Potential of CNG-Diesel Dual-Fuel Internal Combustion Engines for Mobile Applications

Univ.-Prof. Dr. Helmut Eichlseder

Dr. Peter Grabner

7th A3PS Conference “Eco-Mobility 2012”

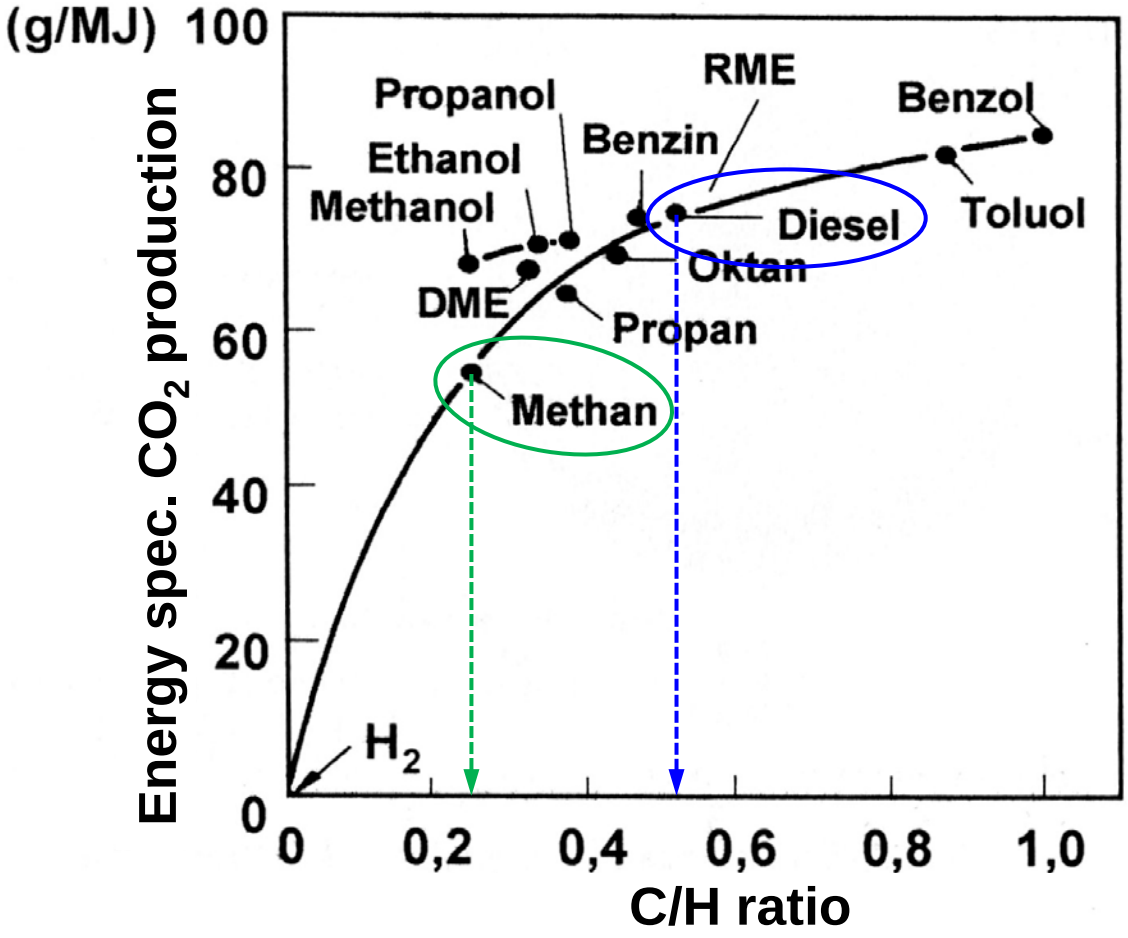
Overview

- Introduction
  - General topics / Motivation
  - Configuration of the Experimental Setup
  - Basic Procedure
- Operating Behavior at CH4 Admixture
- Optima at different Engine Loads
- Summary – Outlook

Motivation

- Reduction of CO_2 Emissions
- Improvement of Soot/NO_x-Trade off
  - (More) Homogenous Mixture
- Proven Technology (State of the art)
  - Short-term Feasibility
  - Integration into existing Vehicle Concepts
  - Pure Diesel Operation possible → low Dependence on the Gas Infrastructure

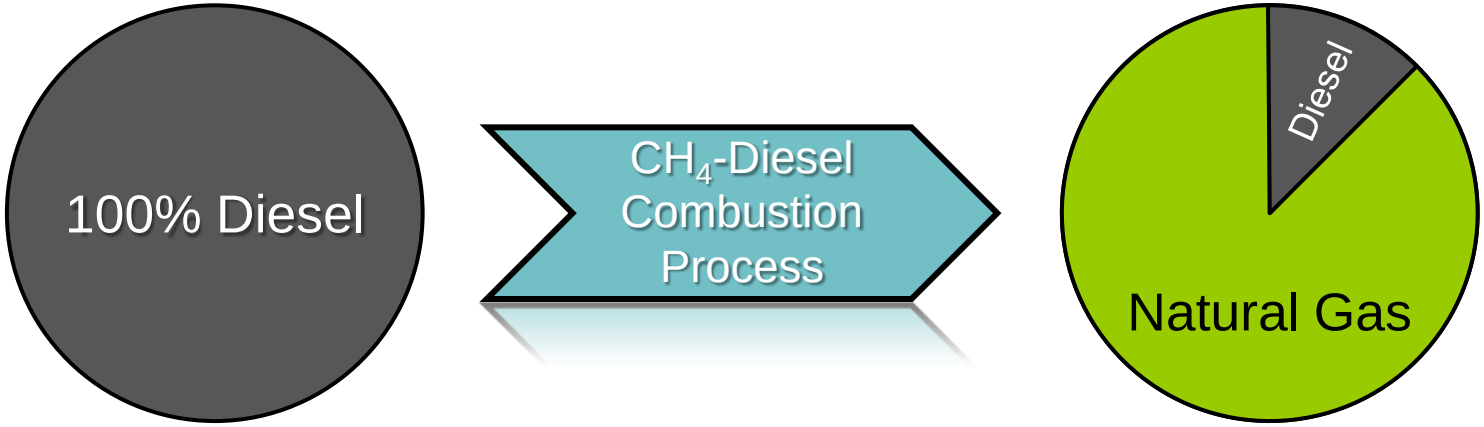
Motivation – CO_2 Reduction



Source: Pischinger, S.

Motivation – CO_2 Reduction

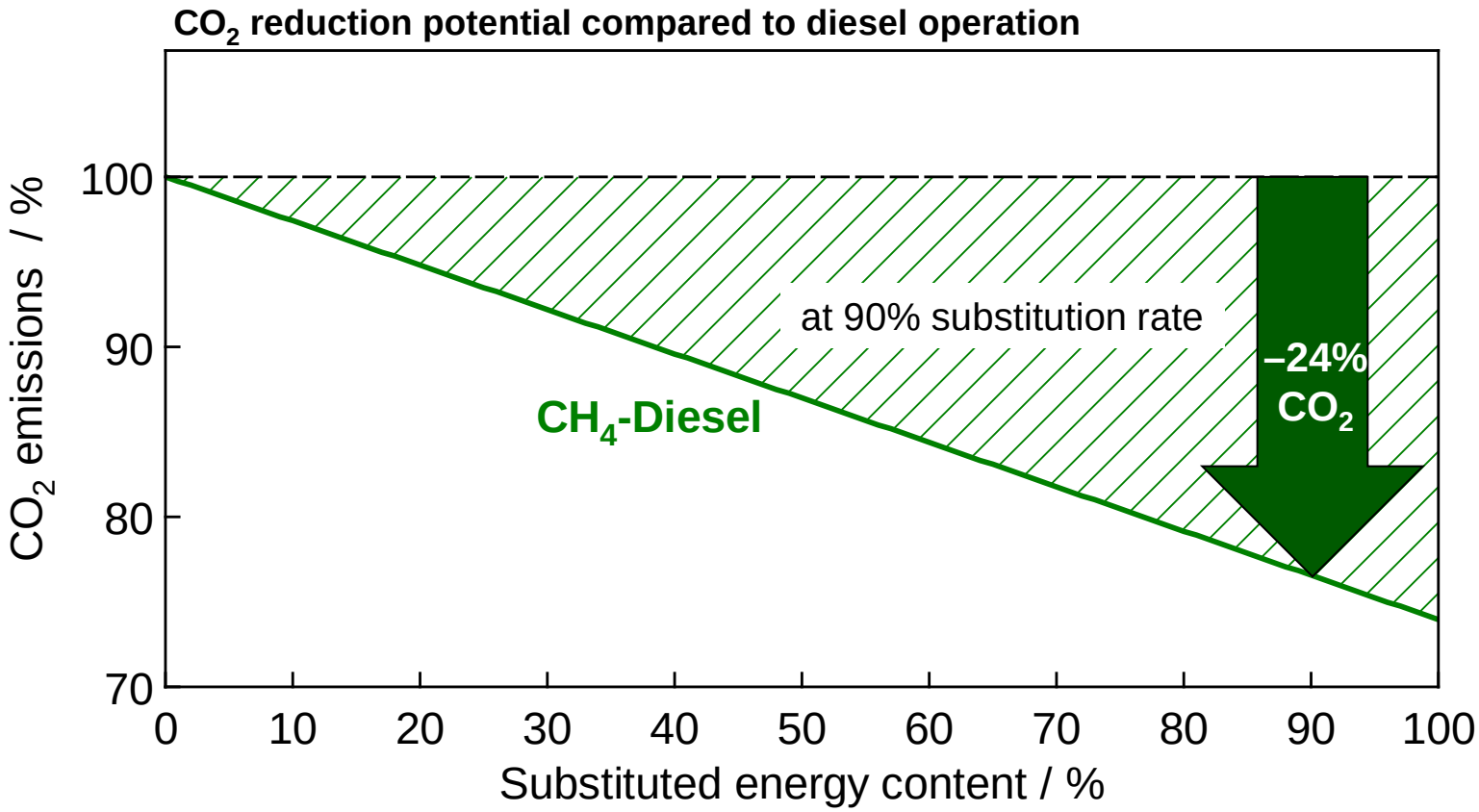
- Basic Idea: Substitution of diesel energy



- Definition of energetic gas content

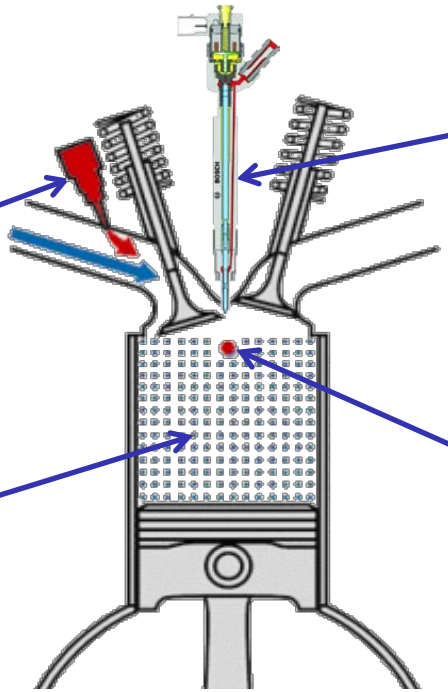
$$x_{\mathrm{CH_4}} = \frac{m_{\mathrm{CH_4}} . H_{\mathrm{u_{CH_4}}}}{\sum_i m_{\mathrm{B}_i} . H_{\mathrm{u}_i}}$$

Motivation – CO_2 Reduction



Experimental Setup

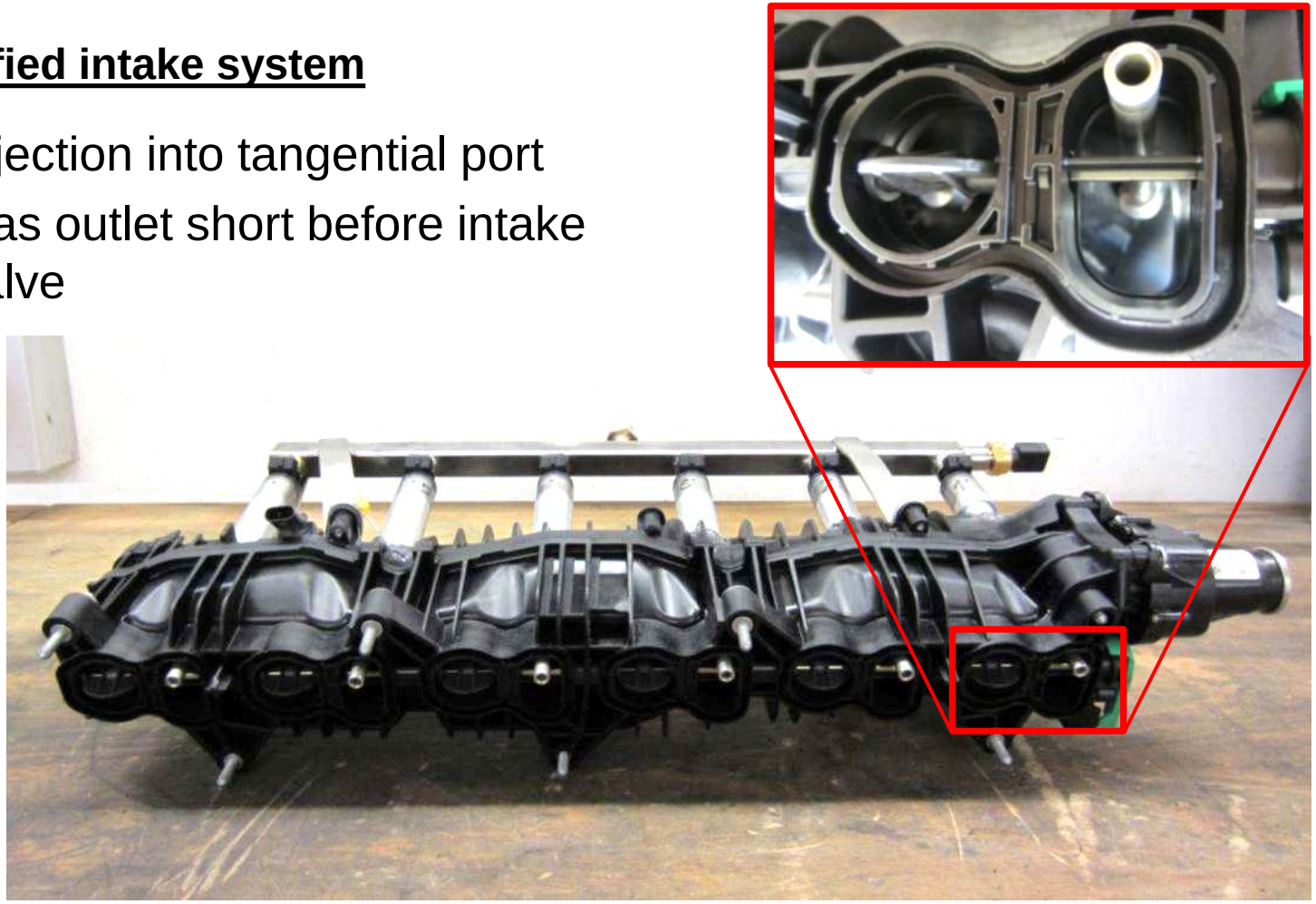
- Intake-synchronized, cylinder-selective injection into the intake port
- Pilot flame ignited operation → only **one** diesel injection
- Start of combustion due to diesel spray (pilot) ignition
- Test engine: passenger car diesel engine with 0.5 L displacement per cylinder (EU5)



Experimental Setup

Modified intake system

- Injection into tangential port
- Gas outlet short before intake valve

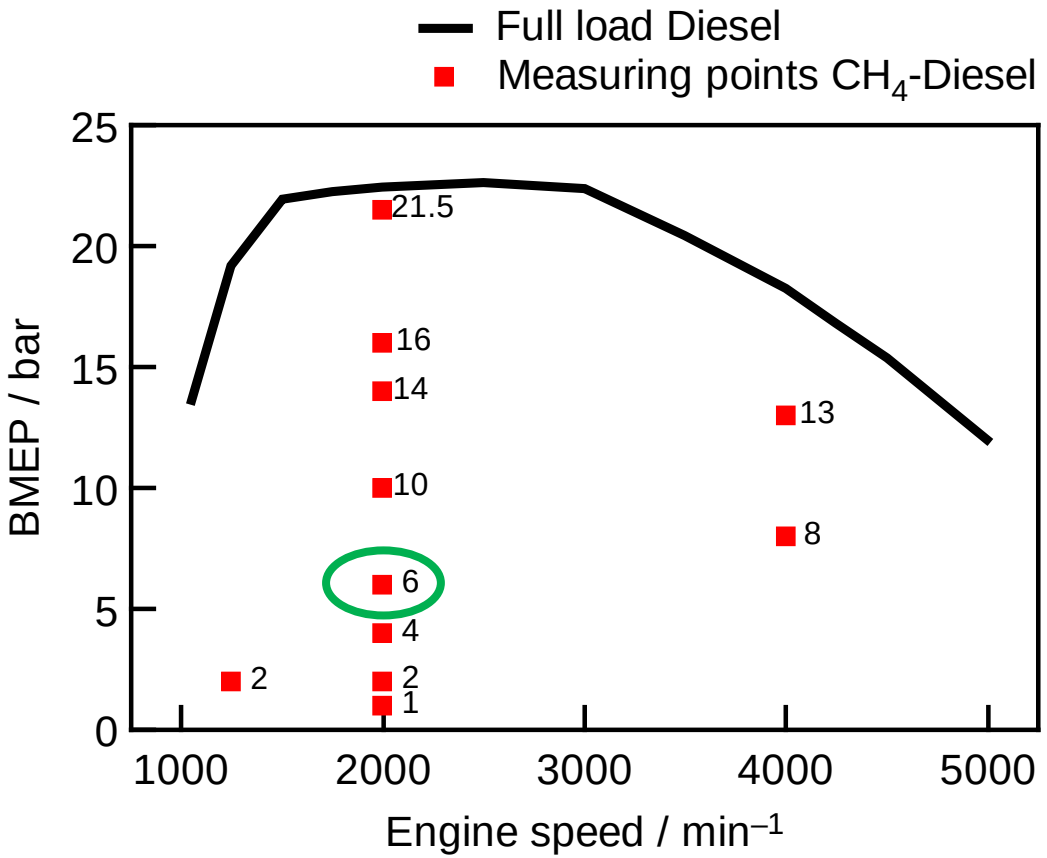


Basic Procedure – Boundary Conditions

- Single diesel injection → pilot flame ignition (acoustics verified)
- maximum possible gas content → highest CO_2 savings
- **Targets:** Compliance with the values of soot, NO_x and efficiency at maximum gas content (stationary operation) compared to the production engine
- Constant 50% energy conversion point
- Implementation of the characteristic parameter λ_{intake}

Basic Procedure – Measurements

Investigations carried out …



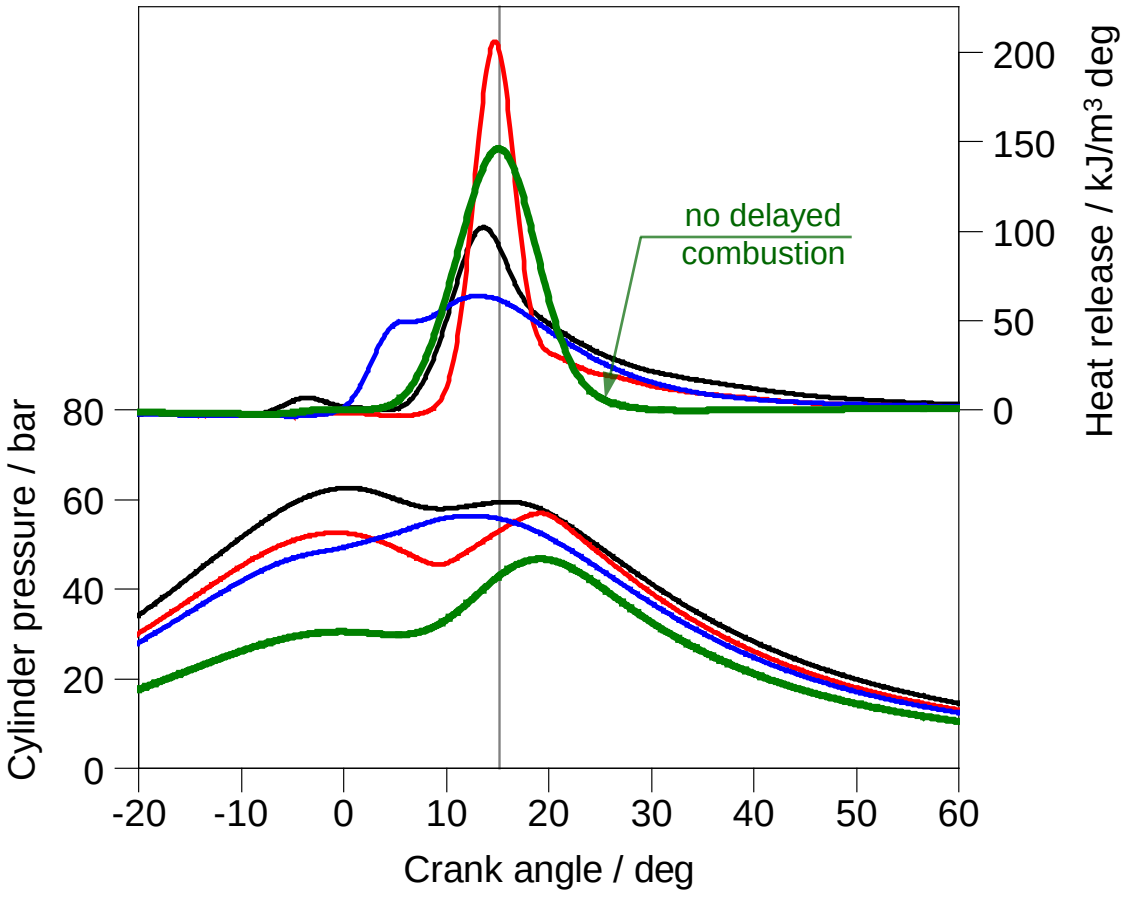
CH_4-Diesel combustion at „2000/6“

Series application:
- 3 injections
- 27% EGR

100% Diesel:
- 1 injection
- w/o EGR

90% CH_4:
- 1 injection
- w/o EGR
- λ_{CH_4} = 2.1
- unthrottled

90% CH_4:
- 1 injection
- w/o EGR
- λ_{CH_4} = 1.3
- throttled



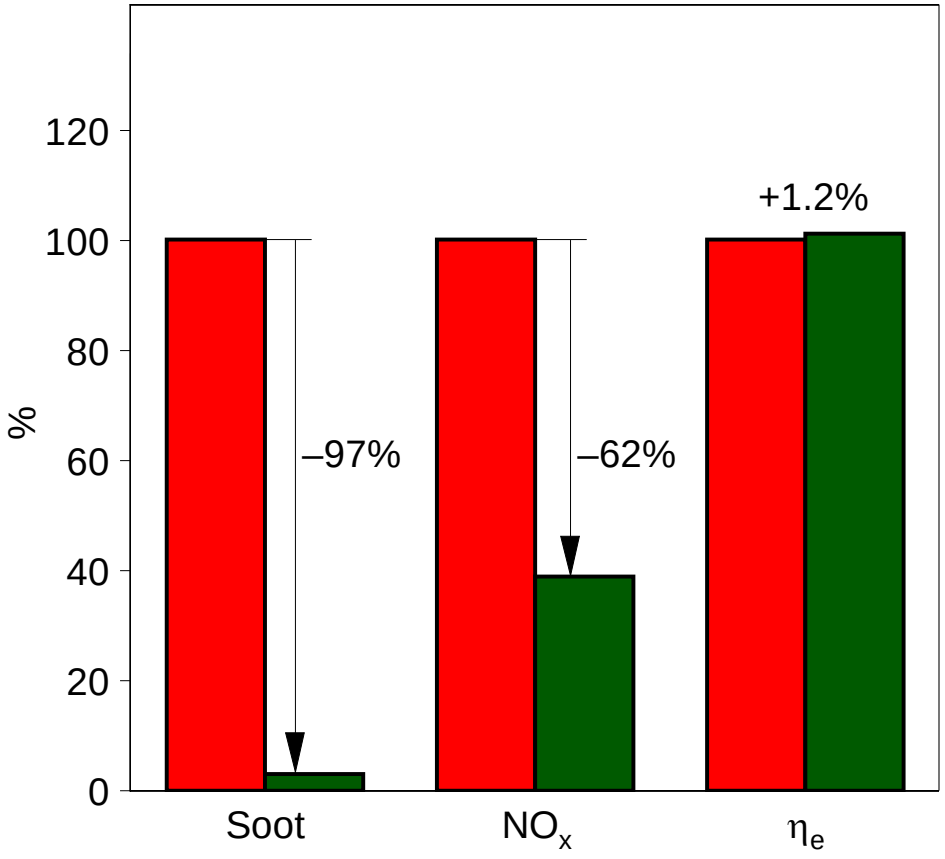
CH_4-Diesel combustion at „2000/6“

- Operation above $\lambda_{CH_4} = 2$ not meaningful
  - Increasing worsening of the combustion
  - Unburned CH_4 in the exhaust gas
  - Decreasing efficiency
- Gasoline engine-like combustion within the ignition limits
  - Reduction of the combustion duration
  - Decreasing CH_4 emissions
  - Efficiency raise due to EGR and throttling

Reached Optimum at „2000/6“

Diesel series point:
- 3 injections
- 27% EGR

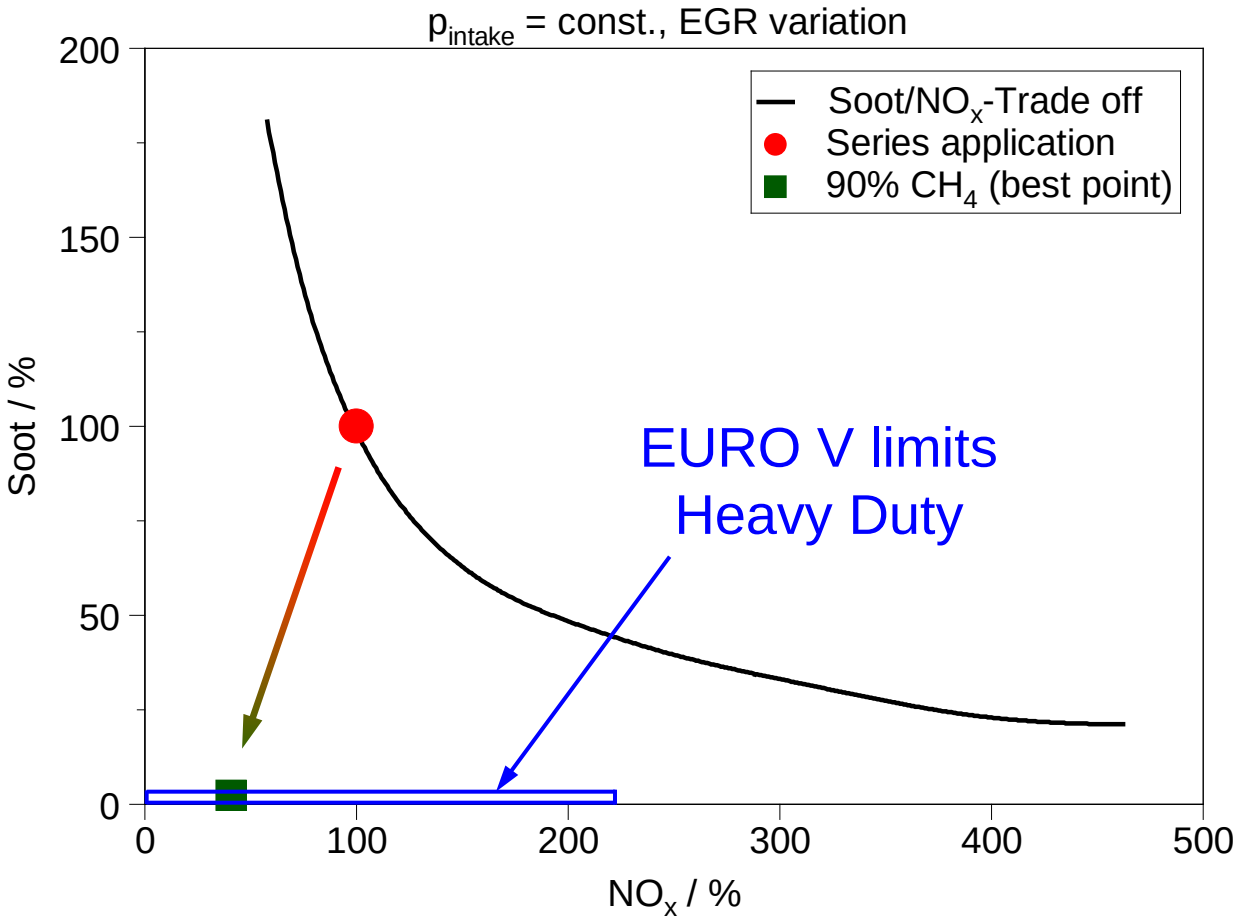
CH_4-Diesel:
- 90% CH_4
- 1 injection
- 34% EGR
- λ_{CH_4} = 1.4
- unthrottled



Reached Optimum at „2000/6“

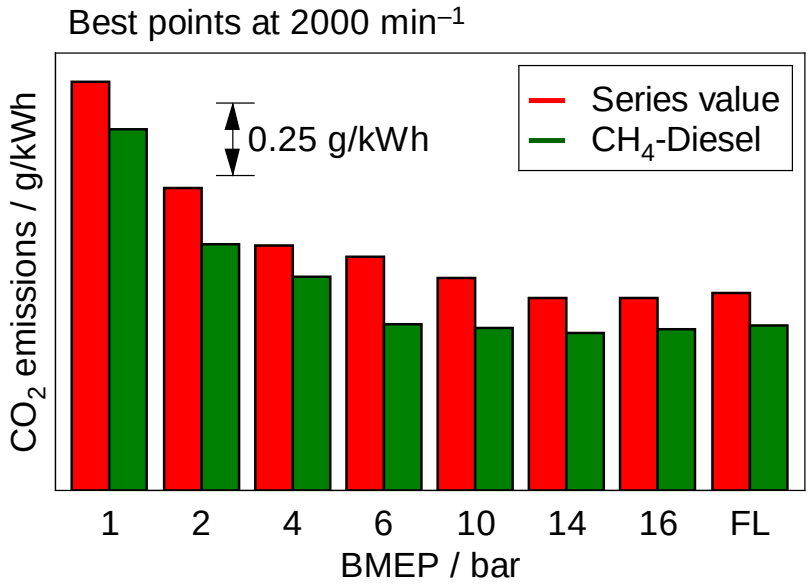
Diesel series point:
- 3 injections
- 27% EGR

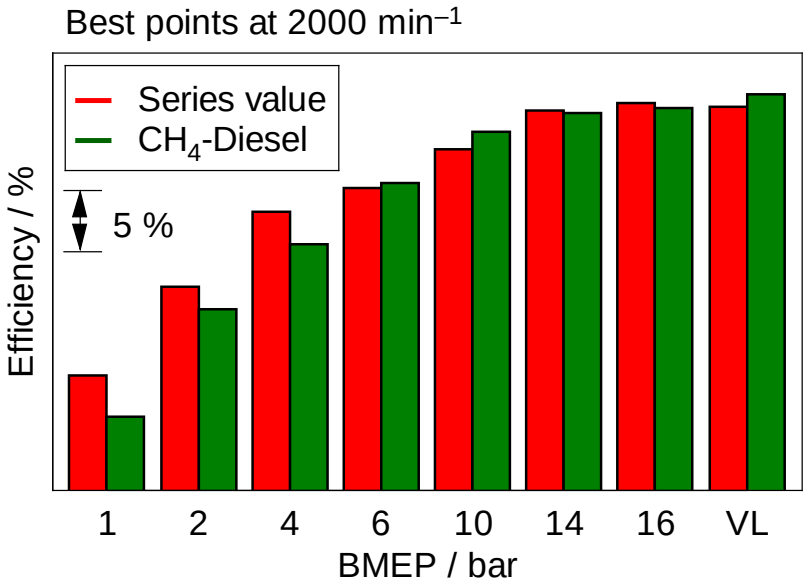
CH_4-Diesel:
- 90% CH_4
- 1 injection
- 34% EGR
- λ_{CH_4} = 1.4
- unthrottled



Load variation at 2000 min^{-1}

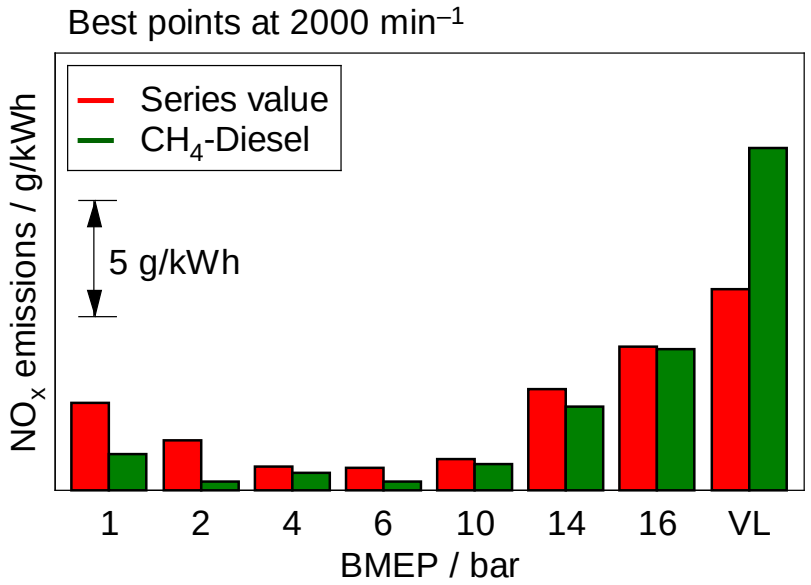
- CO_2 savings above low-load range > 20%
- Low-load range: small substitution rate ⇨ lower CO_2 reduction
- Poor efficiency at low-load
- Better/equal efficiency at higher loads compared to series engine

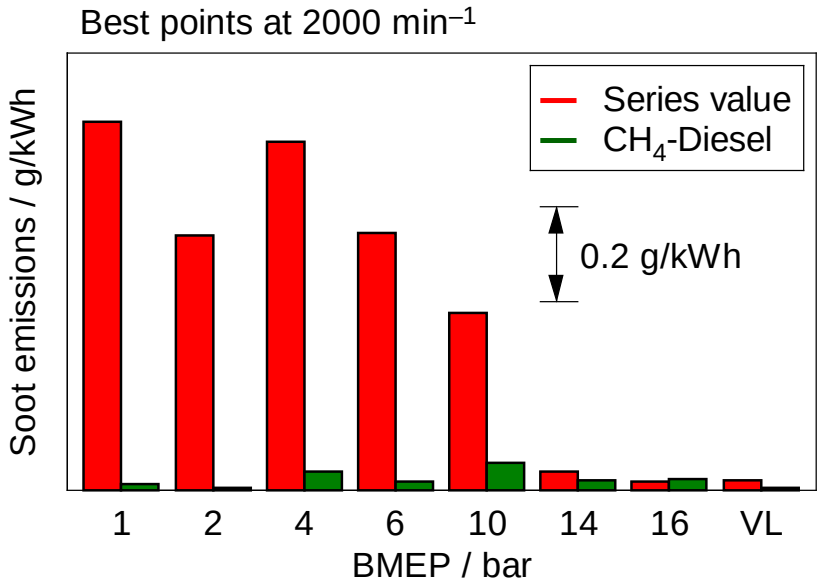




Load variation at 2000 min^{-1}

- NO_x emissions below series engine level
- Full load: NO_x due to gasoline engine combustion significantly higher
- Despite low NO_x emissions extreme low Soot emissions





Advantages of CH_4-Diesel combustion

- Significant CO_2 reduction
- Lower fuel costs

- Efficiency higher than that of bivalent gas Otto engines
- Pure Diesel operation possible ⇨ low dependance on gas infrastructure

Summary

- Operation above $\lambda_{CH_4} = 2$ not meaningful
  - ⇨ Content of CH_4 at low-load range limited (η_e)
- High potential from medium-load upward
- Results verified at different engine speeds
- Possible fields of application of this combustion process
  - Light-/Heavy Duty: long-distance traffic with LNG
  - Off-road sector: construction machines, tractors

} e.g. Biogas

Outlook

- Engine-internal reduction of CH_4 emissions
  - ☞ Modification of combustion chamber geometry
    - ↳ modified piston bowl
    - ↳ flatter injection angle
    - ↳ adjusted cylinder head
- Investigation of transient behavior
  - ☞ Realization of simultanous operation for emission cycles