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Diesel Emissions Basics

Emissions Aftertreatment

NSC vs SCR

What is DEF?

Are there other options to reduce NOx?



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What causes engine exhaust emissions?

• $C_xH_y + [O_2 + 3.77N_2] \rightarrow$

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♦ What causes engine exhaust emissions?
 ■ C_xH_y + [O₂ + 3.77N₂] →

 $CO_2 + H_2O + N_2 + O_2 + CO_2 + H_2O + HC + PM + NO + NO_2 + ...$

DOC DPF NSC/SCR

DOC = Diesel oxidation catalyst DPF = Diesel particulate filter NSC = NOx storage catalyst

SCR = Selective catalytic reduction

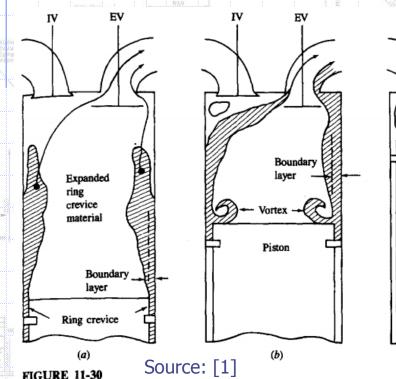
What causes emissions?

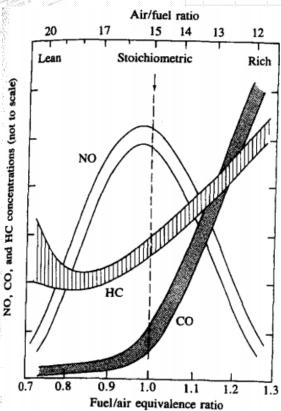
CO + HC are caused by incomplete combustion

(rich mixtures, crevice volumes, flame quenching, etc.)

Vortex

(c)





Schematic of flow processes by which ring crevice HC and HC desorbed from cylinder wall oil film exit the cylinder: (a) exhaust blowdown process; (b) during exhaust stroke; (c) end of exhaust stroke.⁶⁰

What causes emissions?

PM (soot) are formed due to liquid fuel evaporating and undergoing thermal and chemical transformations

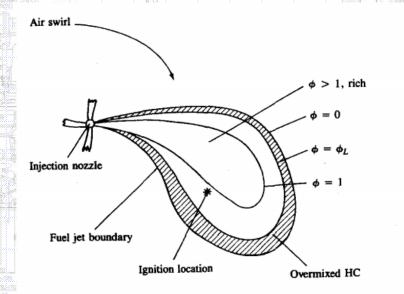


FIGURE 11-34

Source: [1]

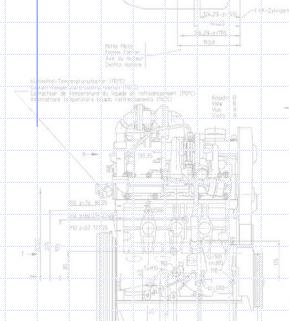
Schematic of diesel engine fuel spray showing equivalence ratio (ϕ) contours at time of ignition. ϕ_L = equivalence ratio at lean combustion limit (≈ 0.3). Shaded region contains fuel mixed leaner than ϕ_L .⁶⁷

What causes emissions?
 NOx are primarily formed due to high temperatures

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Who the heck cares about NOx?

Causes smog (remember smog days?)





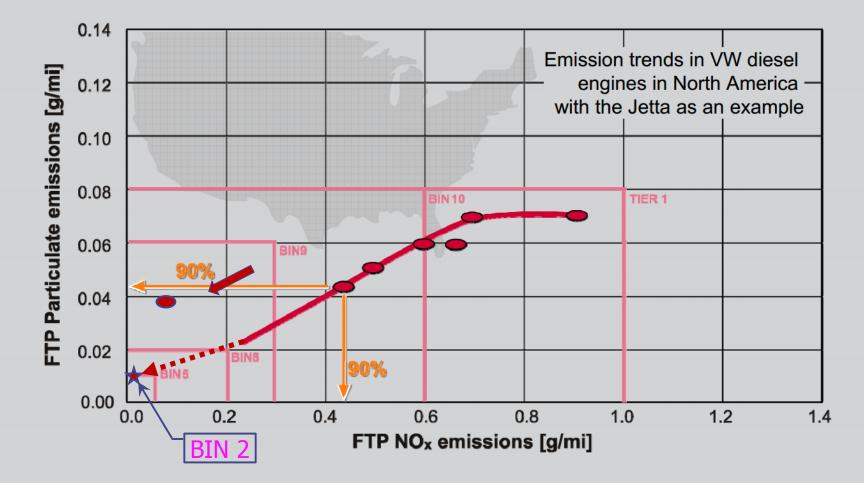
Ontario's coal power phase-out has helped reduce particulate air pollution across the province by 30% in 10 years.

Causes respiratory problems

Who should care about NOx? YOL

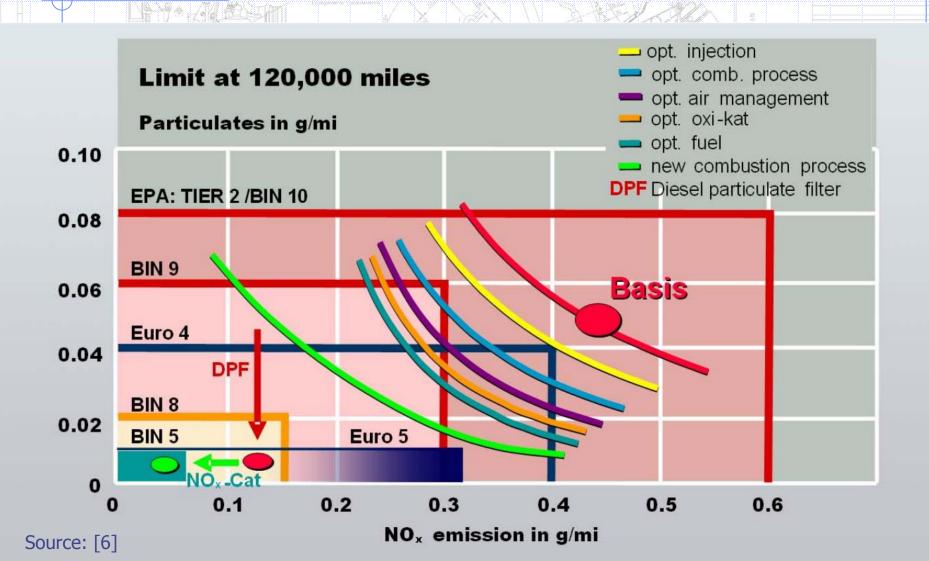
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Adapted from [3]

Diesel Aftertreatment



Diesel Aftertreatment

CRS 2-20

SCR-System

NO_x-Speicherkatalysator

Source: [11]

Integriertes Ventiltriebsmodul mit VVT-Steller

Zylinderdrucksensor

Niederdruck-AGR-Kühler



Saugrohr mit integriertem Ladeluftkühler und Hochdruck-AGR-Ventil

Hochdruck-

AGR-Kanal im

Zylinderkopf

NSC vs SCR

Both NSC (NOx storage catalyst) and SCR (selective catalytic reduction) are equally effective in dealing with NOx.

Both require a chemical reductant

Both have pros and cons

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General Conditions for NO_x Catalytic Converter Systems

1. NO_x-storage catalytic converter (discontinuous)

- $\lambda > 1$: NO_x storage (formation of Nitrates)
- $\lambda < 1$: NO_x release and reduction
- Low sulfur fuel (S < 10 ppm) necessary
- Additional fuel consumption as a result of catalytic converter regeneration

2. Urea SCR catalytic converter (continuous

- Hydrolysis and thermolysis of urea → formation of NH₃
- Reduction of NO_x in the SCR catalyst using NH₃
- · Logistics necessary for the reduction agent, urea
- Customer-friendly topping up of urea at filling stations



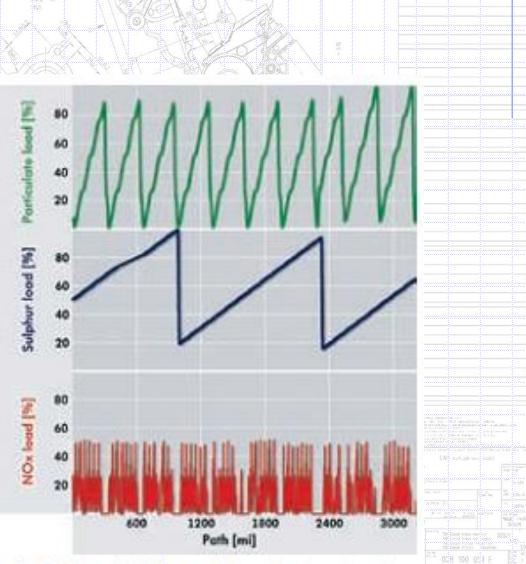
NSC VS SCR

Regeneration conditions

DPF regeneration λ > 1 DPF temperature ~ 650 °C Duration < 15 min

D_eSO_x regeneration λ < 1 NSC temperature ~ 620 °C Duration < 20 min

D_eNO_x regeneration λ < 1 NSC temperature 250 - 450 °C Duration < 15 sec



Source: [5] Figure 12: Graph of regeneration modes in the dynamic driving cycle (standard road cycle)

System Benchmark Test

	NO _x Storage Cat	SCR System
NO _x Red. Potential (Golf)		
FTP	+	+
US06	+	++
NEDC	+	+
NO ₂ Emissions	+	+
HC	-	0
Fuel Consumption	-	0
Required Infrastructure	0	
Servicing	0	-
Packaging Space	-	
Error Rate / Complexity	0	-
Costs	-	

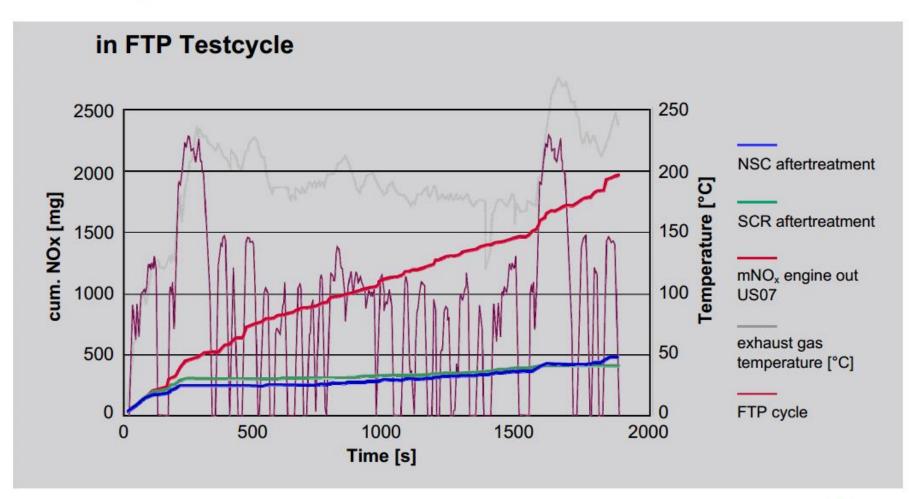


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Source: [3]

NO_x Emission Results of SCR and NSC

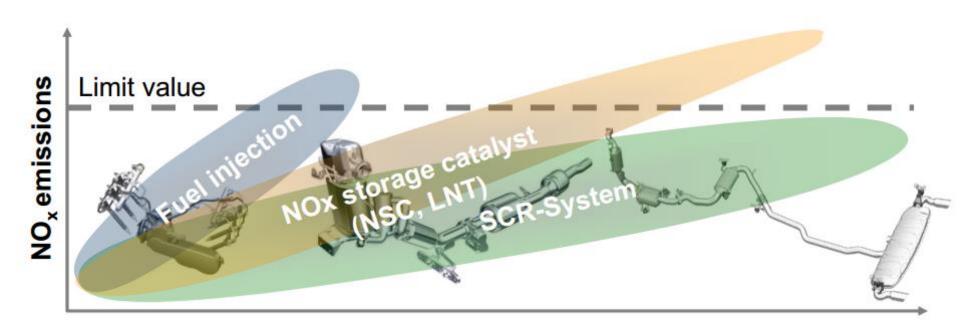
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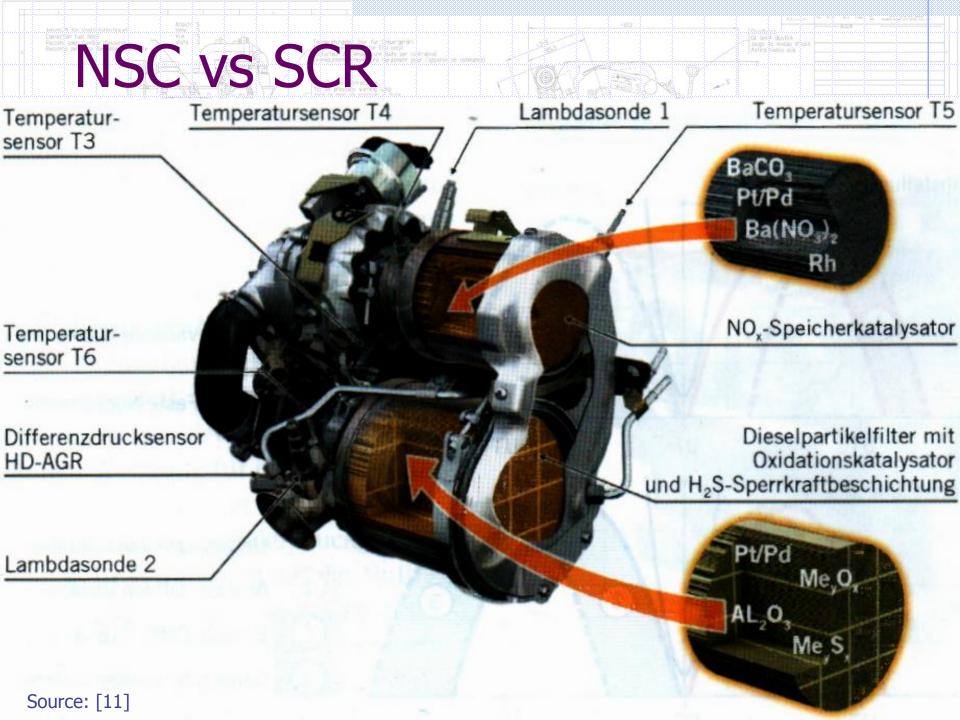
Measures to meet ultra low emission limits

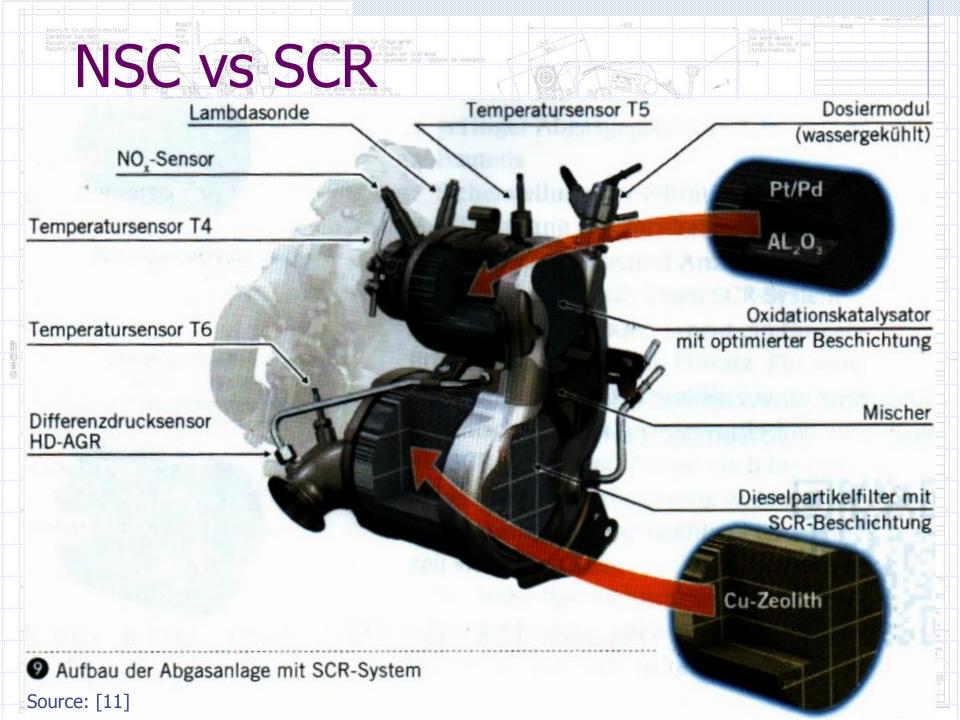




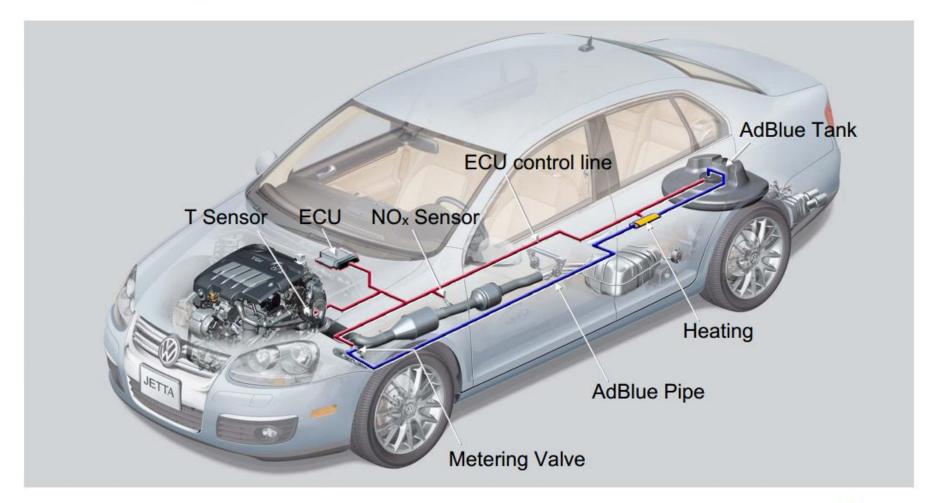
Vehicle weight







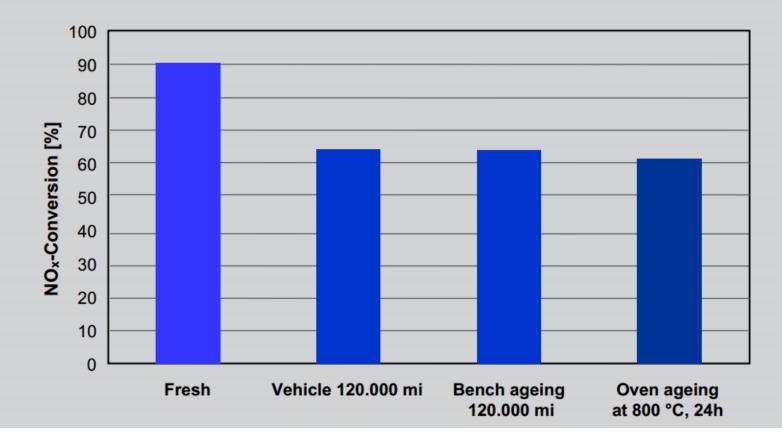
SCR-System Structure





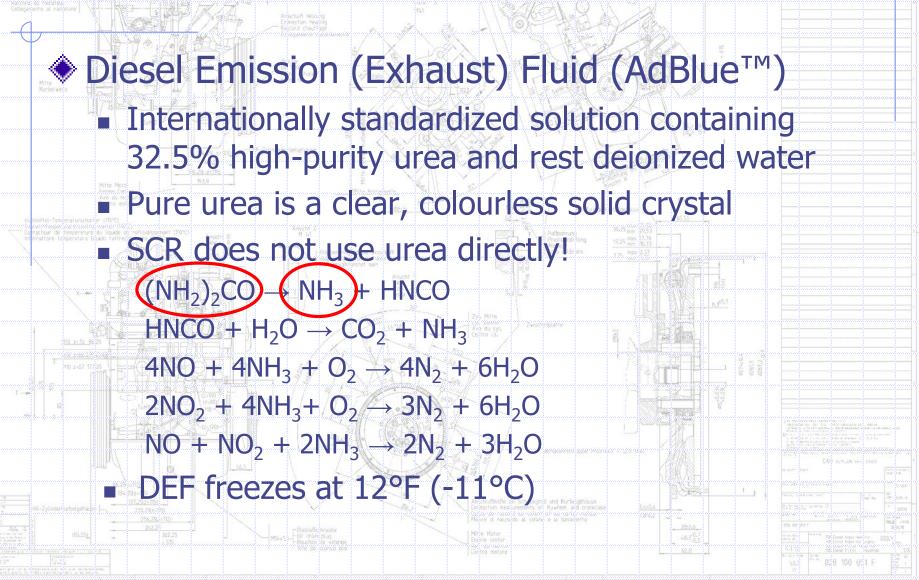
Correlation between Bench and Vehicle Ageing

NO_x Conversion at FTP cycle Golf class, 3500 lbs





What is DEF?



Other Ways to Reduce NOx

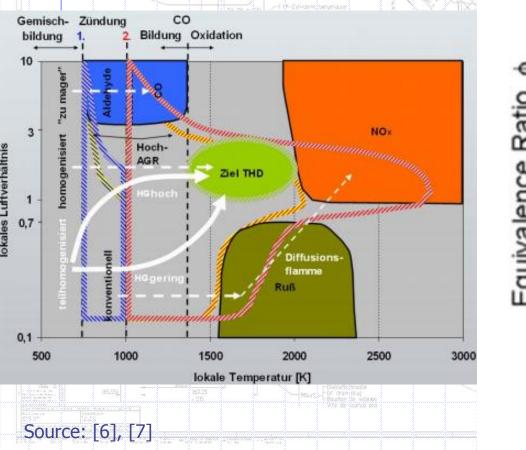
- Emissions reduction from the source combustion process
 - Involves lots of EGR (60-80%) and highly sophisticated control over air flow and injection
 - Many names used in industry: <u>PCCI</u> (premixed charge compression ignition), <u>HCCI</u> (homogenous charge compression ignition), <u>CAI</u> (controlled autoignition), <u>LTC</u> (low temperature combustion, flameless combustion, "smokeless Diesel"

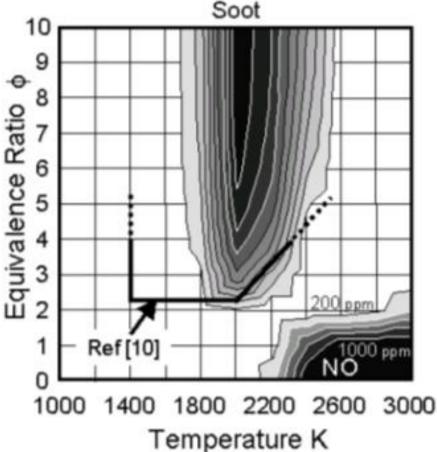
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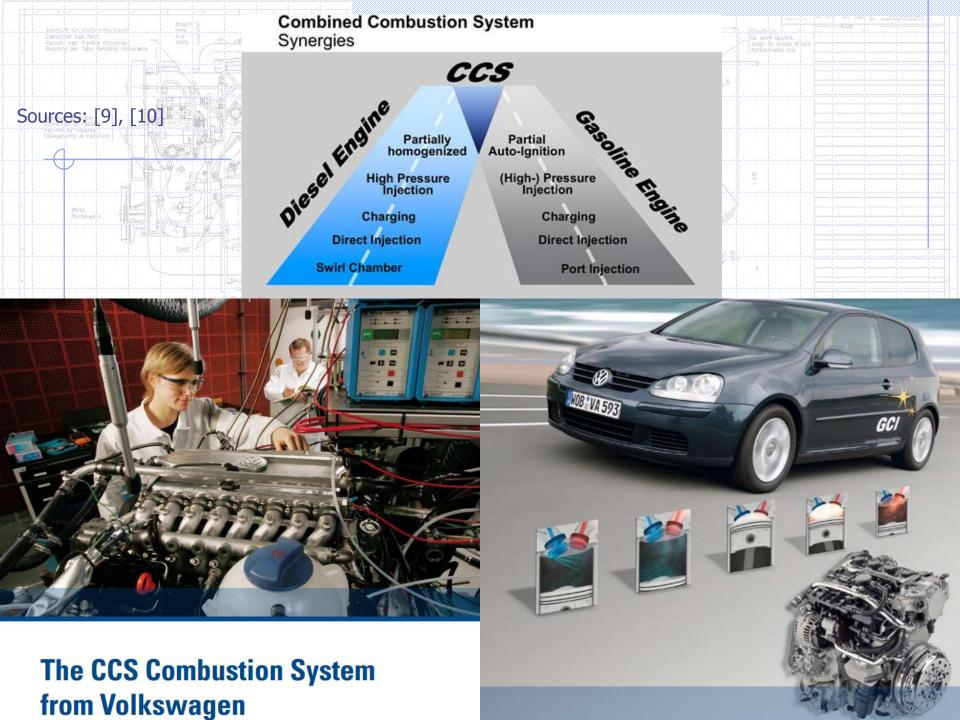
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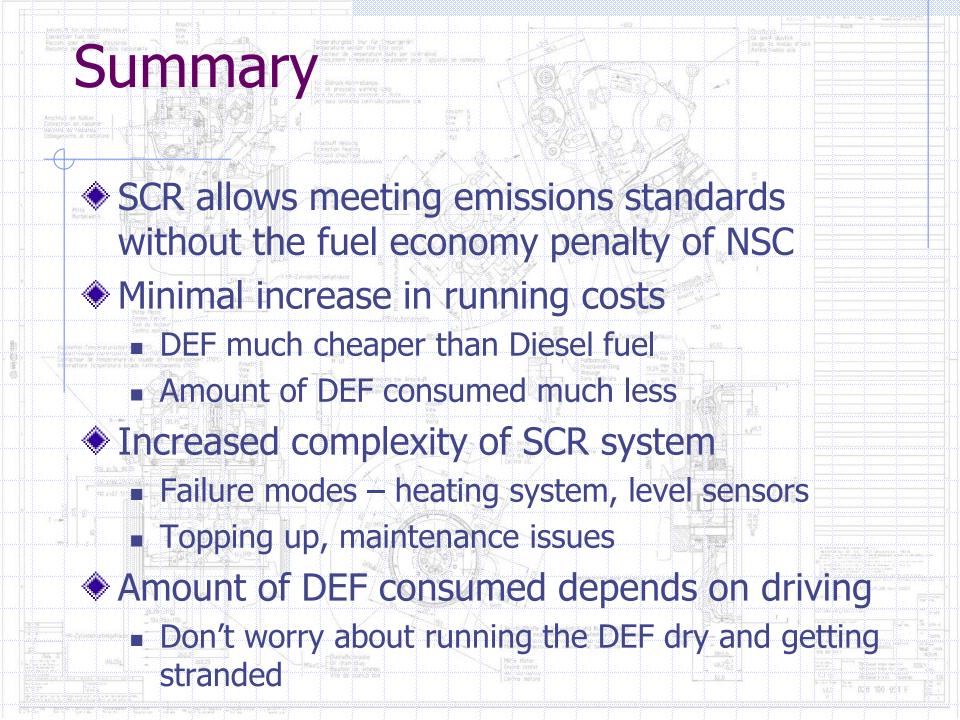
Other Ways to Reduce NOx

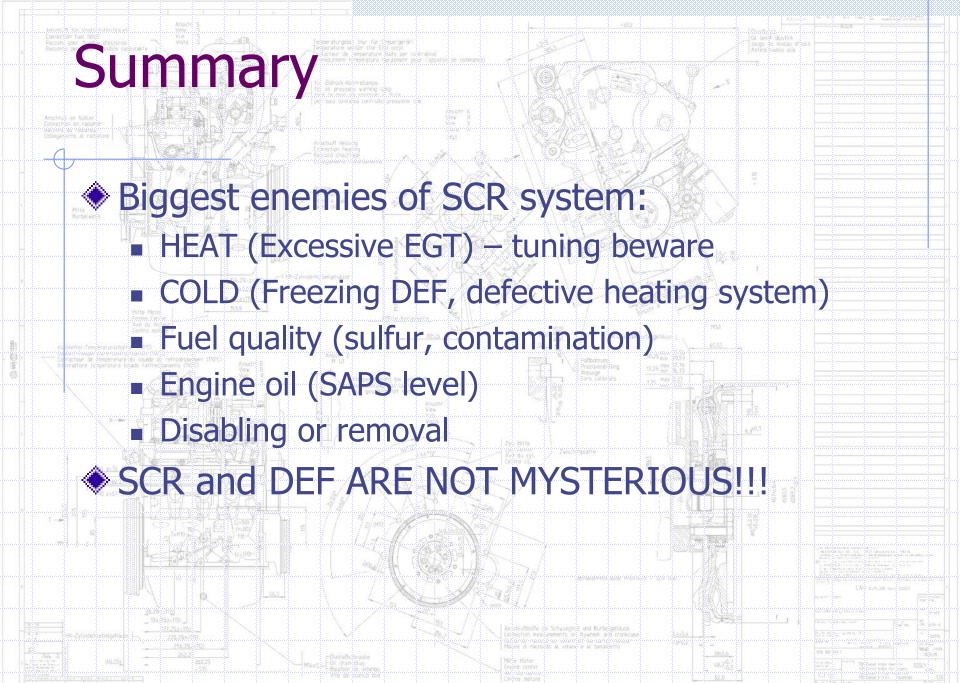
We have the know-how to reduce emissions drastically from right at the source











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