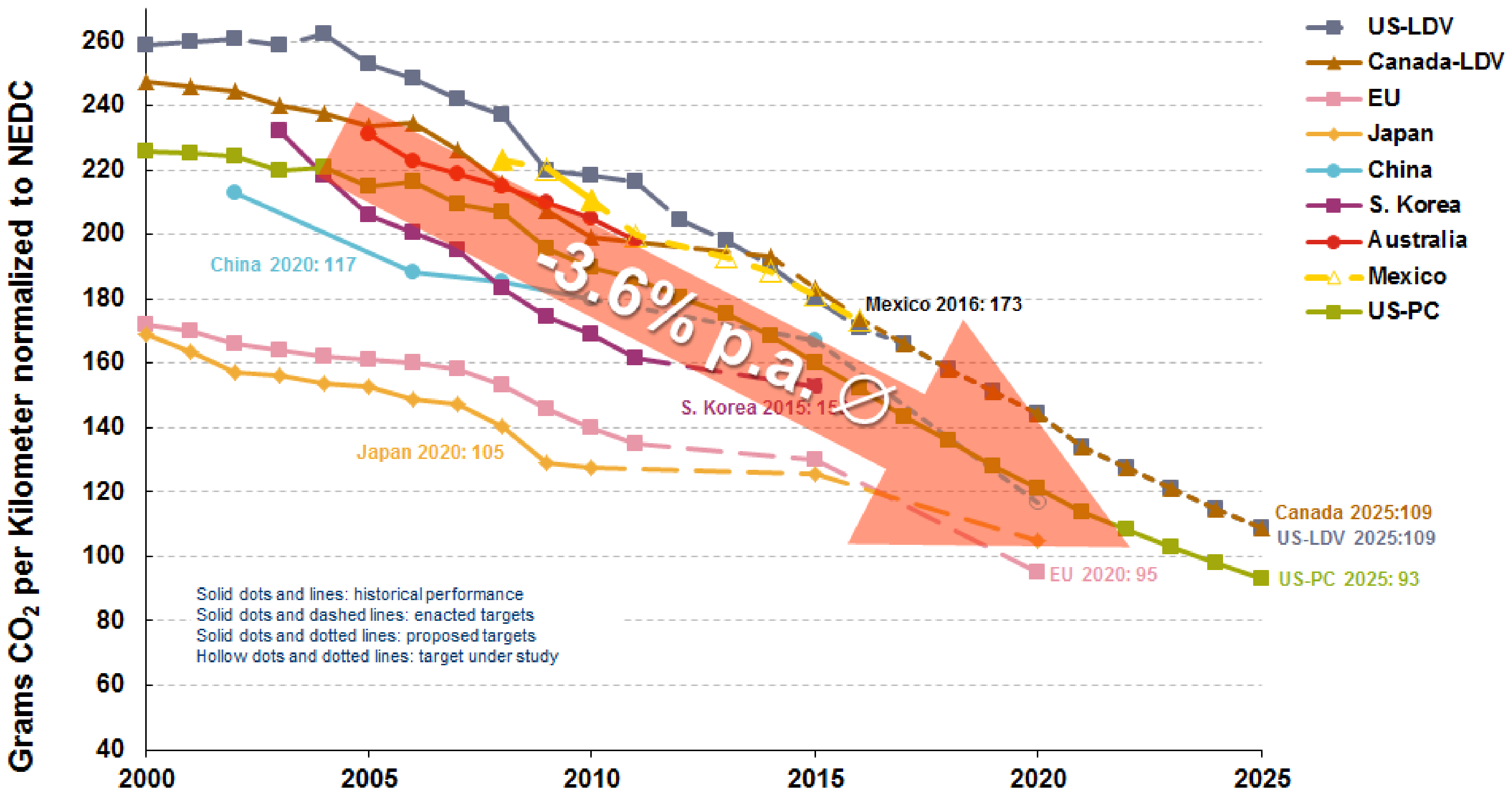
ICE Trends

1st Training in Bahia Blanca, ARG

12-14th of November 2018

Co-funded by the Erasmus+ Programme of the European Union

Worldwide greenhouse gas/CO2 reductions - limits



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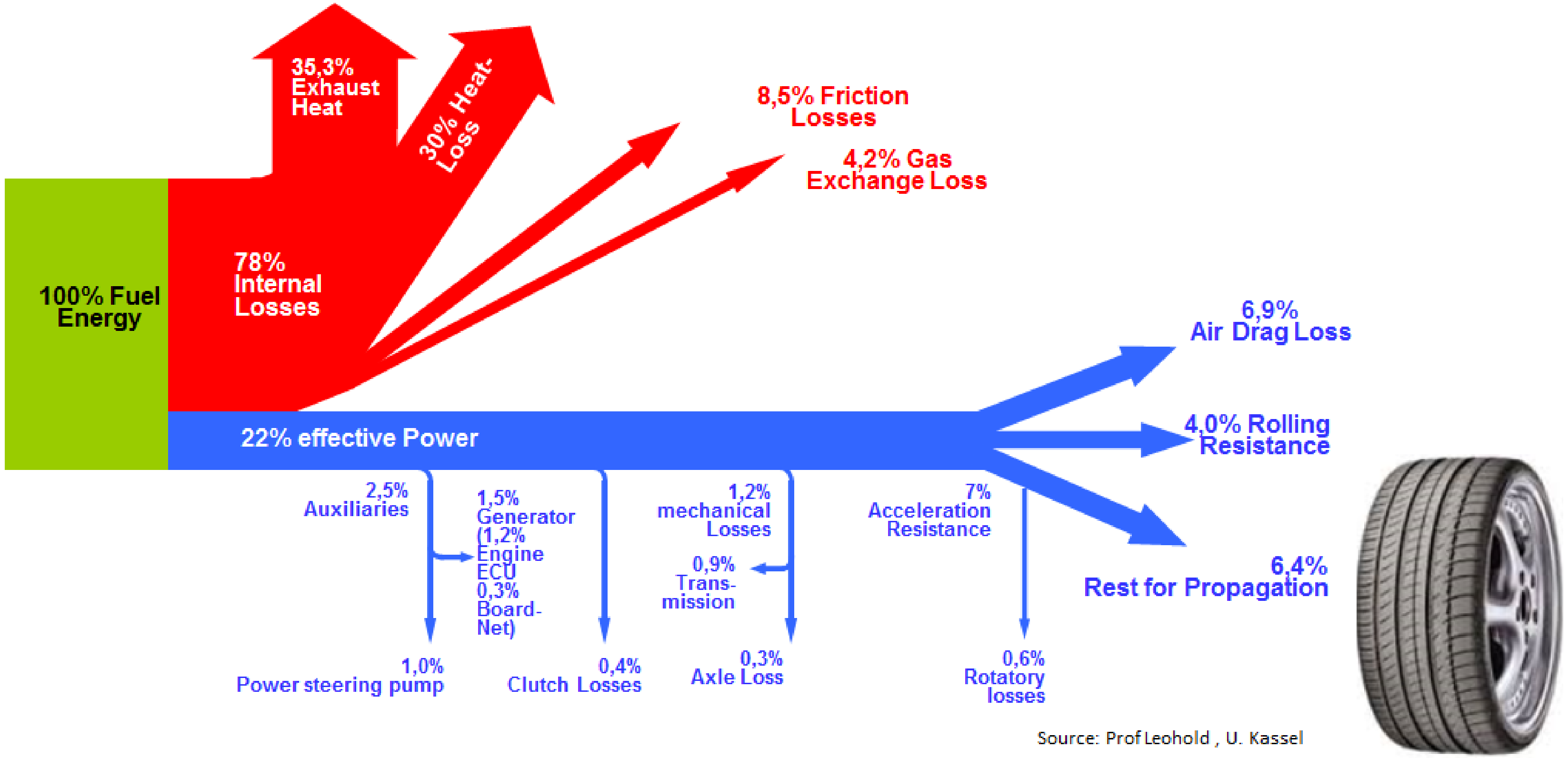
Energy situation of the ICE

- Sankey diagram of the energy flow in a road vehicle with an ICE driving an NEDC (new european driving cycle)



Source: Prof Leohold , U. Kassel

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Active Involvement: group activity

- We build groups of 2 to 4 people

- Group work (5-10min):
- Which measures – from your point of view - can improve the efficiency of internal combustion engines?
- Write down your results!

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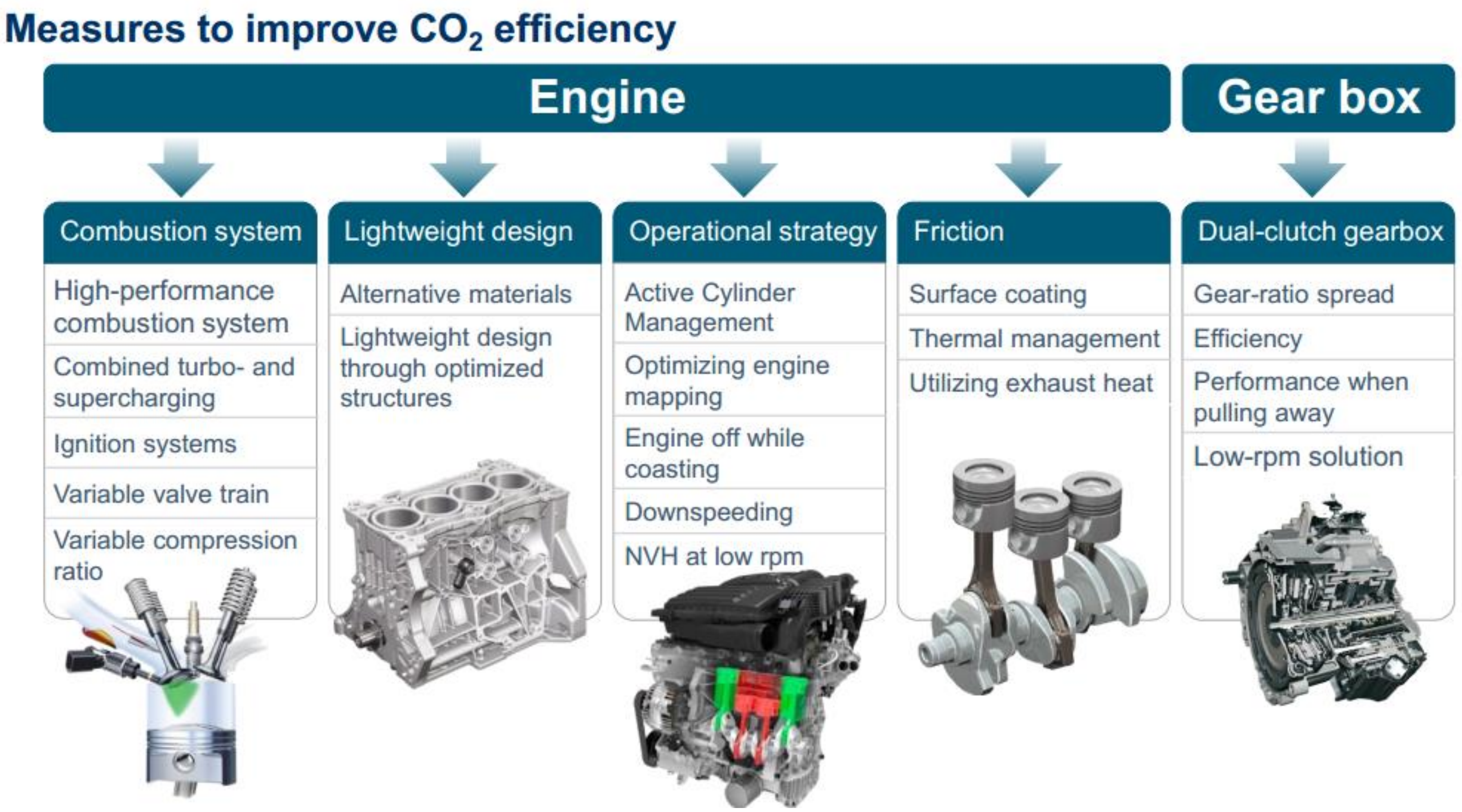
Efficiency measures at ICE and transmission



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Right sizing

Is a combination of:

- „down sizing“
  - using the smallest possible displacement for the required performance
- “down speeding”
  - designing engines for reduced rated speed and higher low end torque
- And reducing the number of cylinders
  - For most applications a modern 3-cylinder engine can replace an older 4-cylinder engine

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Friction reduction

By:

- new materials
- new coatings (e.g. DLC; also in transmission)
- down speeding (reduces friction, also in transmission)
- Use of ball, roller or needle bearings where possible
  - Lower friction
  - Much better for low speeds => start-stop systems

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Friction reduction

DLC Coating on a cam shaft

Improved thermodynamics

of the engine's processes:

- reduction of wall heat losses
- better heat management systems (adaptive cooling)
- introduction of Atkinson and Miller cycles
- other waste energy recovery processes
  - turbo charging
  - Stirling engine
  - Rankine cycle

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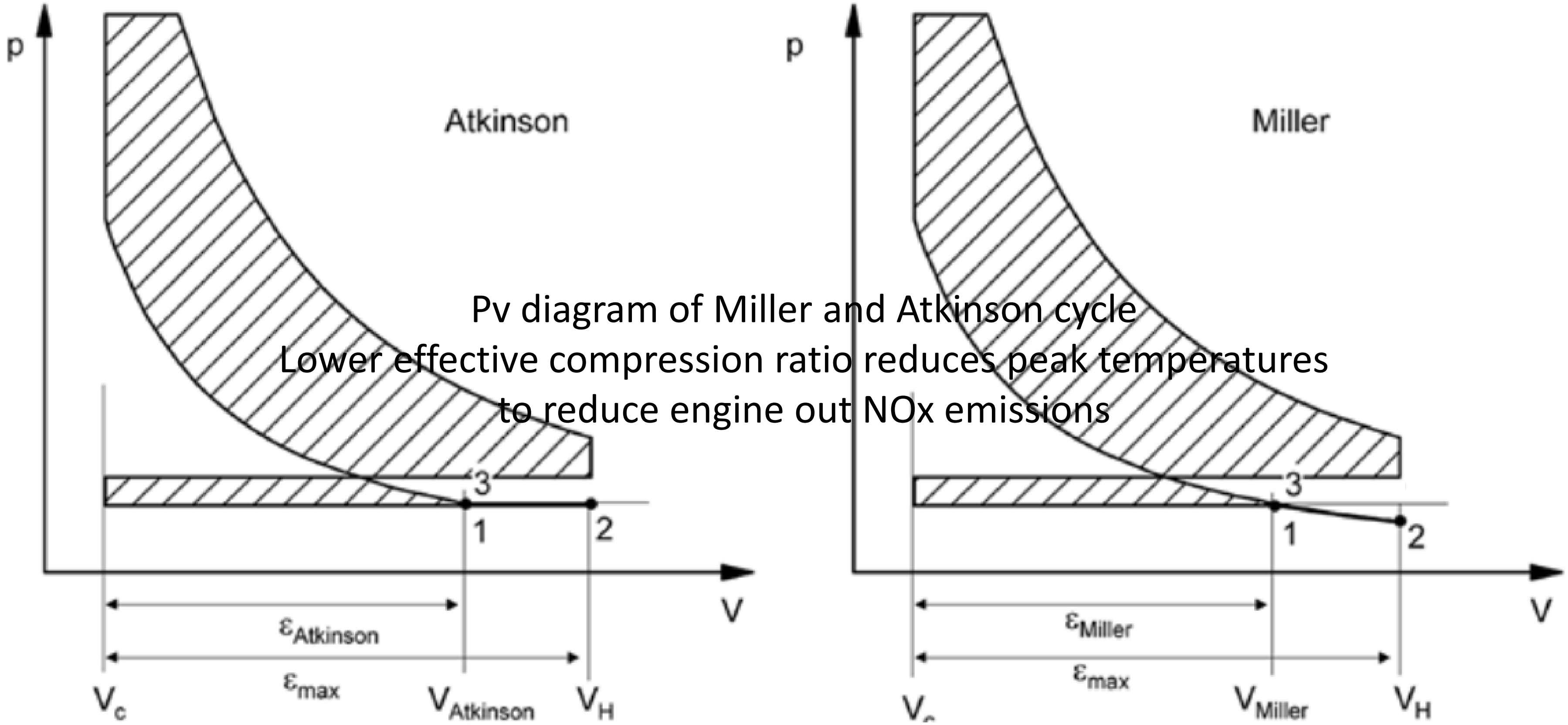
Improved thermodynamics



Pv diagram of Miller and Atkinson cycle
Lower effective compression ratio reduces peak temperatures
to reduce engine out NOx emissions

Pv diagram of Miller and Atkinson cycle
Lower effective compression ratio reduces peak temperatures
to reduce engine out NOx emissions

New combustion systems

- both engine types could make use of advanced combustion systems, which would offer lower engine out emissions.
- These combustions systems aim for air/fuel ratio and temperature ranges where NOx and Soot formation is not possible.
- Unfortunately, these combustions systems still suffer from two shortcomings:
  - they are not feasible across the whole engine map
  - they need sophisticated and expensive control, e.g. for EGR (exhaust gas recirculation)

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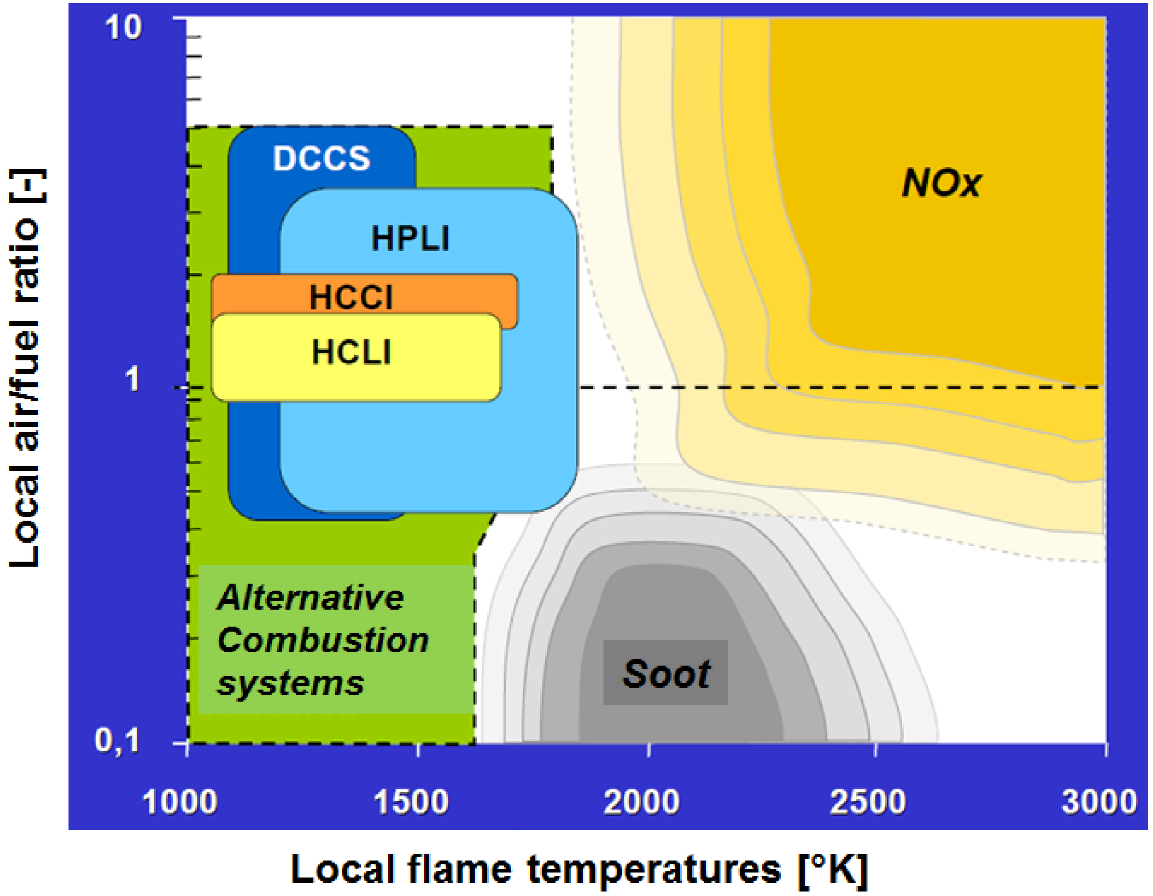
New combustion systems



- **HCCI:** homogeneous charge compression ignition
- **HCLI:** homogeneous charge late injection
- **HPLI:** homogeneous premixed late injection
- **DCCS:** dilution controlled combustion system

Overview of different combustion systems

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Increase of variability

in the ICE such as:

- variable cam shafts (phase and lift)
- for turbo engines: VTG (variable turbine geometry)
- variable auxiliaries:
  - variable oil pumps
  - water pumps
  - alternators/generators
- variable compression ratio
- Increased variability is a new challenge for application engineers

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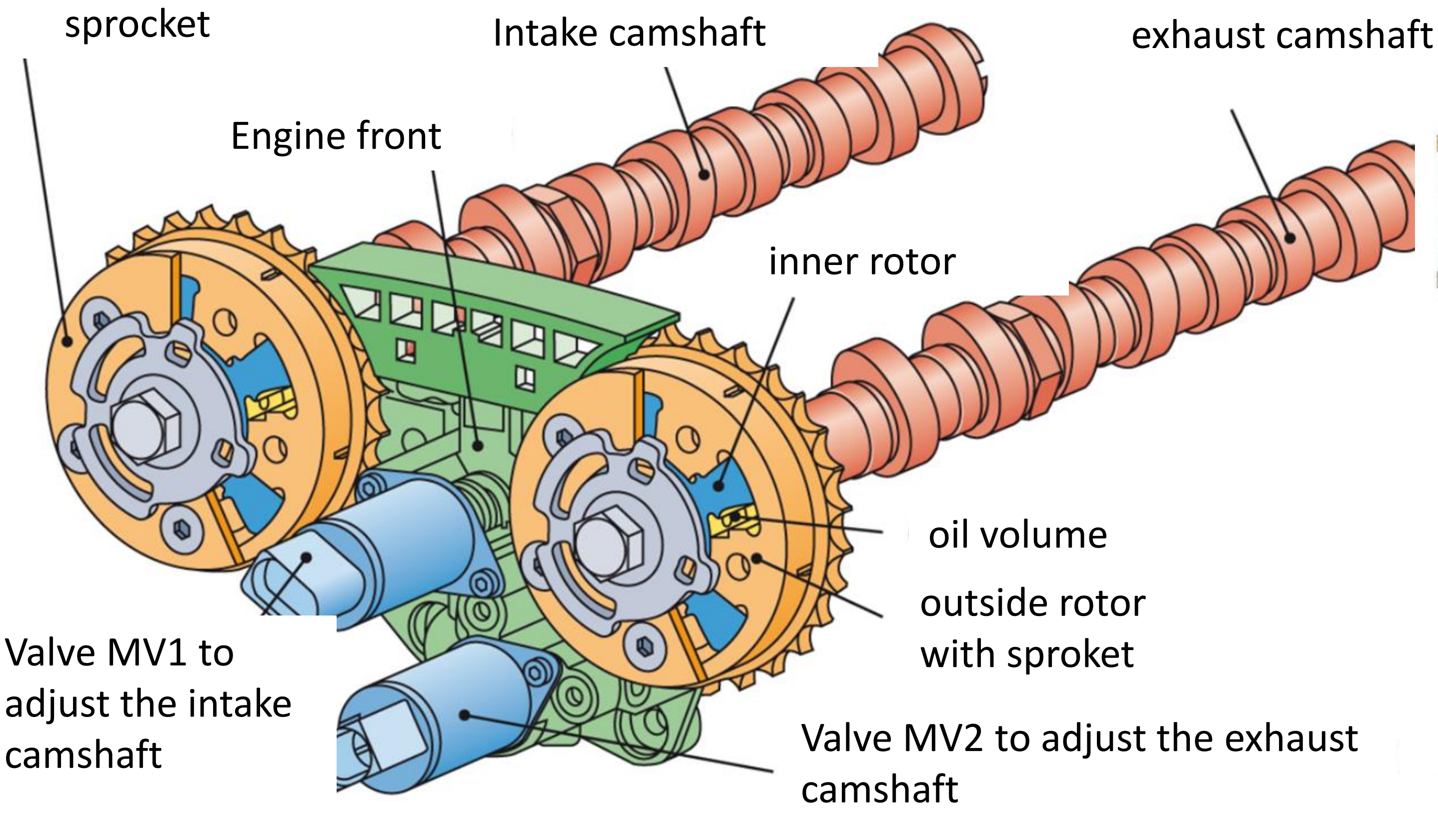
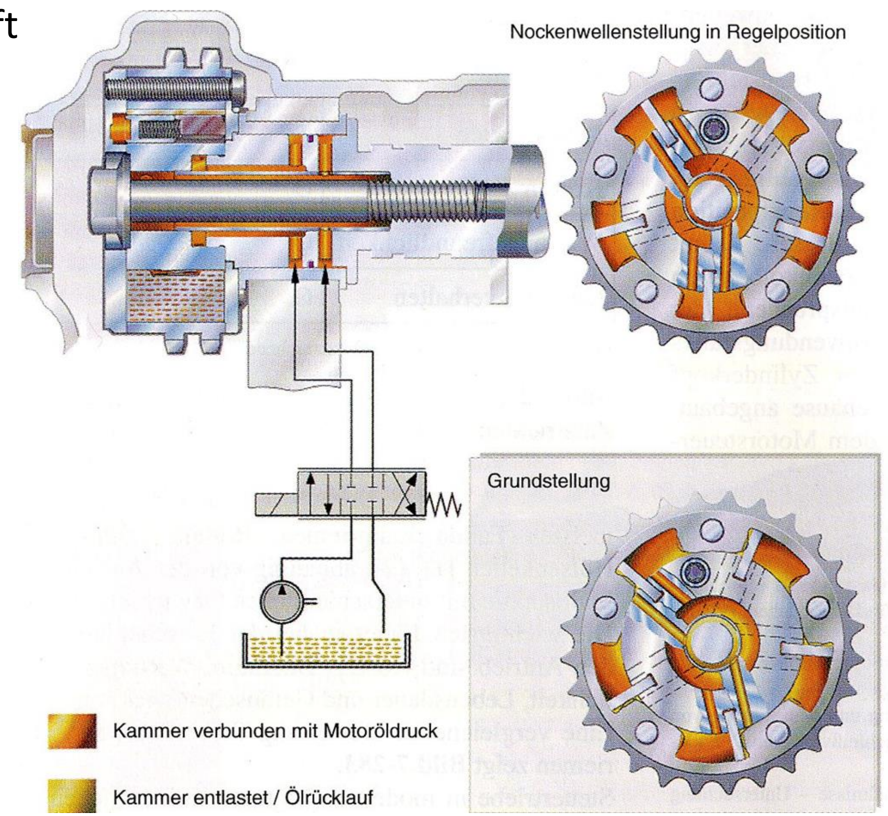
Increase of variability





Examples of variable cam phasing

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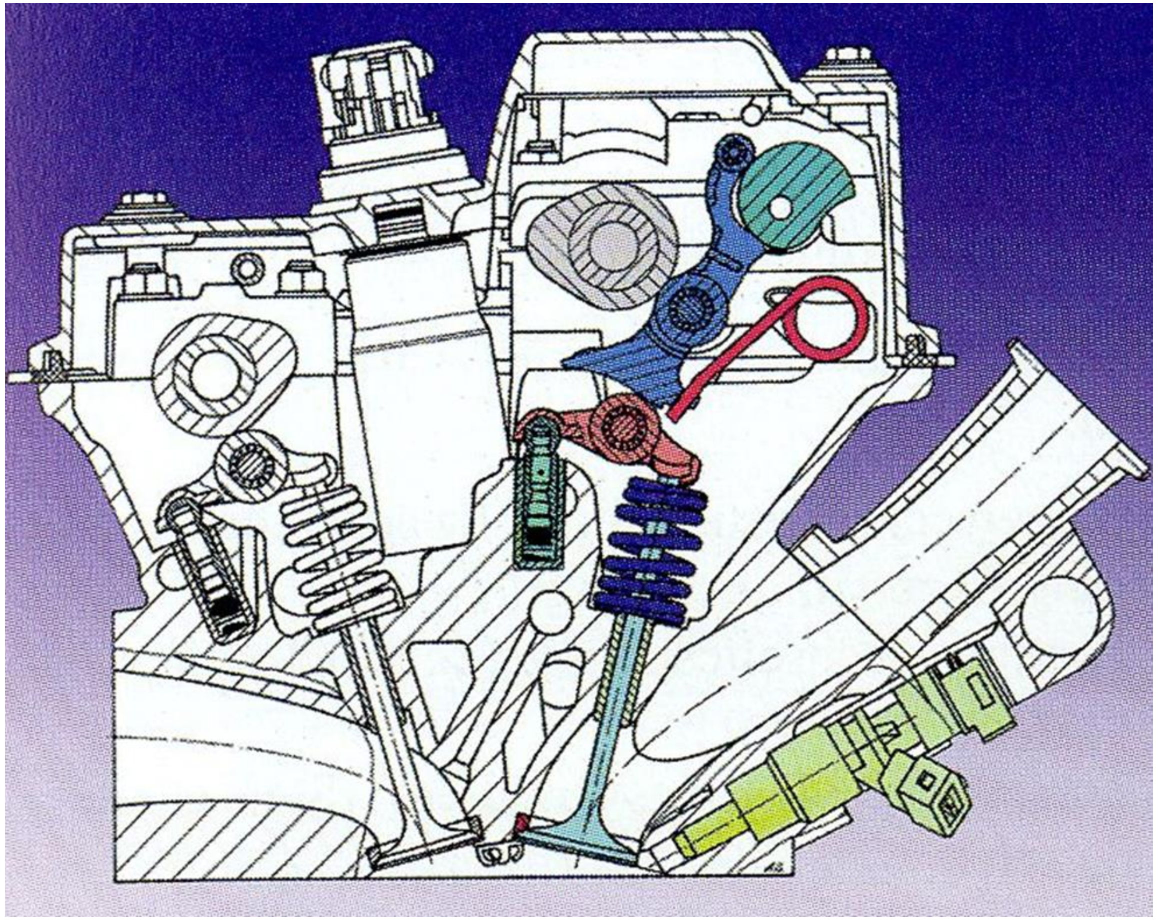
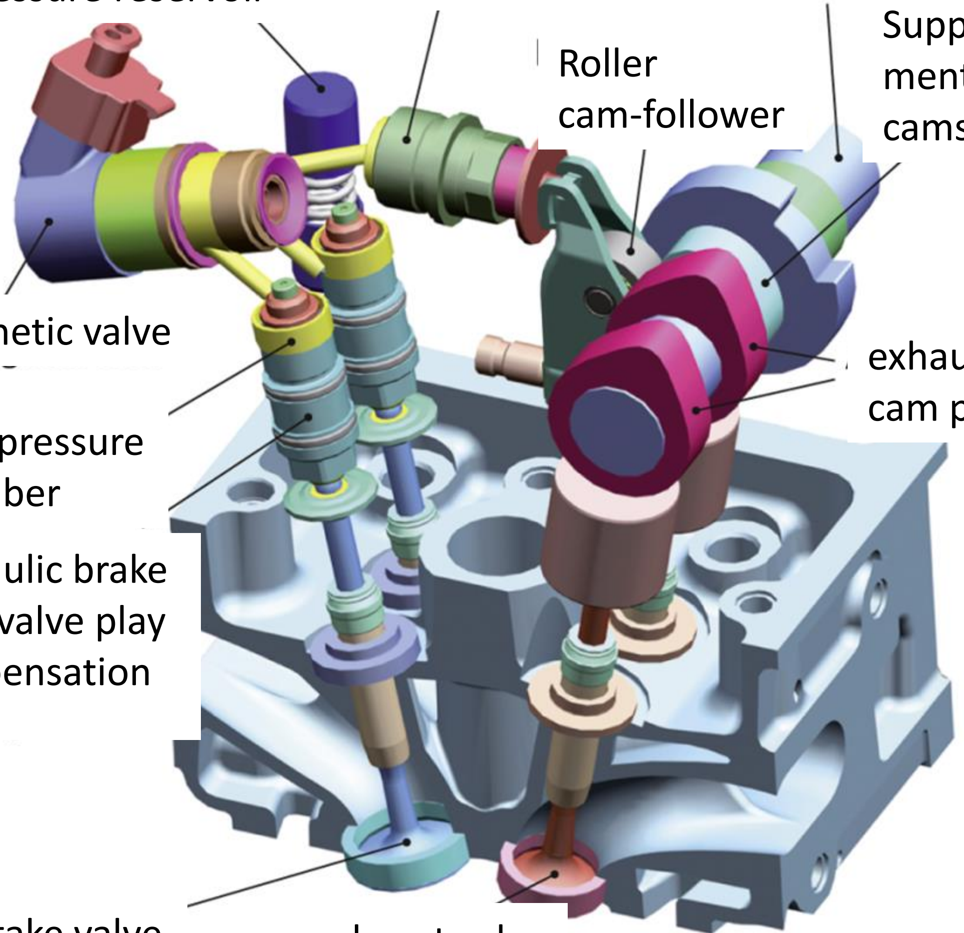
Increase of variability



Examples of variable cam lifting



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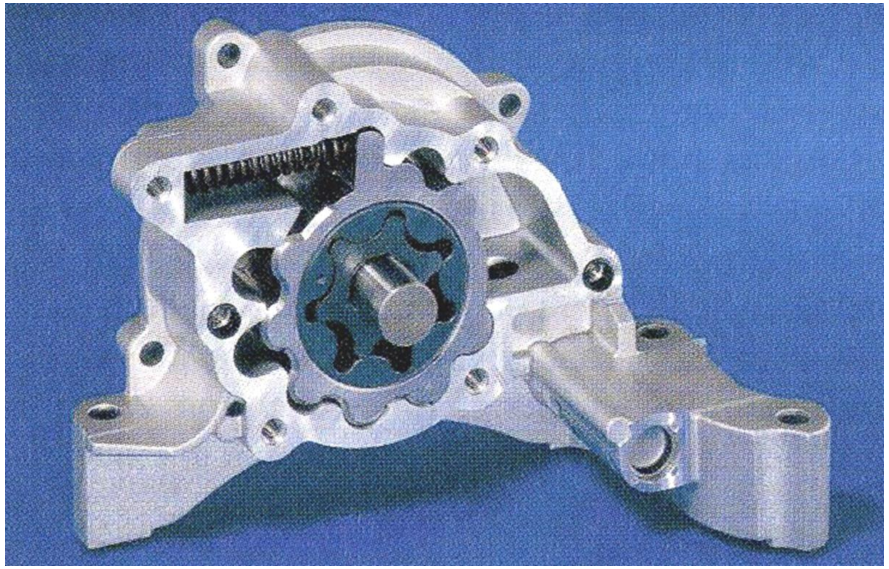
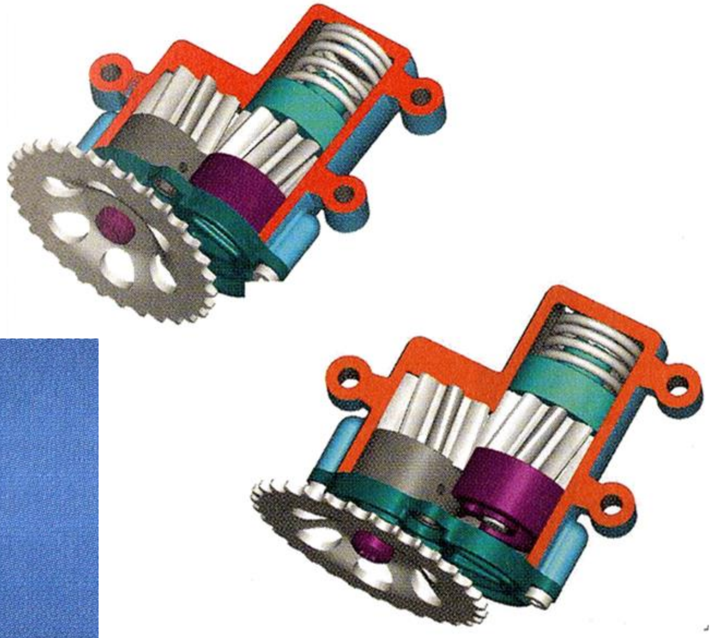
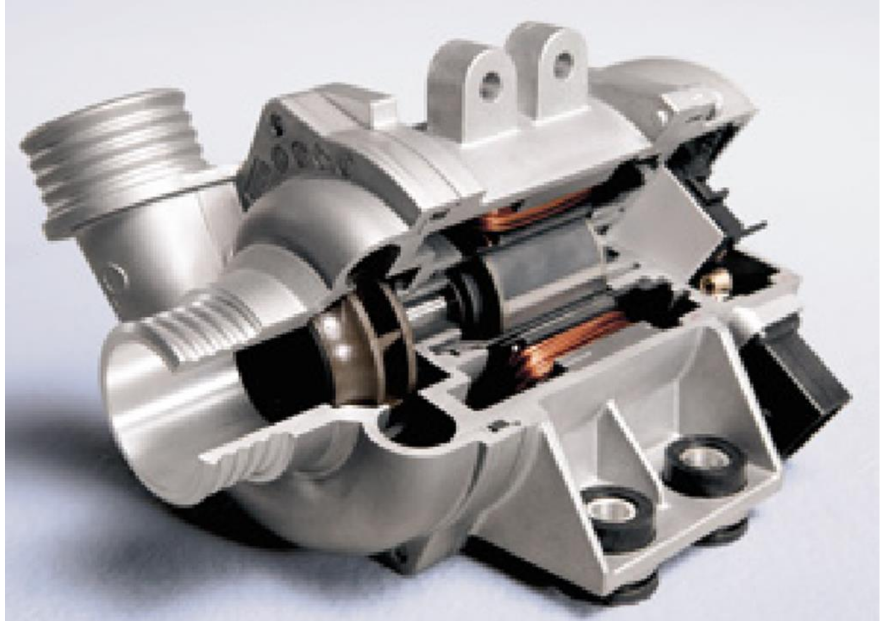
Increase of variability







Examples of variable oil and water pumps

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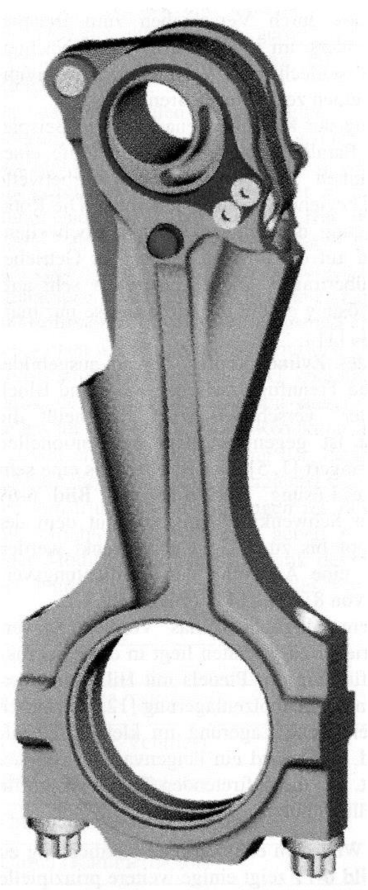
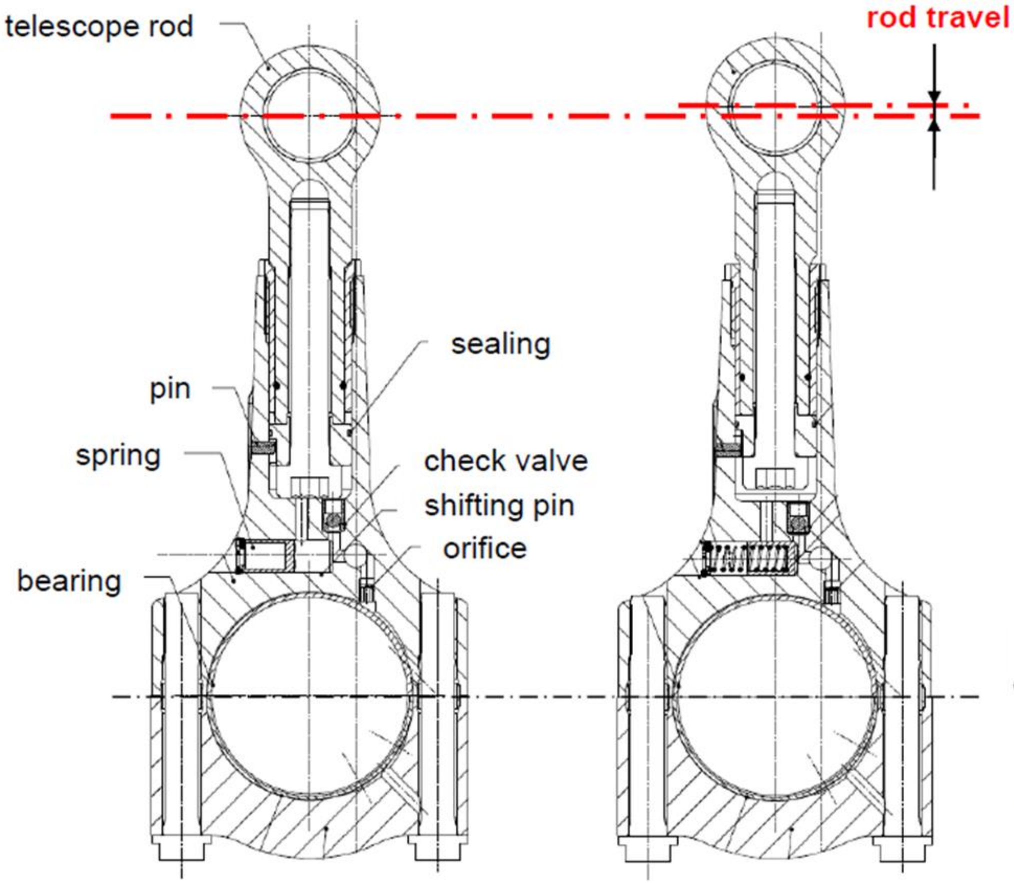
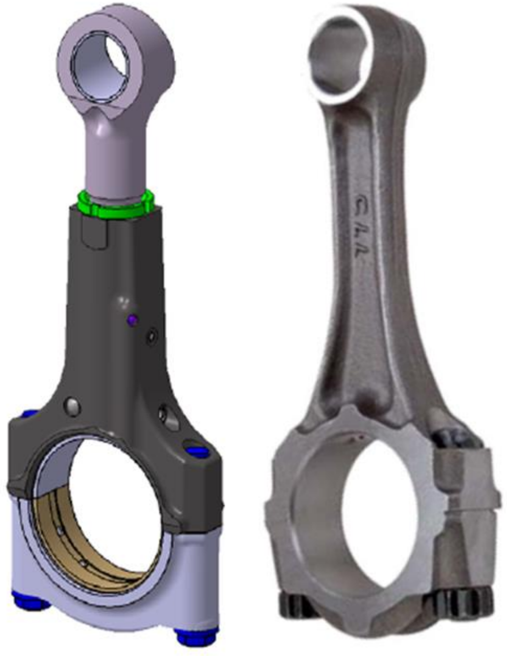
Increase of variability





Nearly same size as conventional conrod



Two different concepts of variable length conrods for VCR (variable compression ratio)

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Other improvements for ICEs

- Support from optimized transmissions
  - Helps to operate the ICE in the range of best efficiency

- Development of alternative/synthetic/bio fuels
  - „zero-impact emissions“
  - CO_2-lean and CO_2-free fuels are possible in closed circulations of resources
  - regrowing bio fuels processed with solar energy
  - Hydrogen production with solar energy

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Exhaust aftertreatment – Gasoline Engine

- Emission reductions are focusing at the cold start and warm up phases where the majority of emissions are emitted
  - After the warm up the emissions are very effectively eliminated by the three-way catalyst, when the engine follows a $\lambda=1$ concept.
- lean burn concept => NO_x in the exhaust must be treated by the $DeNO_x$ catalyst
  - stores the NO_x with Barium and after being filled up, a regeneration phase with rich fuel mixture is needed.
  - During this period the fuel consumption is bad. Hydrocarbons from oil and fuel are being treated by an oxidation catalyst.

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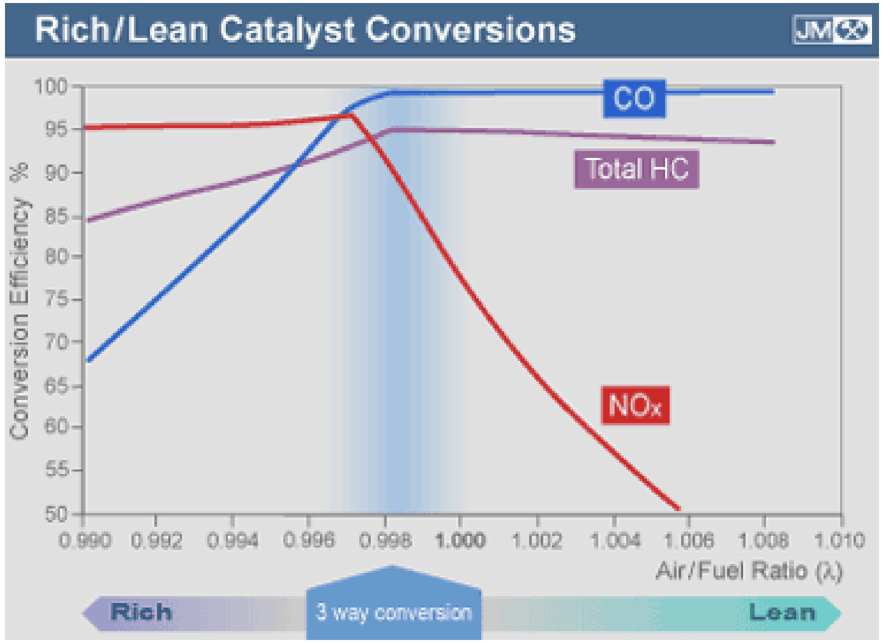
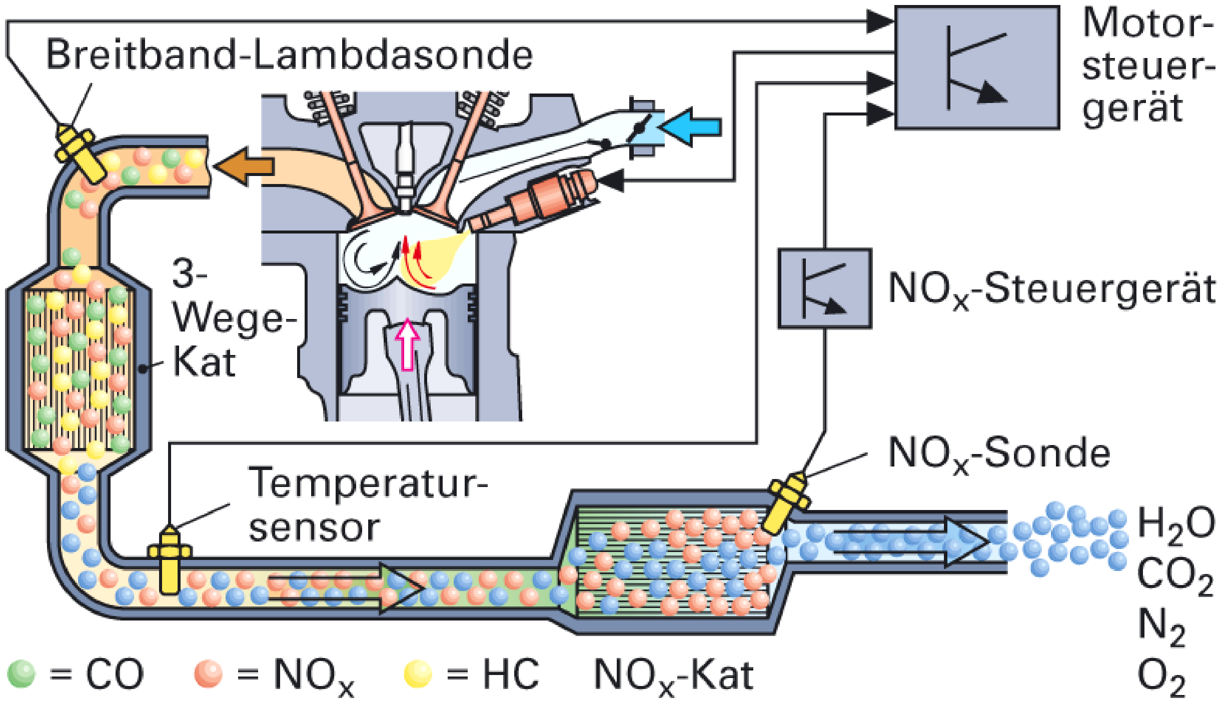
Exhaust aftertreatment – Gasoline Engine





Lean burn leads to higher NO_x emissions

=> additional $DeNO_x$ cat. needed

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Exhaust aftertreatment – Gasoline Engine

- more and more engines use direct injection for better efficiency/better fuel consumption
  - mainly a result of in-cylinder-cooling by the injected fuel
  - the fuel/air mixture process is much shorter than port injected engines
  - combustion process becomes inhomogeneous and particles like in the diesel engines are produced
  - These particles led to the requirement of particulate filters.

- current R&D activities focus on the appropriate application of particulate filters, their regeneration and long-time stability/aging.

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Exhaust aftertreatment – Diesel Engine

In general, the NO_x emissions of a diesel engine can be reduced by:

- Retarded injection timing:
  - worse fuel consumption (combustion center of gravity moves away from the thermodynamic optimum)
  - increased soot emissions
  - combustion noise is improved
- Exhaust gas recirculation:
  - disadvantage is increased soot (particles) emissions and worse fuel consumption
- $DeNO_x$ catalyst:
  - seldom used with diesels; stores NO_x and needs regeneration with rich fuel mixture from time to time

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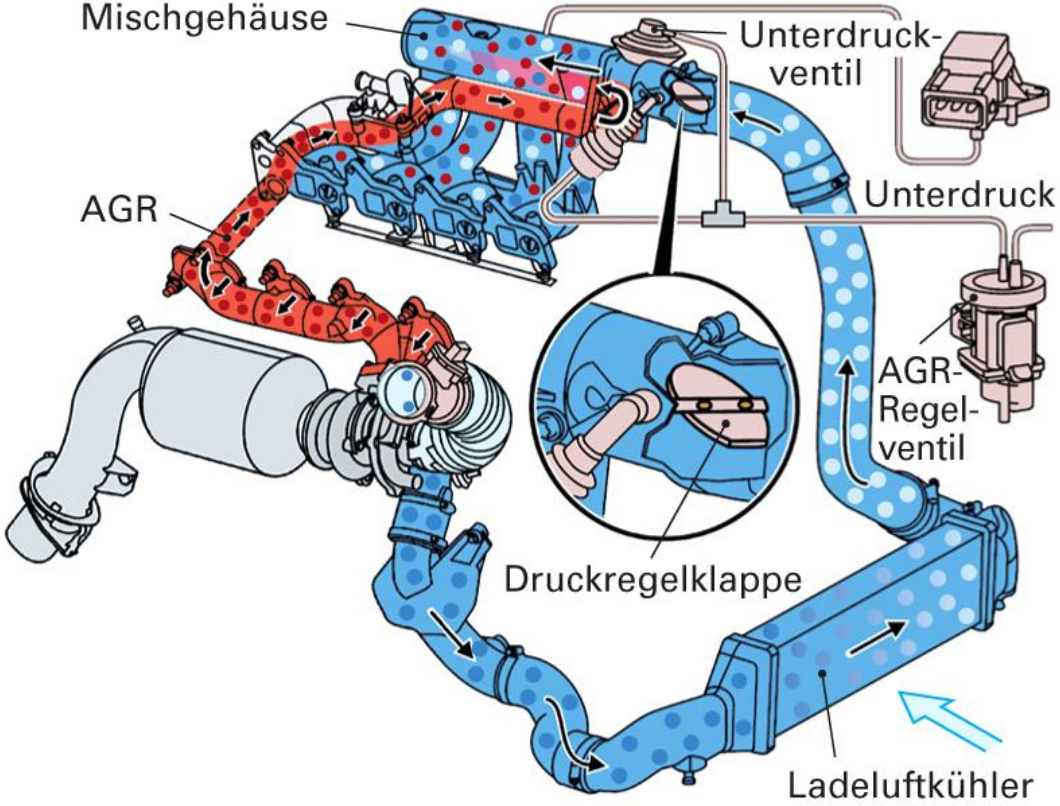
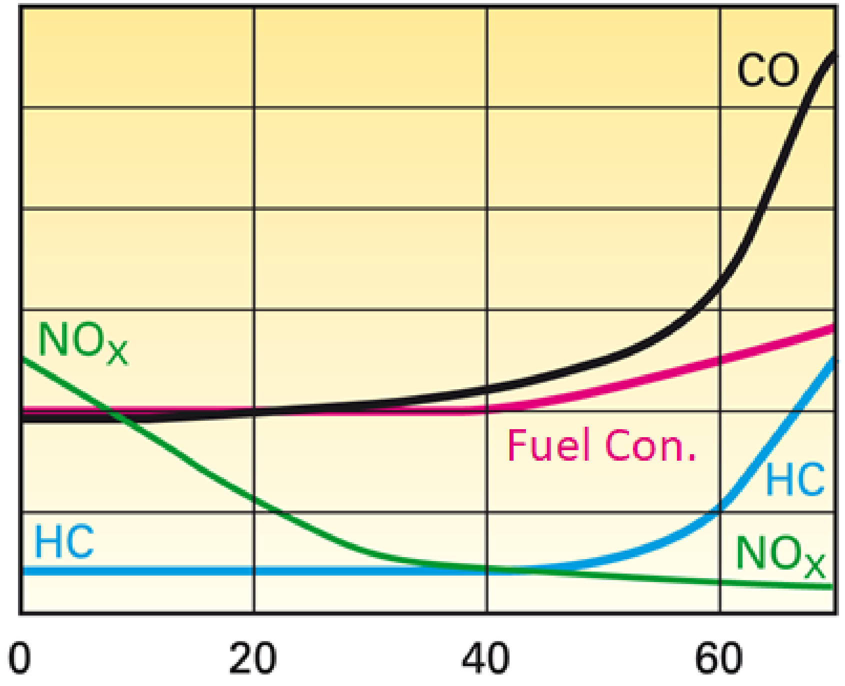
Exhaust aftertreatment – Diesel Engine





Exhaust gas recirculation

System layout example – NO_x reduction due to EGR

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Exhaust aftertreatment – Diesel Engine

- SCR (Selective Catalytic Reduction) System
  - This aftertreatment system allows advanced fuel injection settings (=good fuel consumption) and relative high engine out NO_x emissions
  - NO_x are being reduced in the SCR system by the adding of urea (commercially sold as “adBlue”) to the exhaust gas
- Focus of current developments in SCR systems are:
  - further optimization to improve dosage of adBlue
  - and minimize the slip of ammonia (NH_3)

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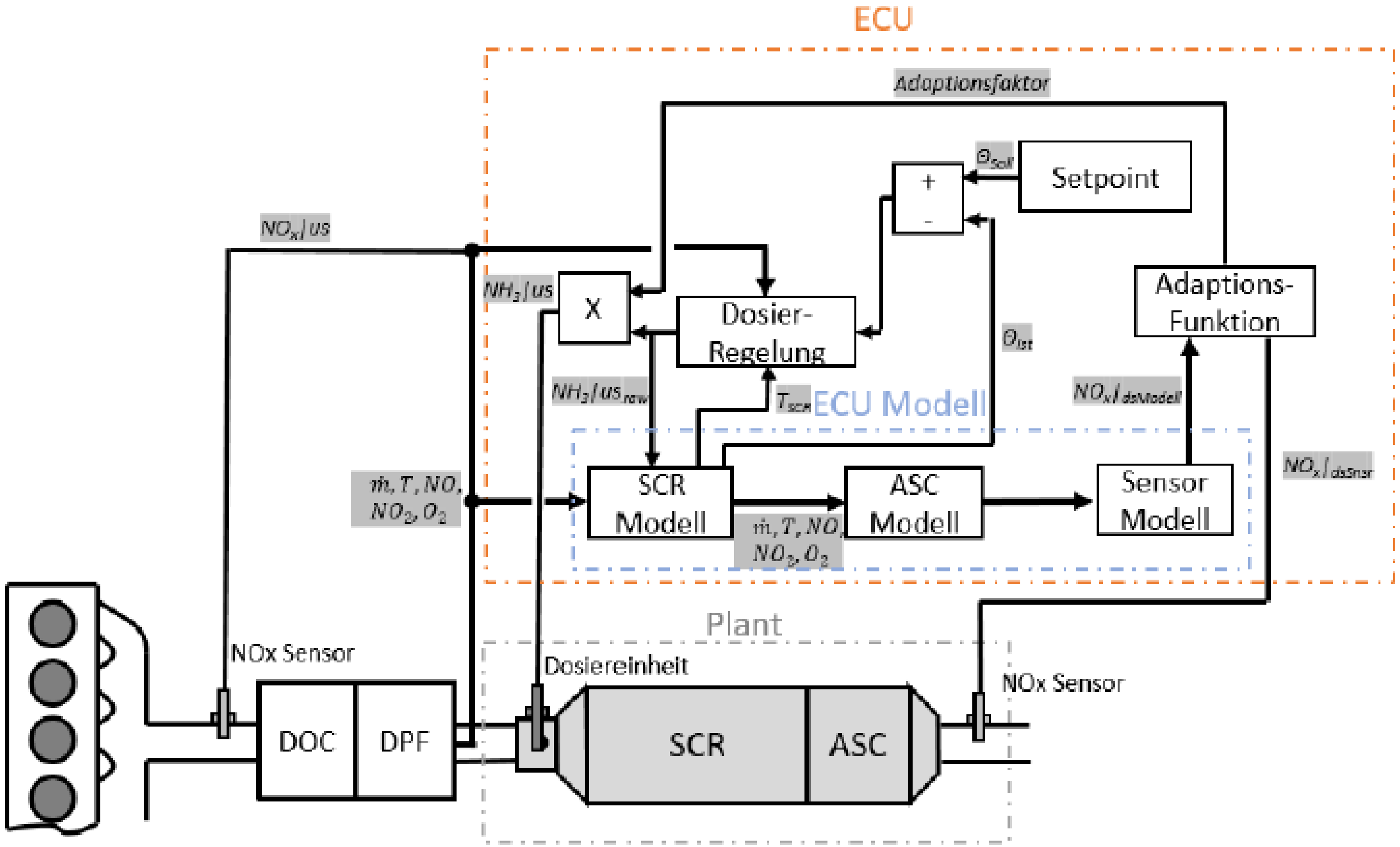
Exhaust aftertreatment – Diesel Engine



Advanced diesel aftertreatment system with 4 catalytic converters

- DOC
  - Diesel Oxidation Catalyst
- DPF
  - Diesel Particulate Filter
- SCR
  - Selective Catalytic Reduction
- ASC
  - Anti-Slip Catalyst for NH3

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