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State-of-the-art and emerging truck engine technologies

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DaimlerChrysler AG

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State-of-the-art and emerging truck engine technologies for optimized performance, emissions and life-cycle-costs

- The challenge for commercial vehicles engine R&D
- Engine technology development until today
- Aftertreatment systems as emerging technologies also for commercial vehicle Diesel engines
- What will be the right technology for US MY07?
- Prerequisites to be established

Focus of R&D efforts

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Engine R&D efforts have to focus on bridging ecological and economical requirements of all stakeholders

Ecology

- **Society**
  - Gaseous and PM Emissions
  - CO_2-Emissions
  - Noise

Economy

- **Truck Operator**
  - Life-Cycle Costs
- **OEM**
  - Profitability
- **Nation**
  - Haulage Costs

Life-Cycle-Costs of class 8 trucks in Europe

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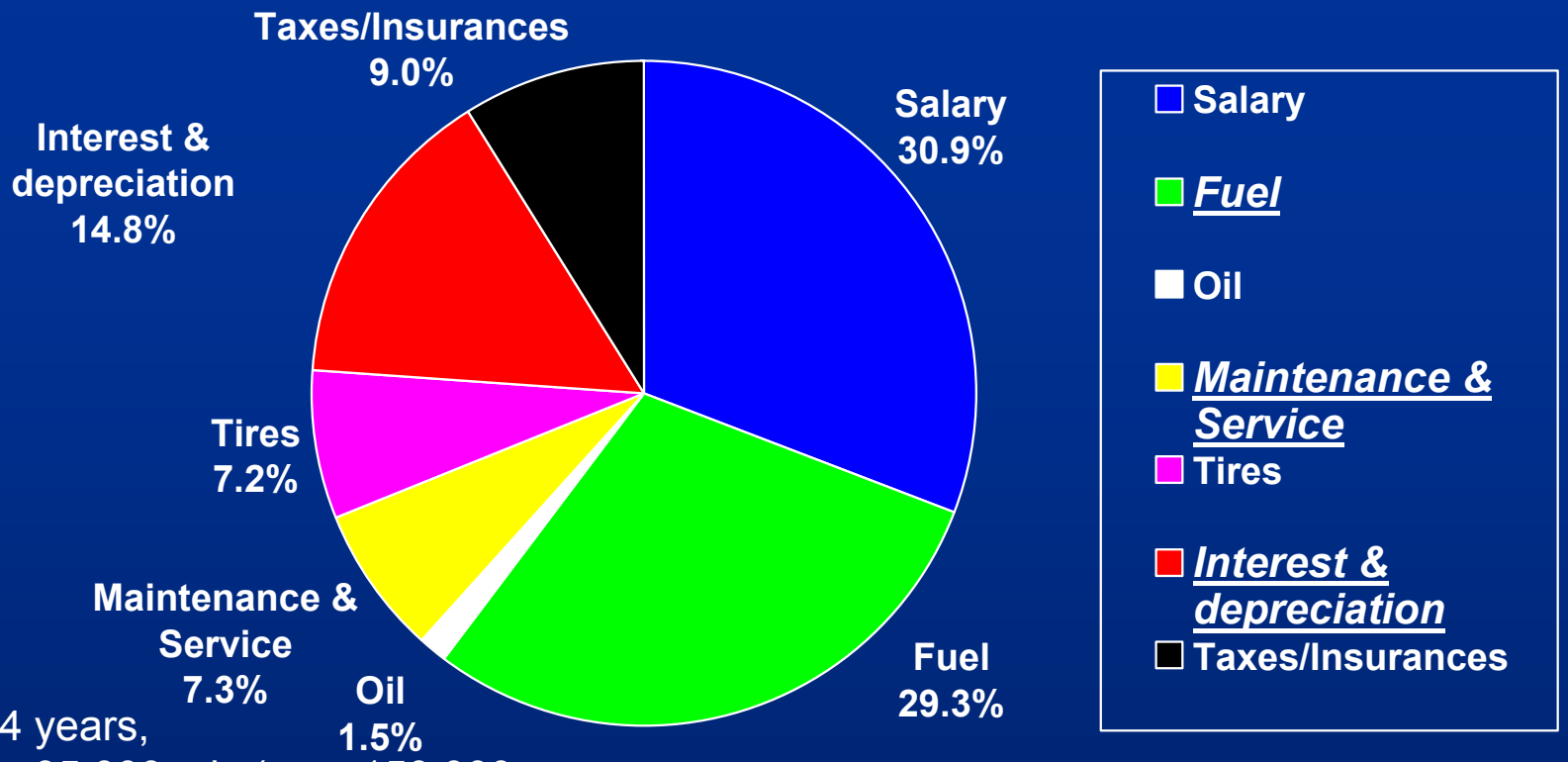
Costs for fuel, purchase and maintenance/service are highly influenced by engine design.



time of use: 4 years,
mileage/year: 95,000 mls (app. 150.000 km),
fuel consumption: 7,35 mpg (32,5 l/100 km)

Worldwide emission standards and respective test cycles

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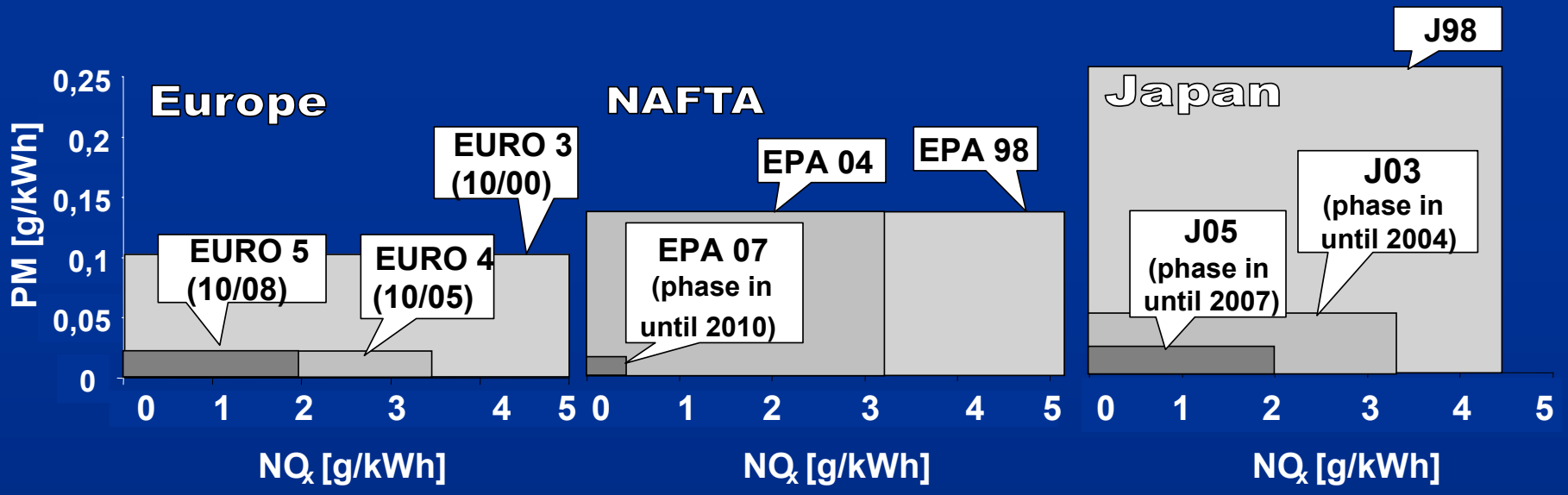
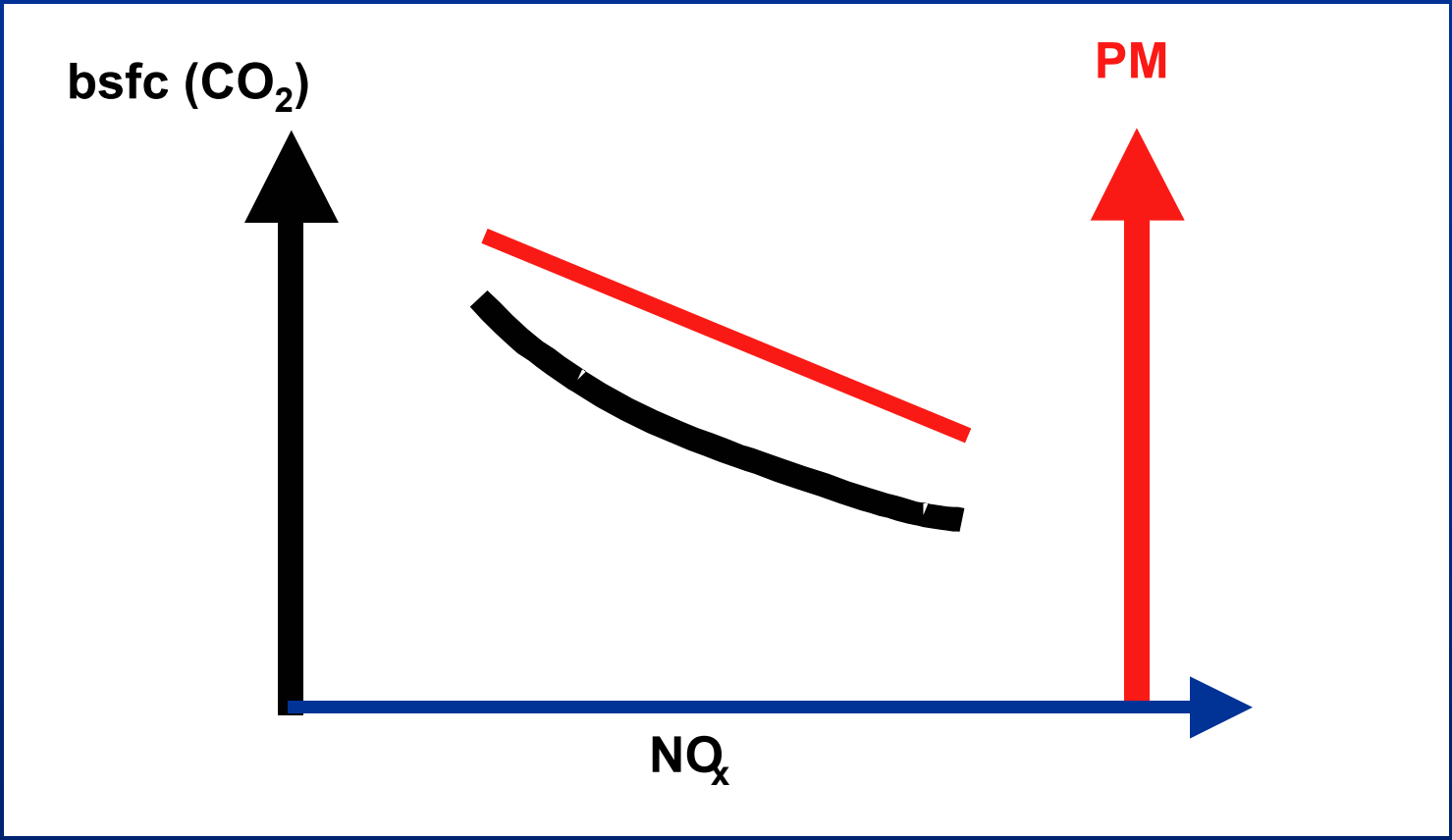


	Test cycles
Euro4/5	*European Steady Cycle (ESC) + European Transient Cycle (ETC)*
EPA 04/07	*Federal Test Procedure (FTP) + European Transient Cycle (ETC*
Japan 05	*Transient (hot start test)*

For Europe, NAFTA and Japan different test cycles are mandatory with different weightings regarding engine speed and load

Trade-off between nitric oxides (NO_x), fuel consumption (bsfc) and particulates (PM)

Traditional measures aiming at lower peak combustion temperature reduce fuel efficiency and increase PM- and CO_2-emission



Average fuel efficiency and speed of a 40t tractor-trailer combination

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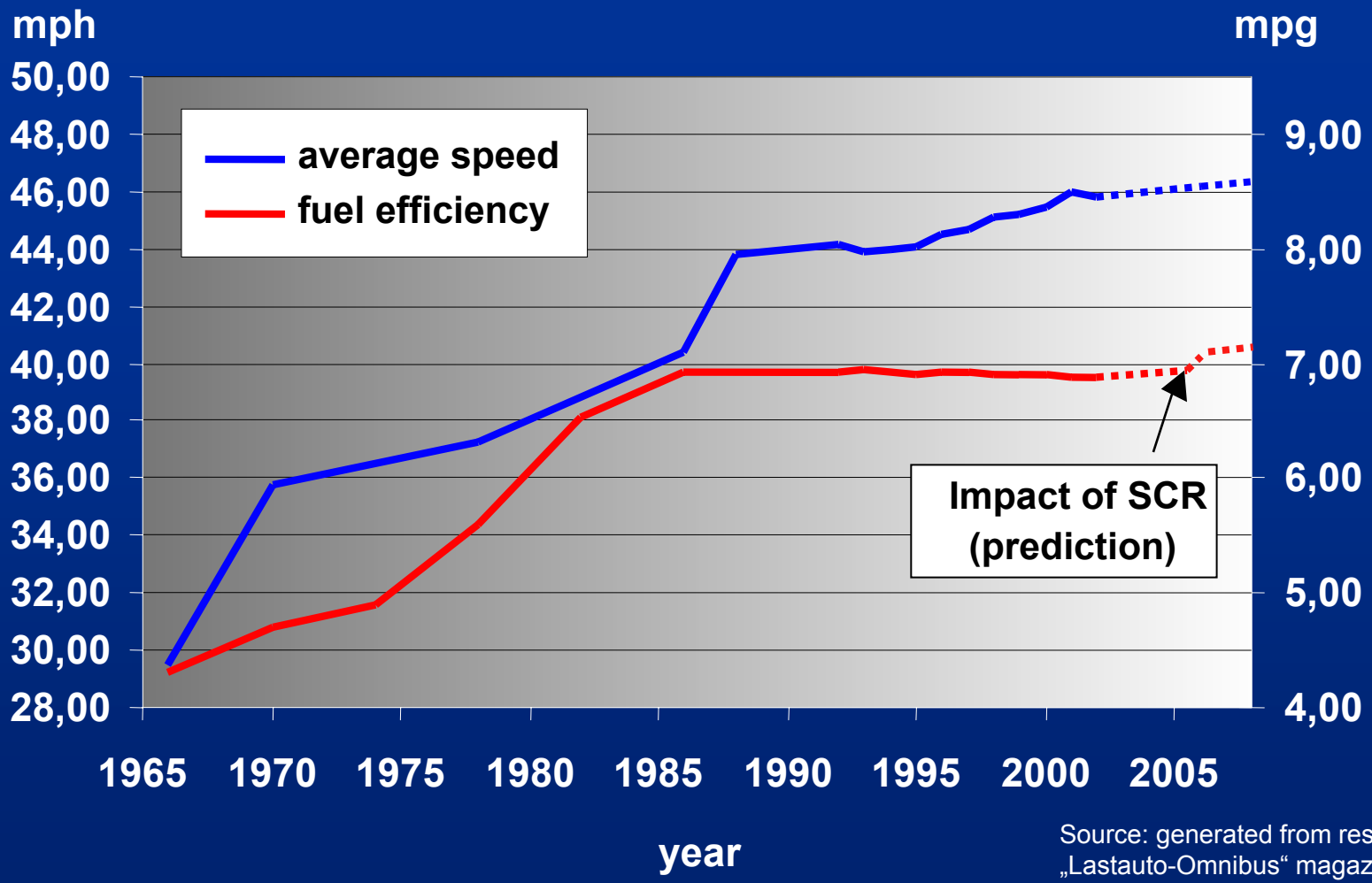
European OEMs have been able to increase transport efficiency in spite of more stringent emissions regulations



Source: generated from results of „Lastauto-Omnibus“ magazine

Measures to fulfill emission standards

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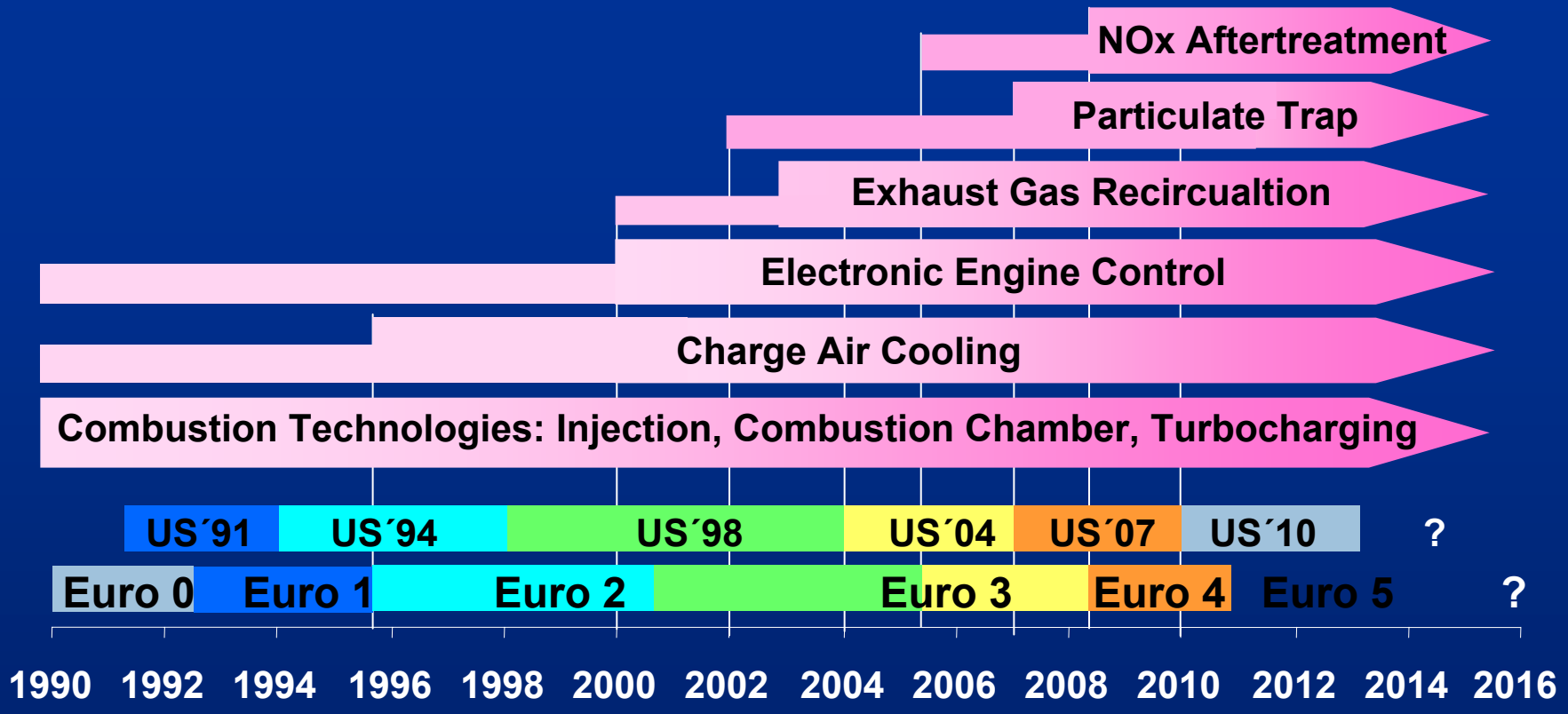

Today‘s exhaust aftertreatment systems for Diesel engines

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NOx aftertreatment

- Adsorber catalyst
- Selective Catalytic Reduction (SCR)

PM aftertreatment

- Continuously Regenerating Diesel Particle Filter (CDPF)

Aftertreatment systems - mode of operation
Adsorber catalyst

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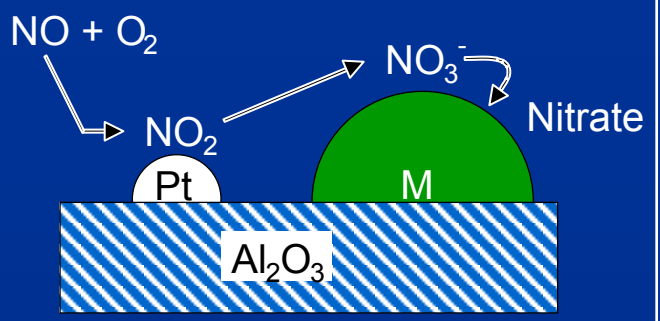
PHASE 1: Regular operating conditions

AFR> 1

- Air-To-Fuel Ratio (AFR)>1
  storage of NOx on catalyst surface:
  - → Oxidation from NO to NO_2
  - → Production of nitrate (out of NO_2)
  - → storage of produced nitrate

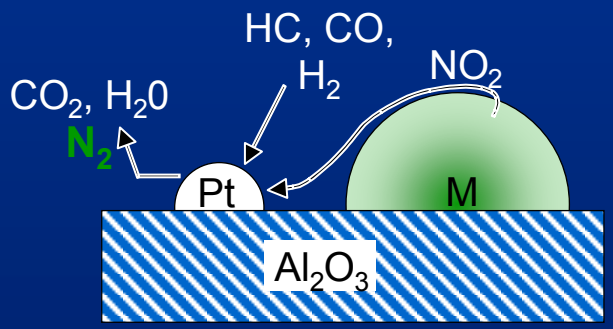


Nitrate-storage

PHASE 2: Brief enrichment (ECU controlled)

AFR< 1

- AFR<1
  Reduction of stored nitric oxides:
  - → back-formation of nitrate to NO
  - → Reaction of NO with CO and H_2
    ($2NO + 2CO \rightarrow 2CO_2 + N_2$)
    ($2NO + 2H_2 \rightarrow 2H_2O + N_2$)



Reduction to nitrogen

Aftertreatment systems - mode of operation
Selective Catalytic Reduction (SCR)

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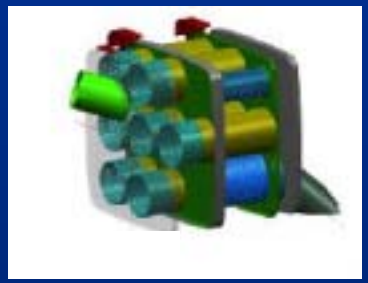
The SCR technology uses urea, respectively ammonia (which forms after decomposition of urea at temperatures >200°C) to convert nitric oxides (NO, NO_2) into harmless molecular nitrogen N_2 and water.



NOx	+ hydrogen +	ammonia
4 NO	+ O_2	+ 4 NH_3
2 NO_2	+ O_2	+ 4 NH_3

→

nitrogen +	water
4 N_2	+ 6 H_2O
3 N_2	+ 6 H_2O

Aftertreatment systems - mode of operation
Continuously regenerating Diesel particle filter

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Combination of oxidation catalytic converter and soot trap

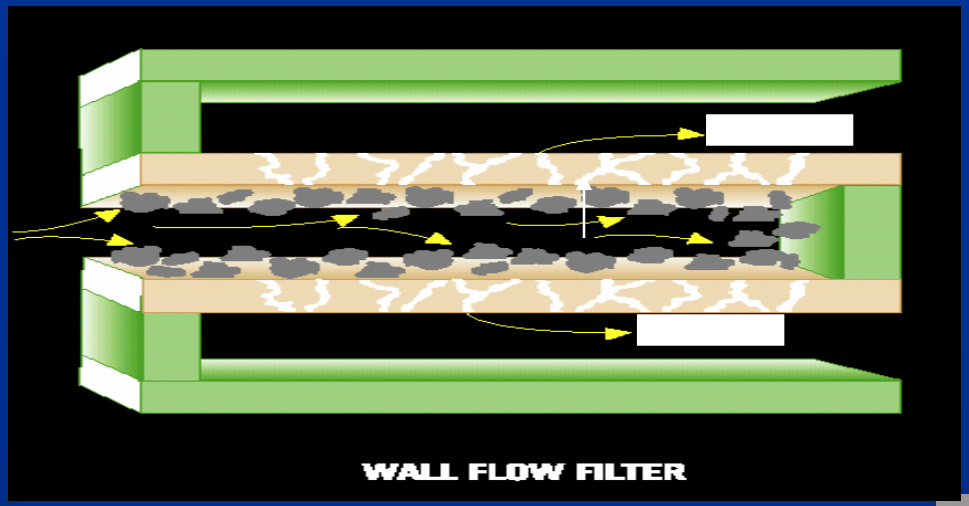
$2\ CO + O_2 \longrightarrow 2\ CO_2$

$4\ HC + 5\ O_2 \longrightarrow 2\ H_2O + 4\ CO2$

$2\ NO + O_2 \longrightarrow 2\ NO_2$

$C + 2\ NO_2 \longrightarrow CO_2 + 2\ NO$

Versions of particulate traps under evaluation

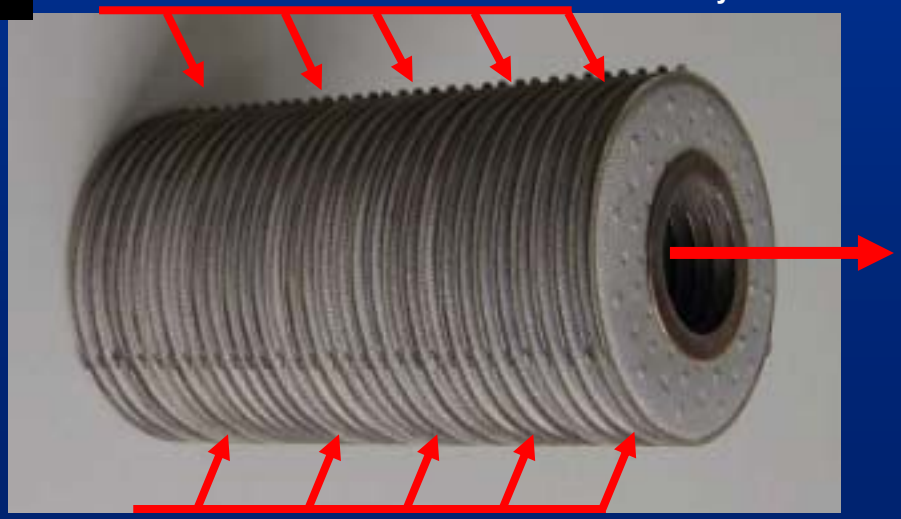


Courtesy Johnson Matthey

Monolith with a high number of filter channels

Sintered metal filter with a low number of filter plates

Courtesy Purem



Strategies for emission reduction for US MY07

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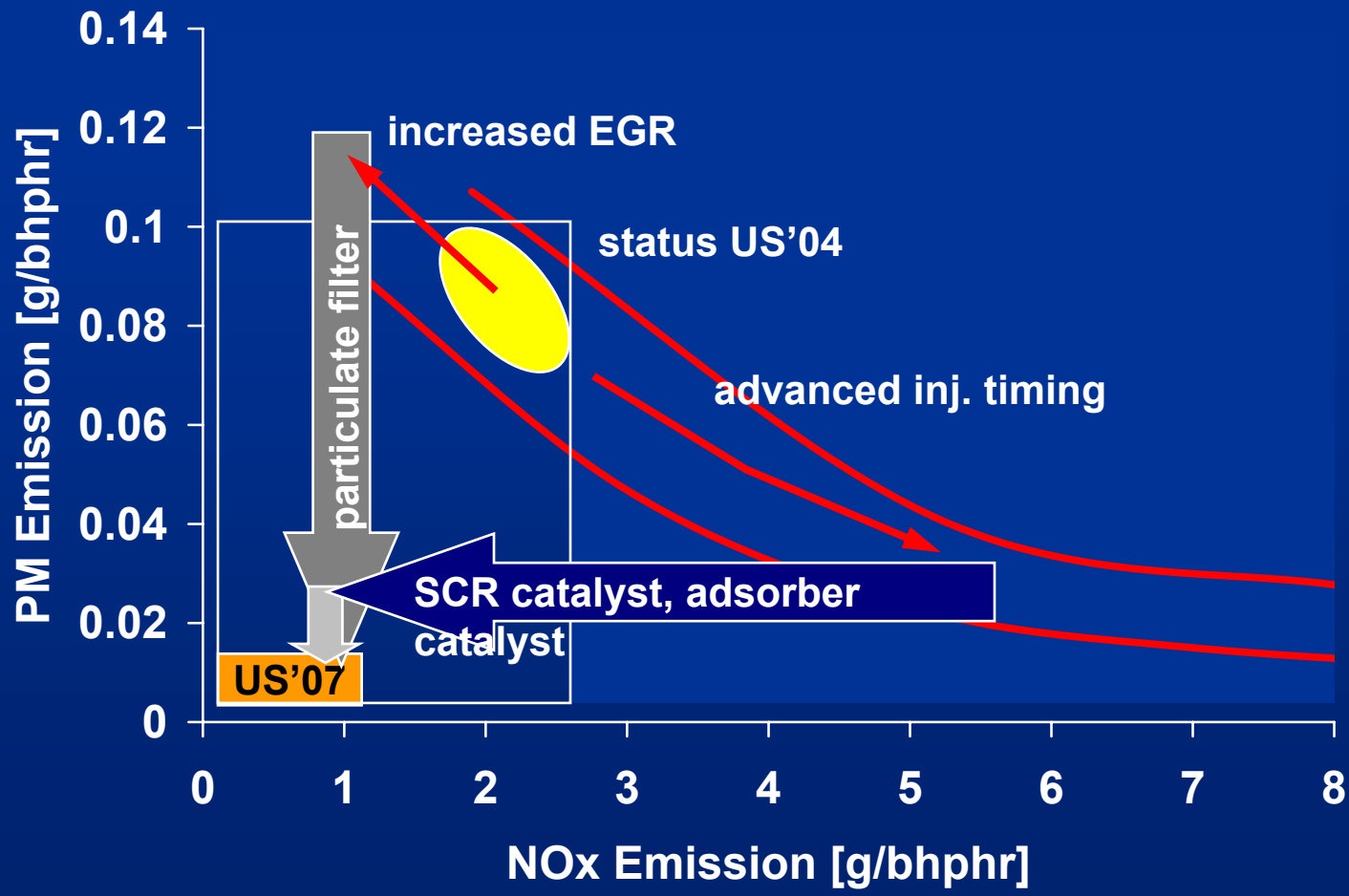
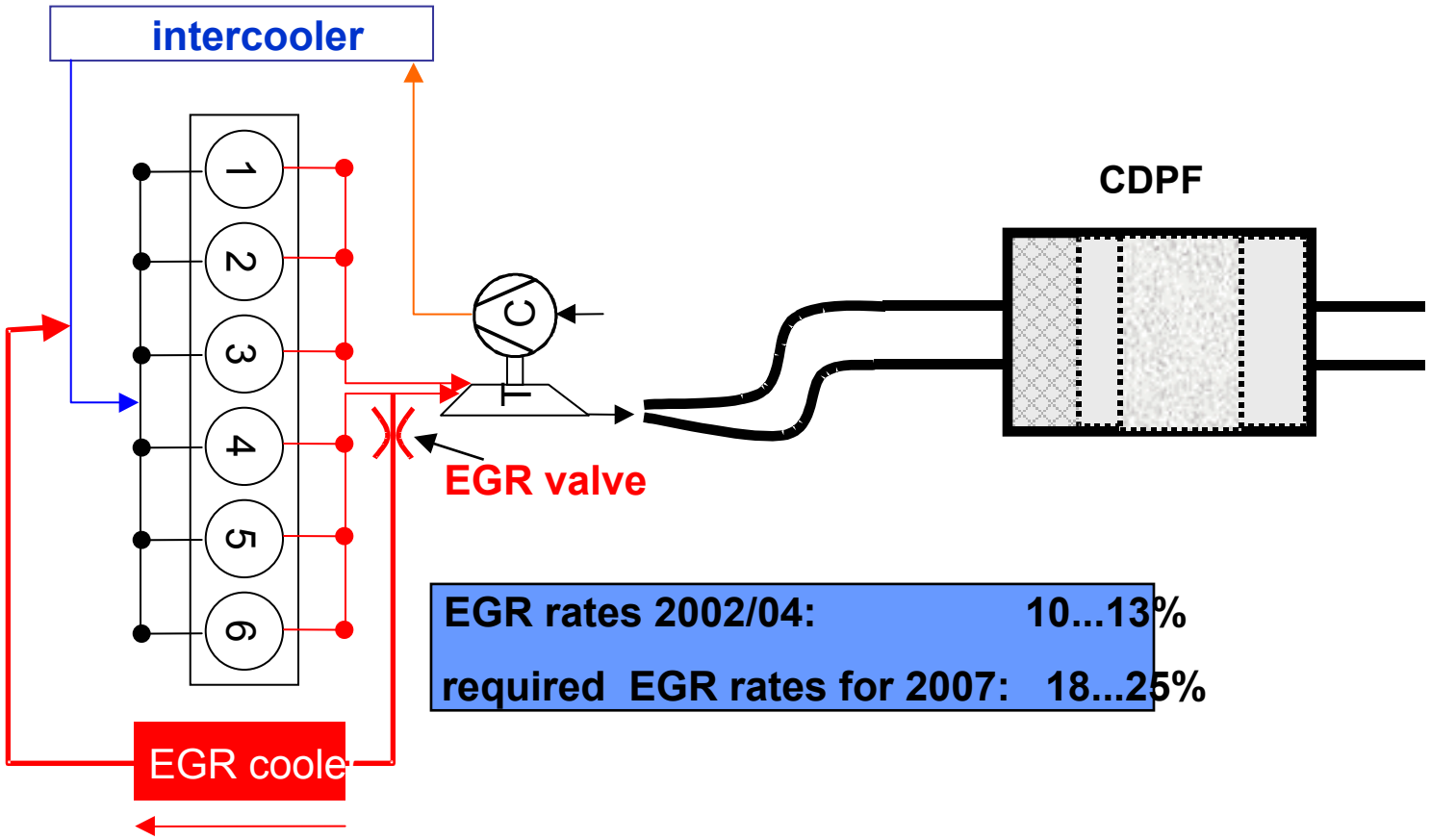


High EGR with CDPF approach

The EGR system for US'07 features approximately twice the EGR rates of US'04



High EGR radiator design comparison for an axle forward truck

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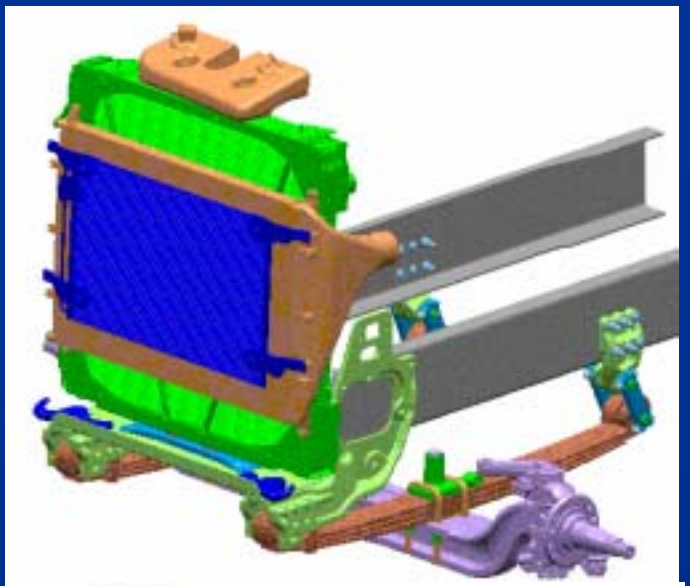
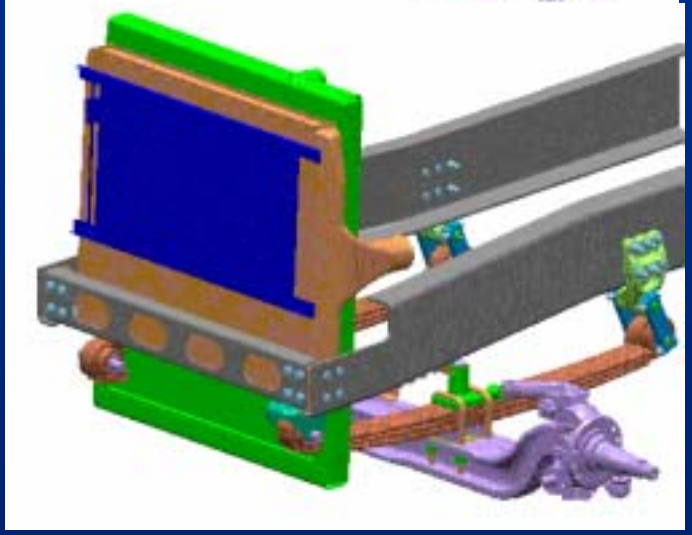


2002/2004 design
crossflow radiator



2007 design
downflow radiator

splayed frame
interference w/ axle forward springs

The SCR and CDPF approach

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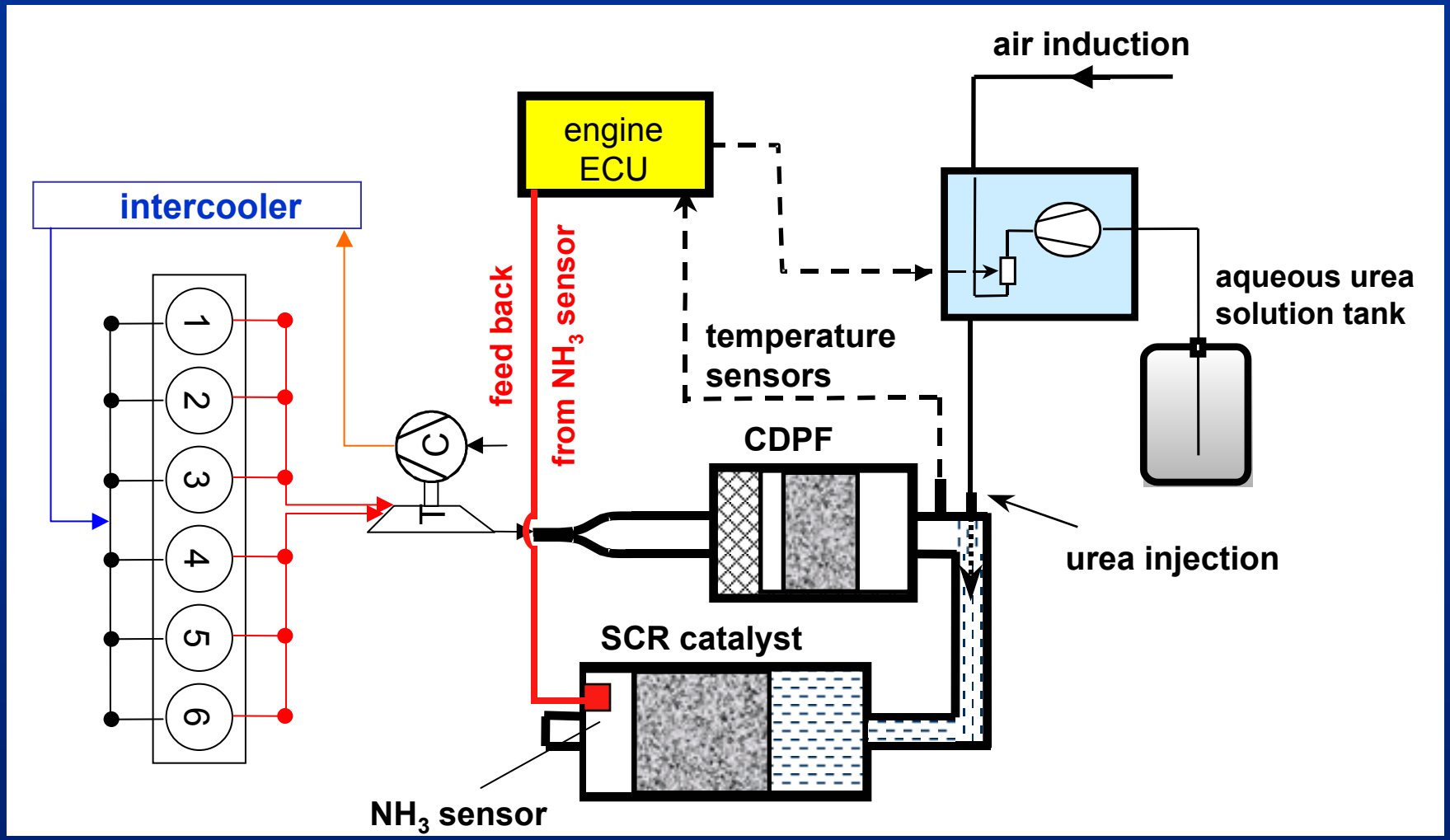

Timelines of different emission strategies

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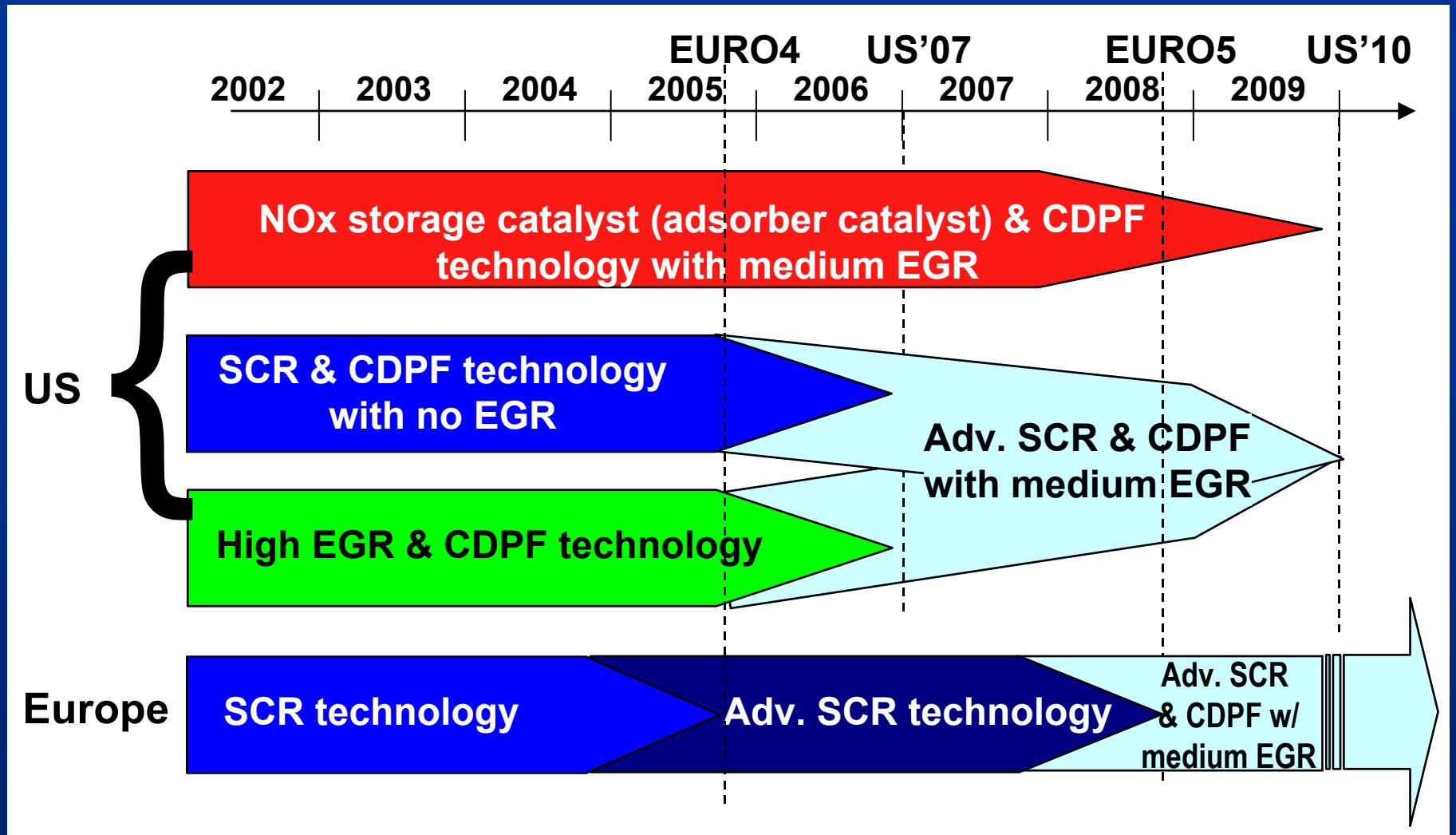

Fuel consumption and CO_2 emission of MY 07 emission strategies

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Life-Cycle-Cost comparison for a long haul truck
(only costs are considered, no prices that include profit and overhead)

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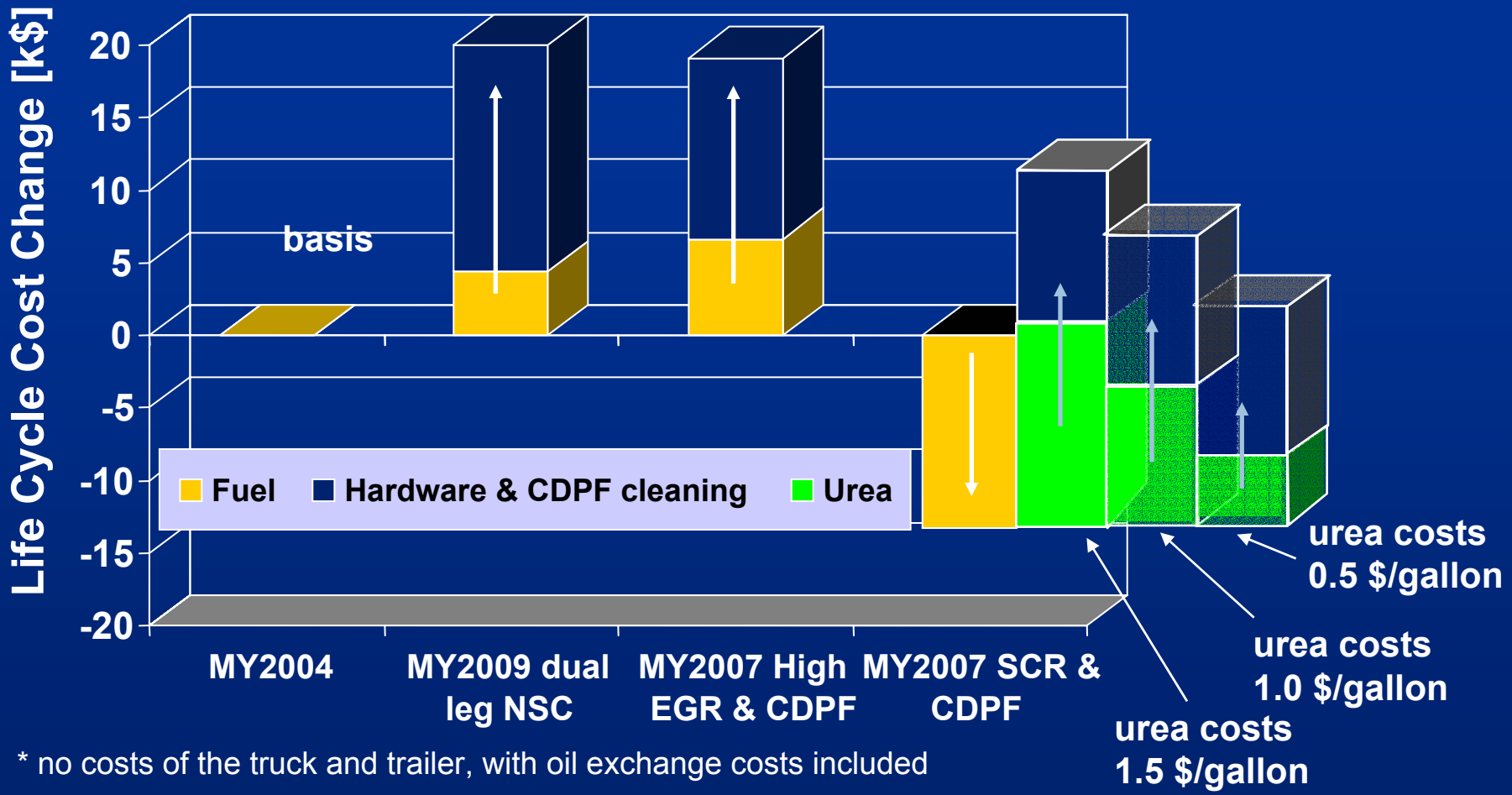
The SCR & CDPF technology reduces fuel consumption and life cycle costs; the cost advantage depends on the urea costs



* no costs of the truck and trailer, with oil exchange costs included

Installation of SCR & CDPF technology in a demonstrator truck

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Two issues need to be resolved in order to enable the introduction of SCR:

- urea supply infrastructure
- securing that system is tamper-proof and working correctly

Urea is

- colorless
- non-toxic
- used in food, agricultural fertilizers, cosmetics pharmaceuticals etc.
- available at required quantity; installed production capacity allows CV supply w/o additional investments

AdBlue is

- the European trade name for 32.5% aqueous urea solution

How does Europe approach the installation of a supply infrastructure for urea solution

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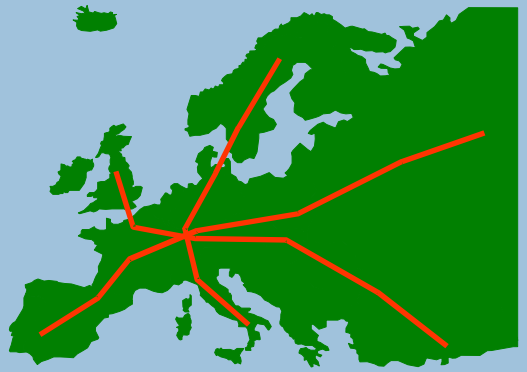
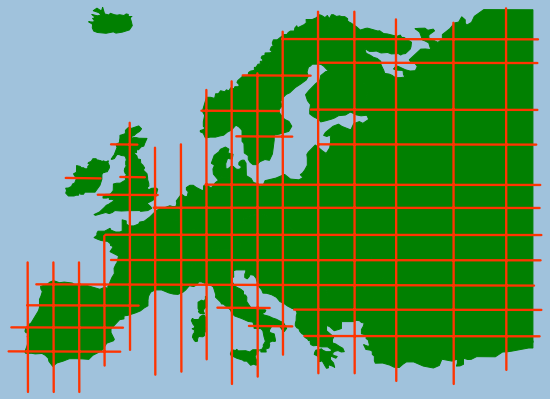
- The urea supply industry has a major interest to establish a urea infrastructure.
- 80% of the entire heavy duty truck diesel fuel is being distributed by local fuel stations which are operated by the fleets themselves.
- Fleet owners will install urea filling stations at their places. Financial support through urea manufacturing companies is in discussion.
- Large highway truck-stops will be equipped with urea filling stations. Other fuel filling stations will install urea supply gradually.

supply of the most important intersections



supply along the most important routes



area-wide supply with minimaldistances

Local AdBlue filling stations

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AdBlue

small filling station

AdBlue

supply unit: 265 gals (1000 l)

TIAX-Report on SCR-Urea Implementation Strategies

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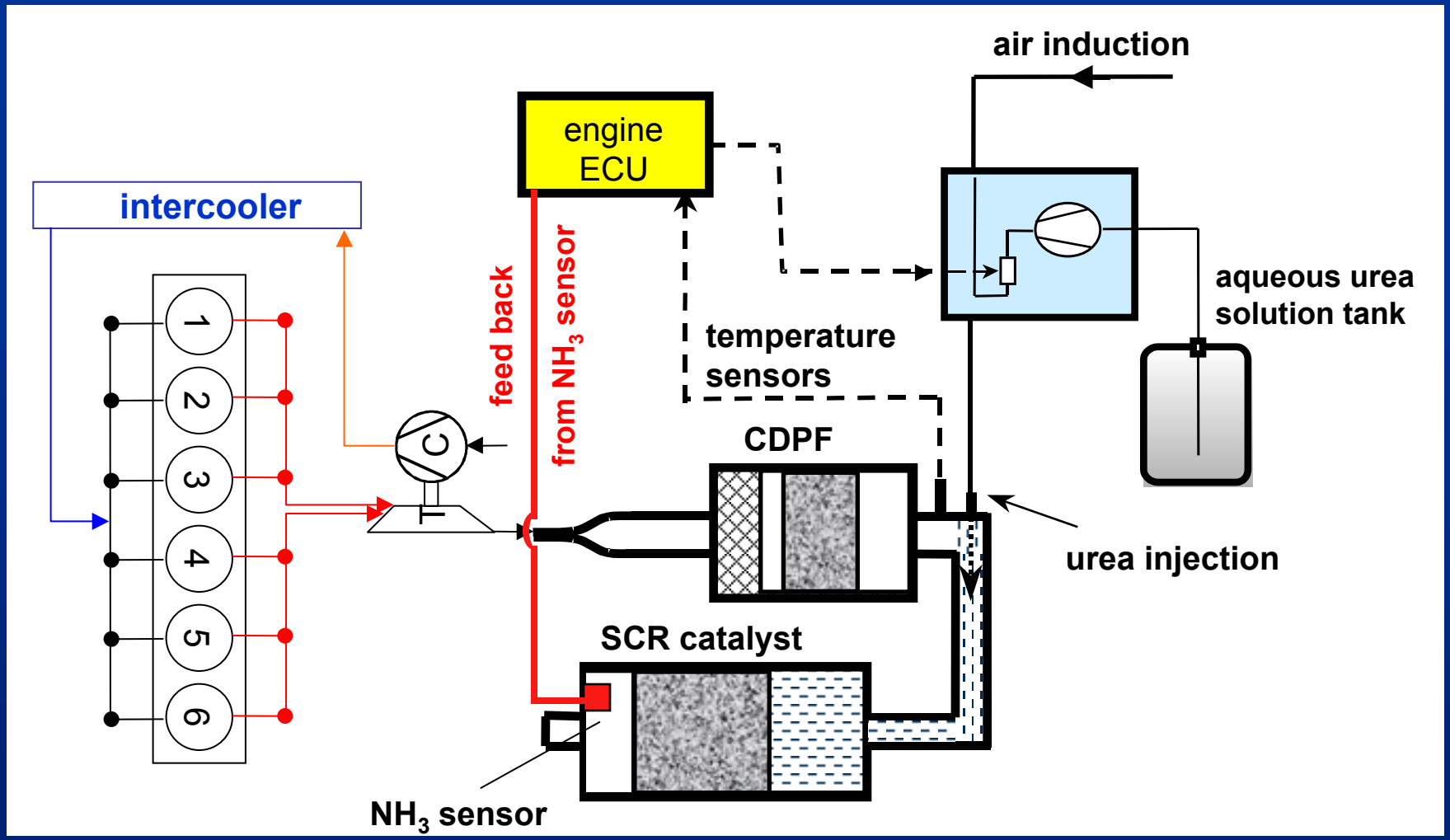
Excerpt from TIAX-Report:

- "Economics favor the SCR/urea technology over the NOx adsorber technology for most applications of long-haul and vocational trucks in the long-term."
- "Economics also generally favor the SCR/urea technology over the NOx adsorber technology in the near-term if early NOx adsorbers have a high fuel penalty (≈5%) and a higher initial incremental cost."
- The study furthermore states that provision of Urea is both possible and economically reasonable if "strong signals regarding manufacturers intentions to provide SCR-equipped trucks" are sent to truck operators and other stakeholders starting 3rd quarter 2003 and no later than mid-2004

Remark: TIAX is a consulting firm which formed from Arthur D. Little's Technology and Innovation business

source: TIAX-report

The SCR and CDPF approach



Emission technology comparison
preliminary estimates as of June 2003

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	High EGR	SCR	NOx Adsorber
Fuel Economy	-3%	+6% (app. 6% urea usage)	-3%
Cooling Requirements	up to 55%	-20%	0%
Power Density	-5%	+6%	0%
Weight	+50 lbs.	-400 lbs.	+200 lbs.
Oil Exchange Intervals	1X	2X	1X
Urea Infrastructure	No	Yes	No
Driver's Responsibility	None	Urea Refill	None