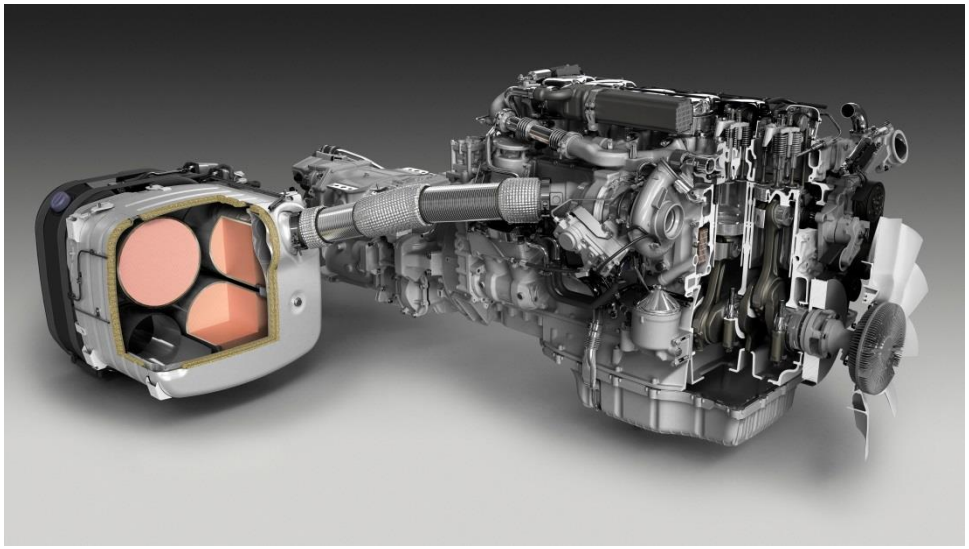
After-treatment of emissions from heavy duty vehicles



Jonas Granestrand

October 22nd, 2013

Who am I?

- 2012: Graduated as M.Sc. in chemical engineering
- Master thesis performed at Scania, focused on ageing of their SCR aftertreatment catalyst
- 2012 – 2013: Research project sponsored by Scania at the Cardiff Catalysis Institute
- 2013 – 201X: Ph.D. student at the division of Chemical Technology, KTH

Agenda

- Overview of emission challenges facing the on-road transport sector
- Focus on aftertreatment
- Scope of my own project

Pollutants from diesel trucks

- Nitrogen oxides (NO_x)
- Particulates
- Hydrocarbons
- CO
- CH_4
- CO_2
- N_2O

Products of incomplete combustion

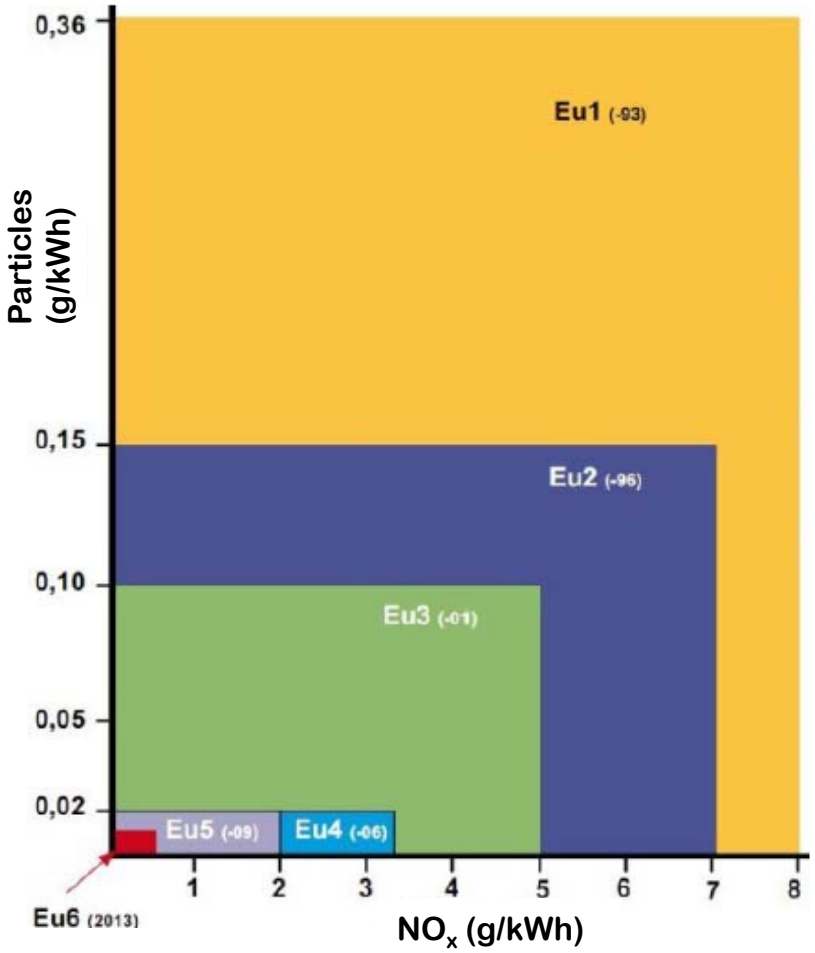
Local pollutants

Greenhouse gases

Reducing green house gas emissions

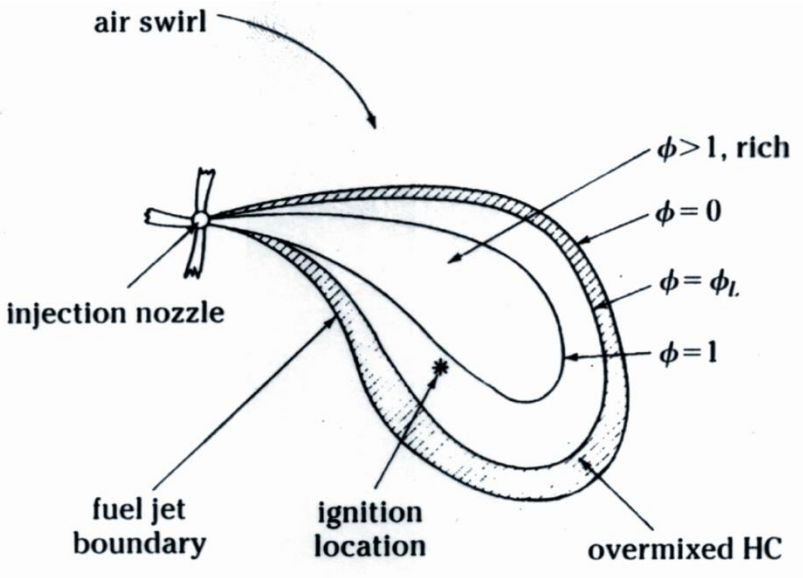
- Improve efficiency
  - Engine hybridization
  - Improved aerodynamics
  - Engine modifications
  - Efficient driving
- Alternative fuels

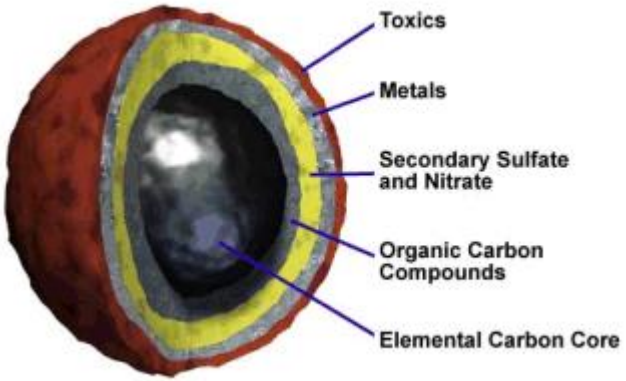
Emission legislation



- Emissions cut by over 90 % compared to 2000
- Euro 6 introduces particle number limits

Particulate matter

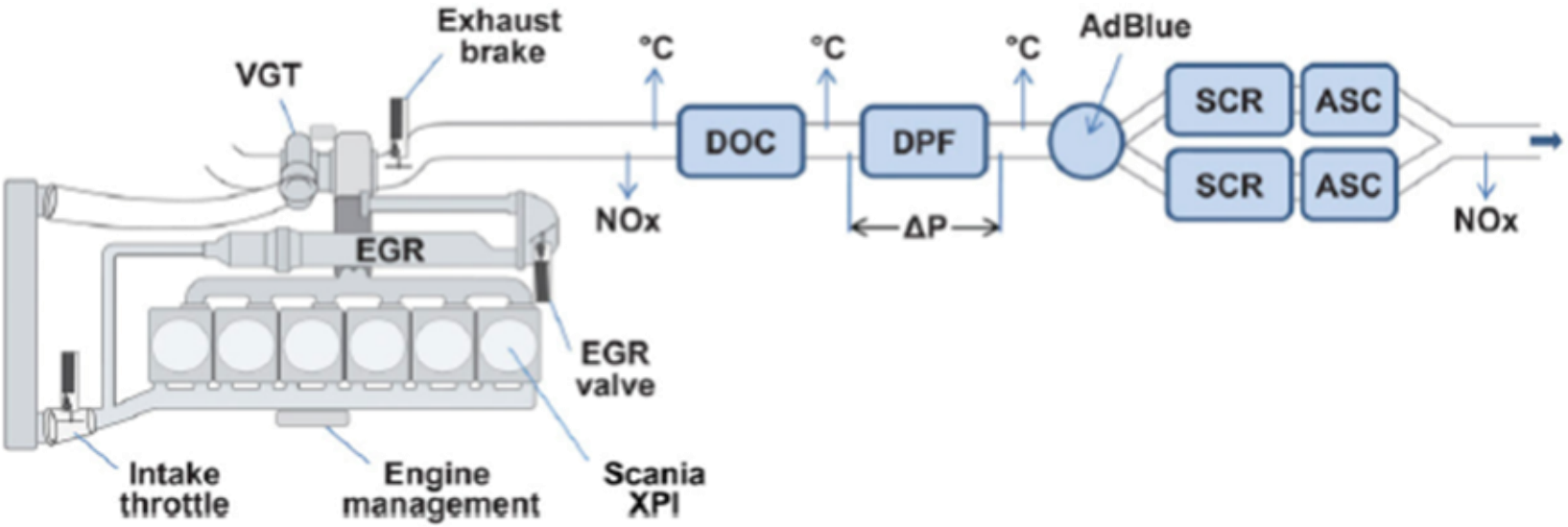




Pollutant reduction strategies

- Reduce the production of pollutants
  - Engine tuning
  - NO_x/particulates trade-off
  - Exhaust gas recirculation to reduce NO_x production
- Tail-end abatement techniques
  - Catalysts
  - Filters

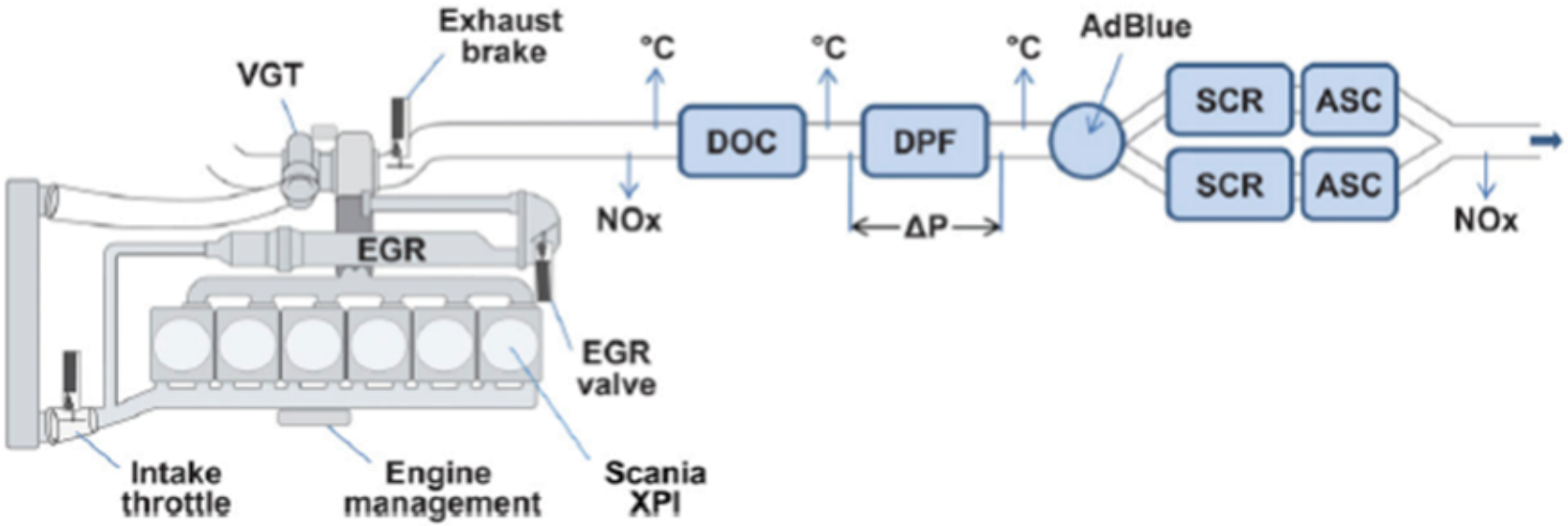
Scania's aftertreatment strategy



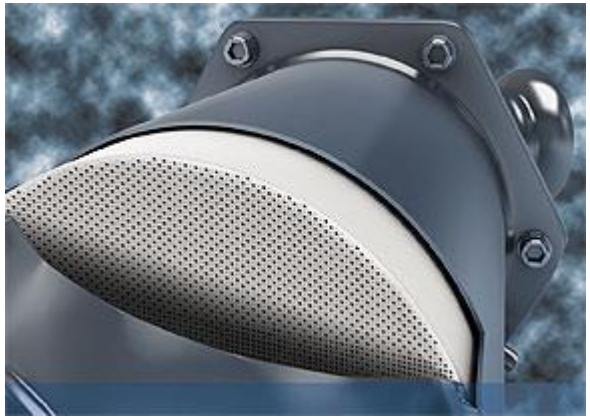
Diesel oxidation catalyst

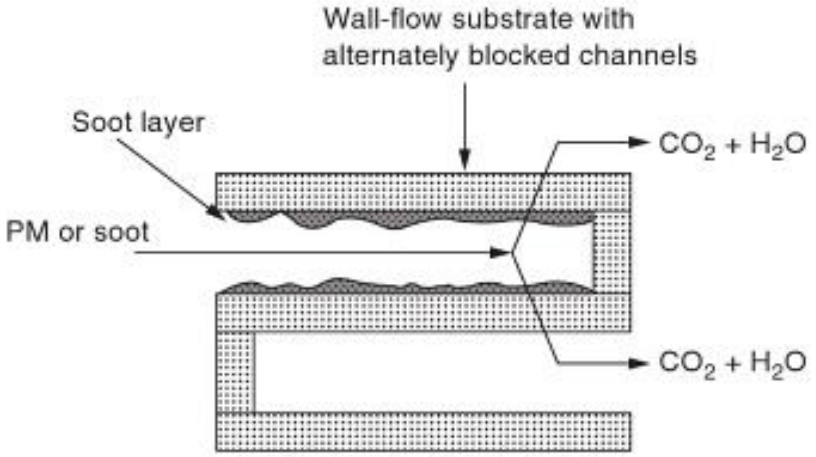
- Oxidizes CO, hydrocarbons and some of the particulates into CO_2 and H_2O
- Oxidizes some NO into NO_2
- Should not oxidize SO_2 into SO_3
- Subjected to harsh chemical environment

Scania's aftertreatment strategy



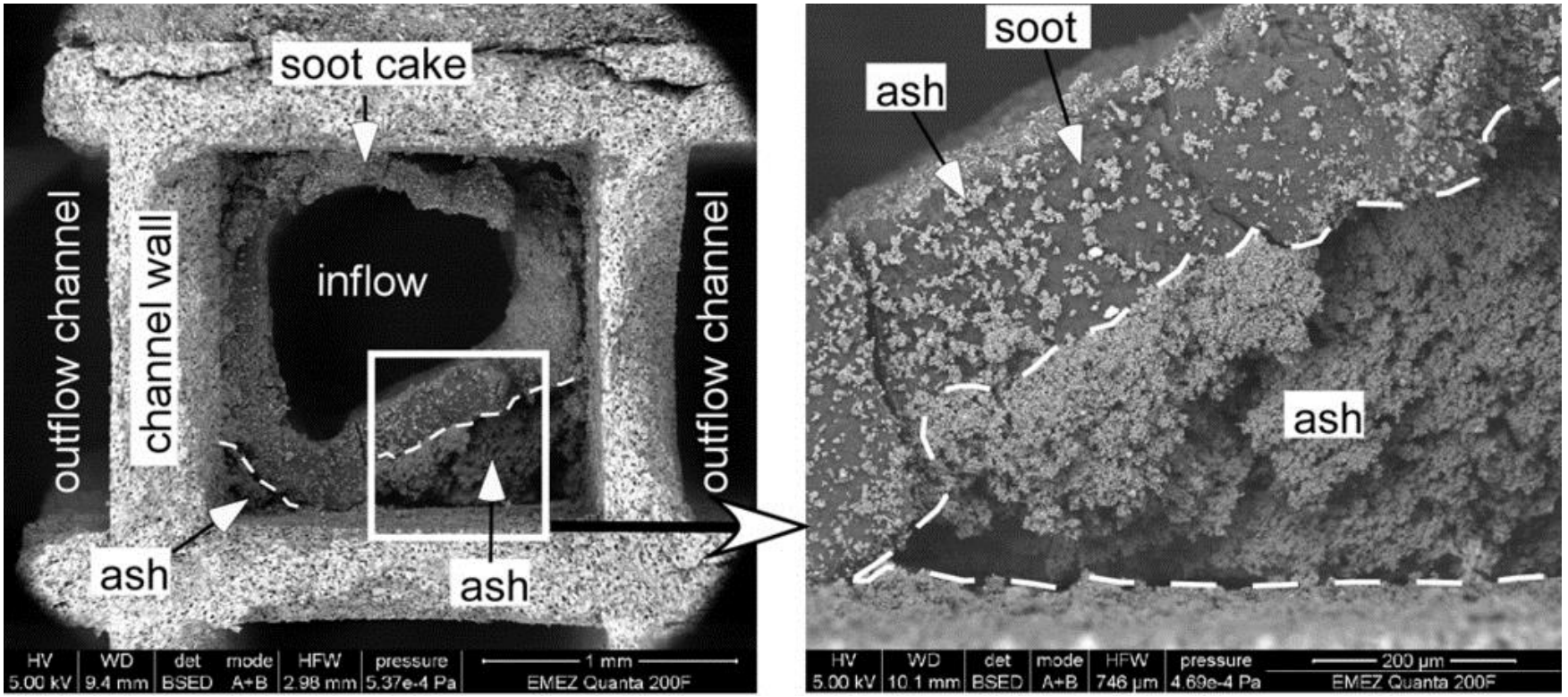
Diesel particulate filter





The filter needs to be regenerated

Filter regeneration



Soot stuck on the walls clogs the filter

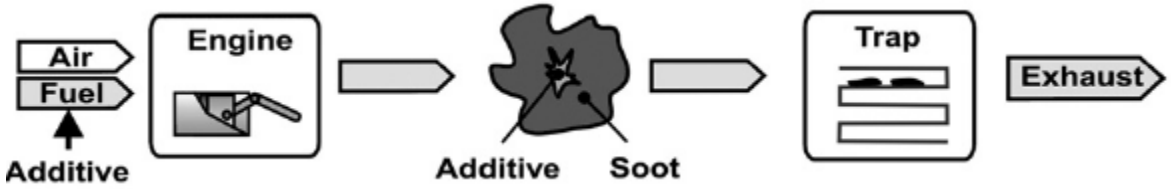
Needs to be burned away periodically

Active regeneration of filter

- Temperature of exhaust gases is actively increased
- Post-injection of fuel
- Increases fuel consumption

Passive regeneration of filter

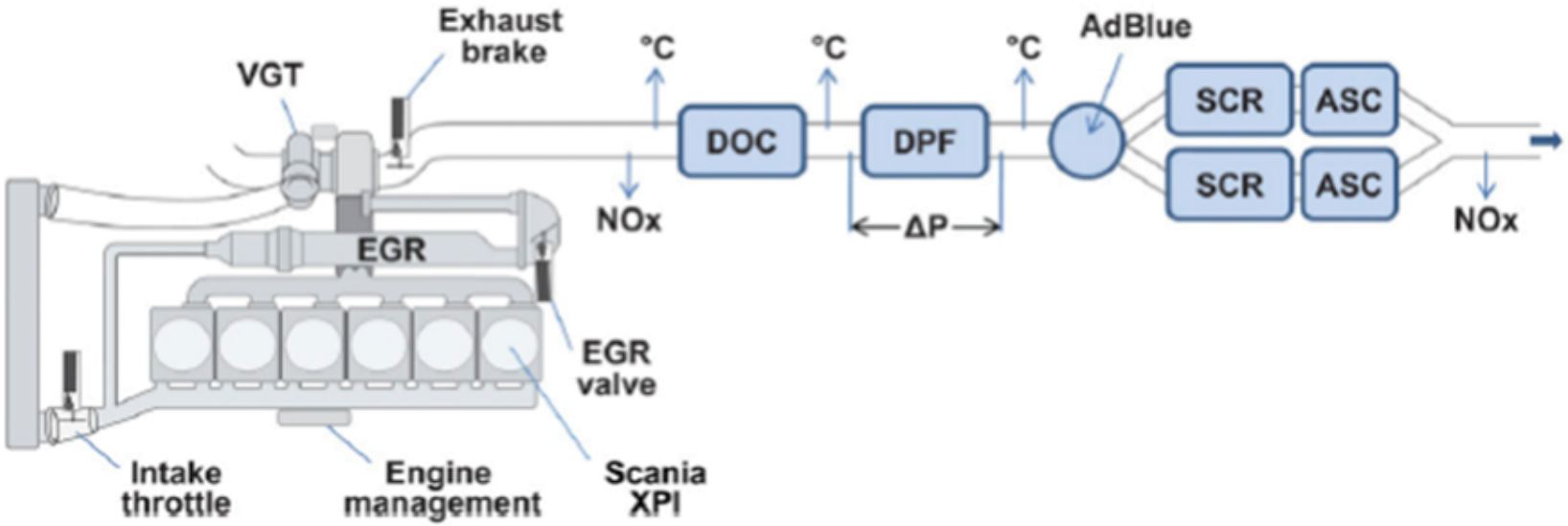
- If the exhaust temperature is high enough, soot in the filter combusts
- Sometimes requires the driver to drive in a particular way
  - Failure to drive properly could be expensive
- Temperature needed for regeneration may be lowered with a combustion catalyst
  - Present on the filter
  - Added as an additive to the fuel



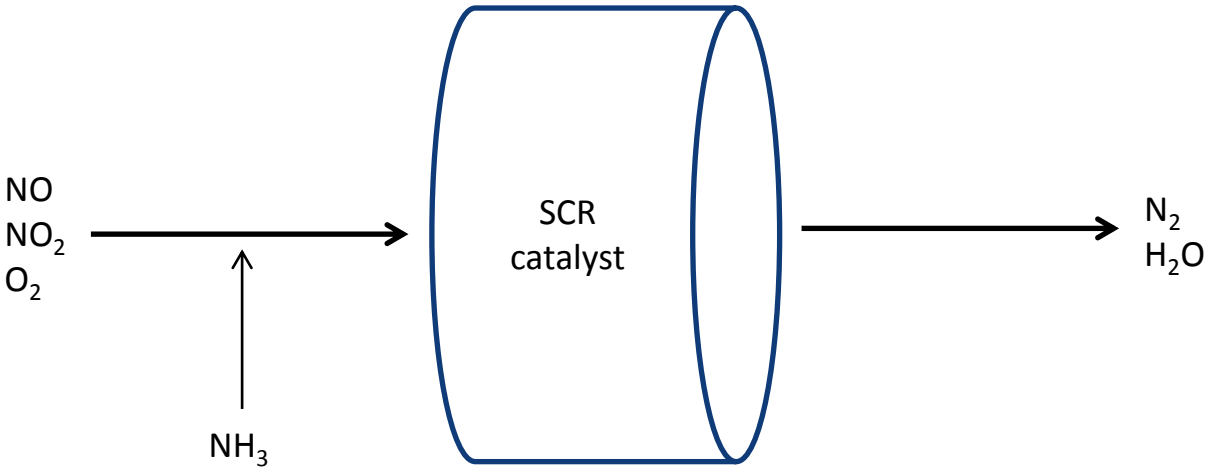
NO_2-mediated passive regeneration

- NO_2 is a more potent oxidant than O_2
- A DOC is placed upstream of the particle filter
- Oxidizes NO into NO_2
- Reduces temperature needed for regeneration
- Energy-efficient

Scania's aftertreatment strategy



Selective catalytic reduction



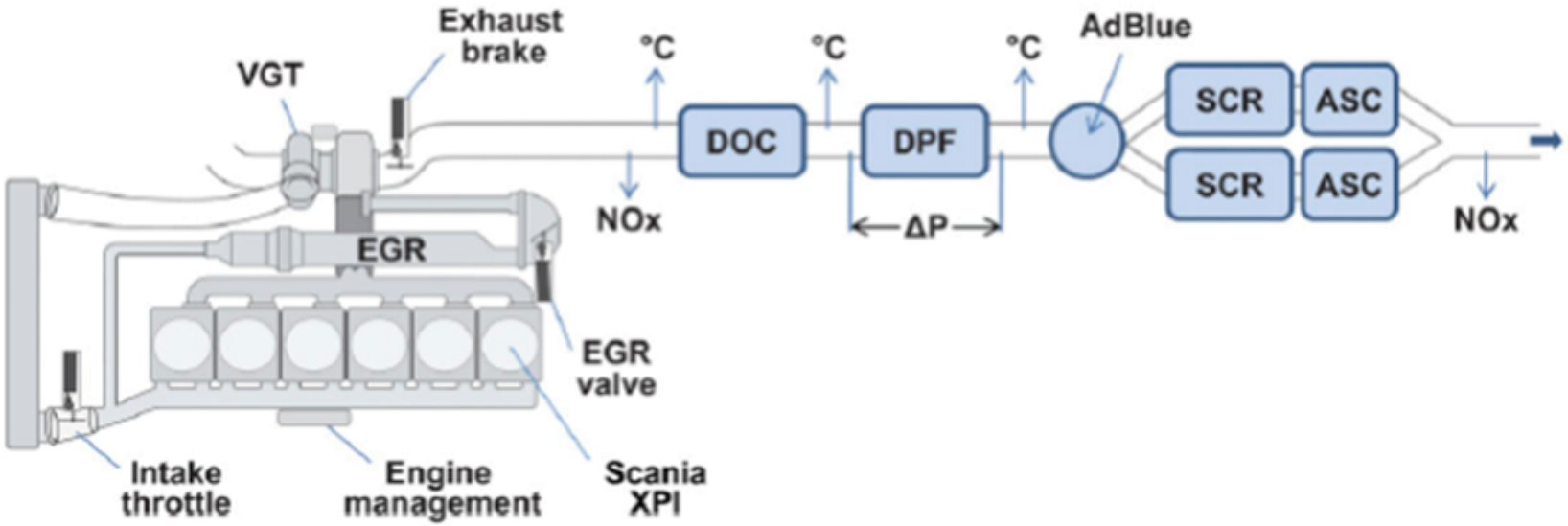
$$4NH_3 + 4NO + O_2 \rightarrow 4\,N_2 + 6H_2O$$

$$4NH_3 + 2NO + 2NO_2 \rightarrow 4N_2 + 6H_2O$$ Fast reaction

$$4NH_3 + 3NO_2 \rightarrow \frac{7}{2}N_2 + 6H_2O$$ Slow reaction

Water solution of urea used as NH_3 precursor

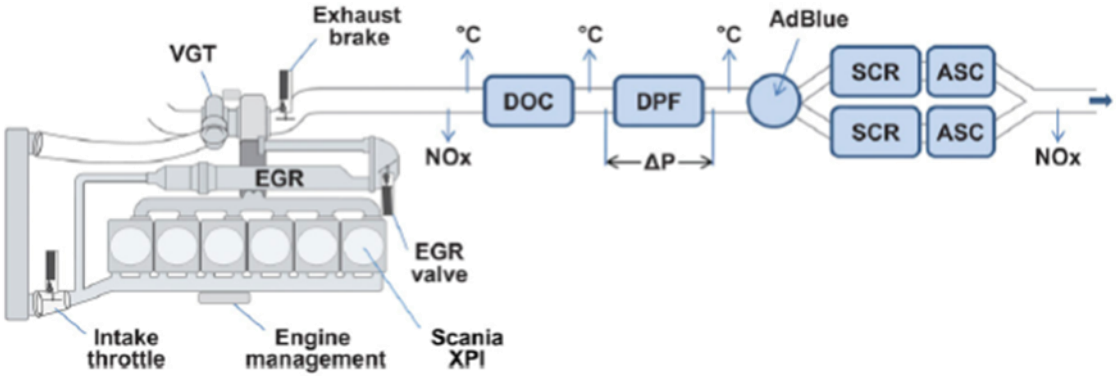
Scania's aftertreatment strategy



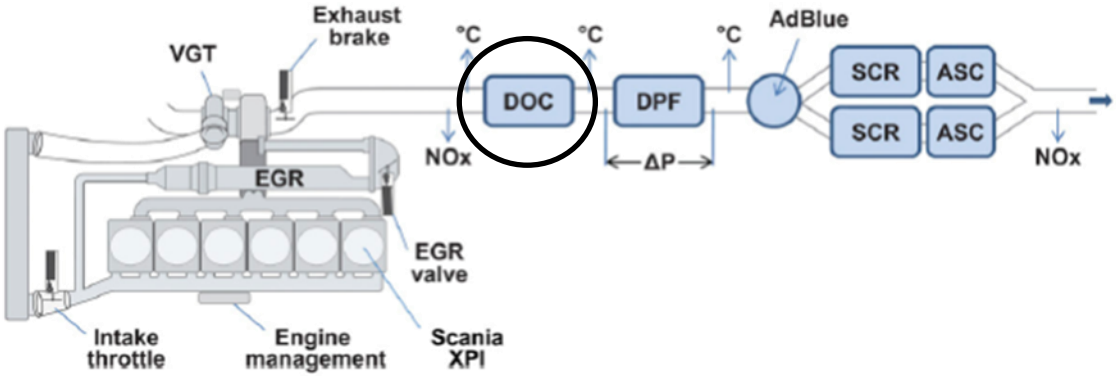
Ammonia slip catalyst (ASC)

- Excess of NH_3 needed for full conversion of NO_x
- To prevent NH_3 emission ASC is used downstream of SCR
- Oxidizes NH_3 into N_2 and H_2O

Scania's aftertreatment – summary



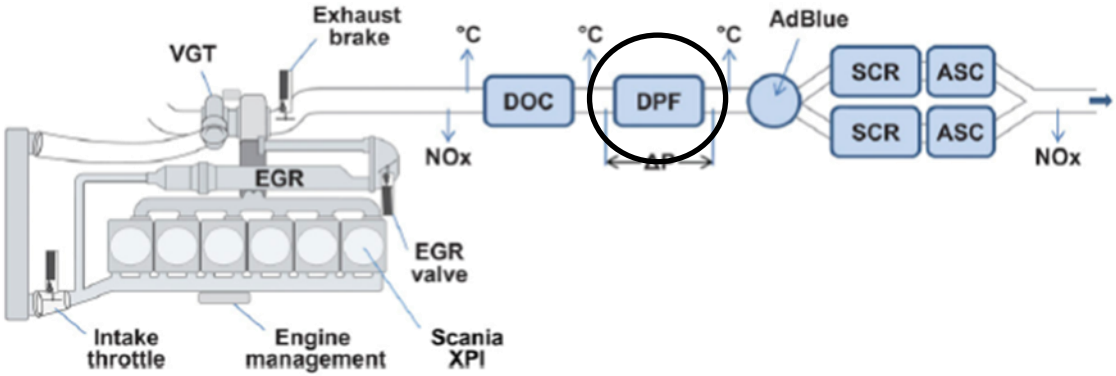
Scania's aftertreatment – summary



DOC Oxidizes hydrocarbons and CO into CO_2 and H_2O

Oxidizes NO into NO_2

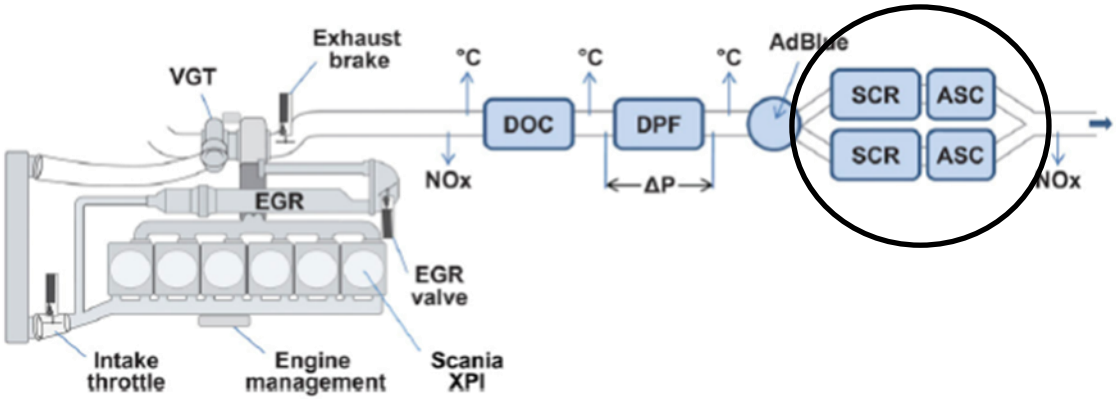
Scania's aftertreatment – summary



DPF traps particulates

NO_2 generated in the DOC helps burn away trapped soot

Scania's aftertreatment – summary



In the SCR catalyst NO_x reacts with NH_3

Excess NH_3 is taken care of in the ASC

The DOC serves a central role in the system

- Takes care of CO and hydrocarbons
- Oxidizes NO into NO_2
- Facilitates particle filter regeneration
- Increases NO_x removal activity

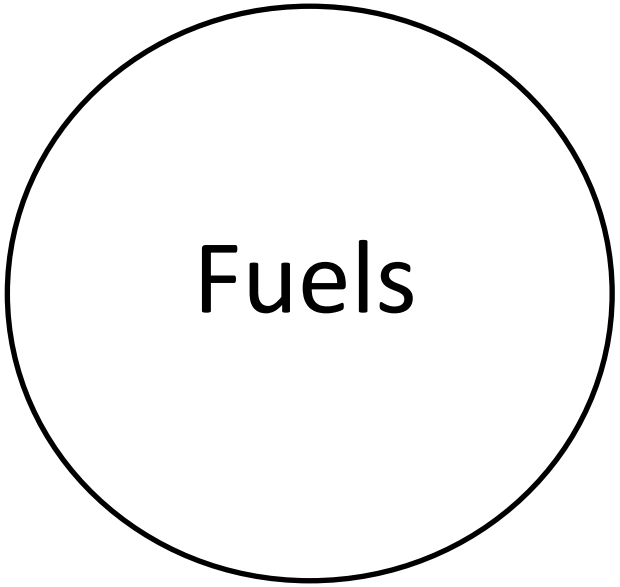
Future challenges

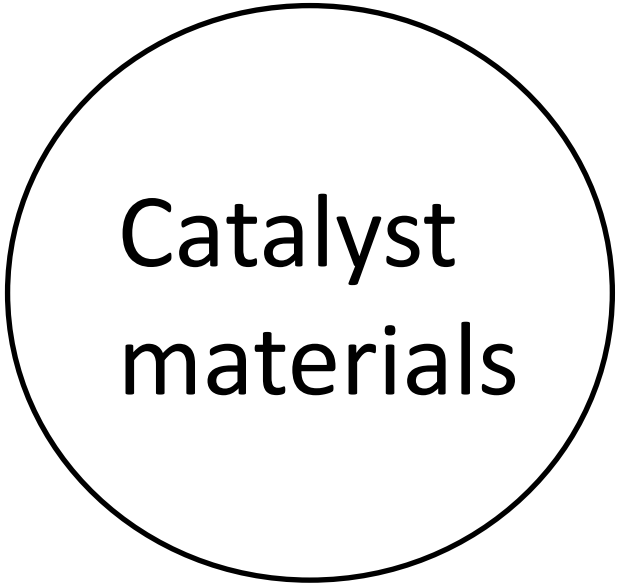
- Catalyst deactivation
  - Thermal deactivation due to high exhaust temperatures
  - Chemical deactivation due to elements from oil or fuel (e.g. Na, K, P)
  - Increased fuel diversity
- Trade-off between engine efficiency and pollutant abatement
- Interaction between all components
- Cold-start
- Difficulties finding space for all the equipment
- Driver education and acceptance

My project

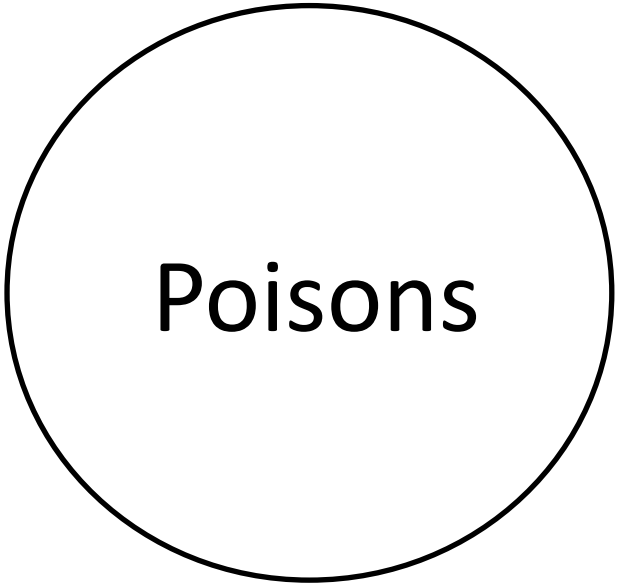
- Development of an oxidation catalyst
  - which optimizes the performance of the entire aftertreatment system
  - which is optimized for fuel diversification
- Verify on lab scale its effect the rest of the aftertreatment system
- Map the effects of poisoning on catalyst performance for different fuels

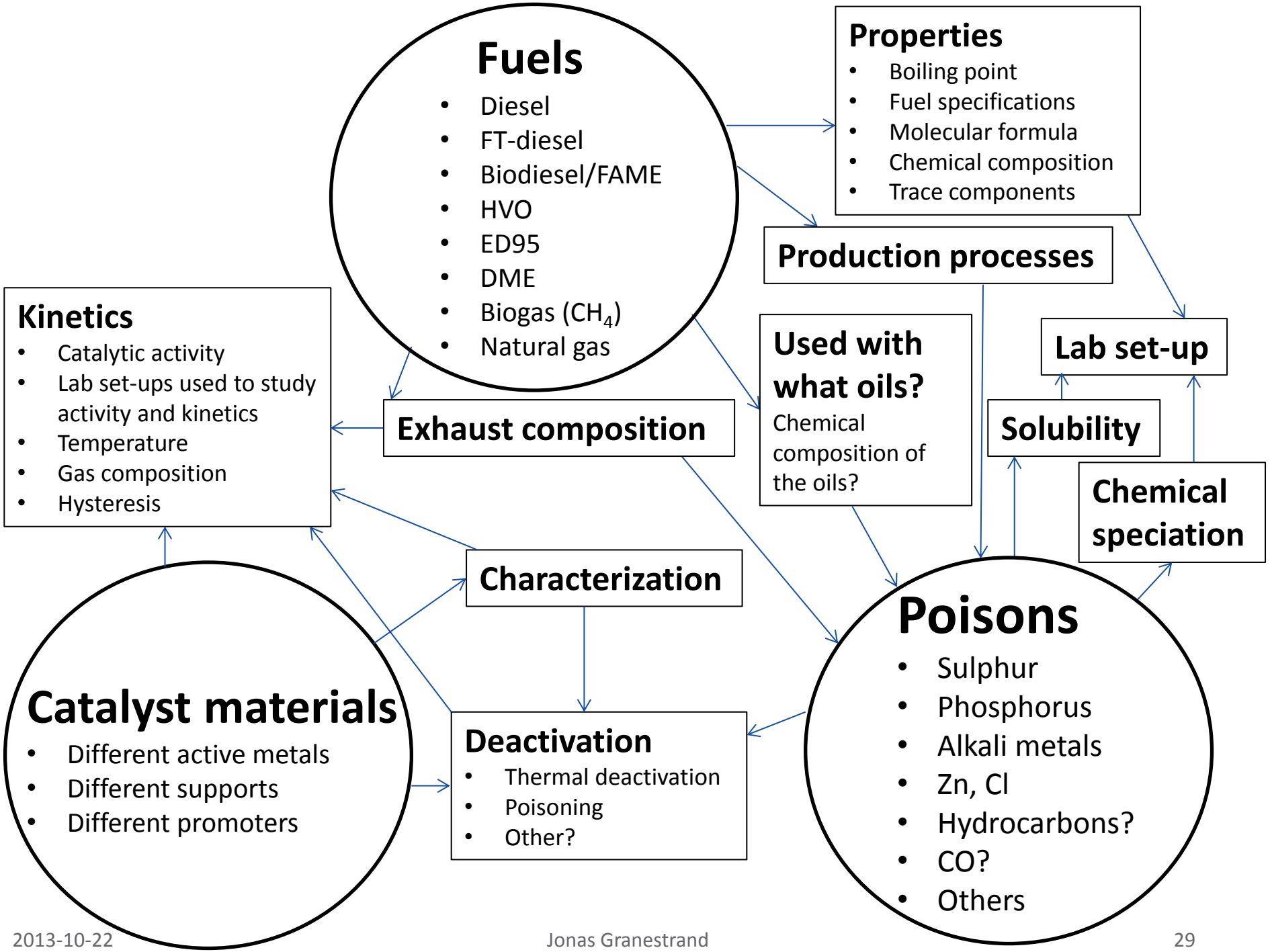
Three main areas to study





How are they connected?




Fuels
Diesel
FT-diesel
Biodiesel/FAME
HVO
ED95
DME
Biogas (CH_4)
Natural gas
Properties
Boiling point
Fuel specifications
Molecular formula
Chemical composition
Trace components
Production processes
Kinetics
Catalytic activity
Lab set-ups used to study activity and kinetics
Temperature
Gas composition
Hysteresis
Exhaust composition
Used with what oils?
Chemical composition of the oils?
Lab set-up
Solubility
Chemical speciation
Characterization
Catalyst materials
Different active metals
Different supports
Different promoters
Deactivation
Thermal deactivation
Poisoning
Other?
Poisons
Sulphur
Phosphorus
Alkali metals
Zn, Cl
Hydrocarbons?
CO?
Others

Acknowledgements

- We gratefully acknowledge the funding received from
  - Scania
  - The Swedish Energy Agency