CLEERS Workshop 2007

Urea SCR- The Volvo Way

Ann W Grant
Volvo Technology AB
Göteborg Sweden

BUSINESS AREAS at AB Volvo

Mack Trucks

Renault Trucks

Volvo Trucks

Volvo Buses

TRUCKS

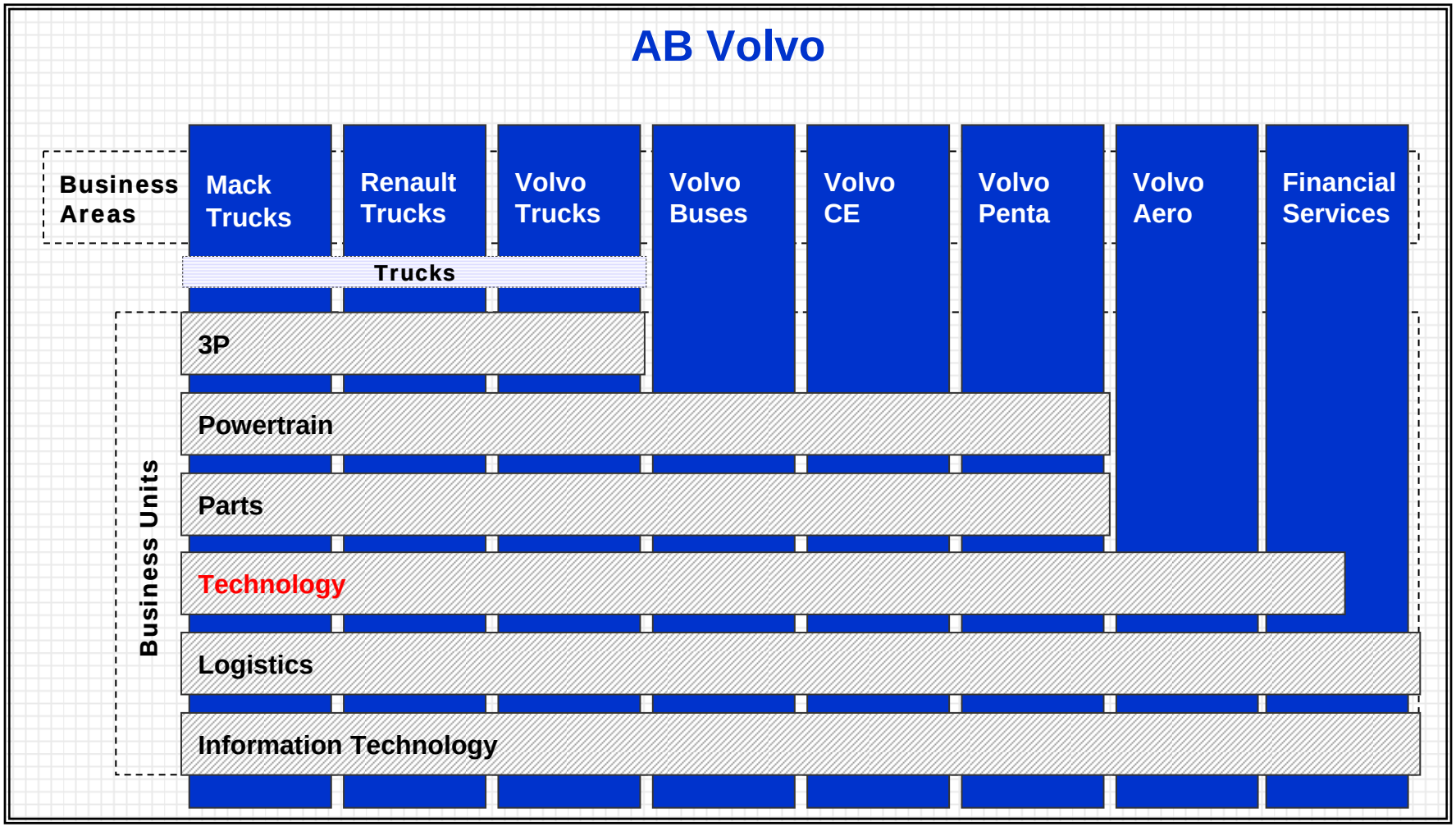
Volvo Construction Equipment

Volvo Penta

Volvo Aero

Volvo Financial Services

Urea SCR- The Volvo Way

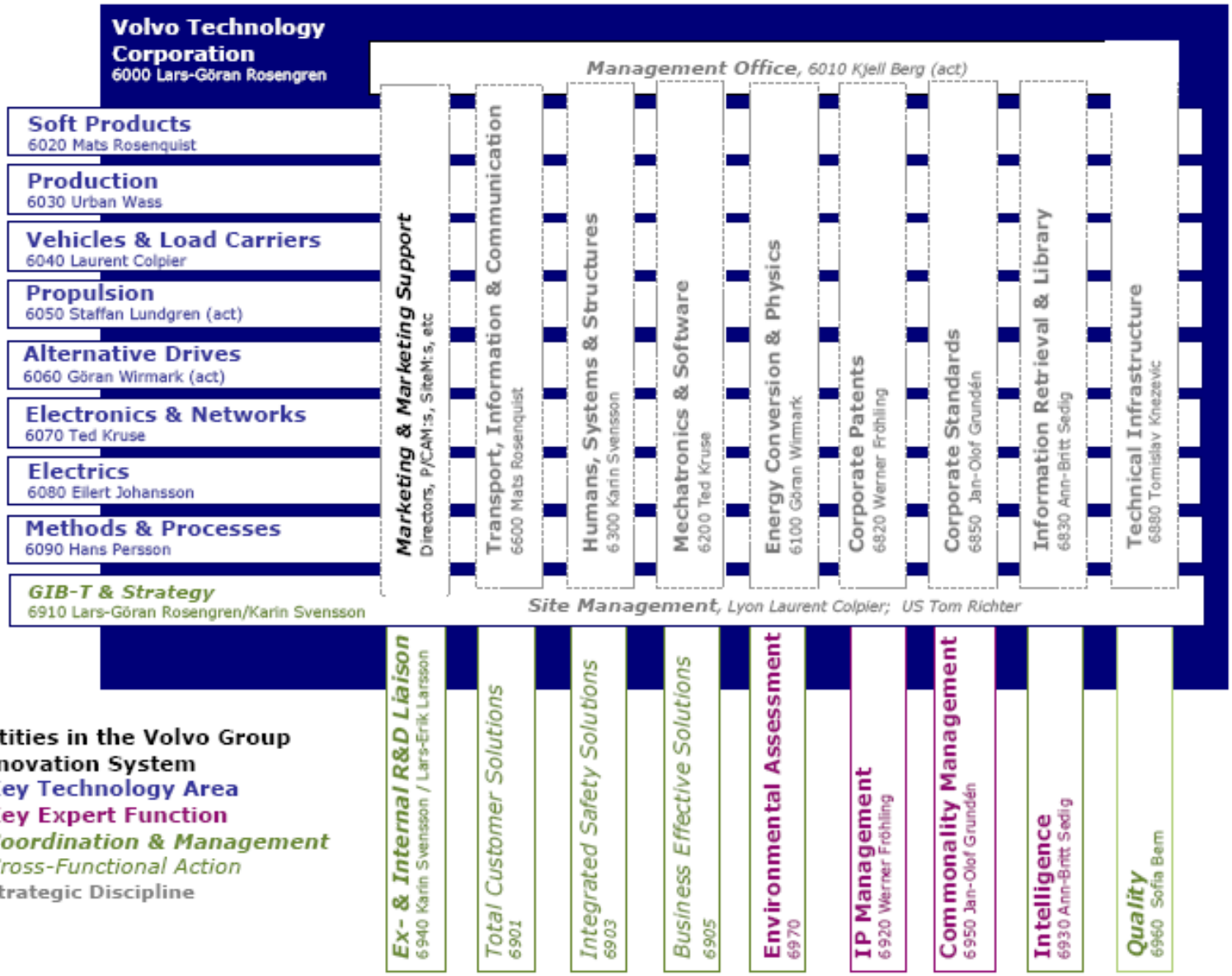


FACTS ABOUT VTEC

- We are 381 employees
- VTEC turnover is €36M
- Established 1969
- Innovation Areas
- services
- production
- vehicles
- powertrain
- electronics
- processes & methods

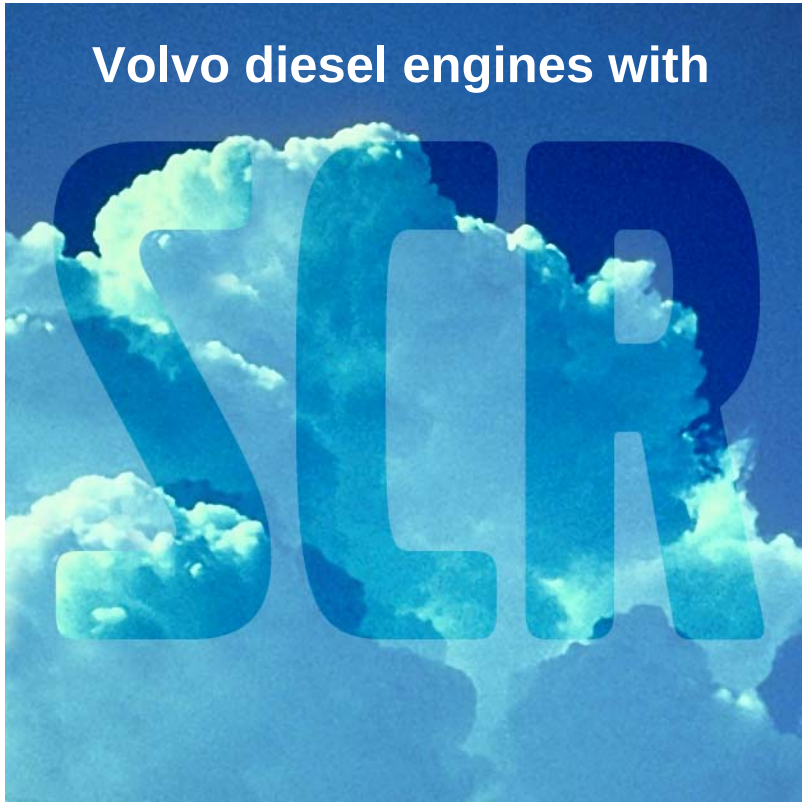
- Innovation Services
- intellectual asset management
- standardisation intelligence

Urea SCR- The Volvo Way



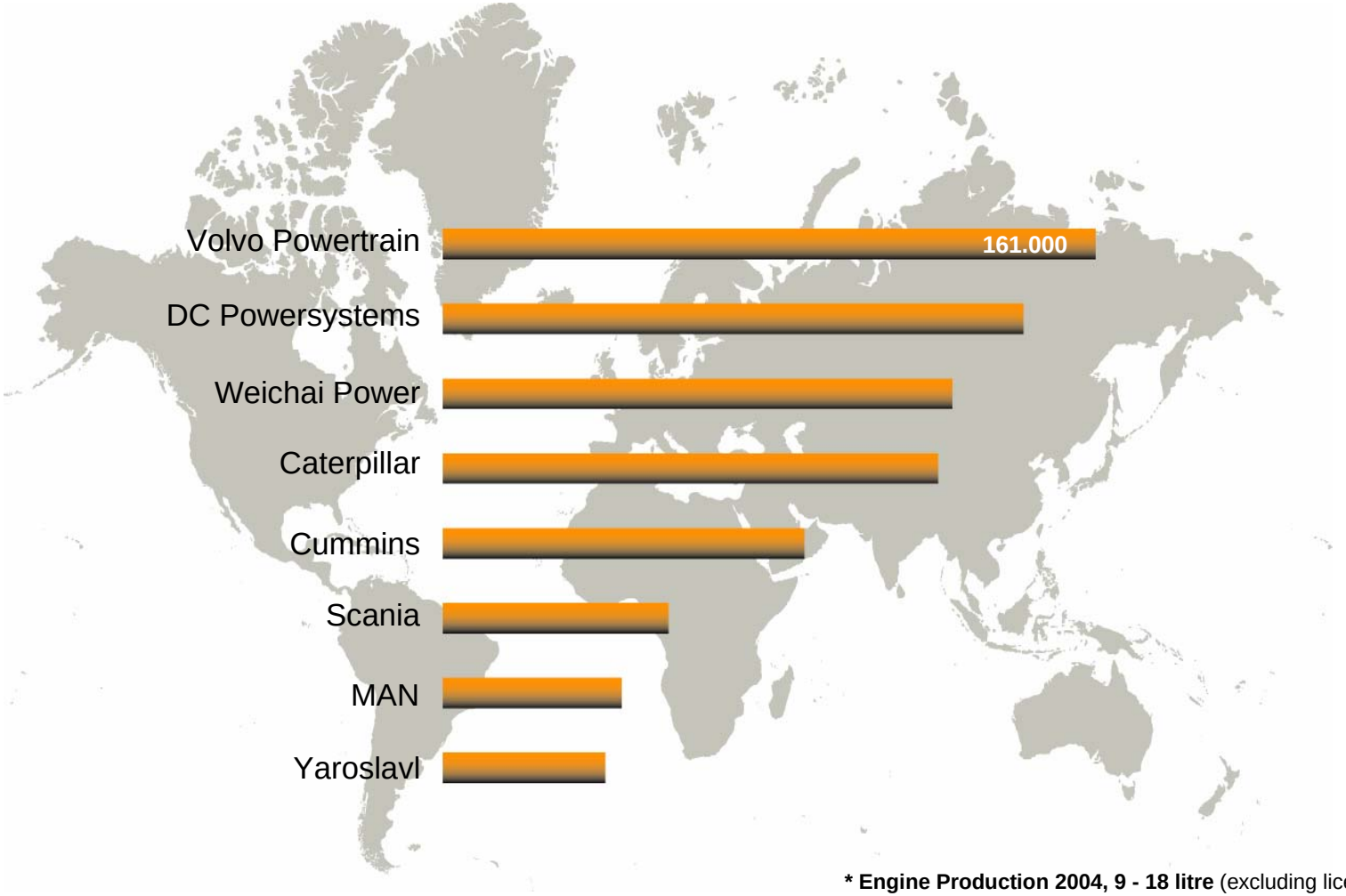
Entities in the Volvo Group Innovation System

- Key Technology Area
- Key Expert Function
- *Coordination & Management*
- *Cross-Functional Action*
- Strategic Discipline



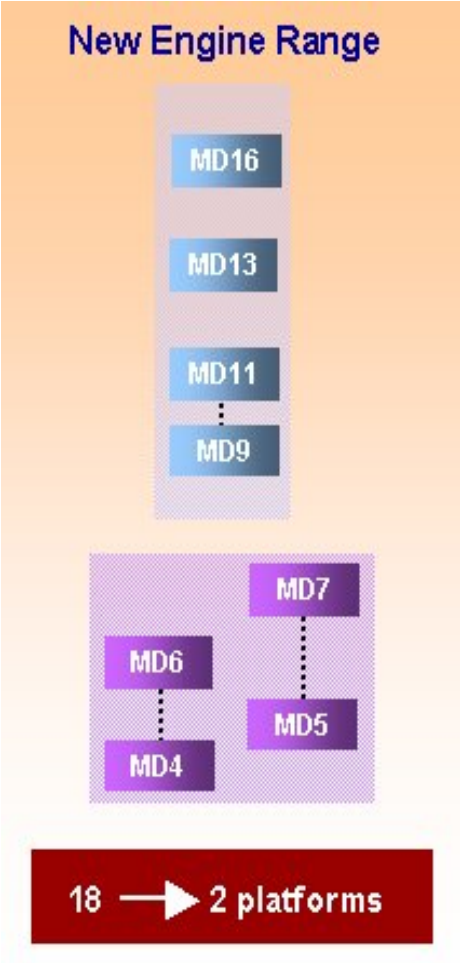
VOLVO TECHNOLOGY FOR EURO 4 AND EURO 5

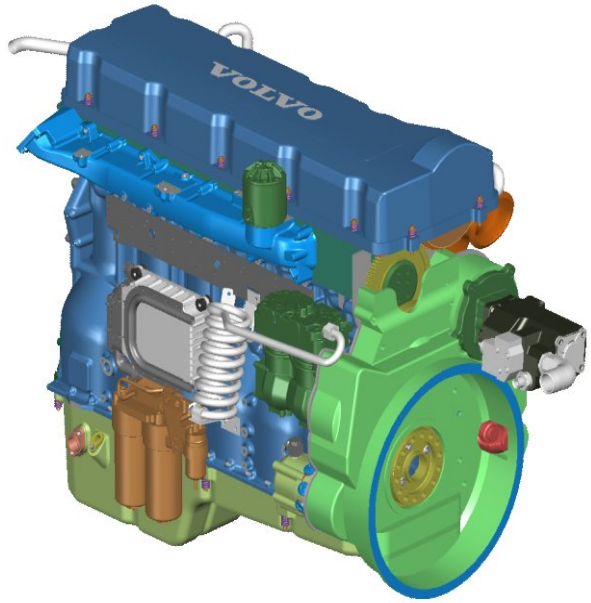
Global production of Heavy Duty Diesel Engines 2004*



*** Engine Production 2004, 9 - 18 litre** (excluding licensees / JV's)

New Heavy Platform - common technology



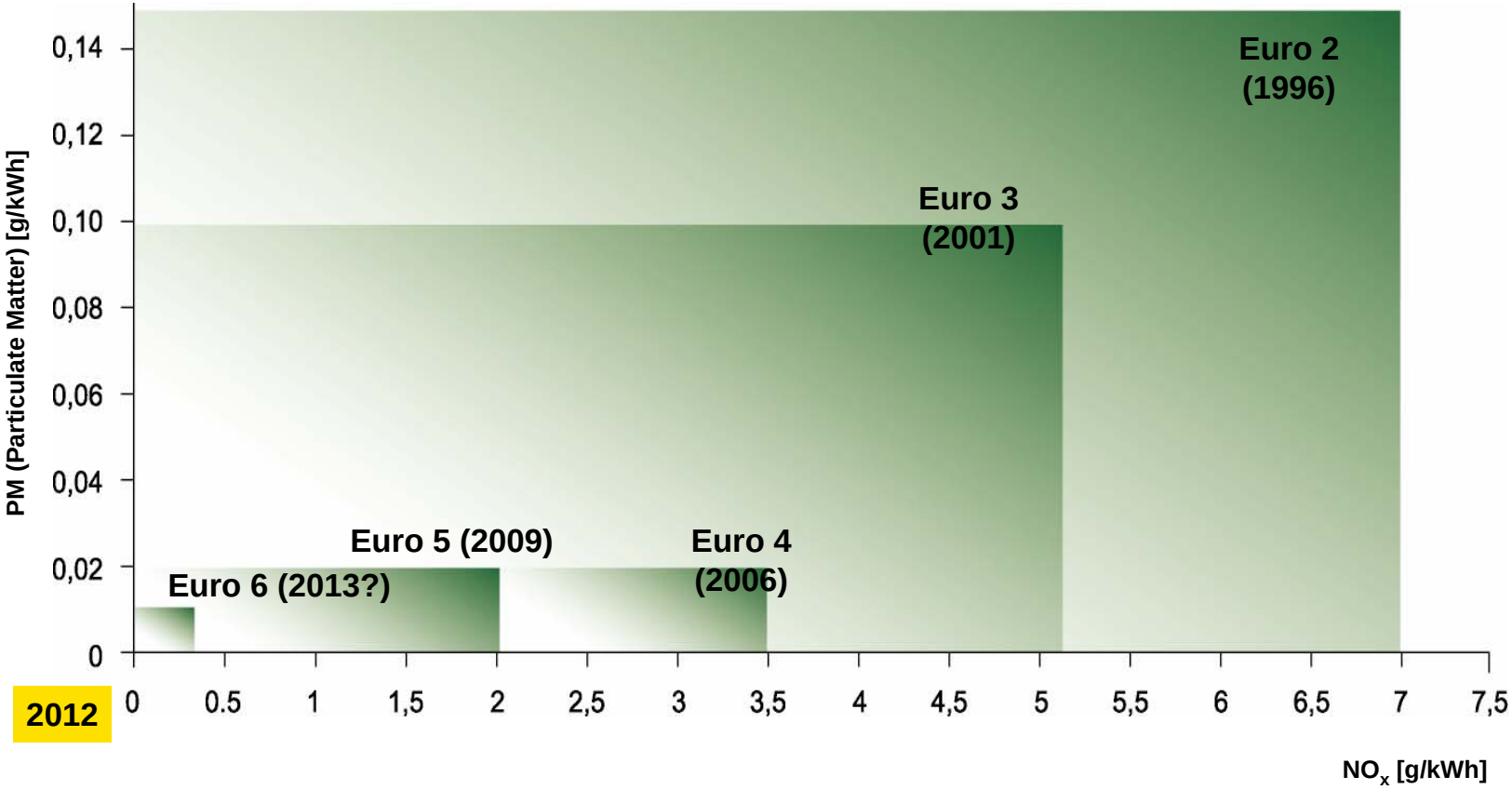


D12RT, 2001-03-29

- One Cylinder Head
- Overhead Camshaft
- Four Valves per Cylinder
- Central Vertical Injector
- Electronic Unit Injectors
- Electronic Management System
- Rear End Transmission
- Integrated Engine Brake
- Wet Liners

Legislative Demands

Exhaust Emission Standards



Urea SCR- The Volvo Way

karna jobbar redan för att klara Euro 5, som gäller från 2009.

– I år går halva vår FoU-budget på 2,5 miljarder kronor till att utveckla motorer som klarar utsläppskraven, säger Scanias FoU-chef Hasse Johansson.

MAN satsar ungefär lika mycket på samma sak.

och få miljörabatter på vägavgifter. Det är inte heller avgjort vilken teknik som är objektivt bättre – på andra sidan 2015 hoppas tillverkarna på ett genombrott för HCCI-motorn, vilket i ett slag skulle minska utsläppen till noll.

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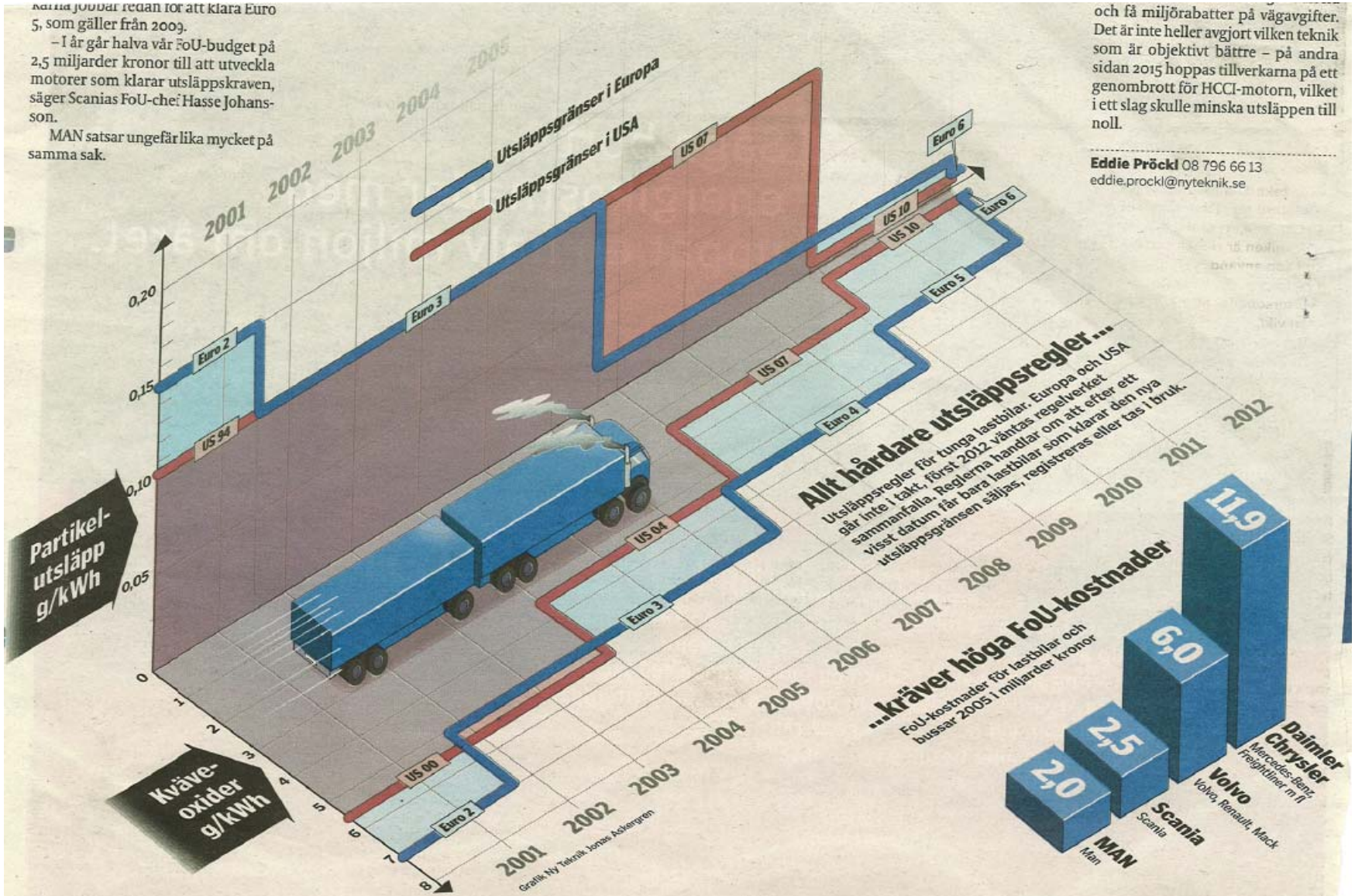
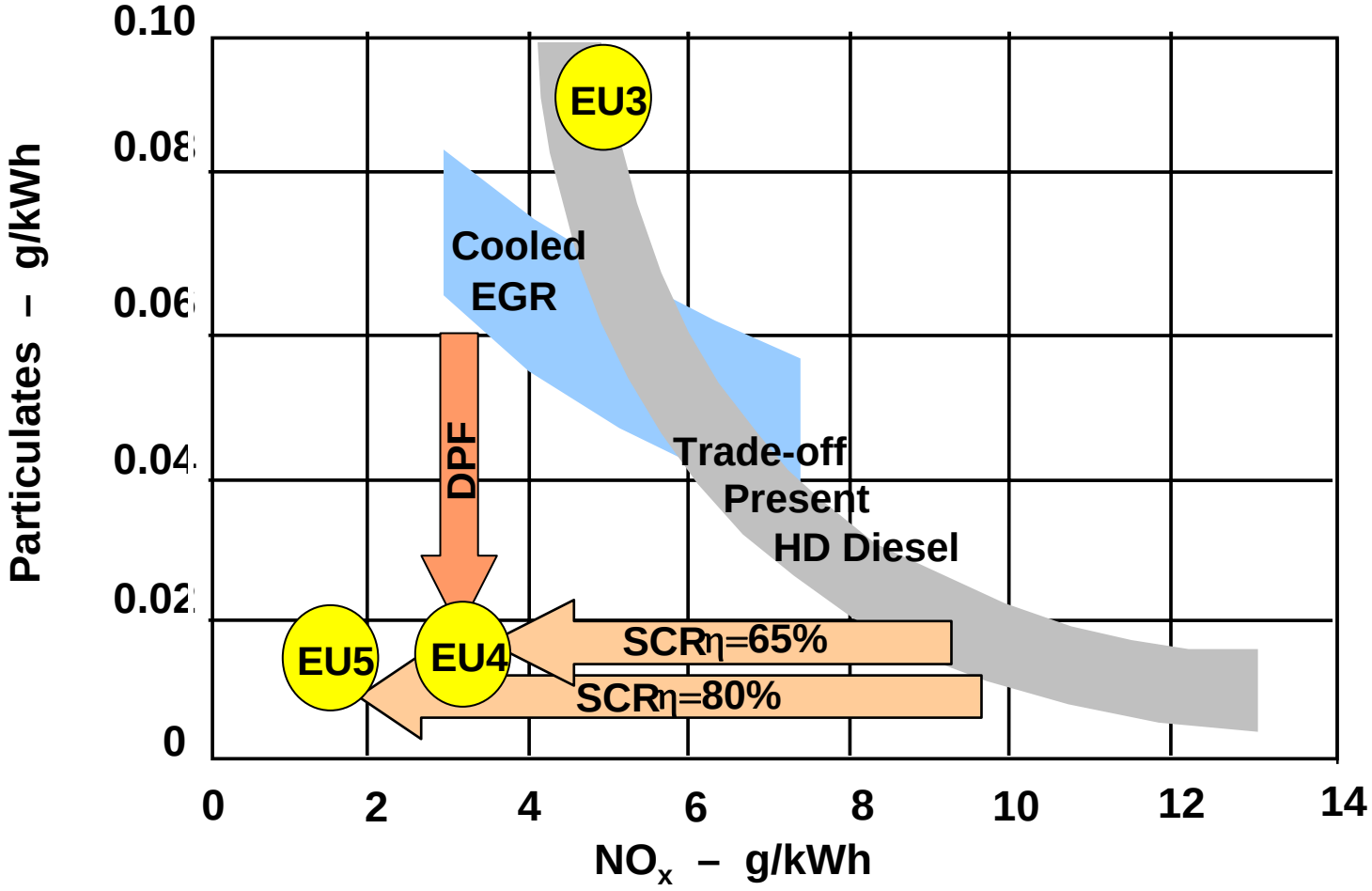


Exhaust Emission Strategy - HD Diesel - Europe



Engine Optimization and Fuel Consumption

- Variation in injection timing

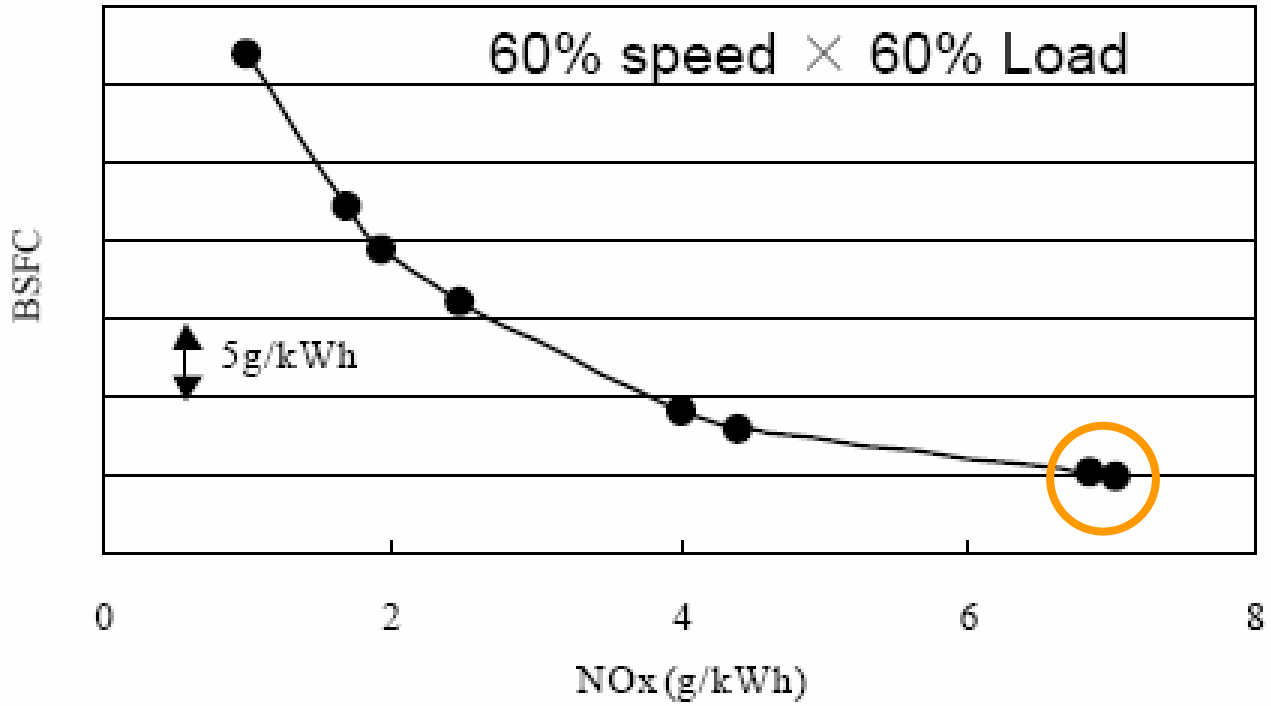


Fig. 10 NOx Fuel Consumption Trade-off

Higher engine-out NOx gives better fuel consumption (~3%)

SCR vs. EGR – Euro 3 baseline

	SCR	EGR
Fuel consumption	☺	☹
Heat rejection	😐	☹
Power density	😐	☹
Reliability	😐	☹
Maintenance	😐	☹
Euro 5/6 capability	☺	☹
Total cost	😐	☹

Euro 4 legal requirement

Certification before Oct 1- 05

Certify new engines for Euro 4

Euro 4 step I Mandatory

Driver warning if:

- AdBlue tank is empty
- Dismounted catalyst
- Lack of AdBlue dosing

Euro 4 step II Additional requirement

Driver warning if:

- > 5 g. NOx/ kWh

40% torque reduction if:

- > 7 g. NOx/ kWh

Oct 1 — **2005**

Oct 1 — **2006**

Oct 1 — **2007**

2008

SCR - Selective Catalytic Reduction

Power plants

Established technology since 1970.
Possibility to reach 95% NO_x-conversion with NH_3
.

Marine applications

Catalytic converters for marine applications to meet NO_x-emission levels <2 g/kWh.

Heavy duty vehicles

Test around the world, mainly Europe.
Meet legal requirement of NO_x-emission <3,5 → 2 g/kWh.

The selected solution UREA SCR

- Oxidation catalyst upstream (NO_2 production)
- Cleanup catalyst for removal of NH_3 slip

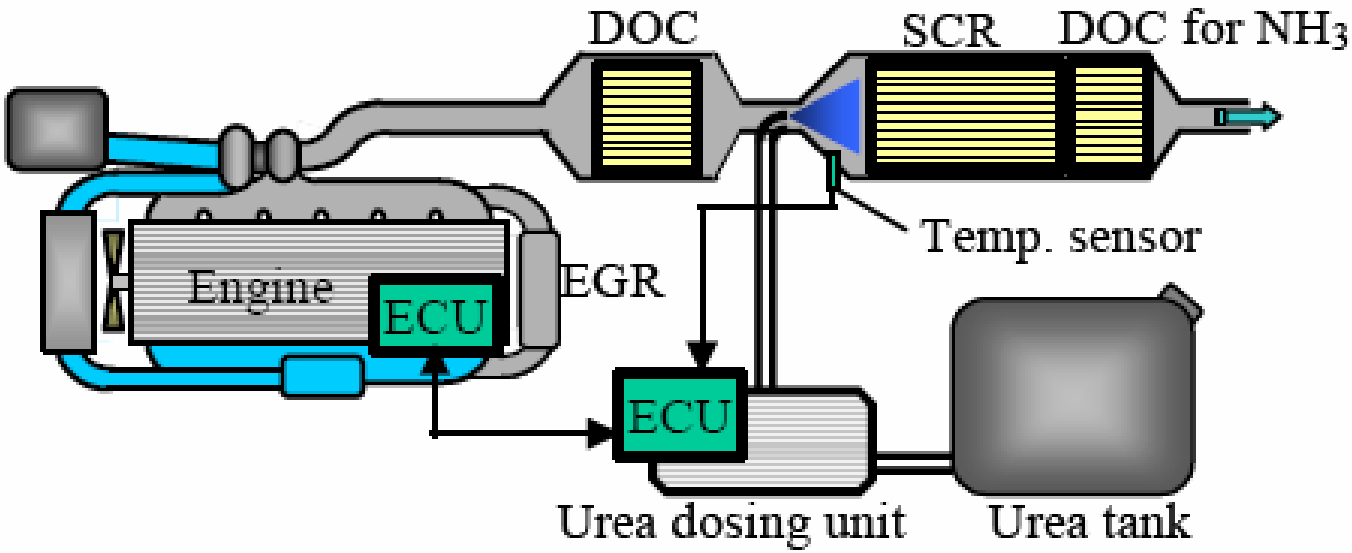
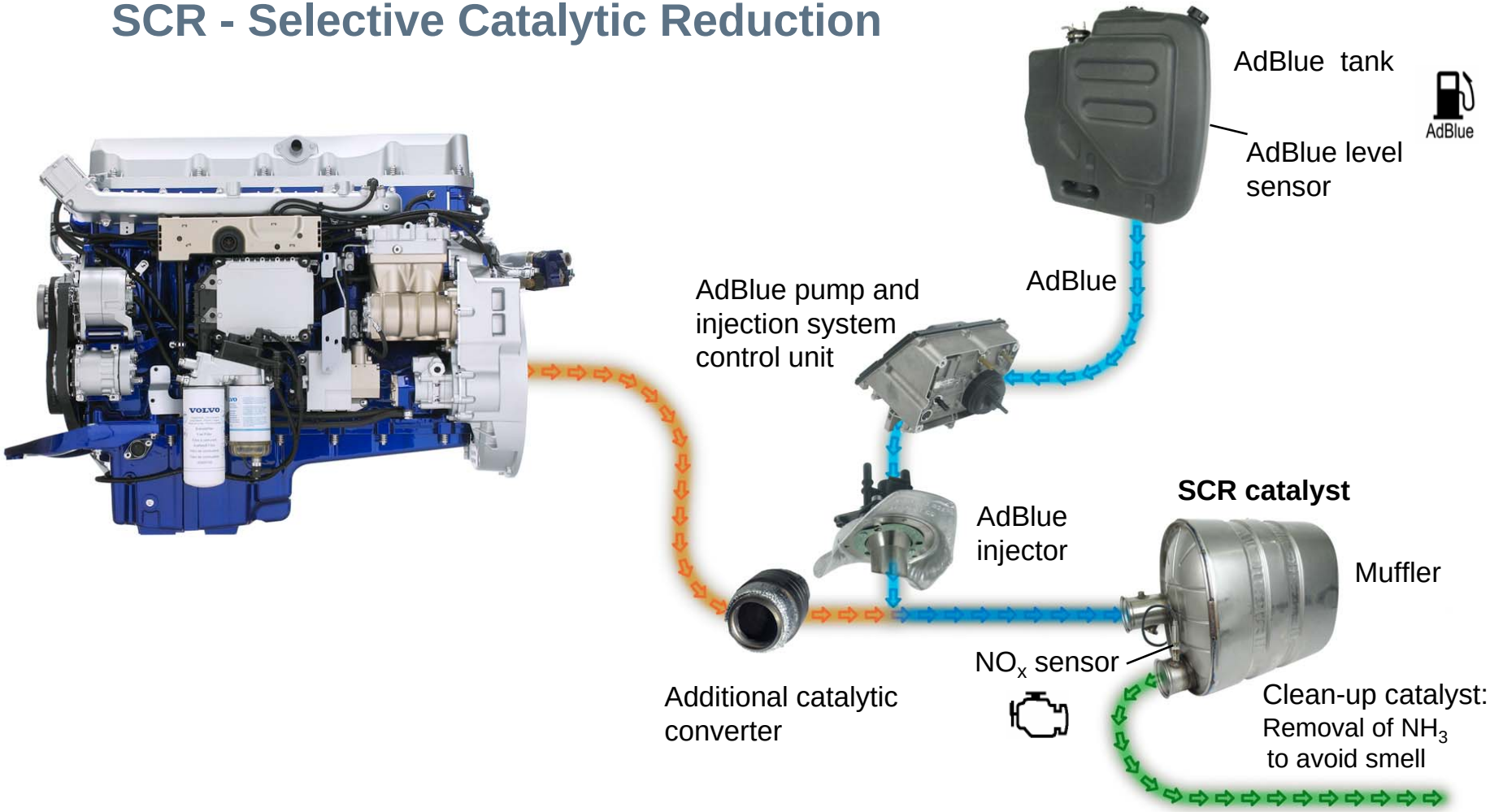
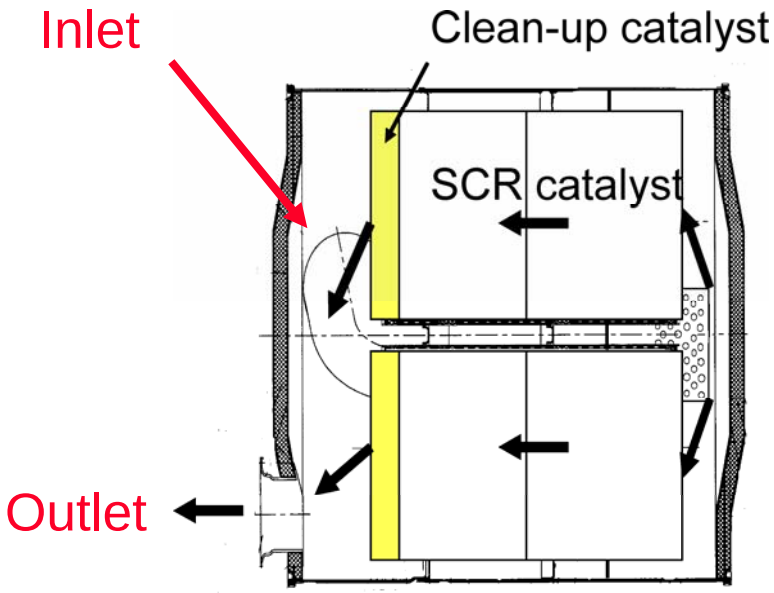


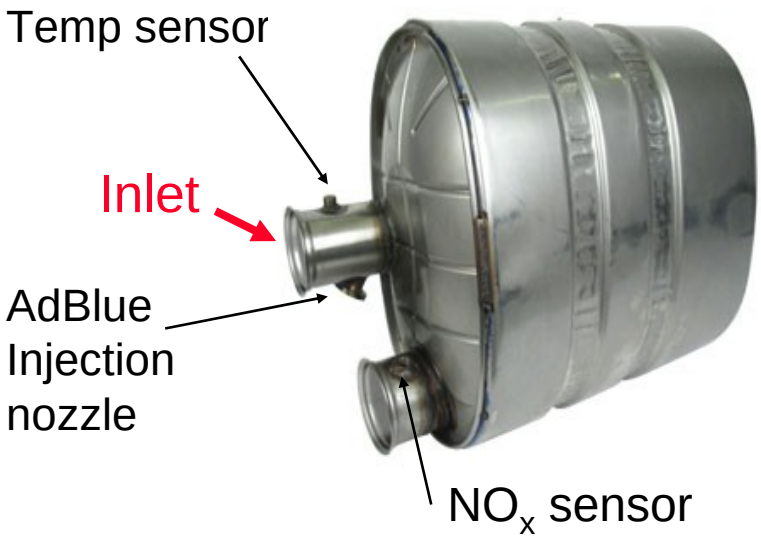
Fig. 1. Schematic of the Urea-SCR System

SCR - Selective Catalytic Reduction



SCR – Muffler and AdBlue injection

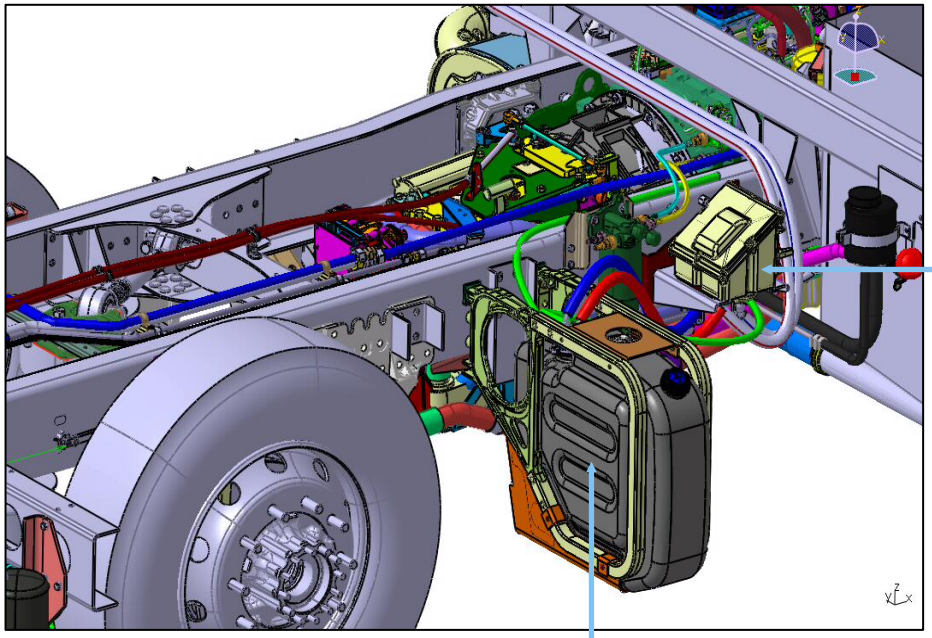




Pre catalyst

AdBlue injection nozzle

SCR installation on Volvo B7R/RLE



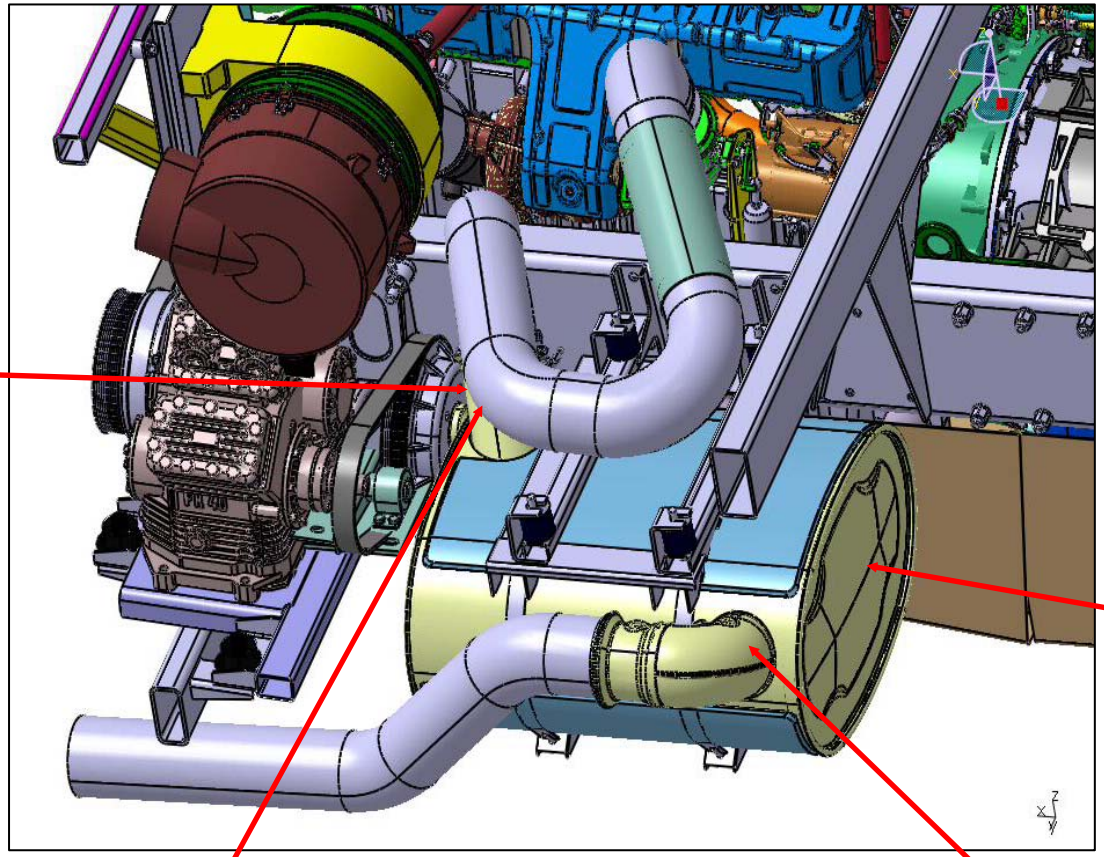
AdBlue pump and dosing unit

Lefthand side variant

AdBlue tank

SCR installation on Volvo B7R/RLE

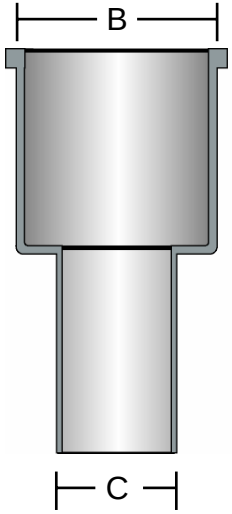
SCR system weight between100 -125 kg



AdBlue tank and filling neck

The industry has agreed on a automotive AdBlue tank filling neck insert standard to facilitate sealed depot system

AdBlue tanks 34, 40 60 l

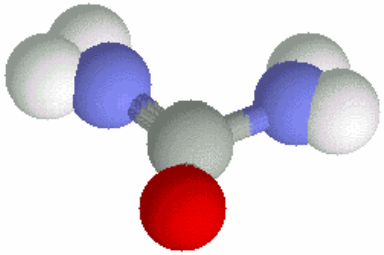


Filling neck insert drawing.

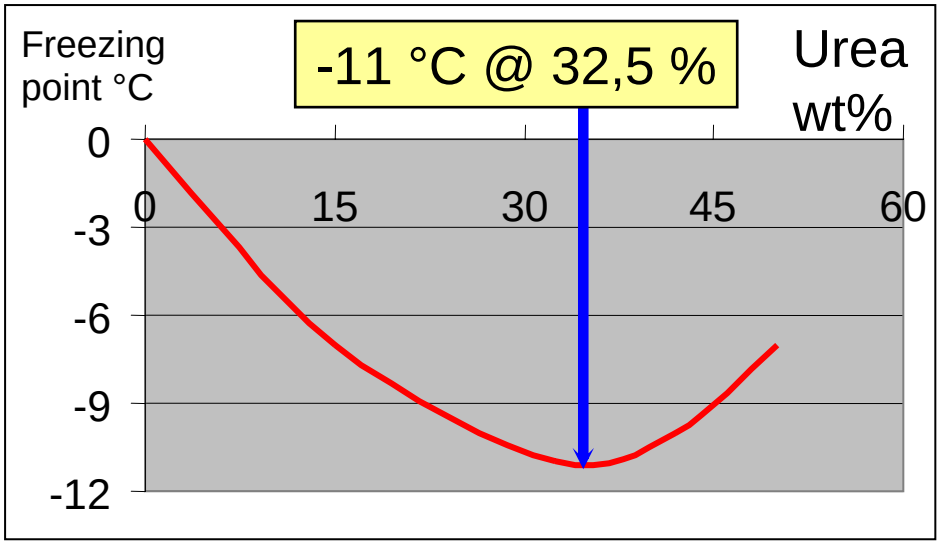
B = 43.5 -/+0.1 mm

C = > 26.8 mm

AdBlue: Urea $(NH_2)_2CO$



- Meets requirements:
  - non toxic, regarded safe to transport, handle and store
  - Frequently used in other applications
    - Fertilizer, food industry …
- Water soluble
  - > 50% (108g/ 100 ml H_2O)
  - 32,5 % **eutectic point**
- Weight 60 g/mol
- Melting point 135 °C
- Meets DIN 70070 standard
- Corrosive to certain metals
  - (zinc, copper, non alloyed steel)
- Produced in large volumes at a stable price



Urea Infrastructure Development: Some European experiences

Basically three avenues for urea distribution

- fuel stations and/or truck stops
- filling in a fleet depot
- Small canisters available for purchase

Automotive Urea Infrastructure

- Urea tank to be filled each time diesel is filled
- On board diagnostics monitor urea level and notify driver
- The infrastructure will be needed to ensure the compliance to emission legislation
- First step is establishment of a minimum infrastructure to ensure the availability for the first trucks and buses on the market

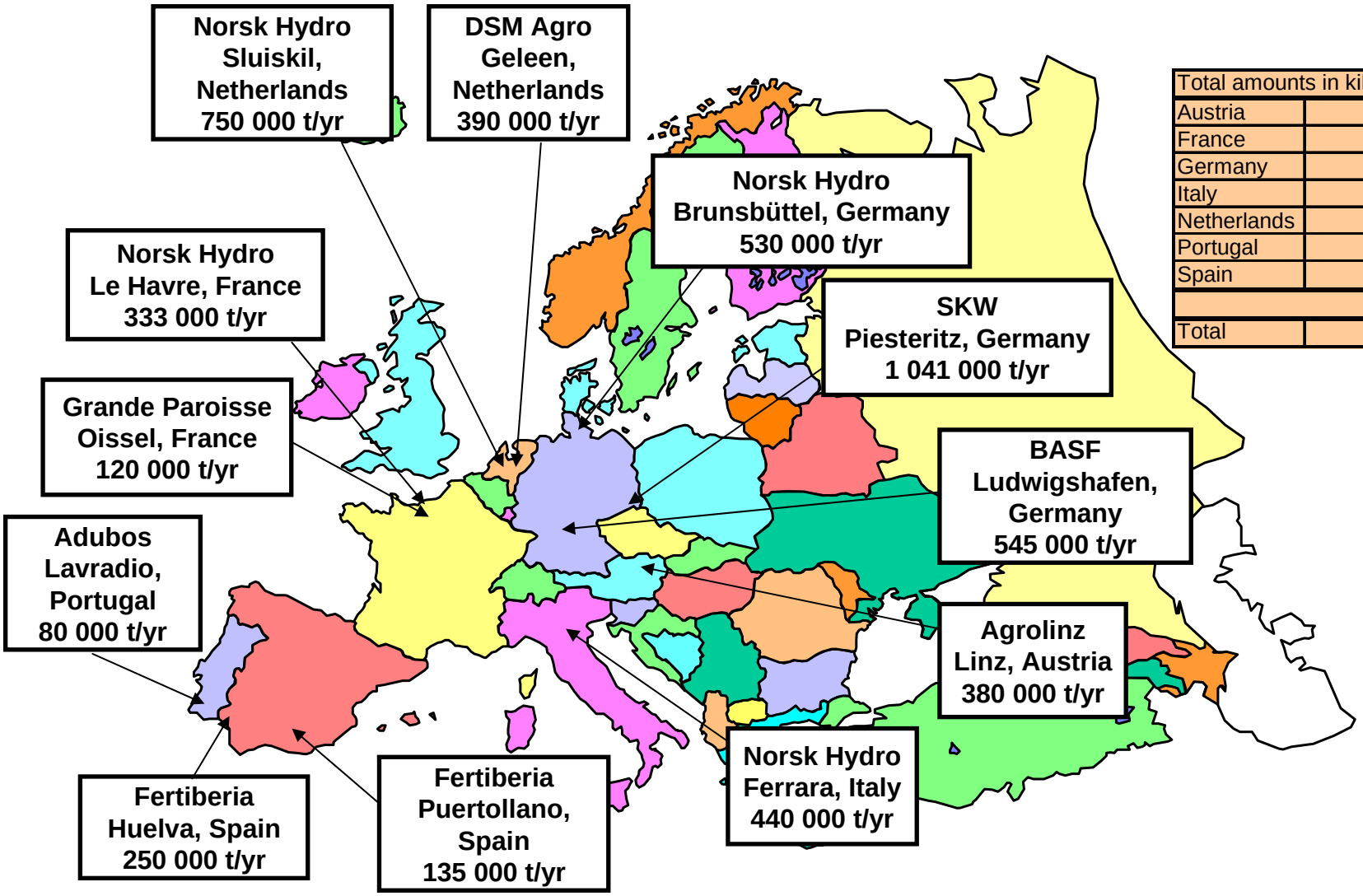
Adblue urea filling – Fuel stations

- Open system
- Major oil companies develops infrastructure (Total, Shell, OMV)
- Slim Line spout nozzle (Elaflex)
- Magnetic Ring in the urea tank filler neck inlet prevents spilling
- Public urea filling station (Total Stuttgart)
- New stations being added continuously
- Website Adblue4you.com shows where Adblue can be found in certain European countries

Urea filling – Depot option

- Sealed / open depot filling system
- Spill-free coupling offers urea filling integrated in a depot system for diesel fuel (Identic)
- Spill free couplings are today used for filling diesel fuel
- Volvo partner YARA (Norsk Hydro) can support customers with infrastructure and AbBlue supplies

Production capacities of urea in 2002



Total amounts in kilotons	
Austria	380
France	443
Germany	2116
Italy	440
Netherlands	1140
Portugal	80
Spain	385
Total	4984

Automotive urea demand estimation

- Estimations of automotive urea consumption up till 2012 has been reported by ACEA
- Annual production of urea in 2002 was approximately 5 million tons. Corresponds to approximately 15 million tons of automotive grade urea.
- Automotive grade urea demand in 2012 is estimated to be approximately 3.5 million tons (20% increase in urea-demand)

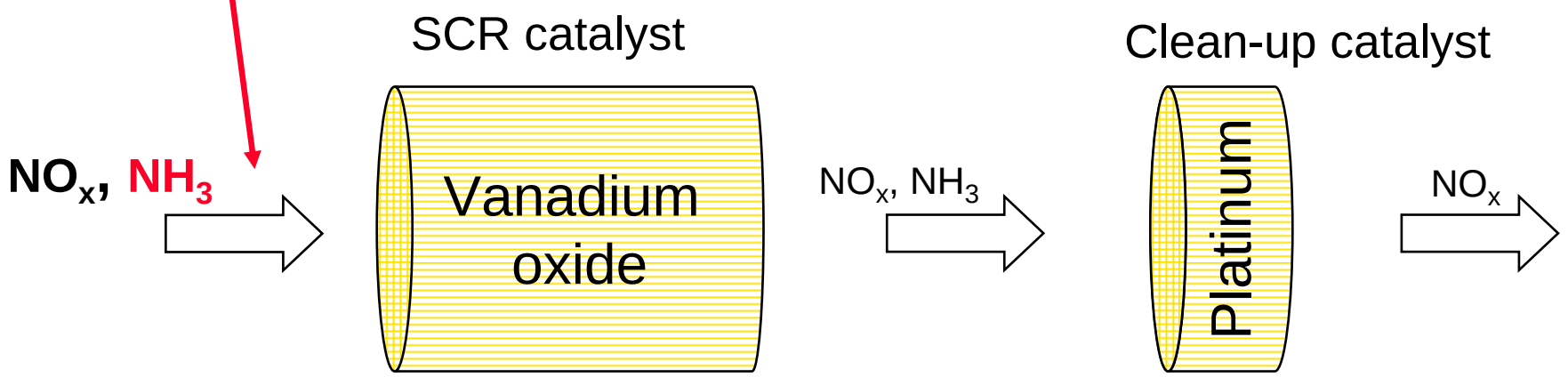
Some issues in Urea SCR: Mobile measurements and Ad-blue dosing strategies for low temperature performance

- Dosing strategy test to define the best dosing strategy for ad-blue for vehicles operating at low temperatures
- 23 vehicle multiyear durability study of a combined DPF/SCR system in the US using mobile measurements

Basic Chemistry of the SCR system

(Selective Catalytic Reduction)

Urea ($(NH_2)_2CO$) decomposes to ammonia (NH_3) and CO_2 in hot exhaust gas (>130 °C) through an HNCO intermediate (thermolysis and hydrolysis)



Clean up catalyst remove surplus ammonia to avoid smell

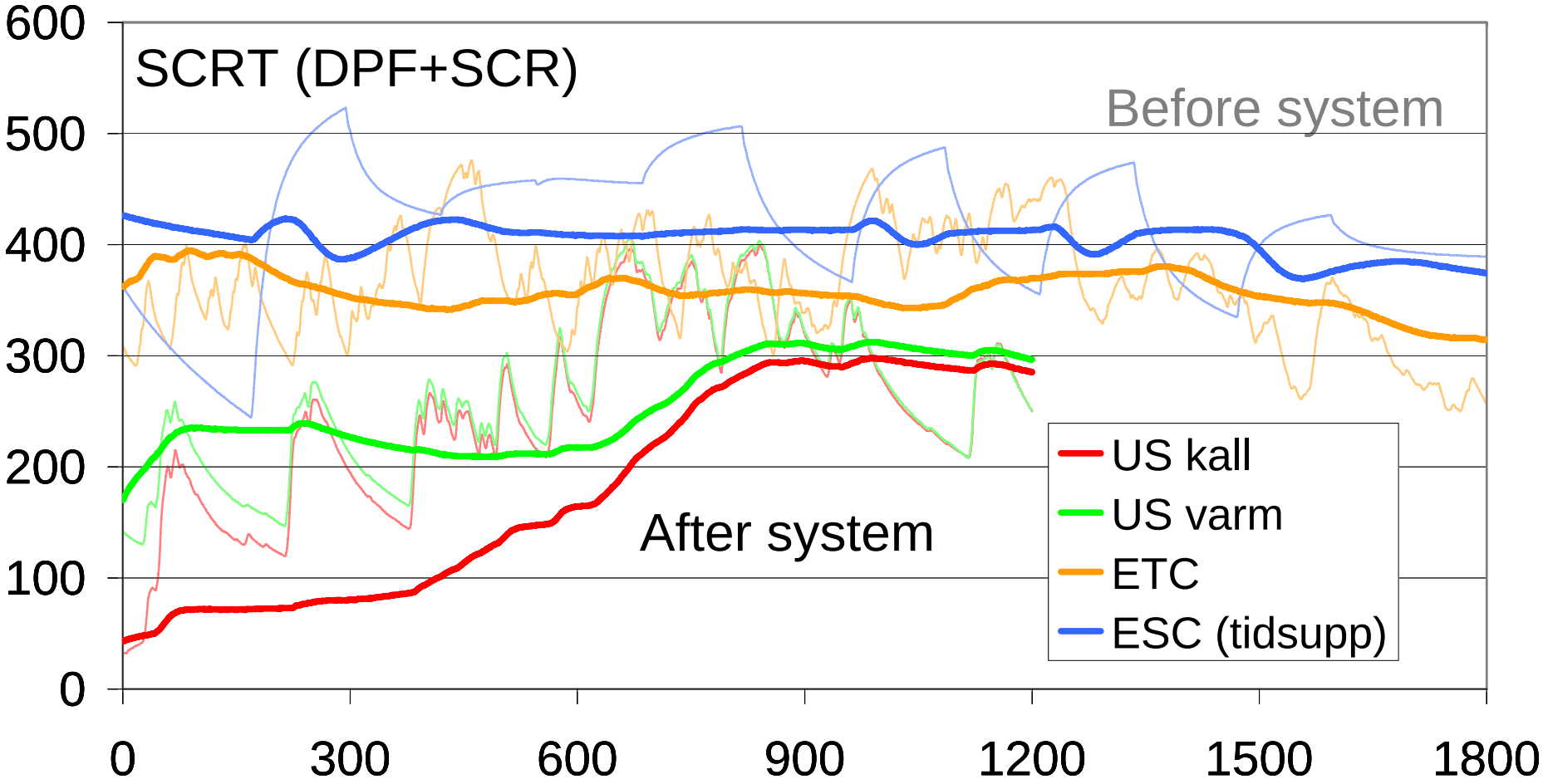
Ammonia reduces NO_x in the SCR catalyst:

- $NO_2 + NO + 2NH_3 \rightarrow 2N_2 + 3H_2O$ *fast*
- $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ *intermediate*
- $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$ *slow*

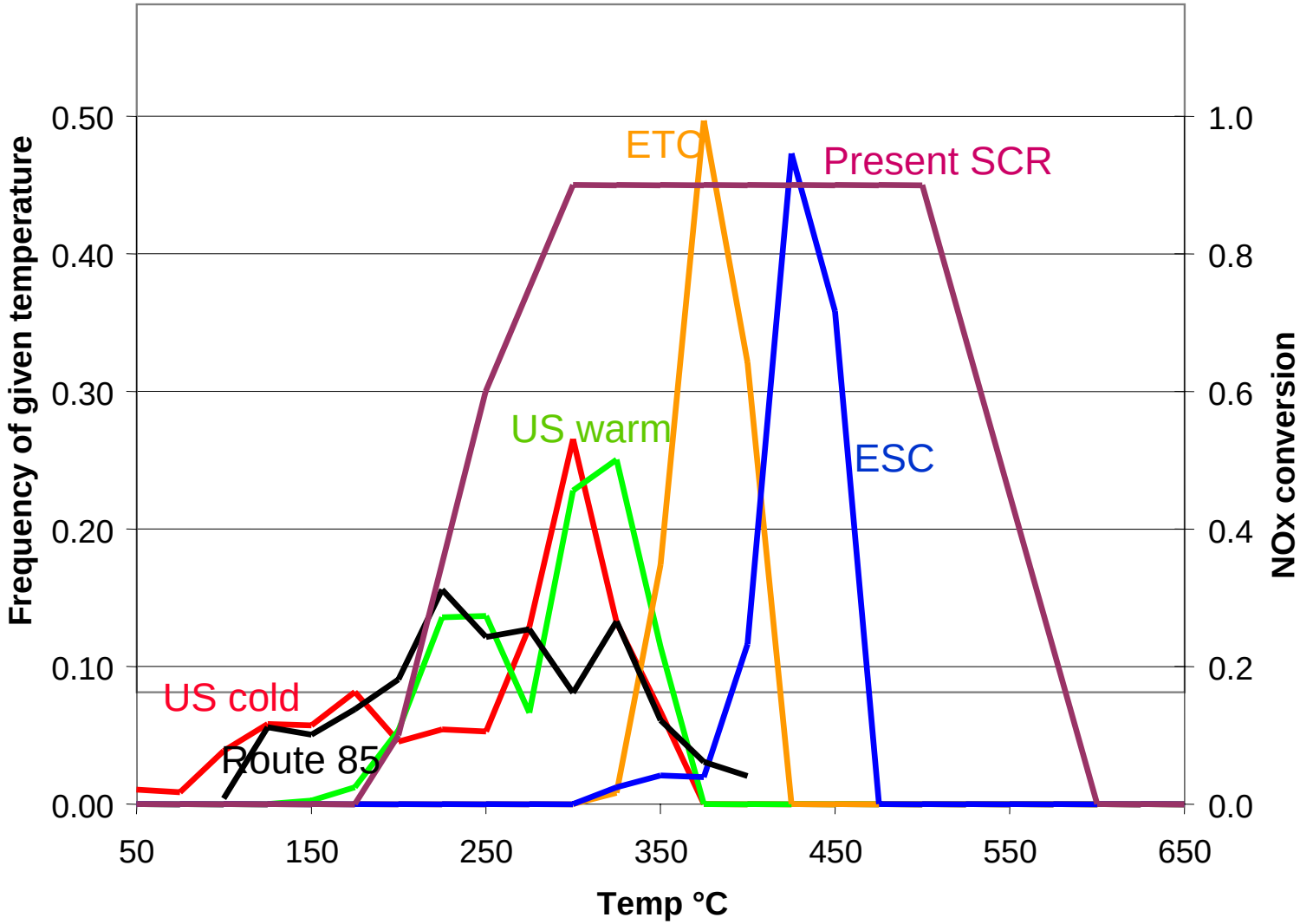
  $\Rightarrow$ $NO/NO_2 = 1/1$ is best

Temperature > 200°C needed

Temperature in exhaust system



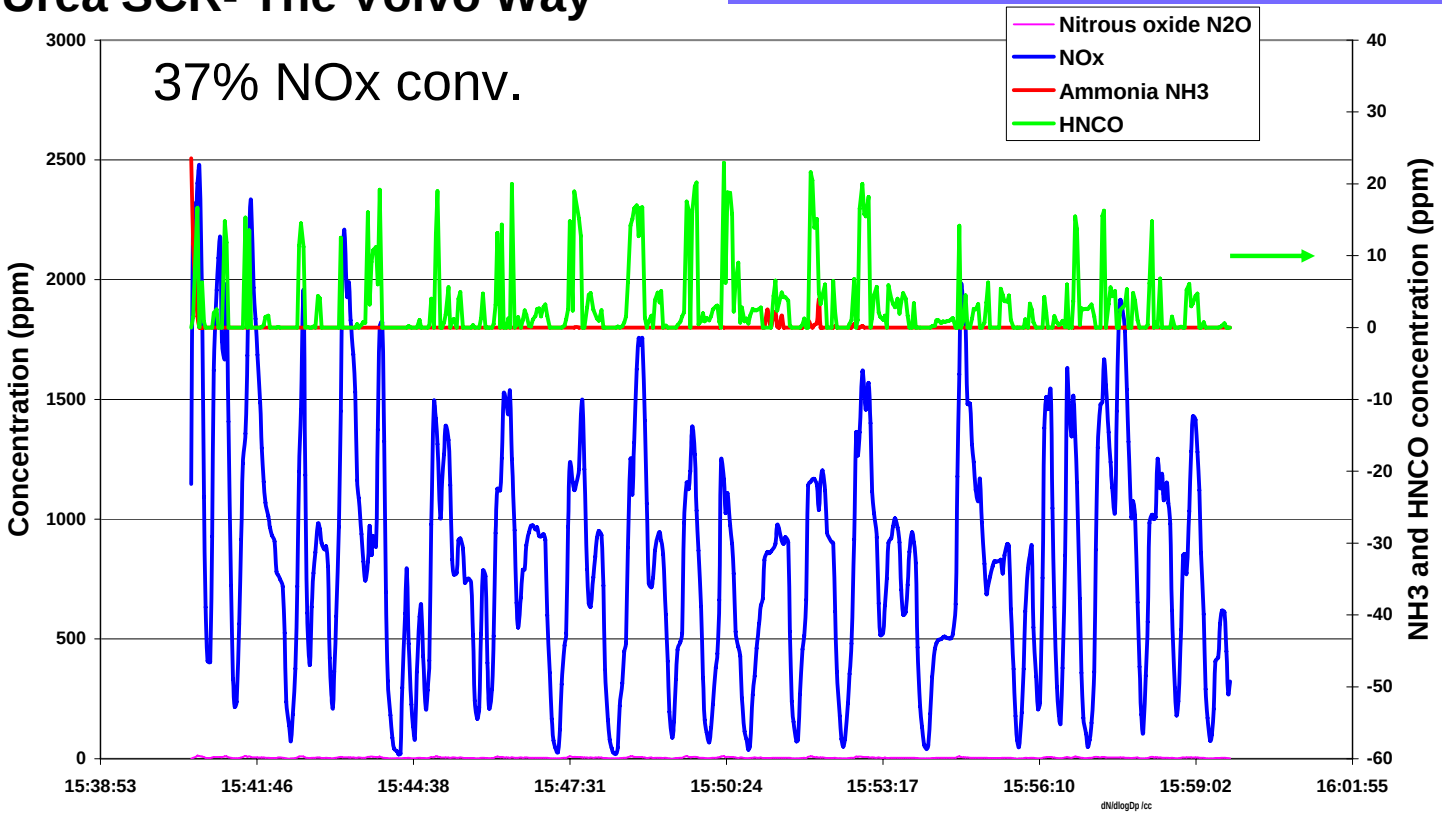
Active temperature range for SCR catalysts

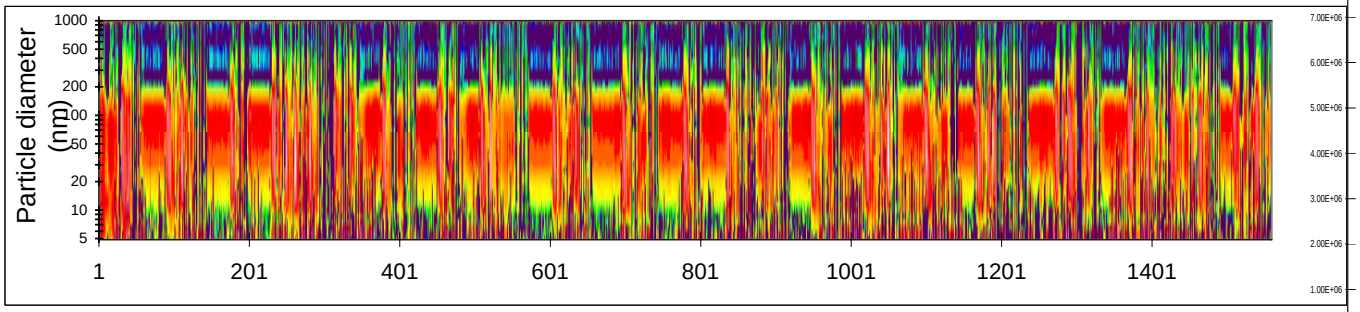


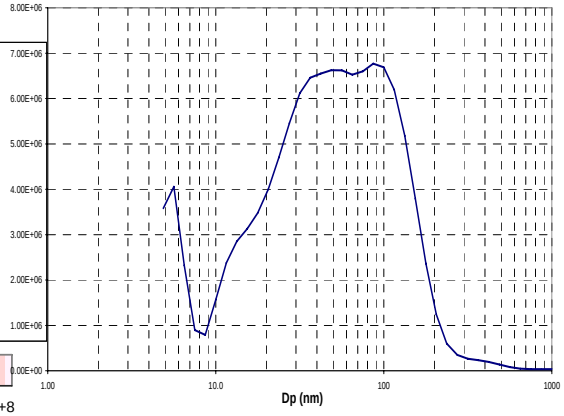
Urea Dosing strategy tests for low temperature operation such as route 85

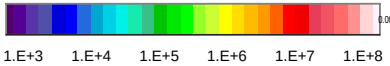
- Three different engine maps were tested using several different urea injection timing strategies and dosing amounts
- Simulated city bus route cycle for low temperature operation (like route 85)
- Monitoring of both gas phase compounds and particulate matter formation with both FTIR and a state-of-the-art particulate matter measurement
- Balance between NOx conversion and NH_3 slip and production of cyanuric acid at too high dosing rates.

Urea SCR- The Volvo Way



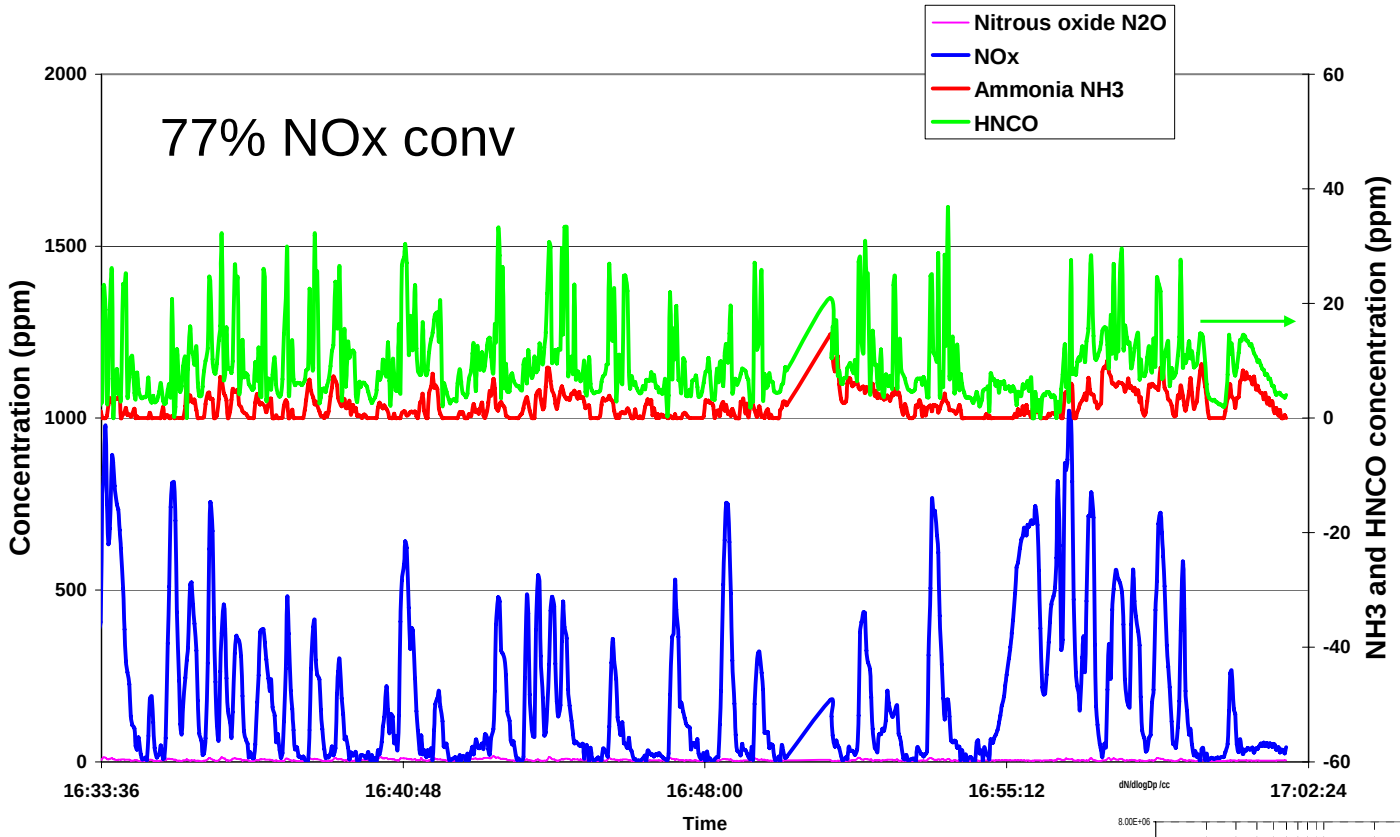


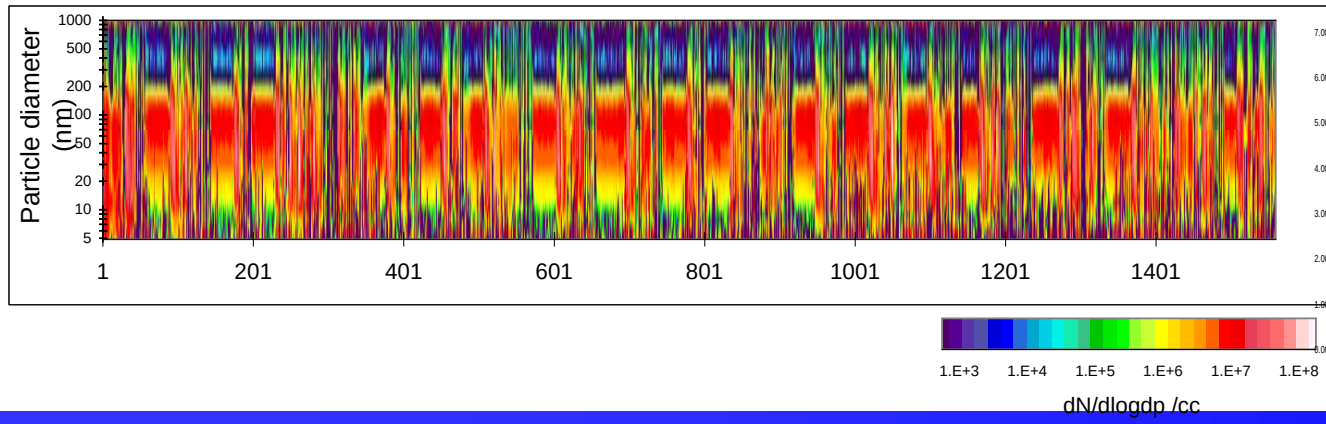


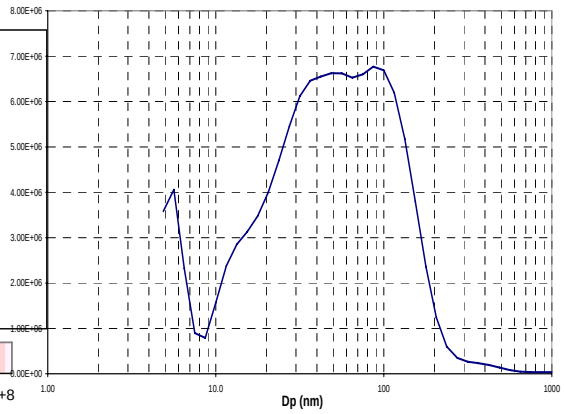


dN/dlogdp /cc

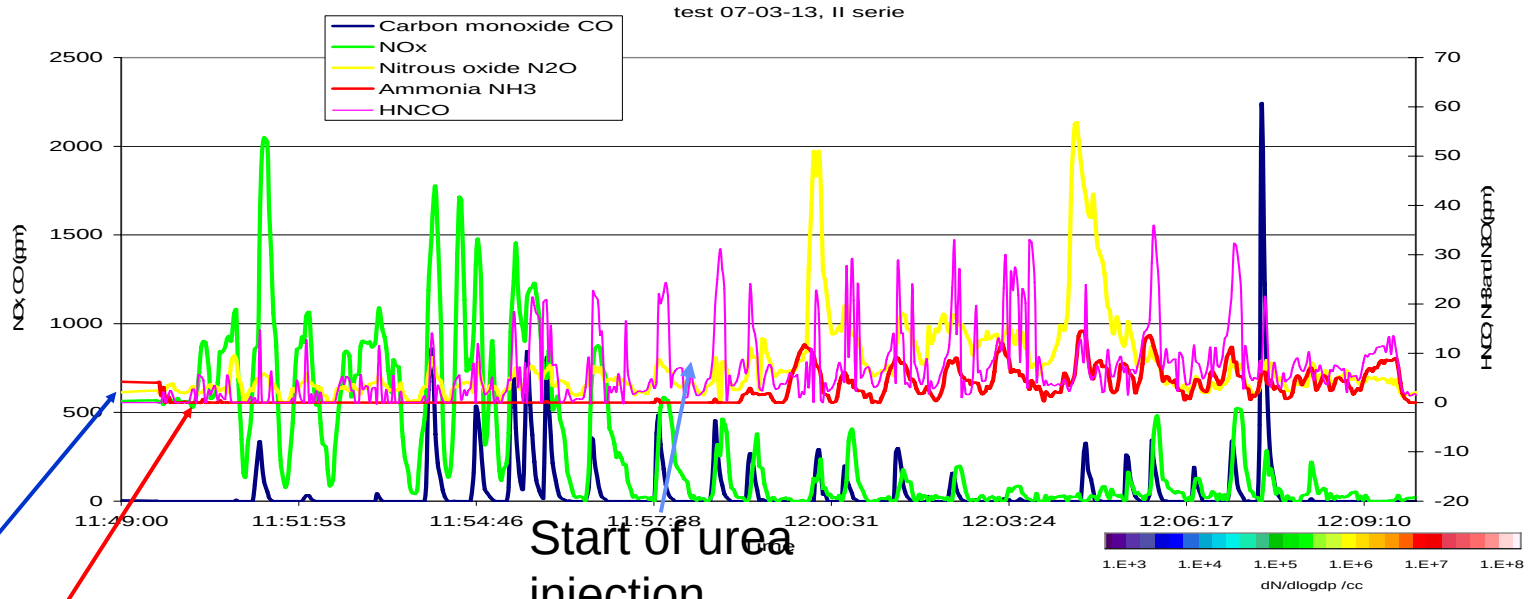
Urea SCR- The Volvo Way





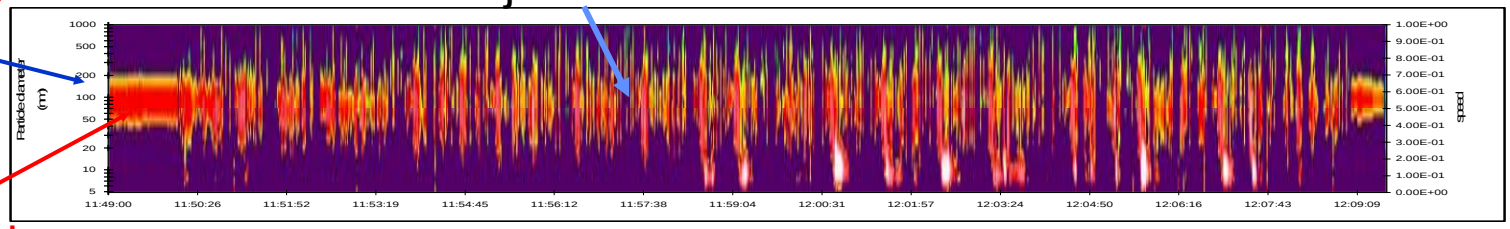


Urea SCR- The Volvo Way

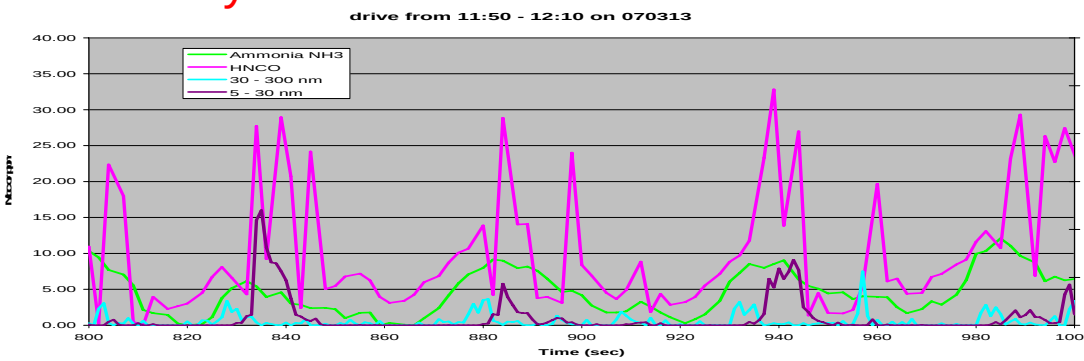


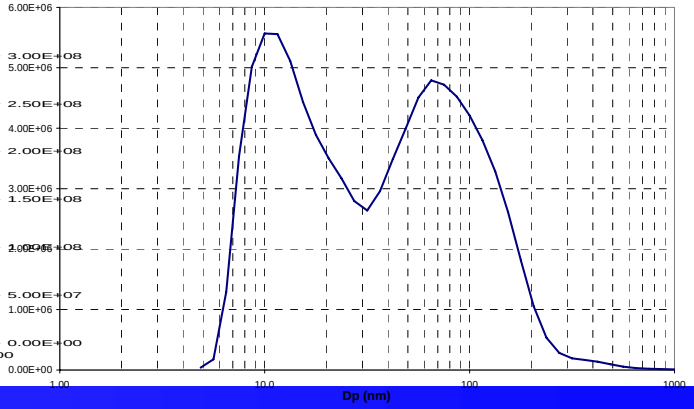
Start of urea injection

Idling



Start of Cycle





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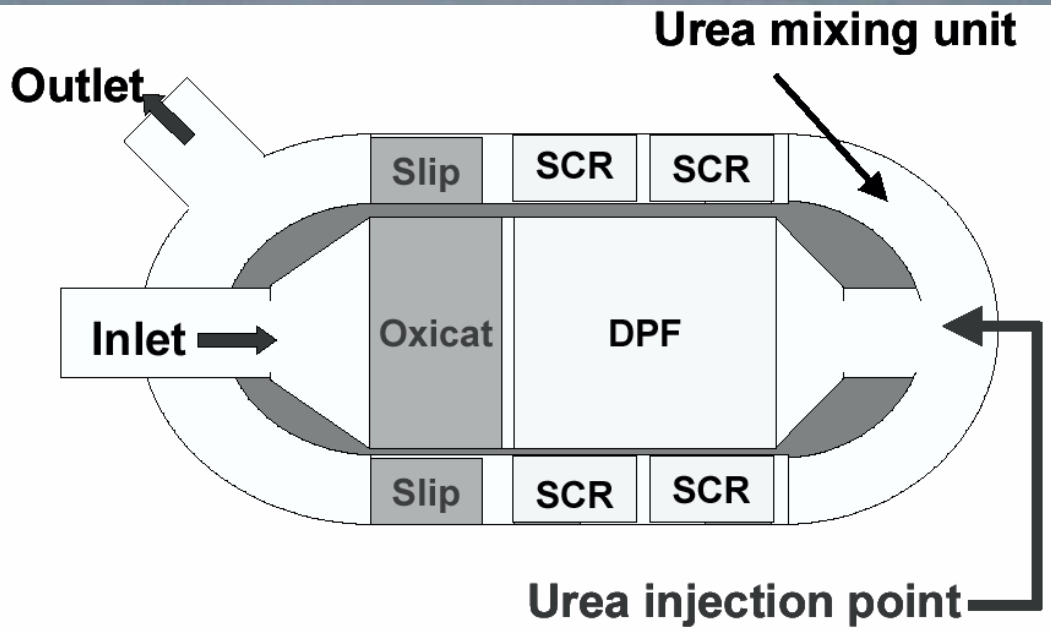
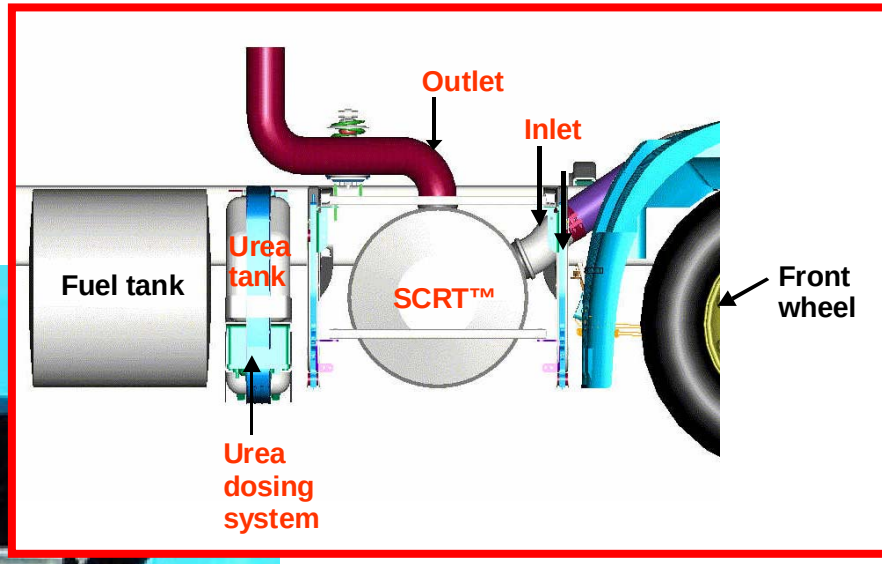


Figure 1: Schematic Representation of the Compact SCRT™ Concept

SCRT System

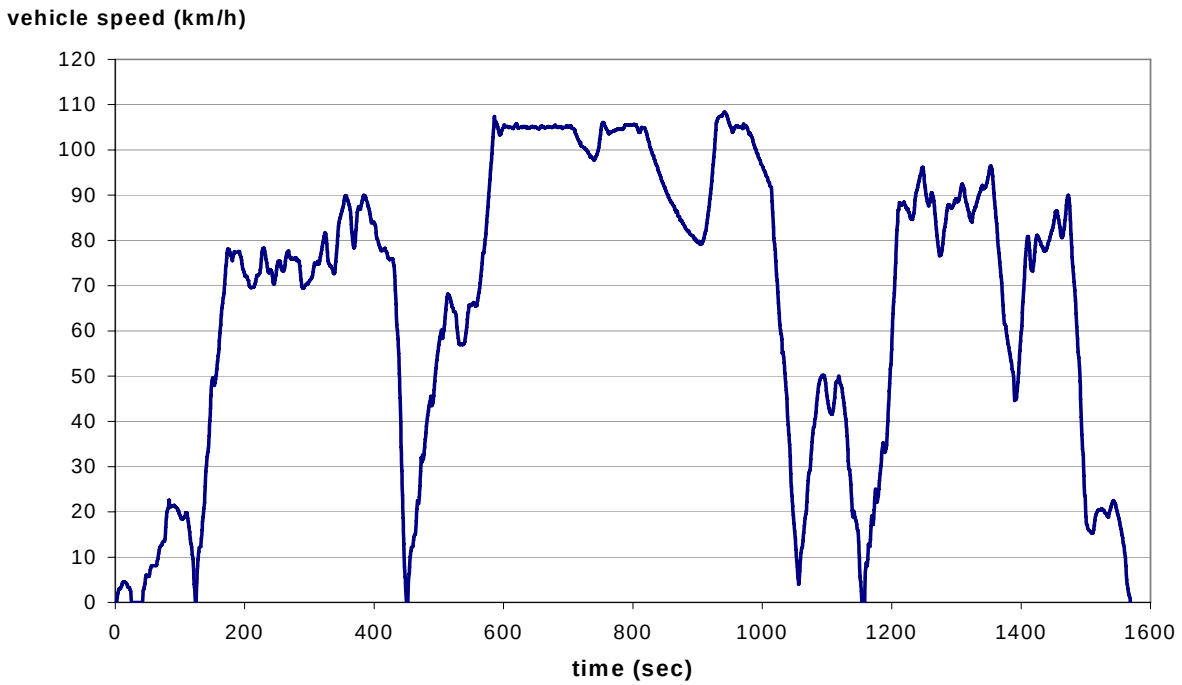

2002 5 17


Outlet
Inlet
Fuel tank
Urea tank
SCRT™
Front wheel
Urea dosing system

Urea SCR- The Volvo Way

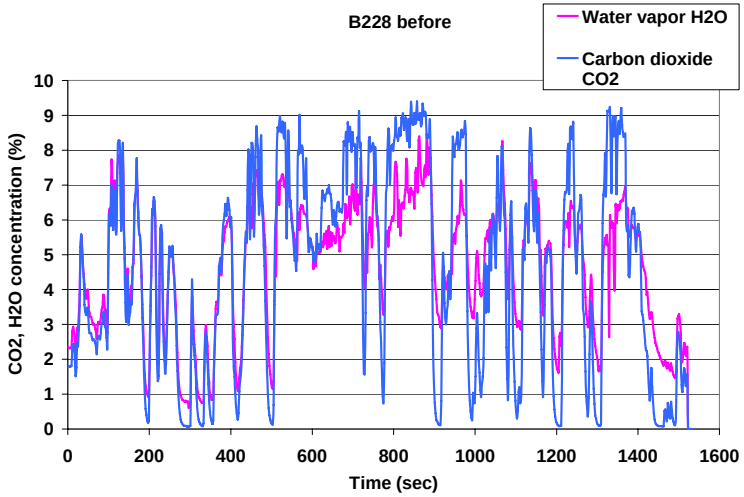
- Multi-year gas phase emission testing of a fleet of 23 vehicles
- Both engine out and tailpipe measurements using mobile FTIR

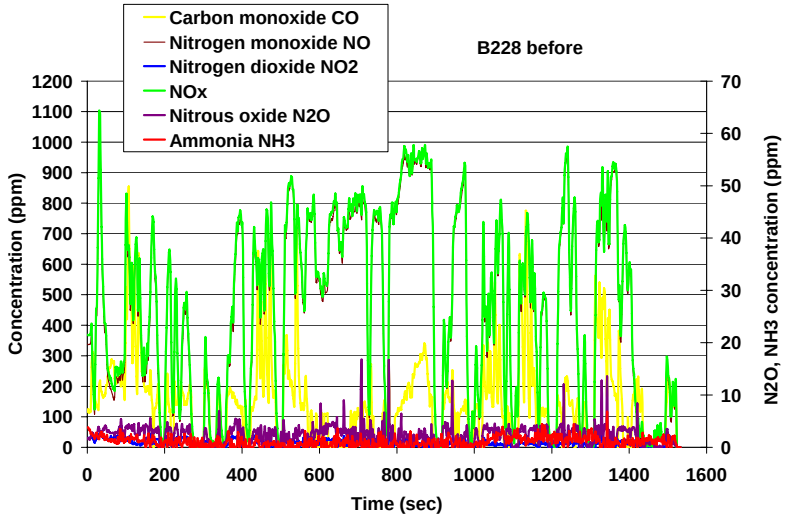
- Engine Volvo D12C 12 liter 465 hp @1300 rpm
- Total 71.5 liter aftertreatment unit (DPF + SCR)
- 18-mile simulated distribution route:

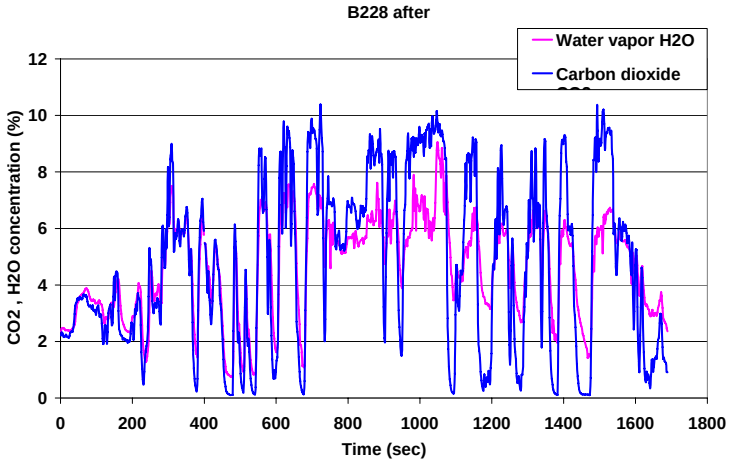


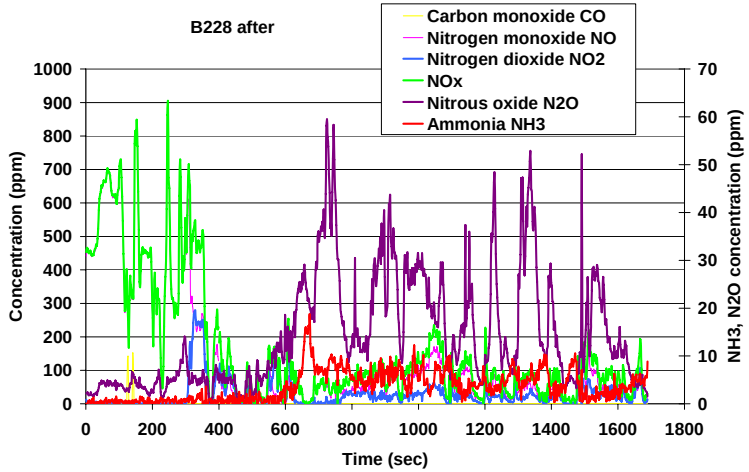
FTIR results from on-road tests on the 18-mile route

Truck B228. Tailpipe emissions upstream and downstream of the CEATS system









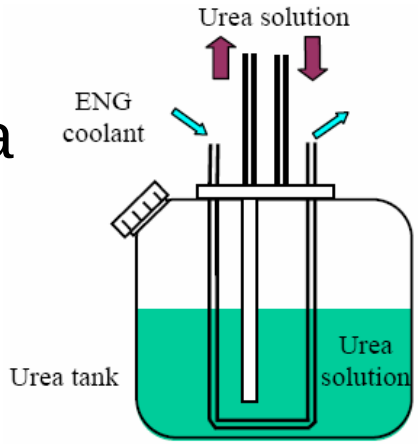
Summary of Emission Results

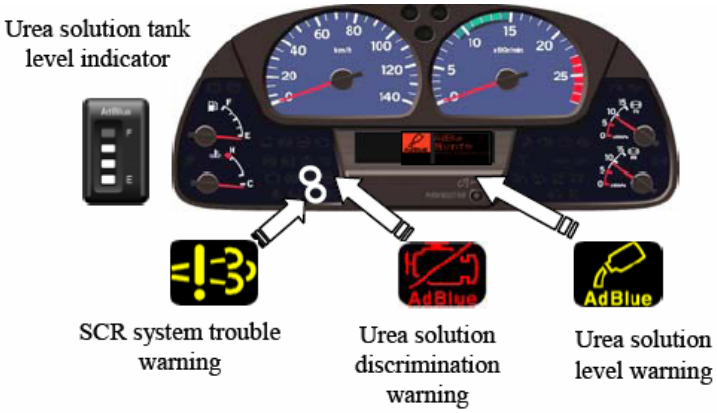
Year	Average NOx conversion	NH_3 slip	US07 NTE compliance within fleet (cold)
October 2004	75 +/- 6%	20 ppm	91 %
June 2005	73 +/- 8%	28 ppm	91 %
June 2006	61 +/- 12%	30 ppm	70%

Overall durability is very good—
Truck mileage varies +/- 150,000 miles
Some trucks have driven over 350,000 miles

Summary

- Optimized engine with SCR for Euro VI and EuroV
- Infrastructure availability and refilling of Urea
- Onboard diagnostics
- More work needed for low temperature applications
- Durability, field tests with total 700 000 km driving without major
- **NOx reduction >75% possible**





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