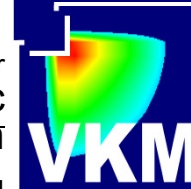


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Lehrstuhl für
Verbrennungskraftmasc
hinen

Prof. Dr. Rudolf Flierl



diesel-CNG-mixed combustion

Benefits of simultaneous Combustion of
Diesel and Compressed natural Gas

Technische Universität Kaiserslautern
Lehrstuhl für Verbrennungskraftmaschinen
Postfach 3049, 67653 Kaiserslautern



1 Gas-Diesel-Combustion

- Motivation
- System
- Targets

2 Results of Diesel-CNG-Mixed Combustion of a Euro3-Nfz-Engine

3 Results of a modern Commonrail-V6-Engine

4 Outlook



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Diesel-CNG-Mixed Combustion

Benefits of simultaneous
Combustion of Diesel and
Compressed natural Gas

Diesel-CNG-Mixed Combustion

Motivation



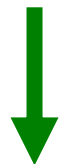
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CNG — Diesel

Combined
Combustion



Benefits



compensation

Homogeneous
Combustion

Heterogeneous
Combustion

Emissions (PM, CO₂)
Better combustion Sound
Smell
Costs

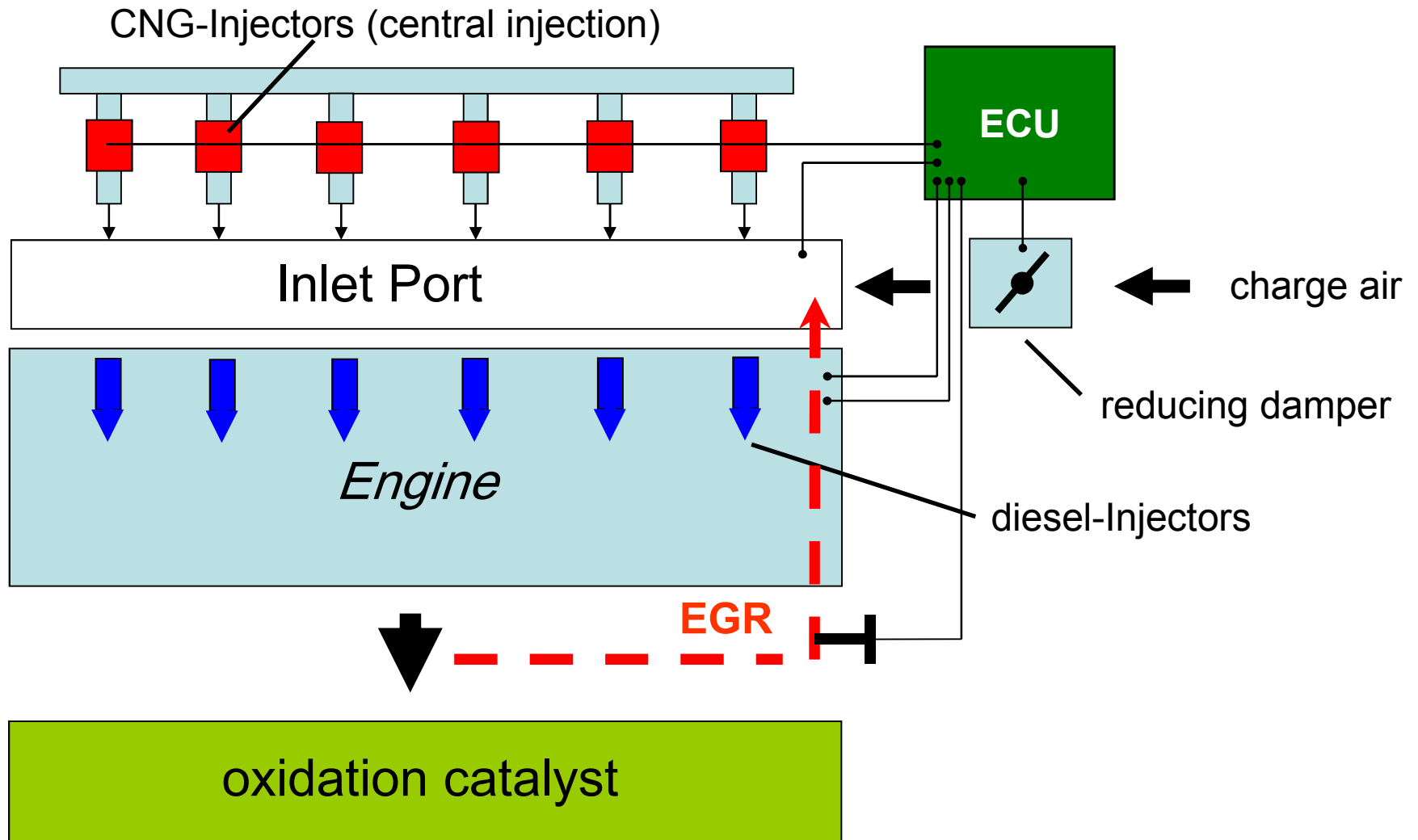
effectiveness
HC and CO Emissions

Diesel-CNG-Mixed Combustion System

System



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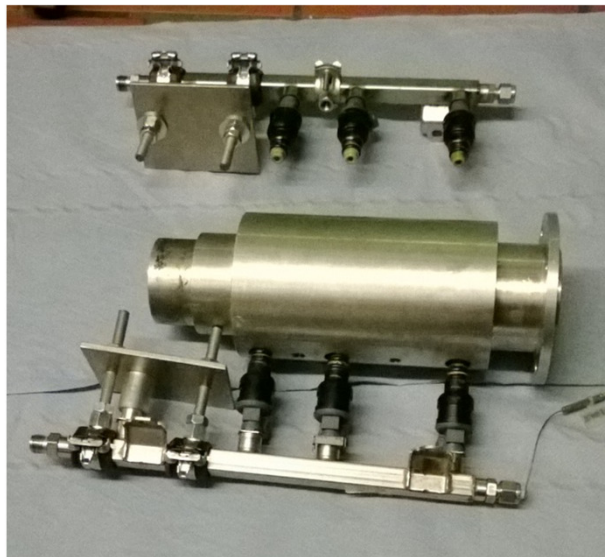


Diesel-CNG-Mixed Combustion

Injector flange



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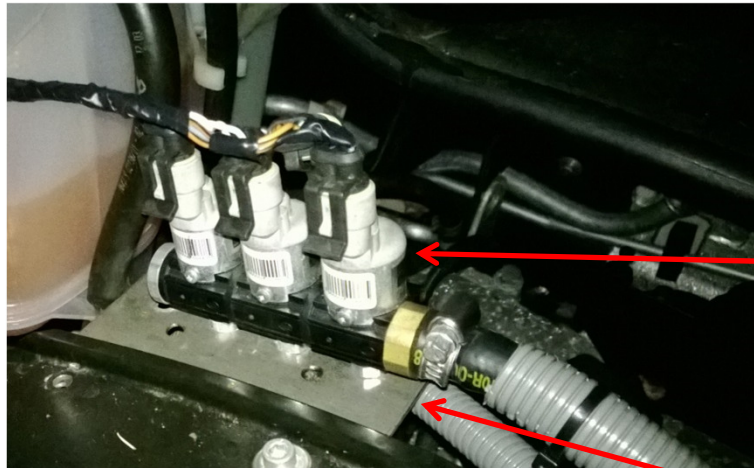


Diesel-CNG-Mixed Combustion

installation example for a central injection into the inlet system

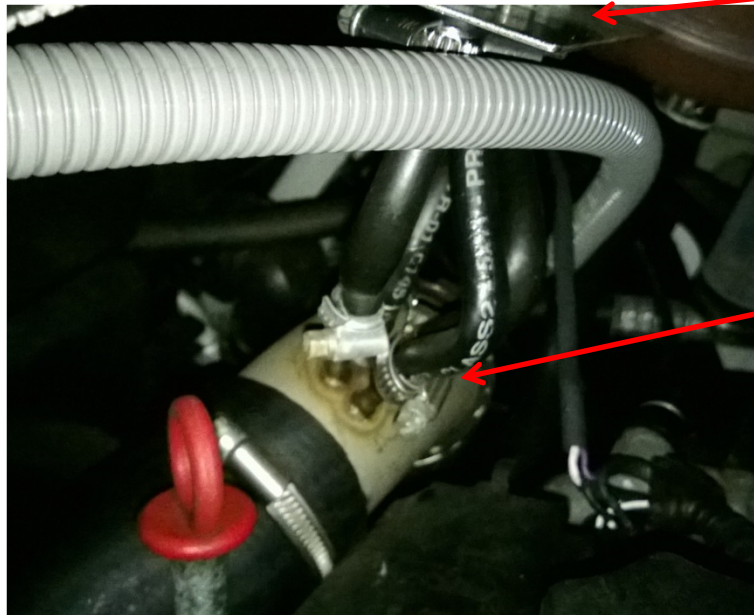


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CNG-injector

injector installation platform

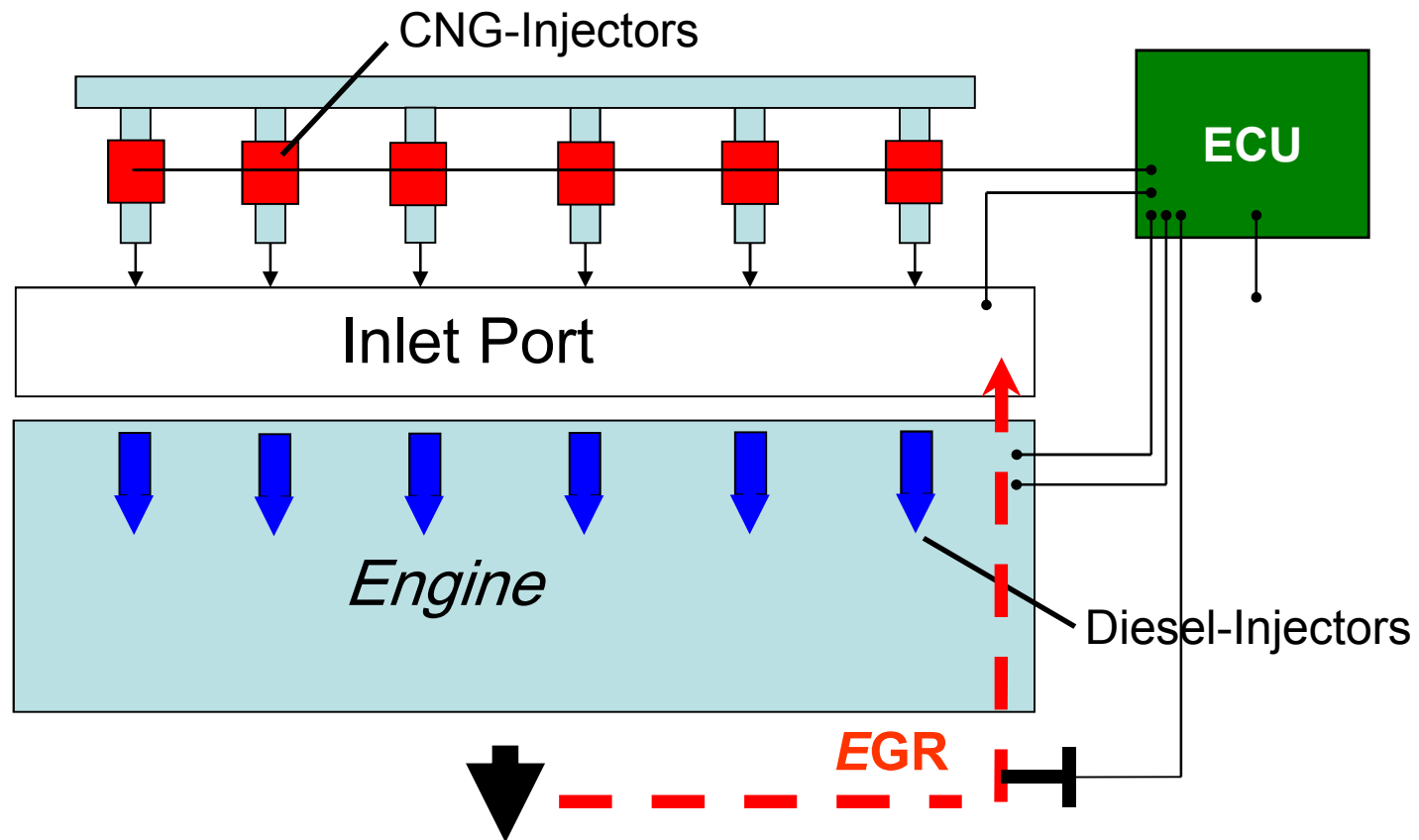


Part of the inlet system – point of central CNG-injection

System

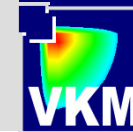


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Diesel-CNG-Mixed Combustion

Targets



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- **maximise energetic CNG percentage**
- **maximise power efficiency**
- **solid design endurance**
- **maximum reduction of CO2 Emission**
- **Reduce Soot-Emissions**



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CR-V6-diesel engine - diesel-CNG-mixed combustion

CR-V6-diesel engine with CNG-Diesel

variation: energetic CNG-ratio

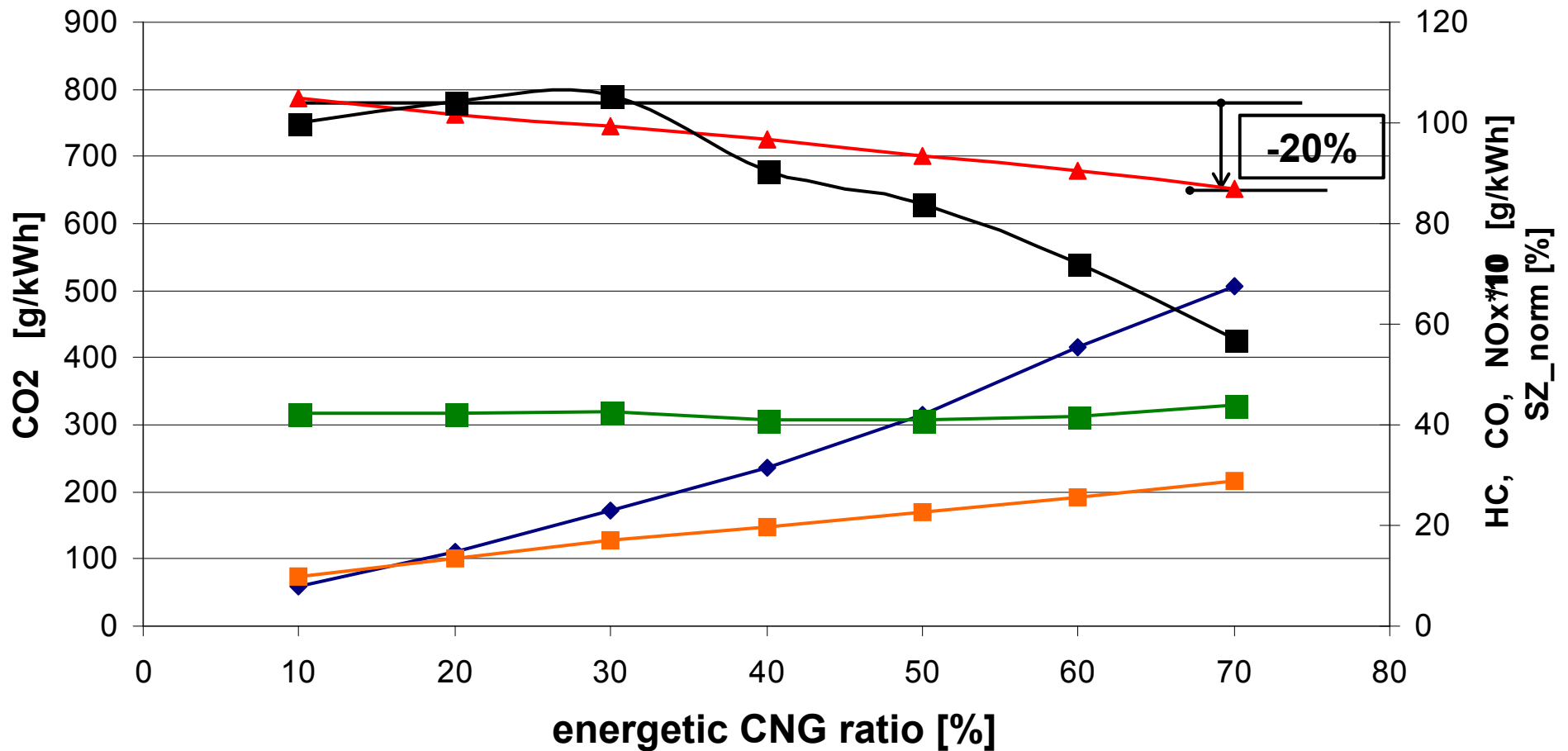


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V6 CR-Diesel
2000_4bar
phi Pii =const.
Ladedruck =const.
Drall=0
AGR=0

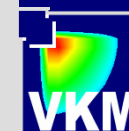
specific emissions

—▲— CO2 —◆— HC —■— CO —■— NOx —■— SZ_norm [%]



CR-V6-diesel engine with CNG-Diesel

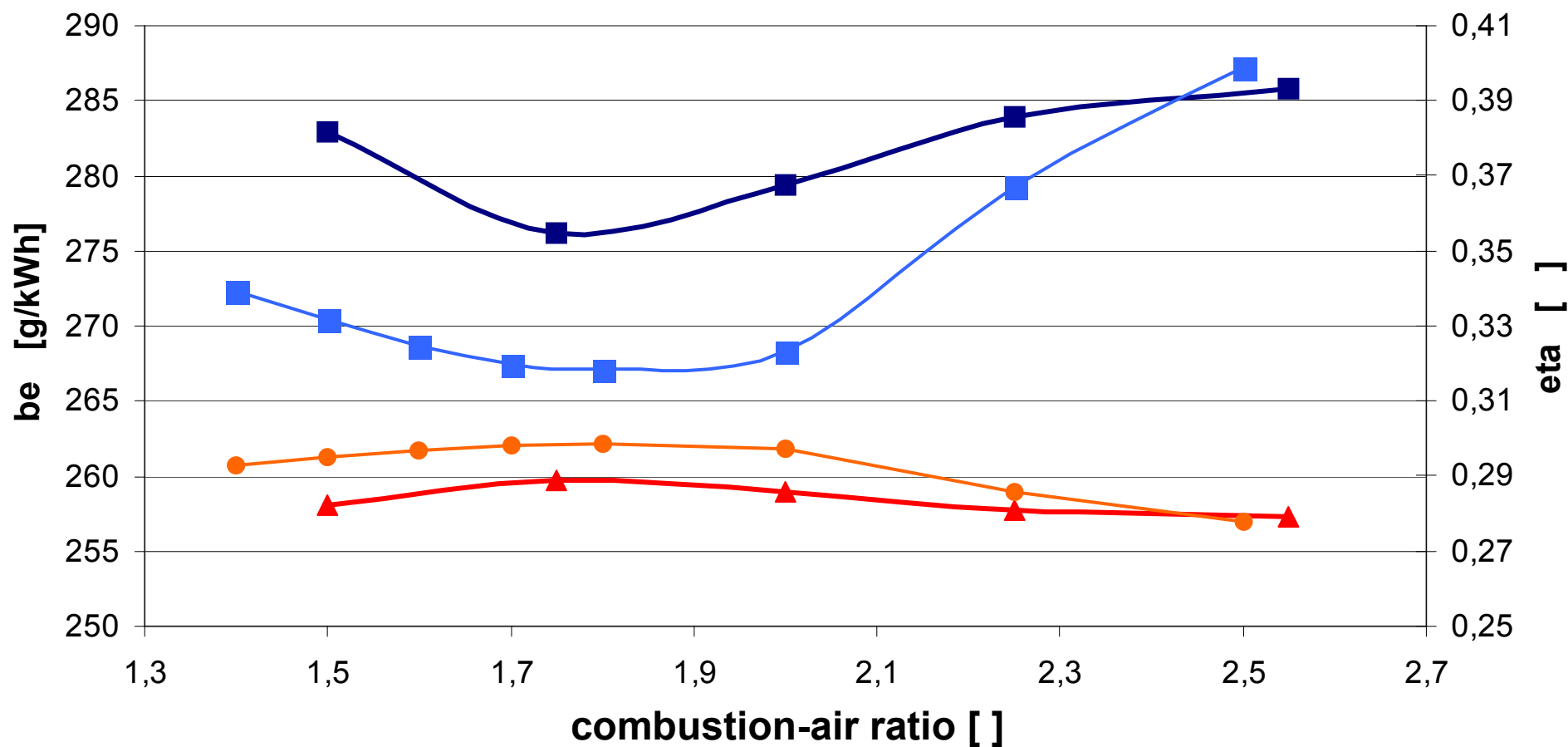
Variation: combustion-air ratio VTG+DK vs DK



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V6 CR-Diesel
2000_4bar
phi Pii=const.
XCNG=50%
Drall=0
AGR=0

parameter



CR-V6-diesel engine with CNG-Diesel

Variation: combustion-air ratio - VTG and DK

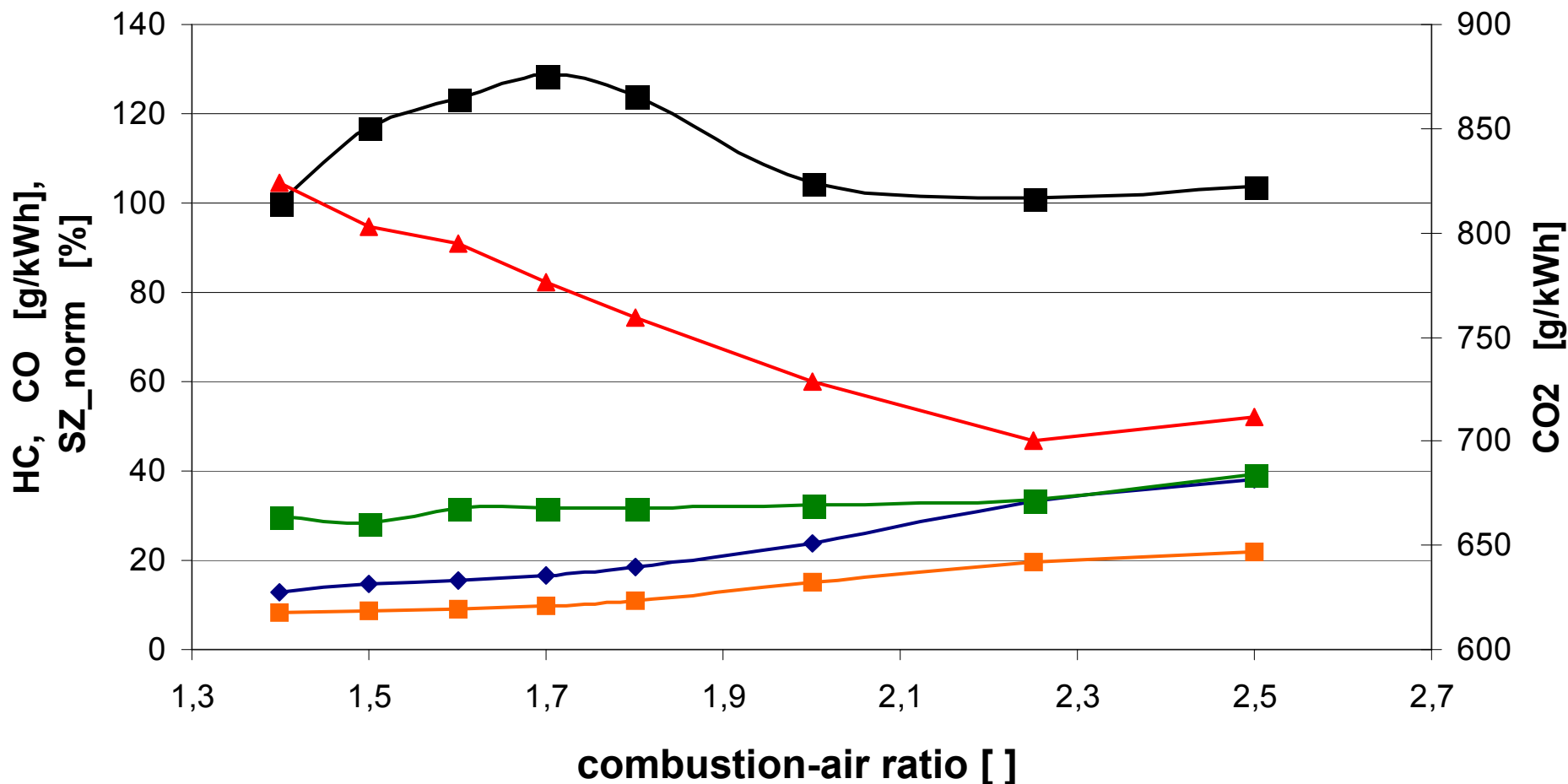


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V6 CR-Diesel
2000_4bar
phi Pii=const.
XCNG=50%
Drall=0
AGR=0

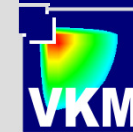
combustion-air ratio - Labda variation - VTG + DK

◆ HC ■ CO ■ NOx ■ SZ_norm ▲ CO2



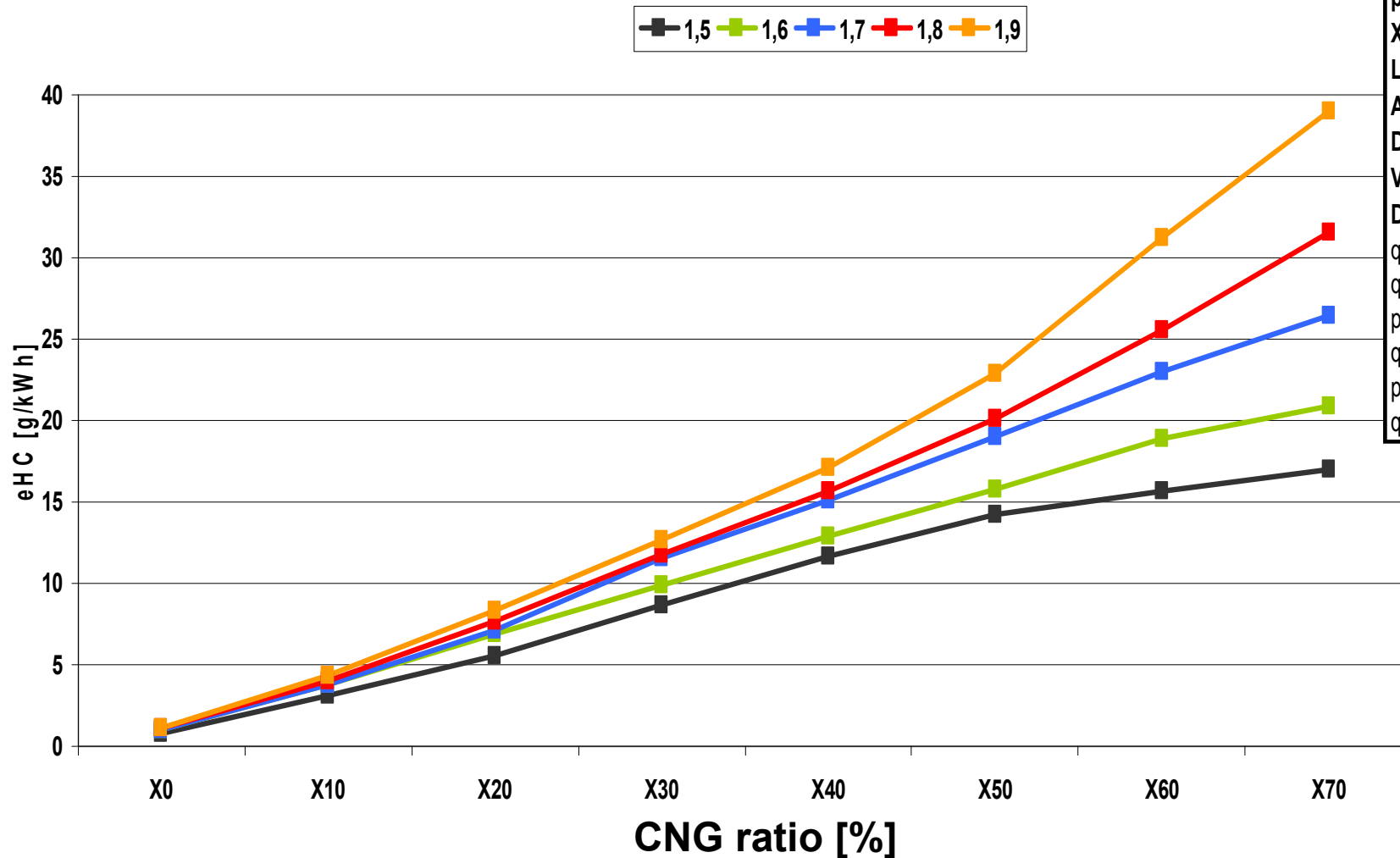
CR-V6-diesel engine with CNG-Diesel

HC-emissions: combustion-air ratio variation



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specific emissions HC



2,7l-V6-TDI
n = 2000 1/min
pm,e = 4 bar
XCNG = var.
Lambda = var.
AGR = 0%
Drall = 0
VTG = min
DK = variabel
qPI2 = const
qPI1 = const
phiPI1 = const
qMI = variabel
phiMI = const
qPol1 = 0

CR-V6-diesel engine with CNG-Diesel

pilot injection 1: injected fuel quantity variation

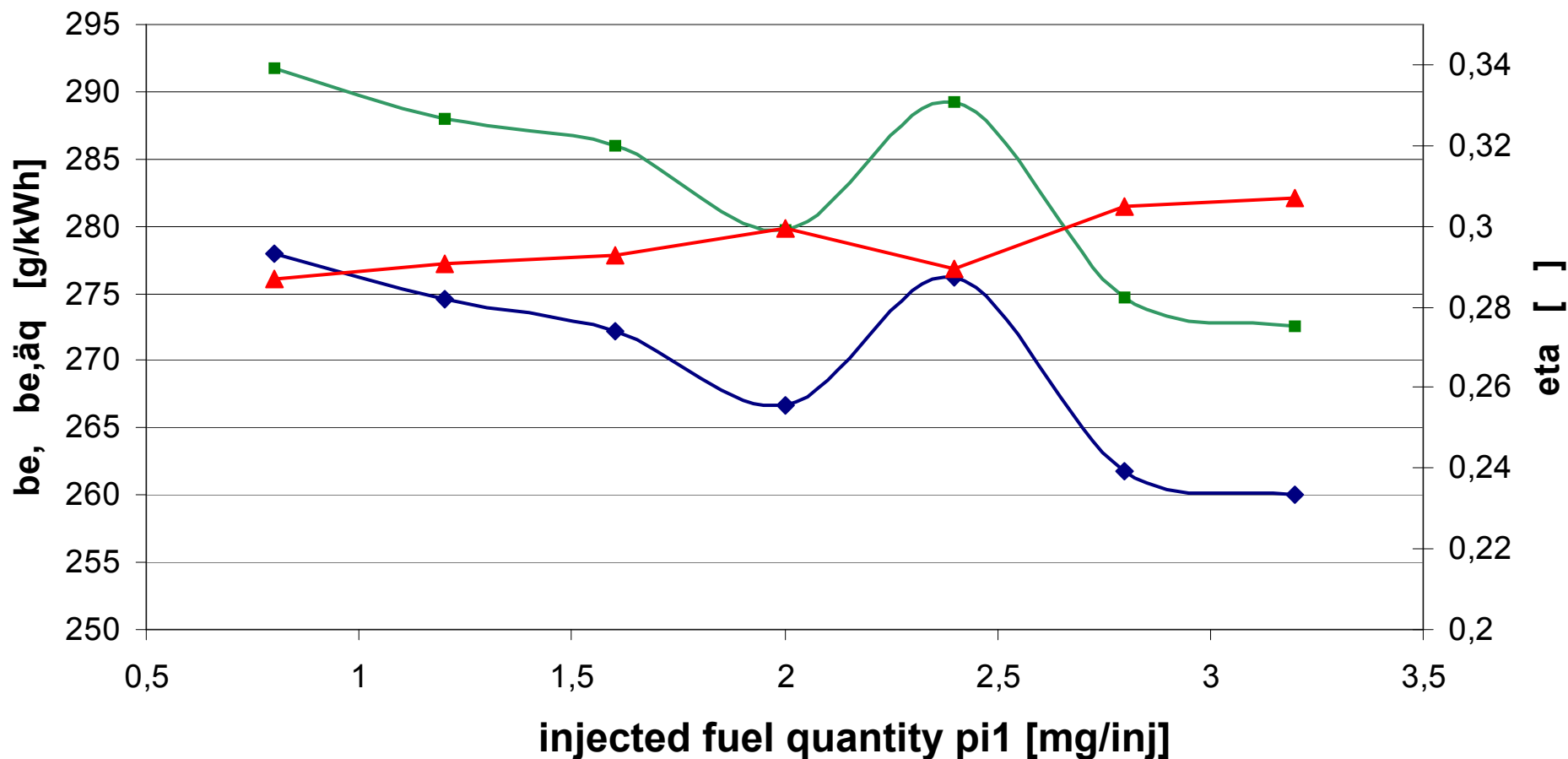


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V6 CR-Diesel
2000_4bar
phi Pii =const.
Lambda 1,7
XCNG=50%
Drall=0
AGR=0

parameter

◆ be ■ be,äq ▲ eta



CR-V6-diesel engine with CNG-Diesel

pilot injection 1: injected fuel quantity variation

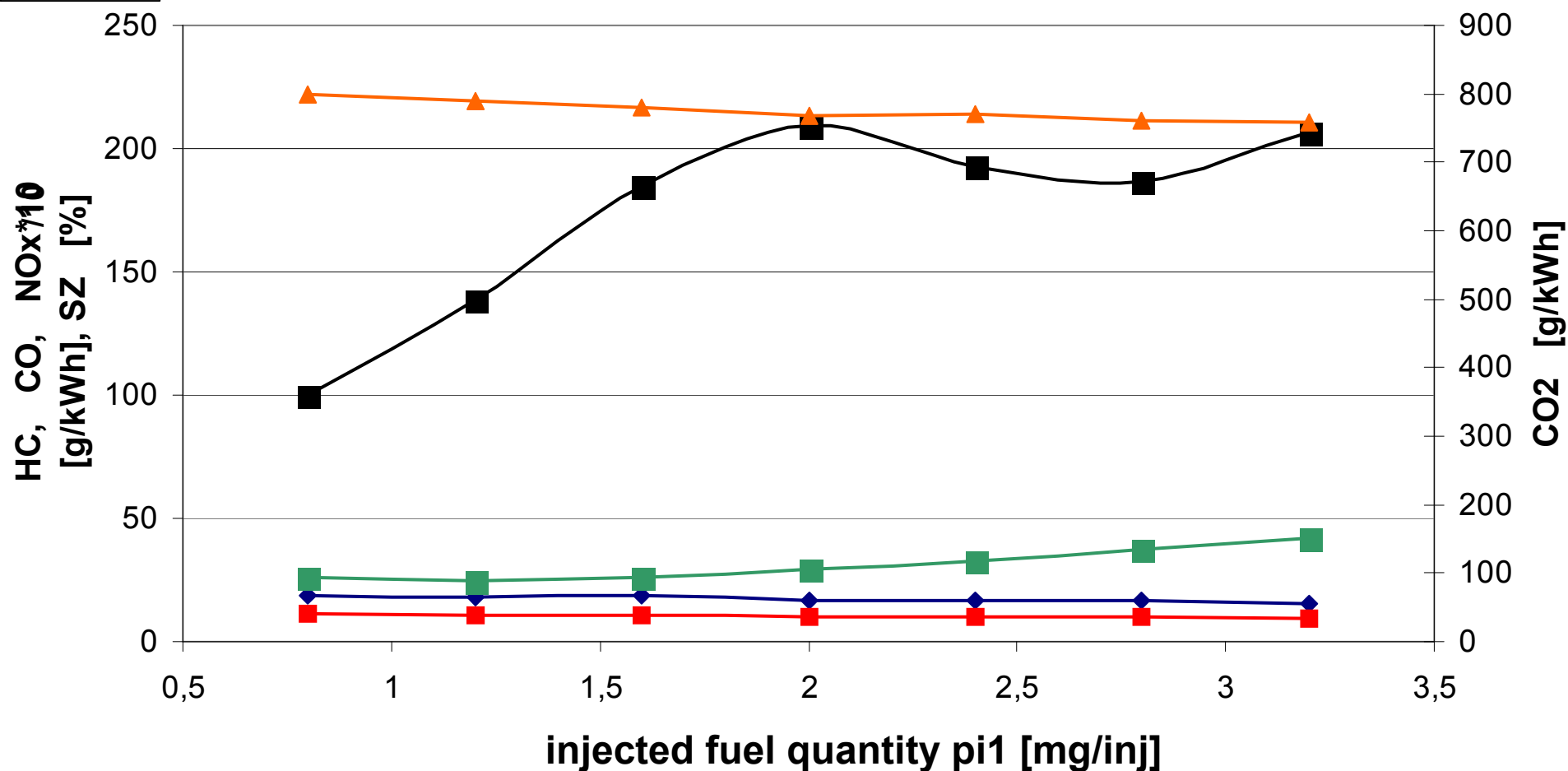


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V6 CR-Diesel
2000_4bar
phi Pii =const.
Lambda 1,7
XCNG=50%
Drall=0
AGR=0

specific emissions

◆ HC ■ CO ■ NOx*10 ■ SZ_norm ▲ CO2



CR-V6-diesel engine with CNG-Diesel

pilot injection 1: fuel injection timing variation

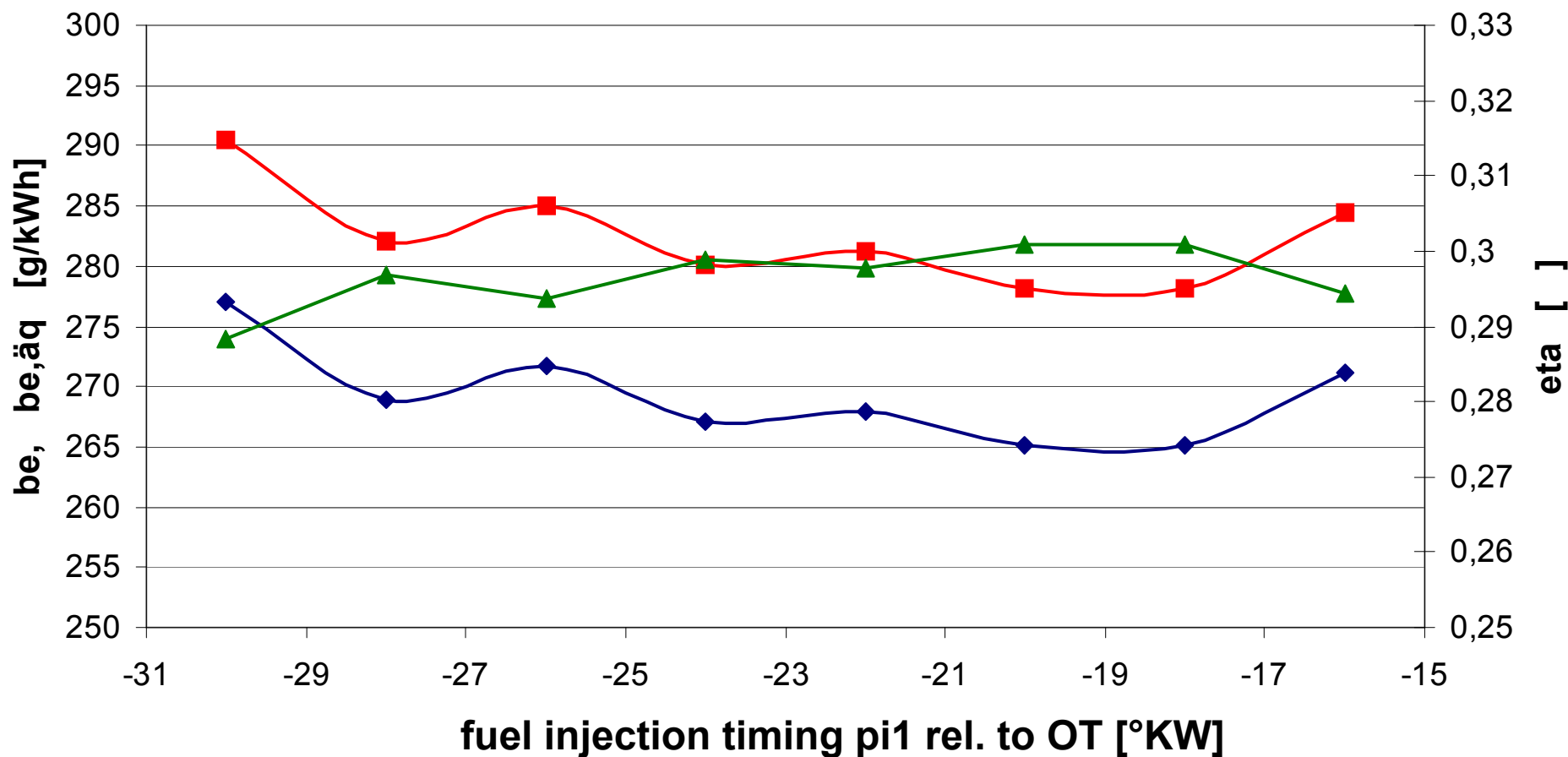


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V6 CR-Diesel
2000_4bar
qP1 =2mg/inj
Lambda 1,7
XCNG=50%
Drall=0
AGR=0

parameter

◆ be ■ be,äq ▲ eta



CR-V6-diesel engine with CNG-Diesel

pilot injection 1: fuel injection timing variation

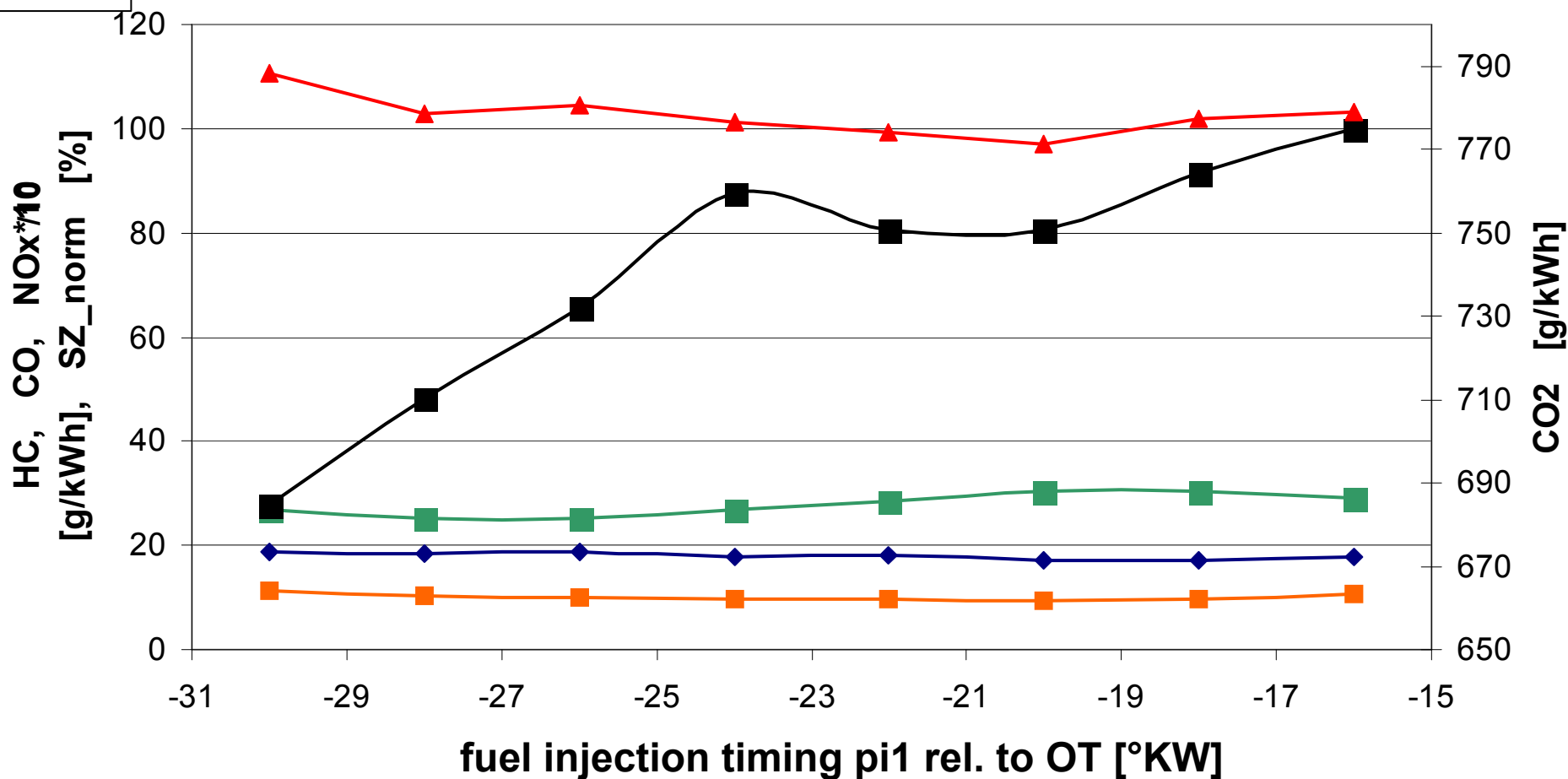


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V6 CR-Diesel
2000_4bar
qP1 =2mg/inj
Lambda 1,7
XCNG=50%
Drall=0
AGR=0

specific emissions

◆ HC ■ CO ■ NOx*10 ■ SZ_norm ▲ CO2



CR-V6-diesel engine with CNG-Diesel

abstract



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- **energetic CNG-ratio up to > 55% possible**
- **soot emission reduction: 30 % – 40 %**
- **NO_x-emissions: constant level**
- **rise of HC- und CO-emission can be managed by oxidation catalyst**
- **particulate amount linearly dependent on energetic CNG-ratio (particle size distribution nearly constant)**
- **only low loss of real efficiency (~1 abs-%)**
- **fuel cost reduction potential**
- **CO₂-reduction potential up to 23%**



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Thank You.

Results of CNG-Diesel-Mixed Combustion of an Euro3- Utility Vehicle

CNG-Diesel-Mixed Combustion

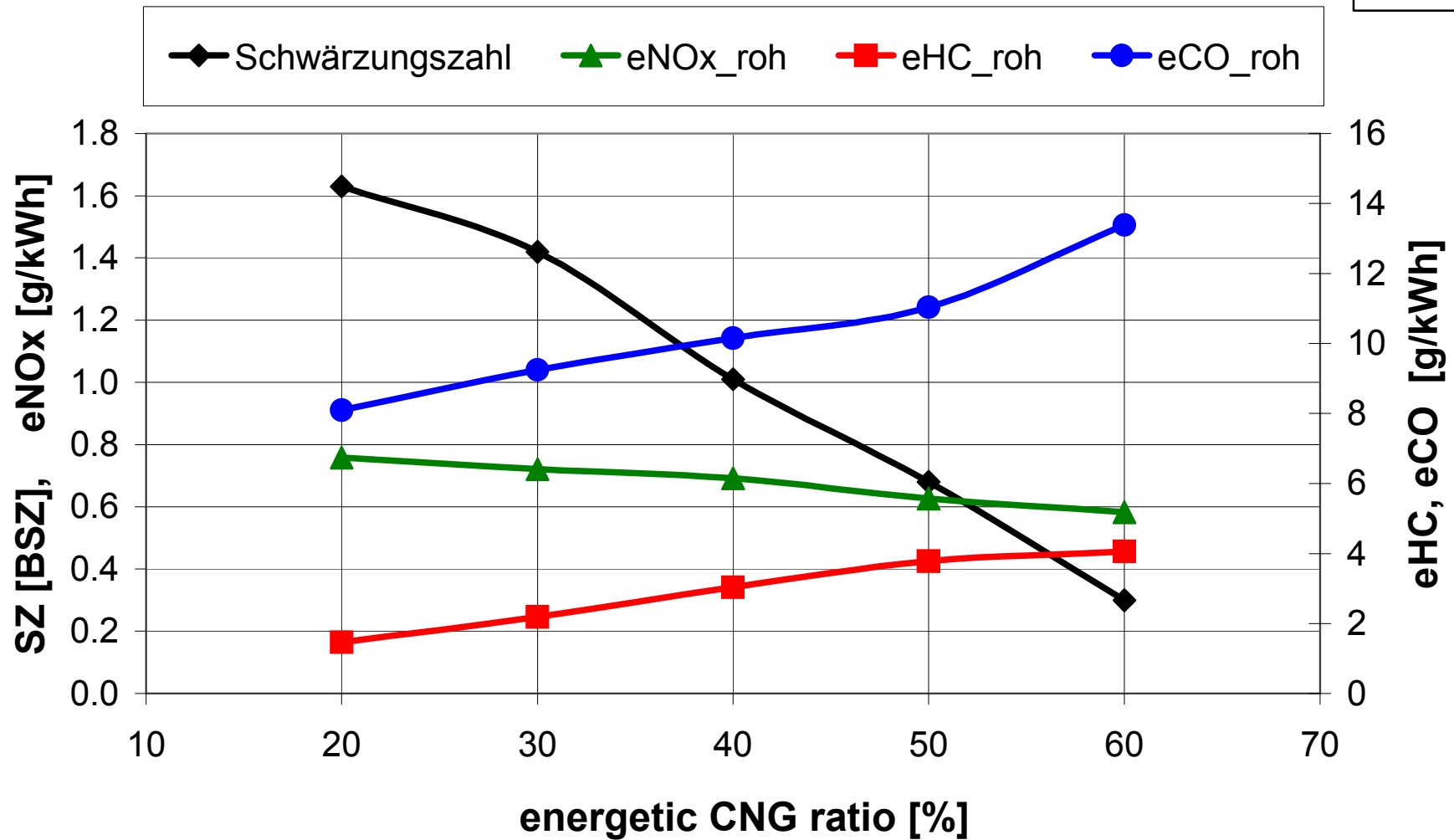
Results



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specific emissions

B50
Lambda 1,5
AGR ein



CNG-Diesel-Mixed Combustion

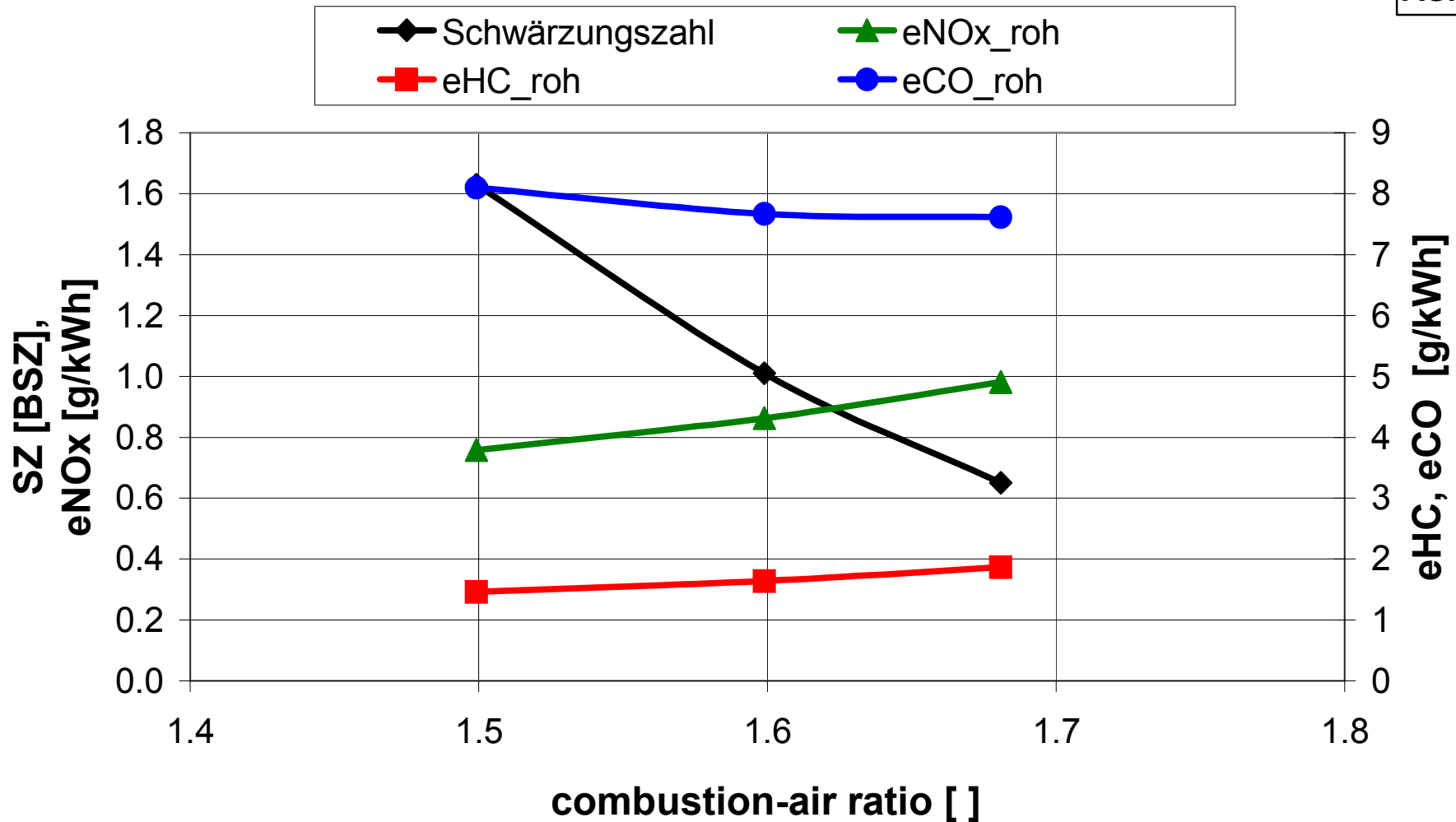
Variation: combustion-air ratio



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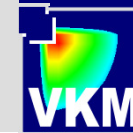
B50
 $X_{CNG}=20\%$
AGR ein

specific emissions



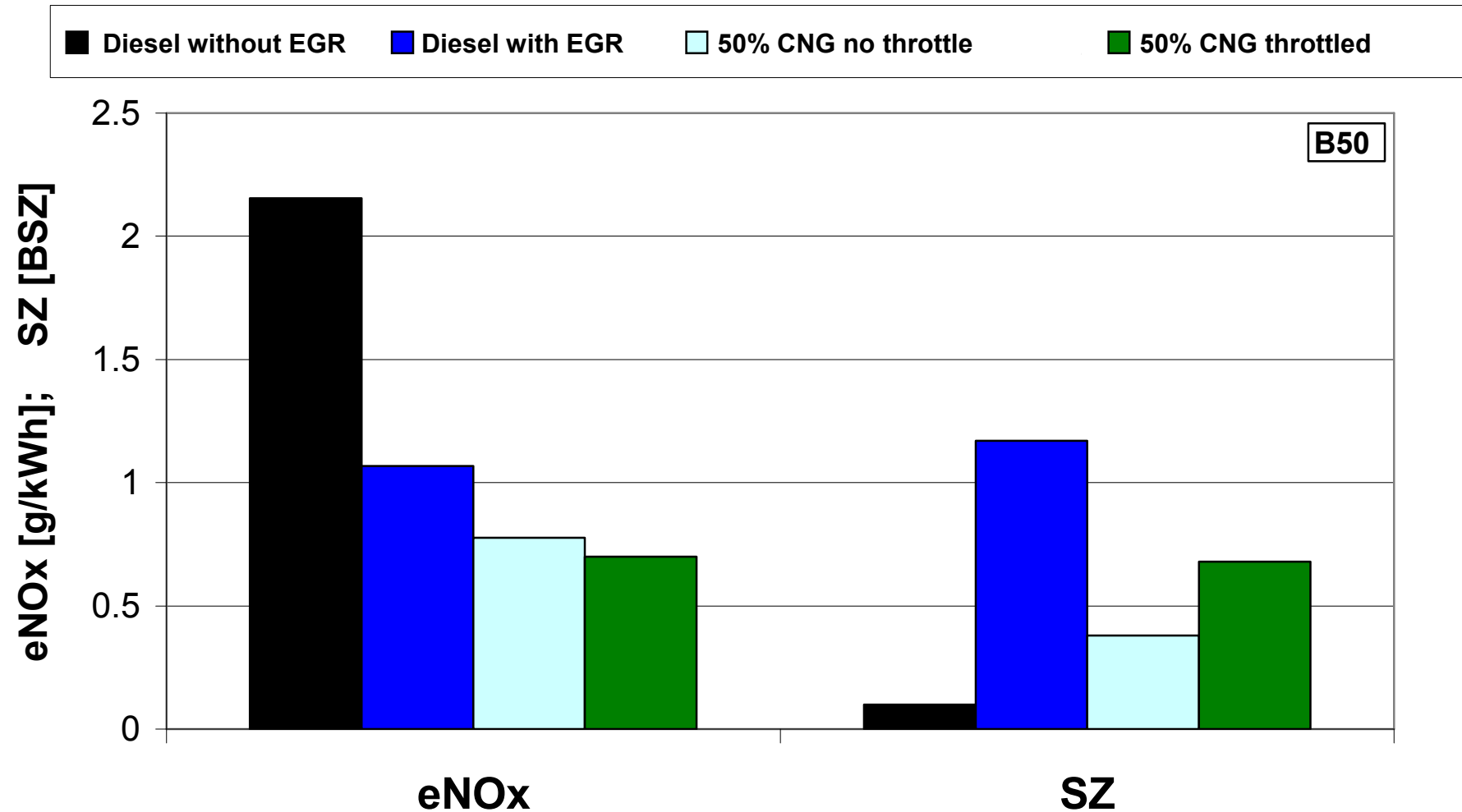
CNG-Diesel-Mixed Combustion

NOx- and soot emissions



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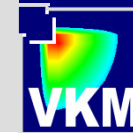
NOx- and soot emissions



Anmerkung: 50% CNG ohne Anpassung des Zündzeitpunktes, mit Oxidationskatalysator

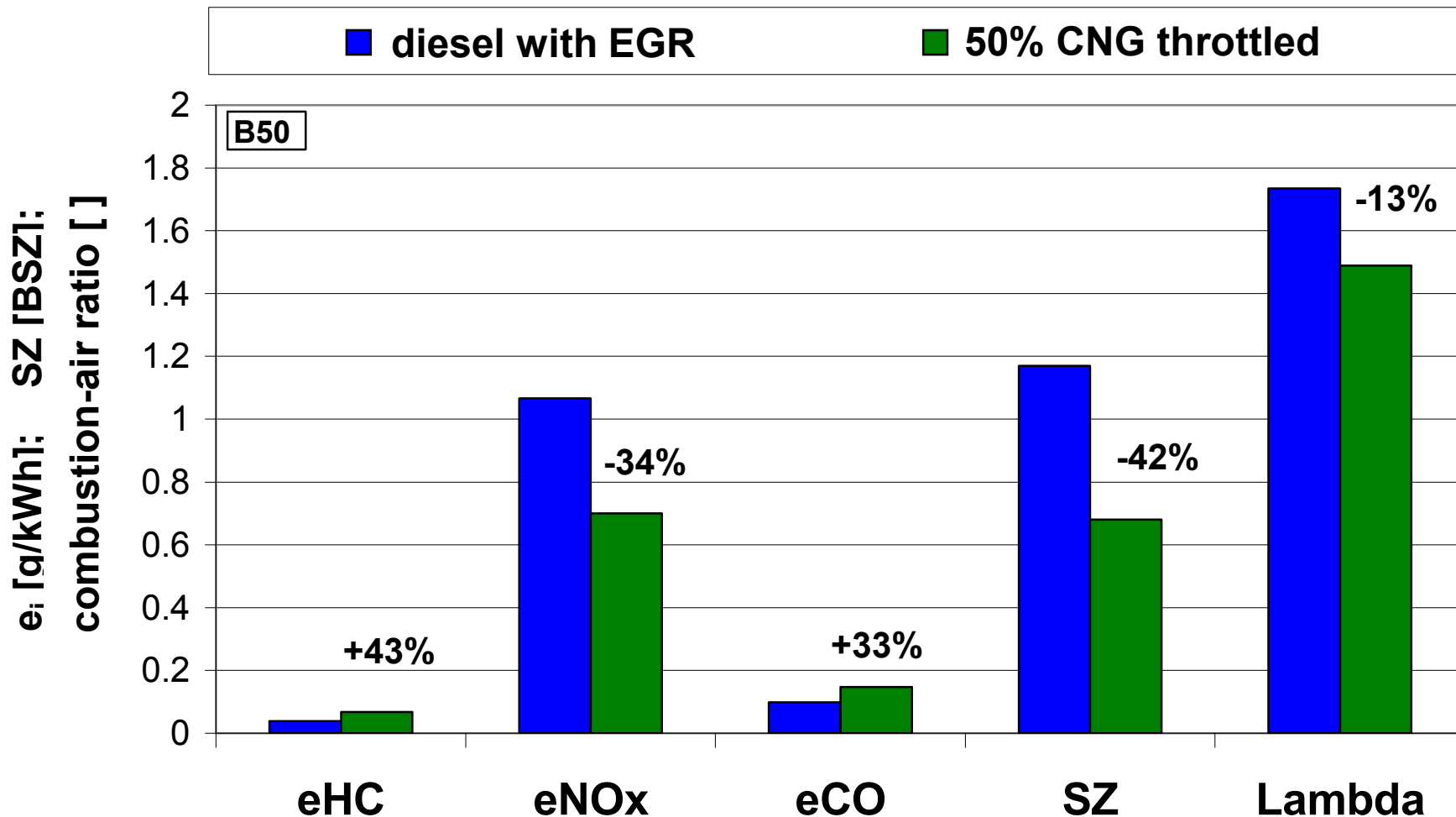
CNG-Diesel-Mixed Combustion

diesel vs diesel-CNG mixed combustion



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Emissionen im Vergleich: Diesel vs. CNG-Mischbetrieb



Anmerkung: 50% CNG ohne Anpassung des Zündzeitpunktes, mit Oxidationskatalysator

CNG-Diesel-Mixed Combustion

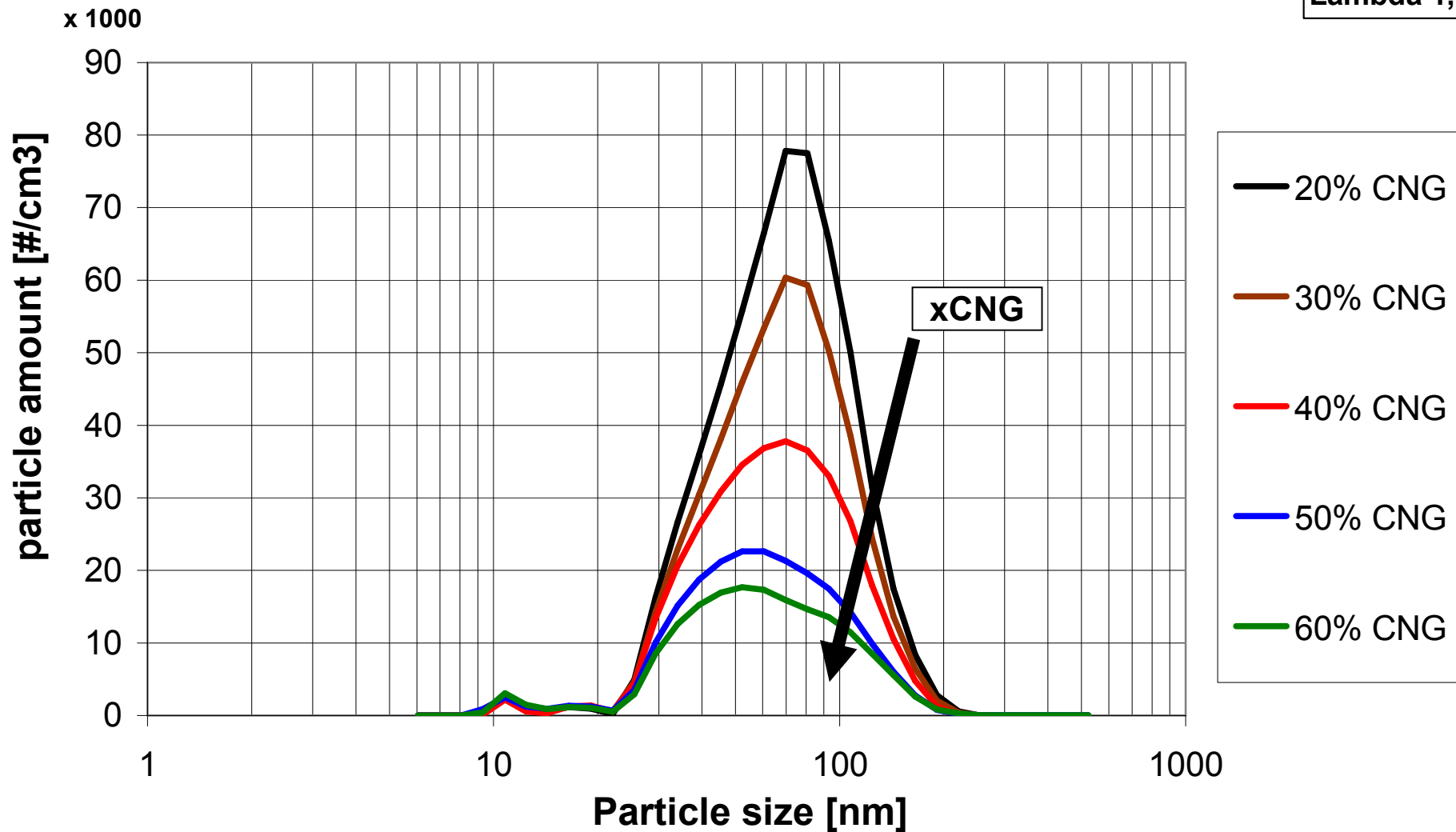
particle size distribution: energetic CNG-ratio variation



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B50
AGRein
Lambda 1,50

particle amount - energetic CNG-ratio variation



CNG-Diesel-Mixed Combustion

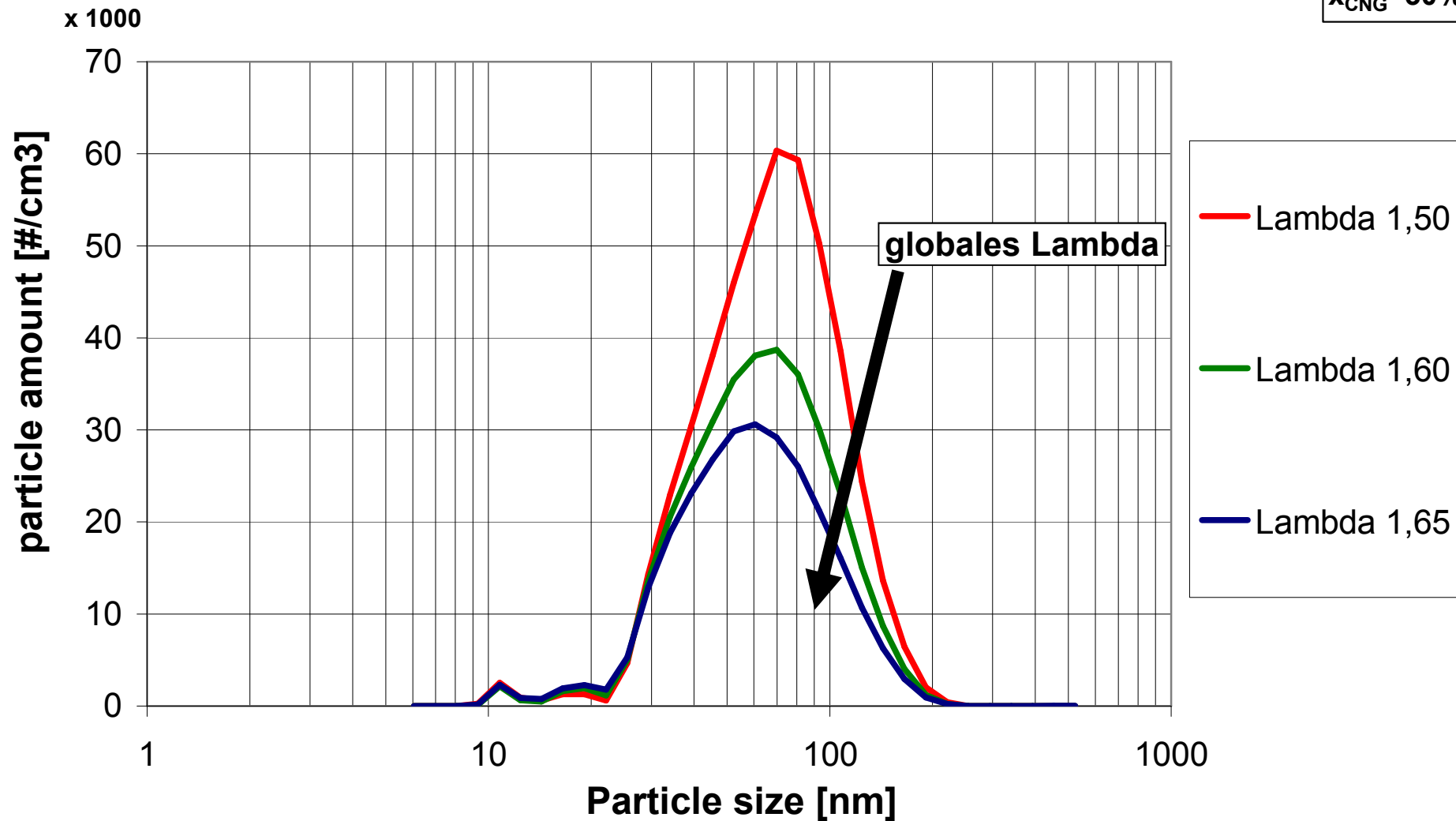
particle size distribution: combustion-air ratio variation



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B50
AGRein
 $x_{\text{CNG}}=30\%$

particle amount - combustion-air ratio variation



CNG-Diesel-Mixed Combustion

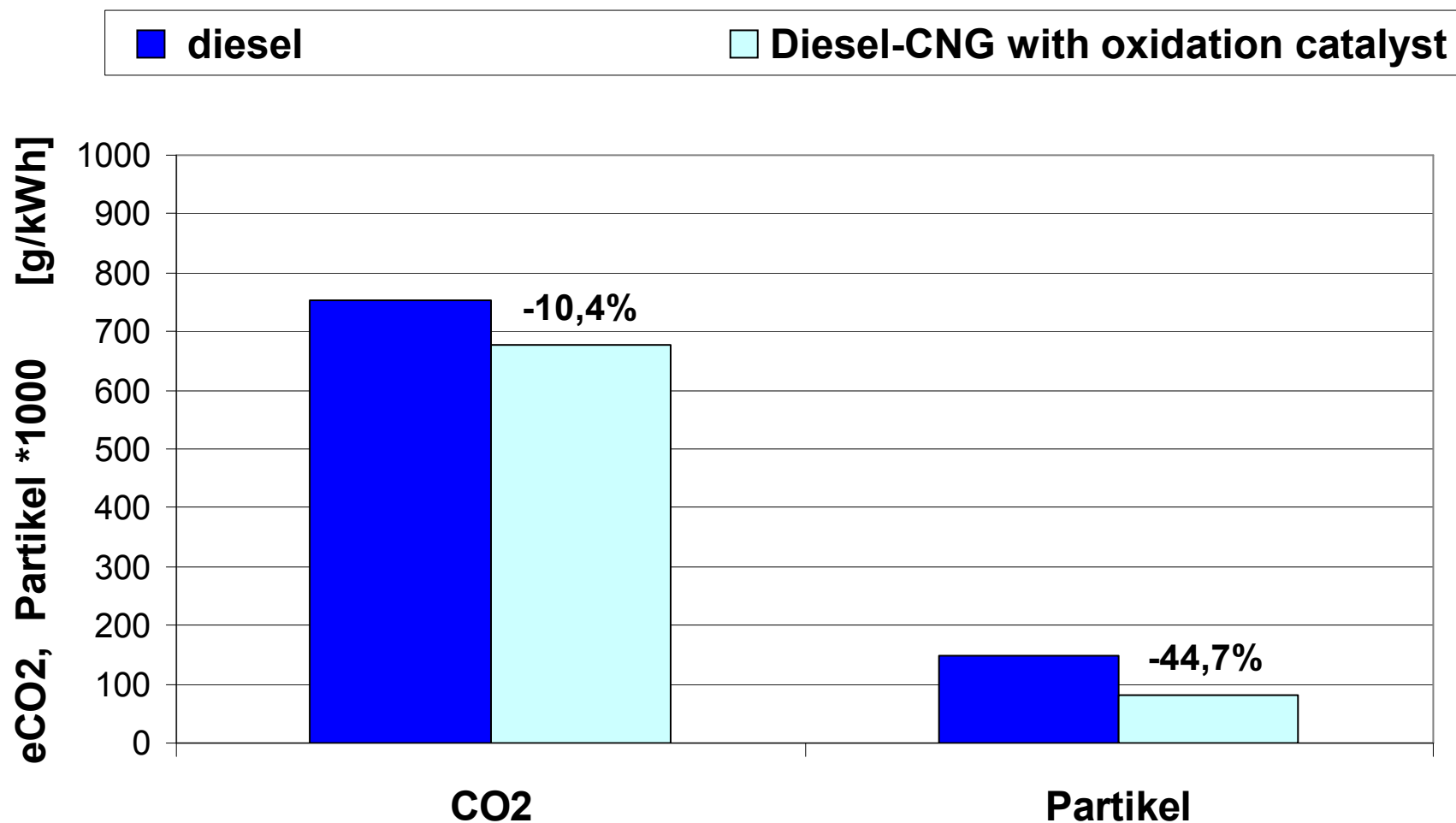
ESC-test for EU-standard



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ESC-Prüfzyklus

CO₂ and particle emissions



CNG-Diesel-Mixed Combustion

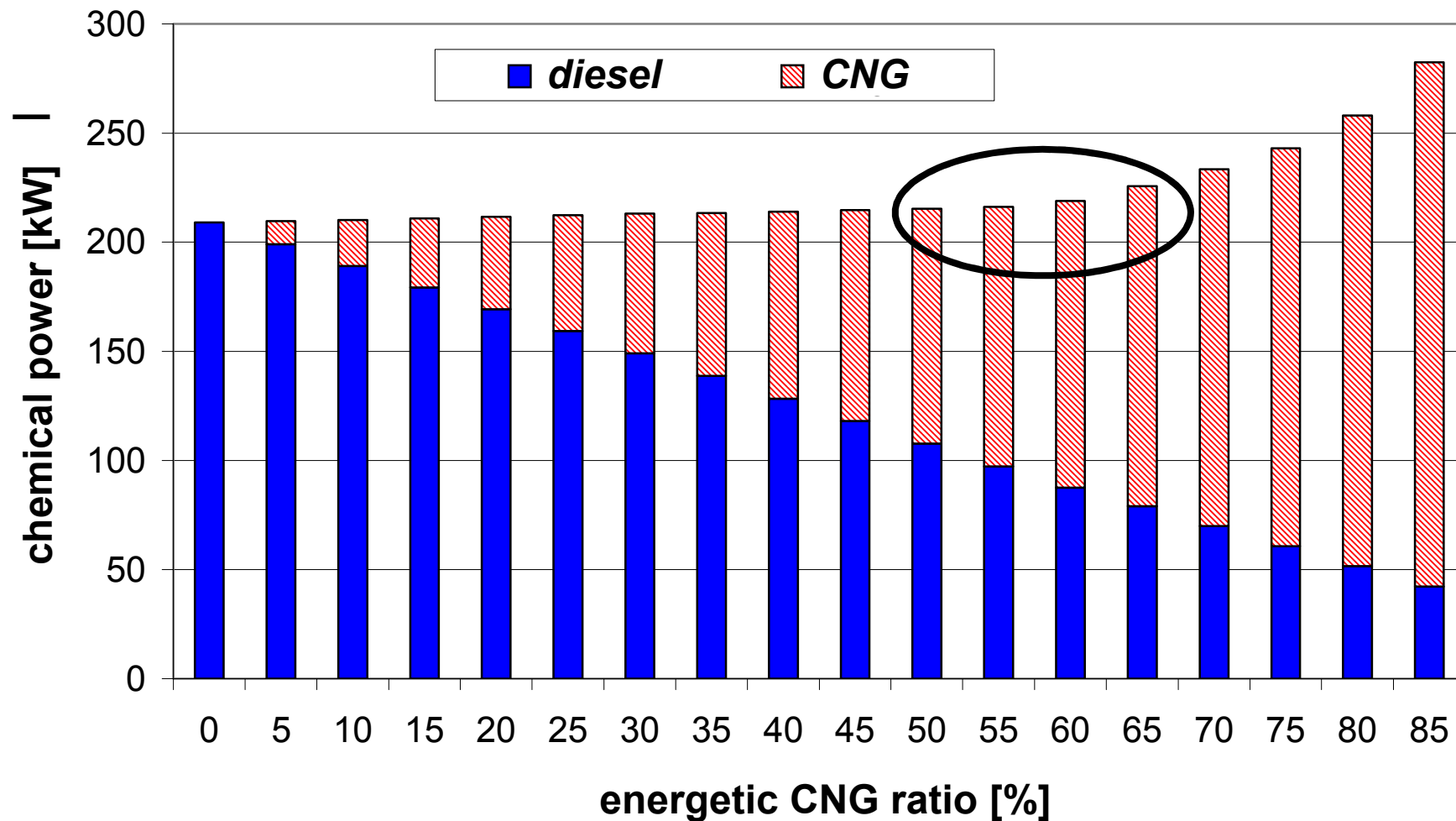
simulation: use of fuel energy



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Simulation
const. BP, mittlere Last
Lambda = const.

use of fuel energy



CNG-Diesel-Mixed Combustion

simulation: efficiency and cost



11.06.2013

Simulation
const. BP, mittlere Last
Lambda = const.

efficiency and cost

