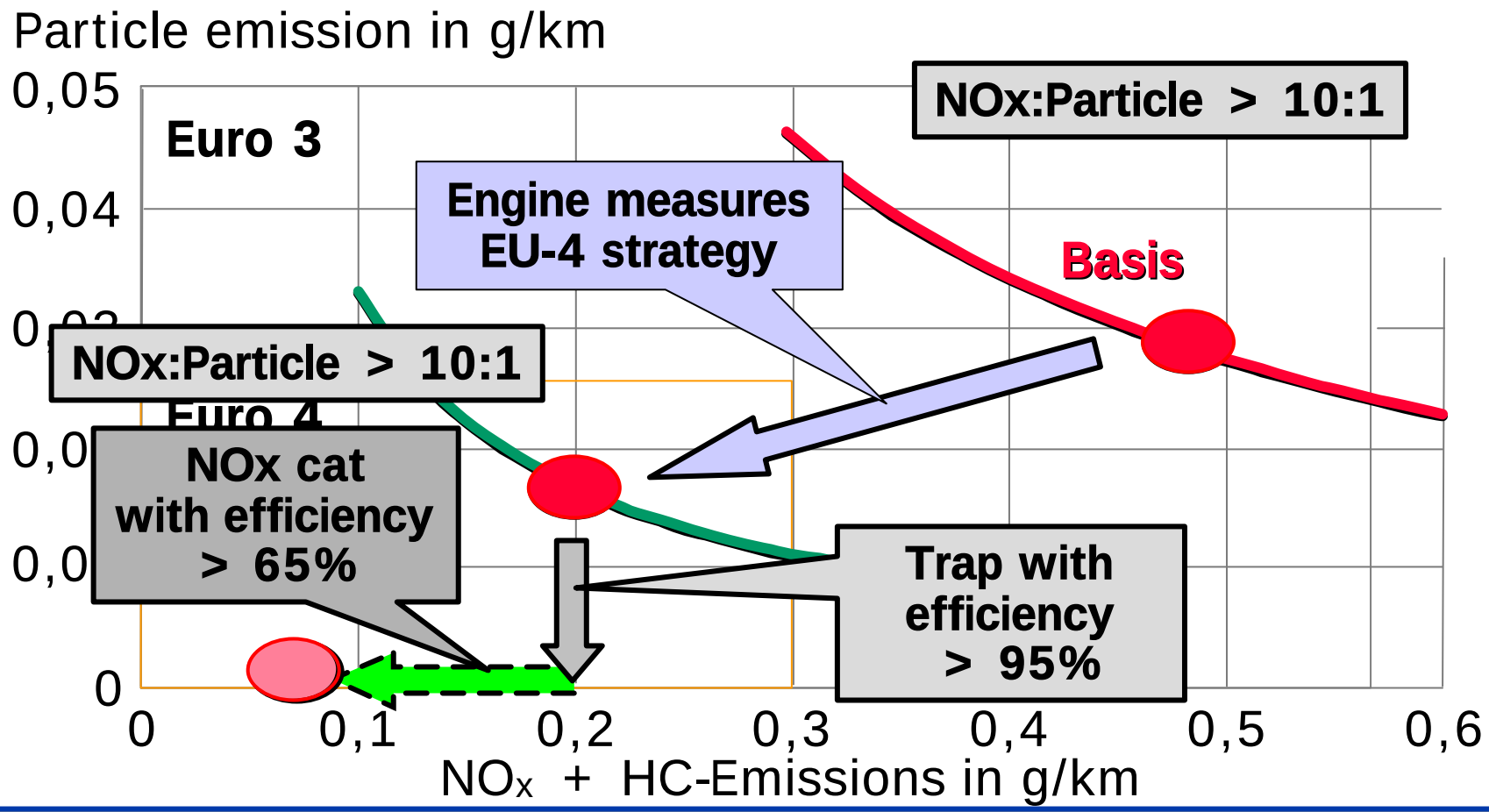
Strategies for future diesel development

Version 2



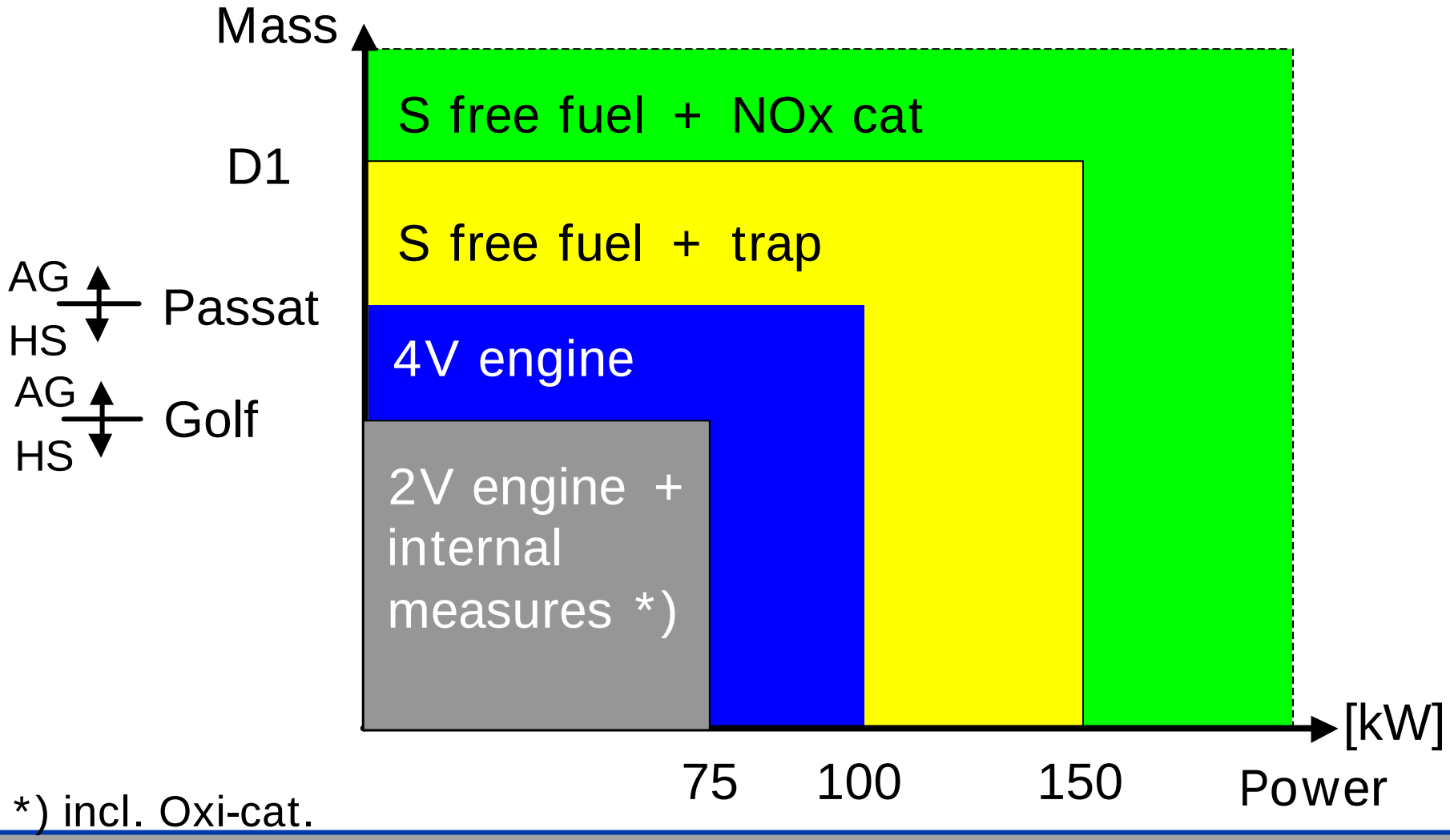
Strategies for future diesel development

Version VW



VW-Reduction strategy for Euro 4

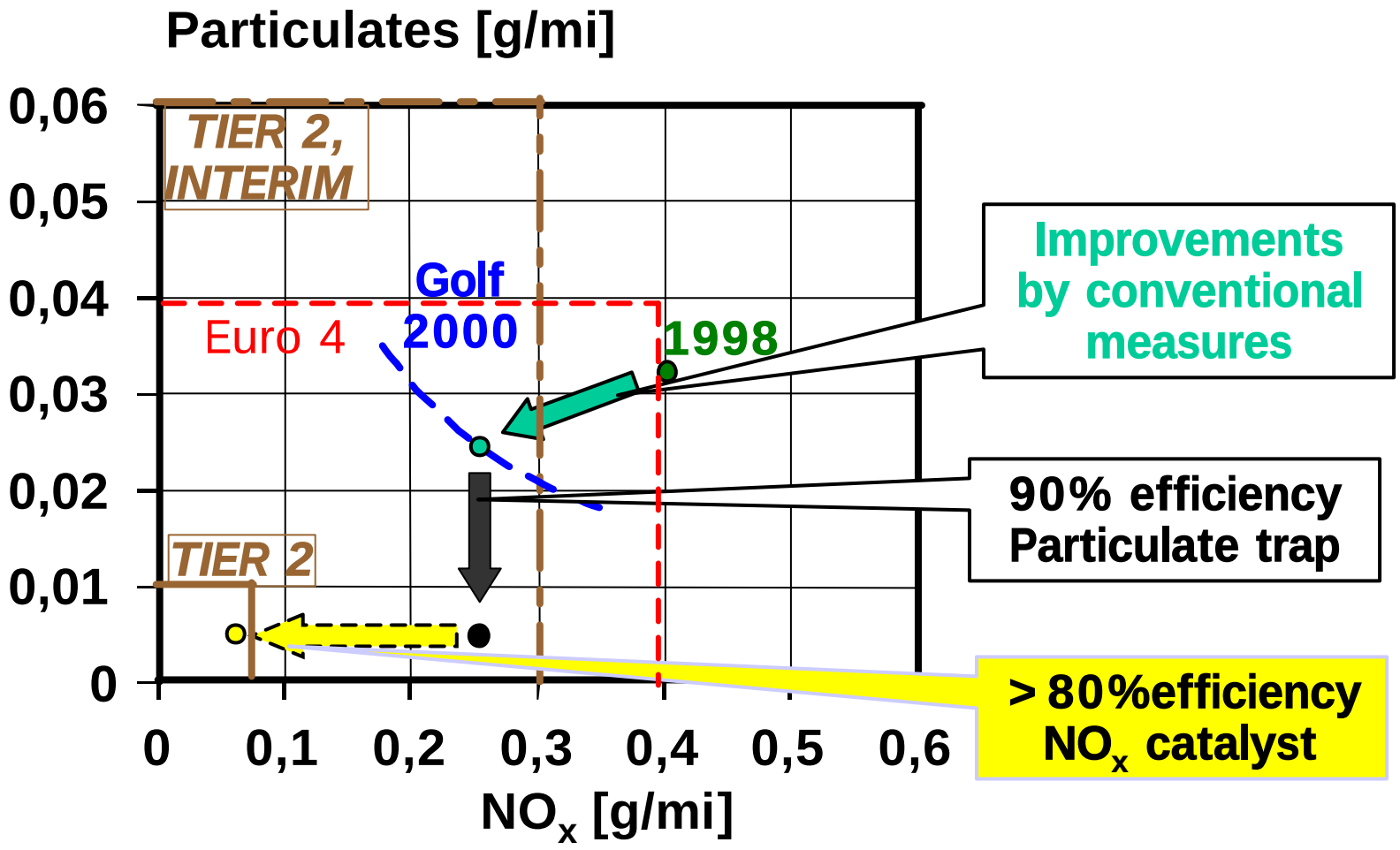
in combination with improved fuels



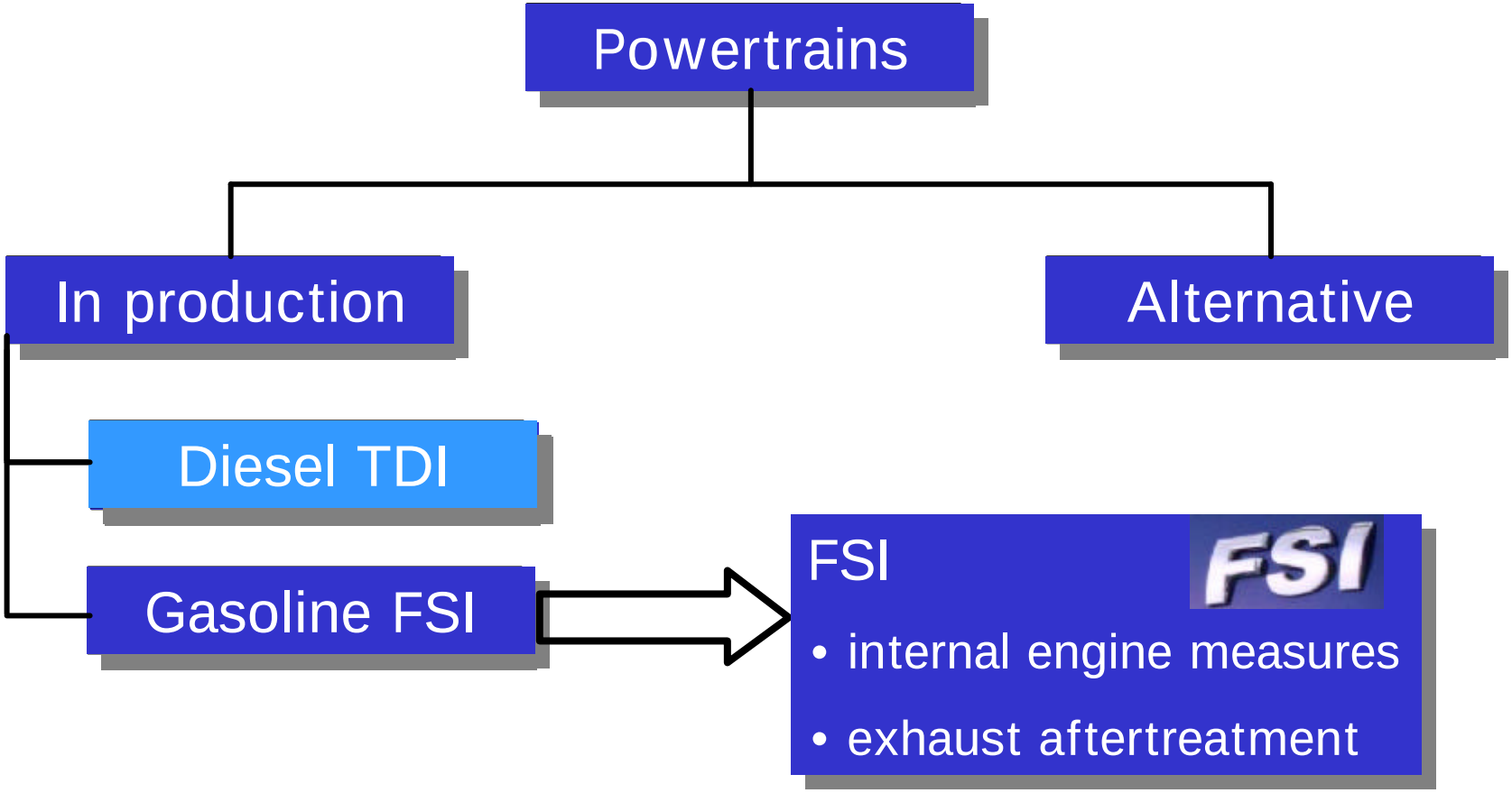
*) incl. Oxi-cat.

Potential for reduction of emissions

Example for a Golf with manual transmission

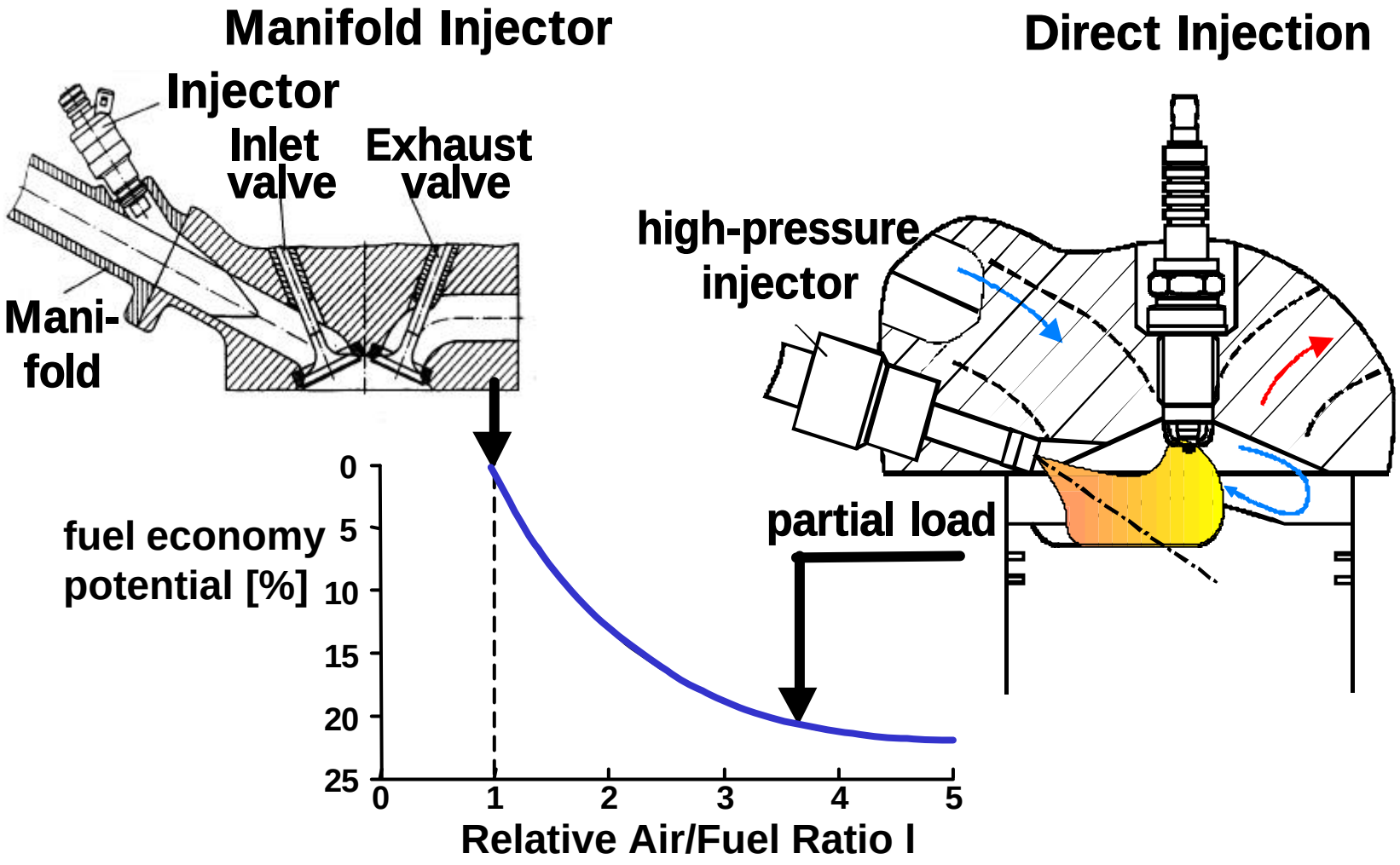


Approaches to maintain individual mobility



Spark-ignition engine with direct injection

Fuel Economy Potential



Efficiencies of internal combustion engines

Reduction of fuel consumption

100 % spark ignited engine (gasoline)

- 10 … - 15 % direct injection gasoline engine (FSI)

- 15 … - 20 % compression ignition engine (IDI diesel)

- 25 … - 30 % turbo direct ignition diesel engine (TDI)

We need the gasoline and the diesel engines

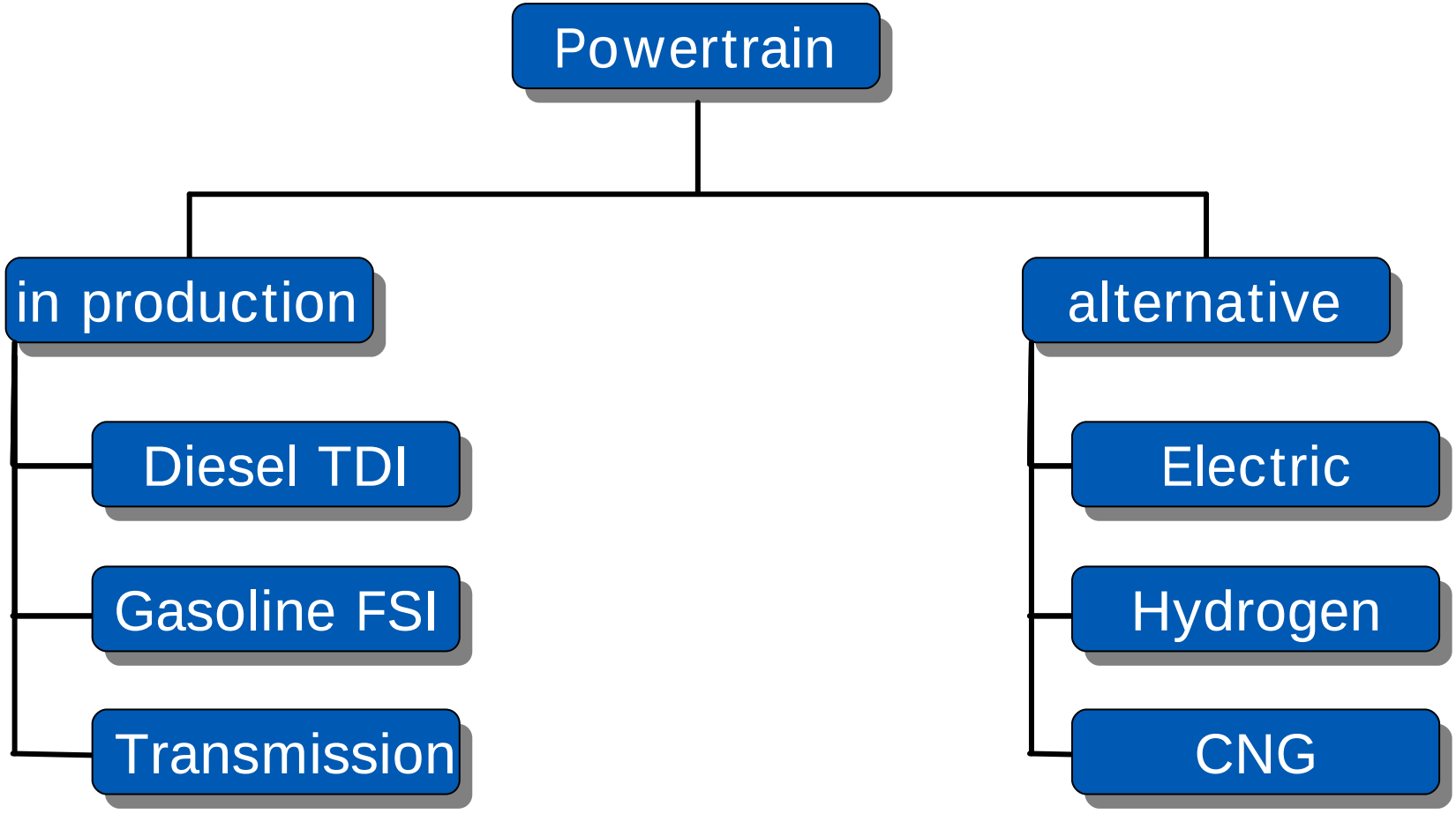
- **the gasoline and the diesel engines are the most advanced concepts at present and even in 20 - 30 years will be the most popular powertrains**

- **the gasoline engine is the concept for extreme air quality requirements**
  - **Ultra low emissions**

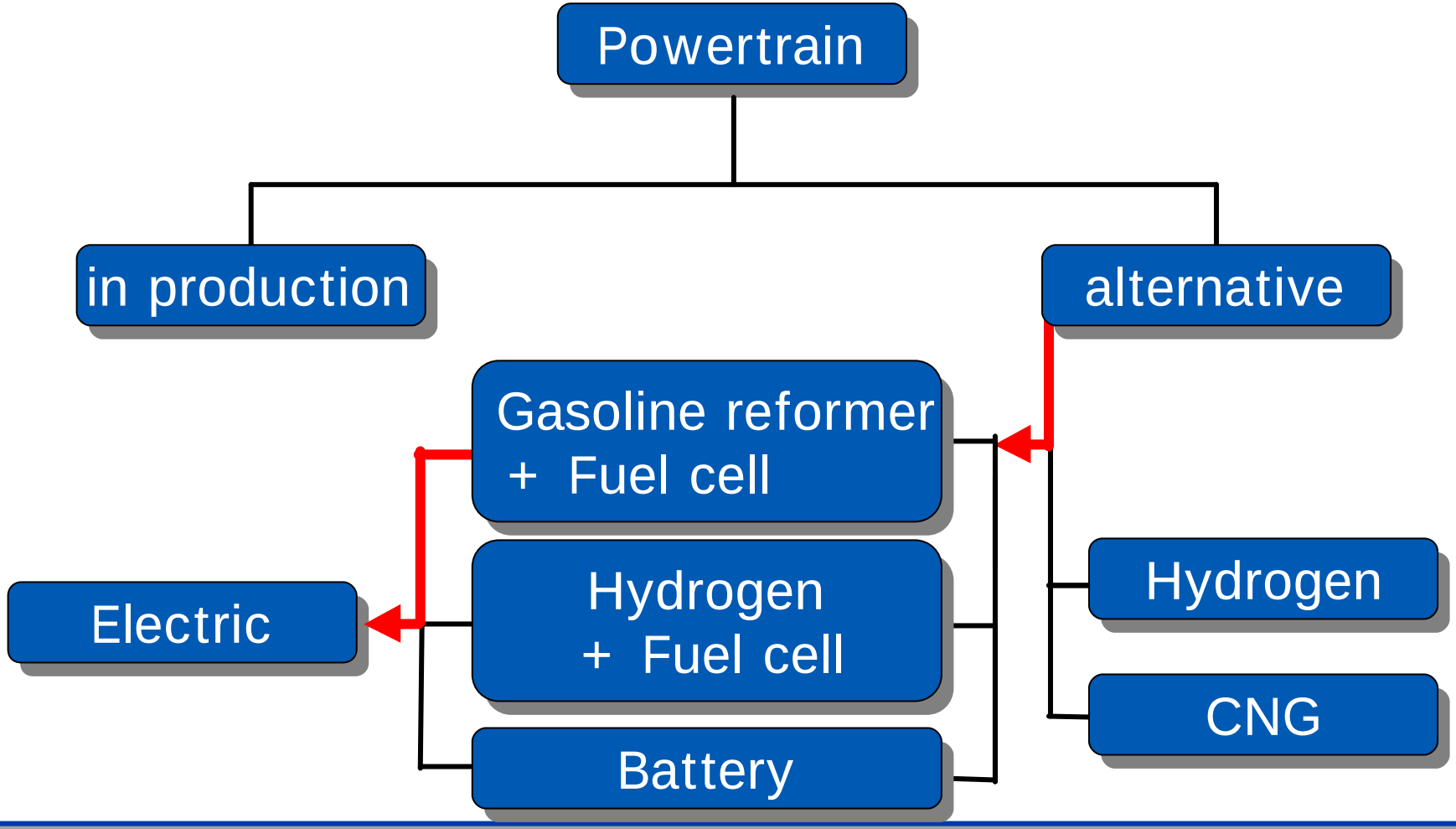
- **the diesel engine is the concept for saving energy resources and reducing CO_2 emissions**
  - **High fuel efficiency (low CO_2 emissions)**
  - **High emission stability**

- **the gasoline and the diesel engines need for further development low sulphur fuels**

Maintaining individual mobility

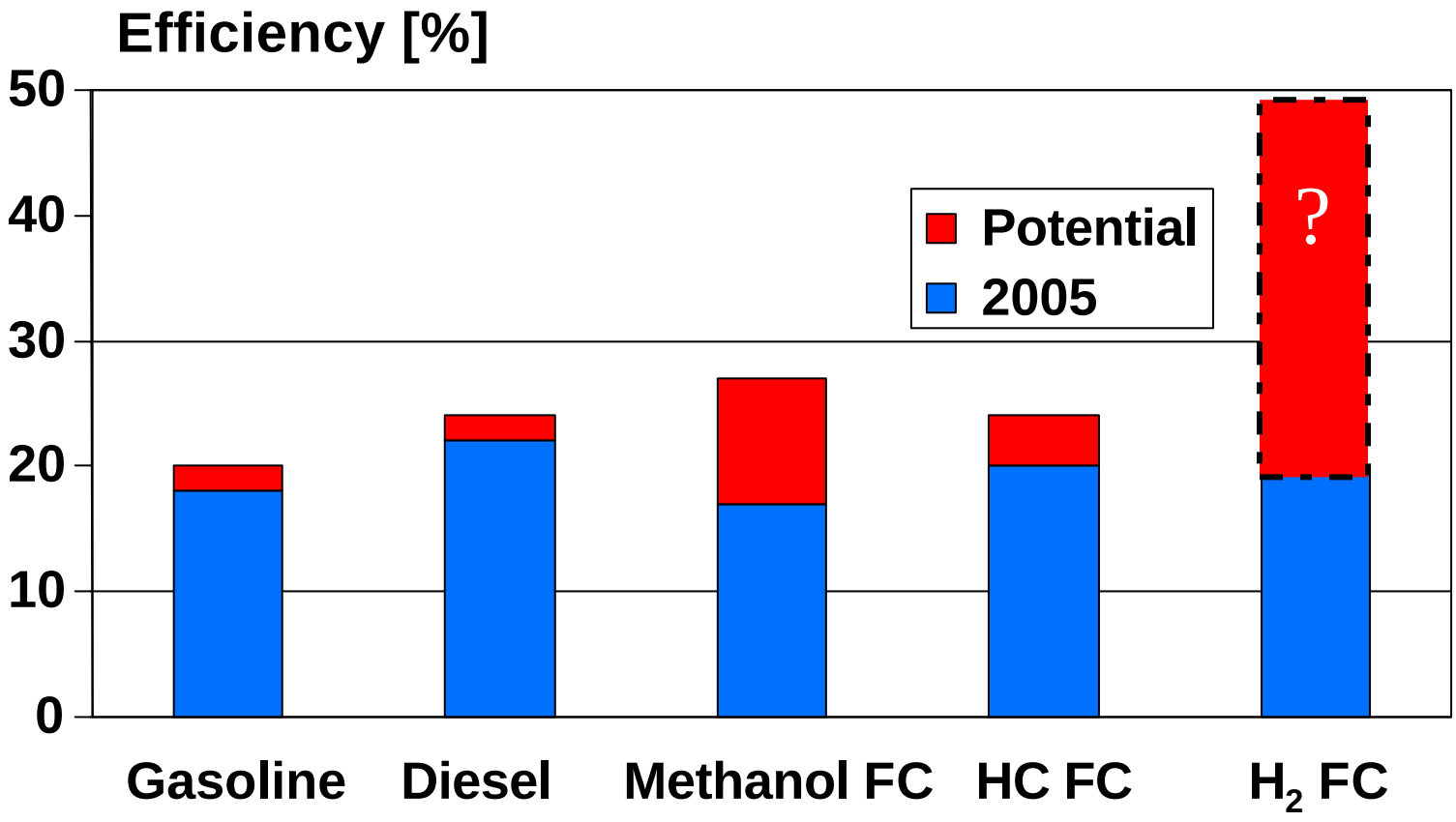


Maintaining individual mobility



Comparison of modern propulsion concepts

Total efficiency incl. fuel production, transport and vehicle operation



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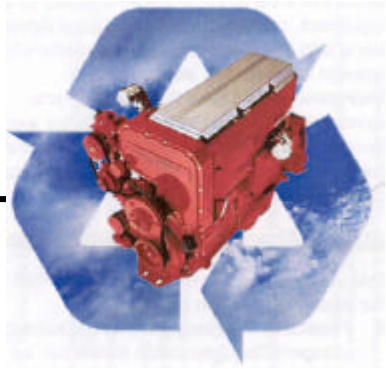


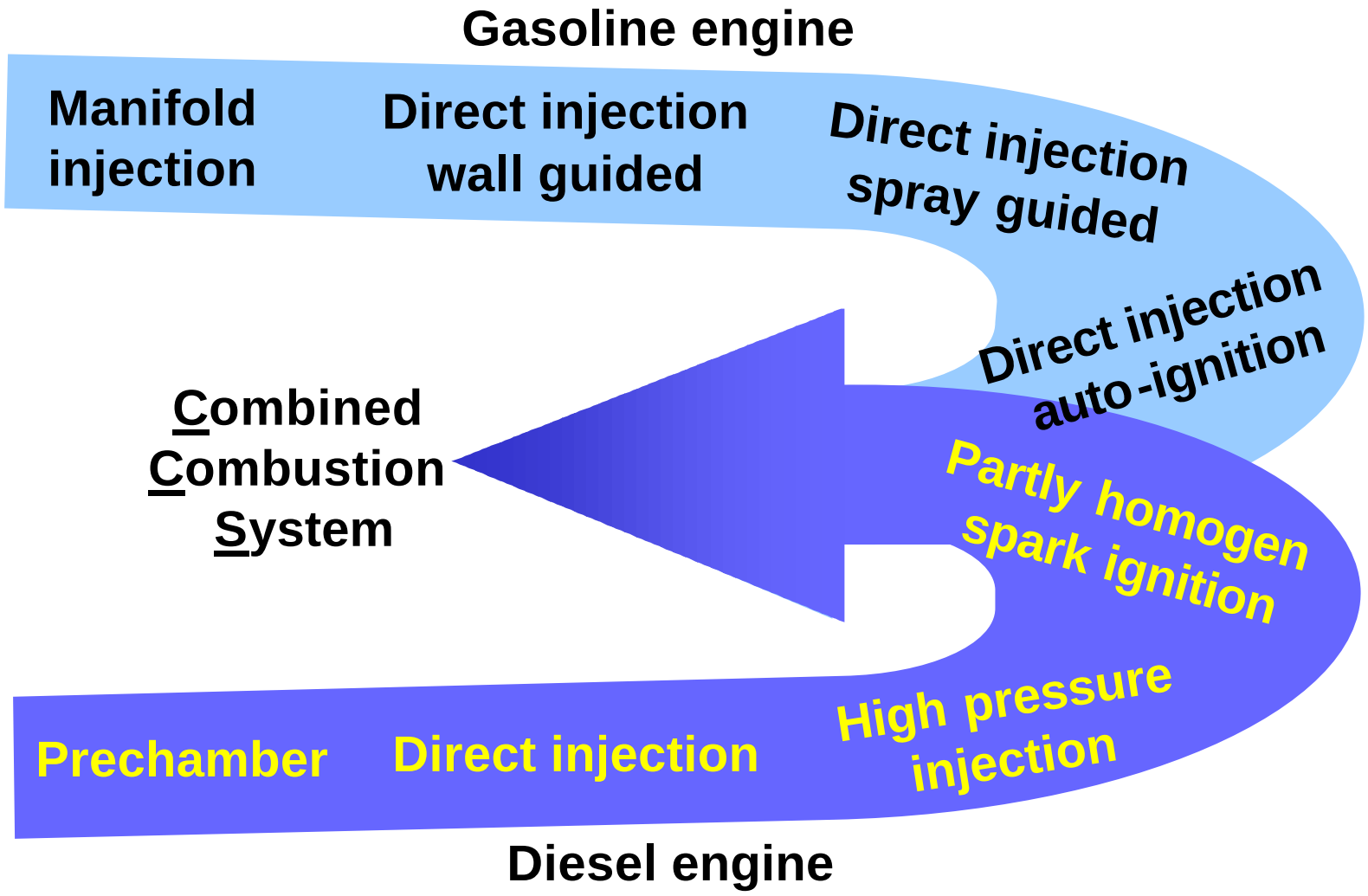
1. Mobility- today and tomorrow

2. Innovative vehicle design

3. Powertrain concepts

4. Outlook and conclusions

Further development of internal combustion engines



Conventional fuels (today)

Å

- high storage density
- high ecological standard
- economical
- easy handling
- infrastructure world-wide available

⊖

- limited resources for fossil fuels
- reduction potential for greenhouse gases limited
- complicated reformation for fuel cells

SynFuels from fossil sources
Conventional fuels

Å

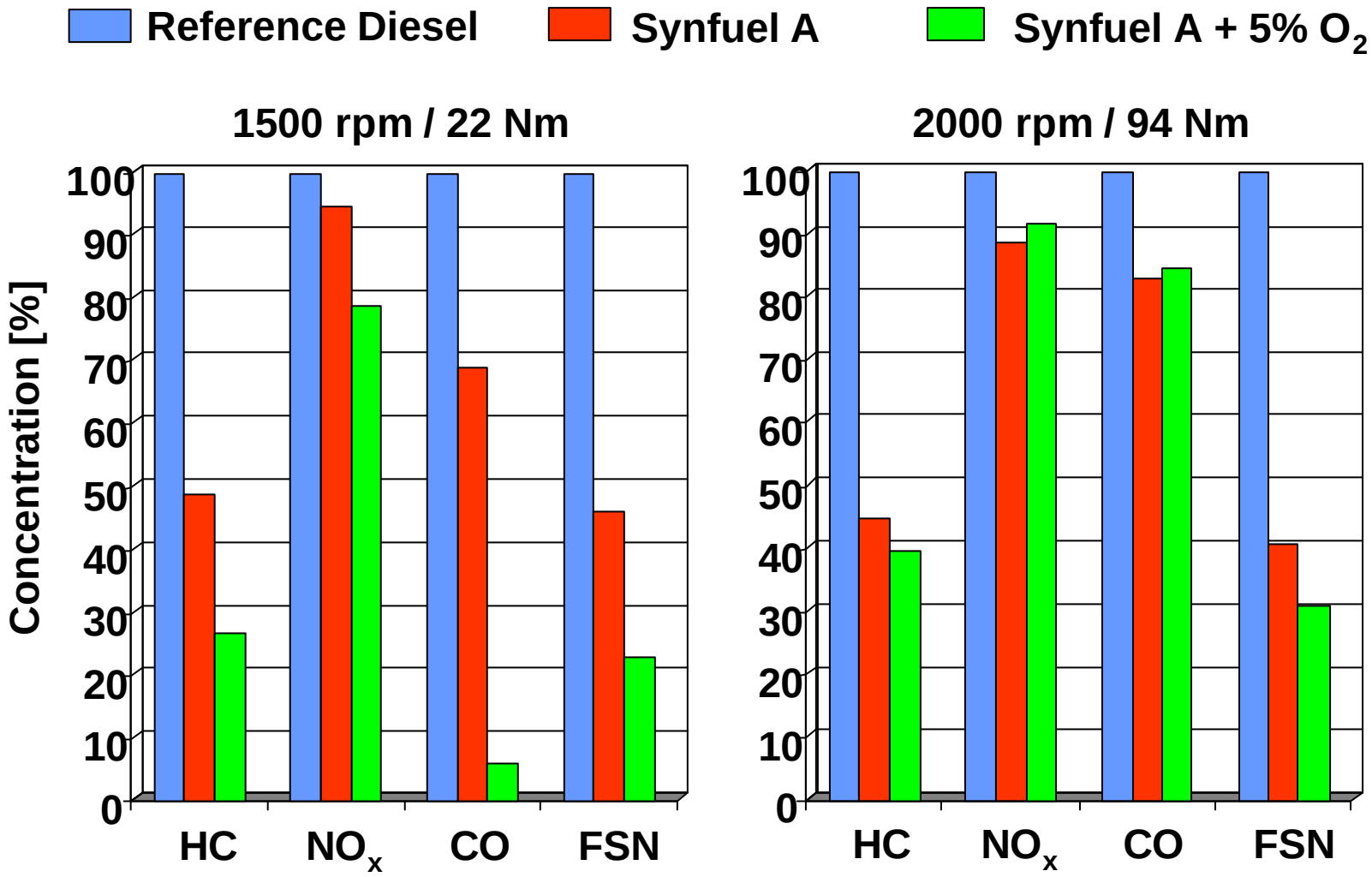
- can be used as today‘s fuels
- potential for further fuel consumption reduction
- economical production from NG possible
- transition to fuels from regenerative sources
- infrastructure can be used

⊖

- limited resources when from fossil sources
- reduction potential for greenhouse gases limited
- reformation for fuel cells necessary

➡ **short to mid term solution**

Reduction of exhaust gas emissions by using a SynFuel



SunFuels from regenerative sources
Conventional fuels

Å

- can be used as today‘s fuels
- chance for new and optimized combustion systems
- longer availability by using regenerative sources
- extended reduction potential for greenhouse gases
- infrastructure can be used with minor modifications

⊖

- extremly more expensive than today‘s fuels
- reformation for fuel cells necessary

➡ **mid term solution**

Hydrogen
Regenatives energy sources

Å

- sustainable
- without CO_2 emission in the energy chain
- non limited resources

but: 3 technology barriers

⊖

- no storage media for mobile application
- no infrastructure
- no sustainable production with acceptable costs

long term solution

Conclusions

- The individual mobility grows and must be sustainable
- Optimization of the vehicle weight requires innovative concepts
- Mid term: conventional powertrain concepts with innovative improvements (engine and transmission)
- Long term: alternative concepts
- New fuels are required based on well-to-wheel analysis
- Challenge: environment and customer‘s desire