A3PS

Rethinking Propulsion.

Emission Behavior and Efficiency of SI Engines Operated with Biogas

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Alternative Propulsion Systems and Energy Carriers

Austrian, European and global R&D- and demonstration projects, research institutions and funding programs

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in cooperation with

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   - **Part Load**
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4. **Comparison of different Biogas qualities (CO_2-content)**
5. **Conclusions**

Motivation

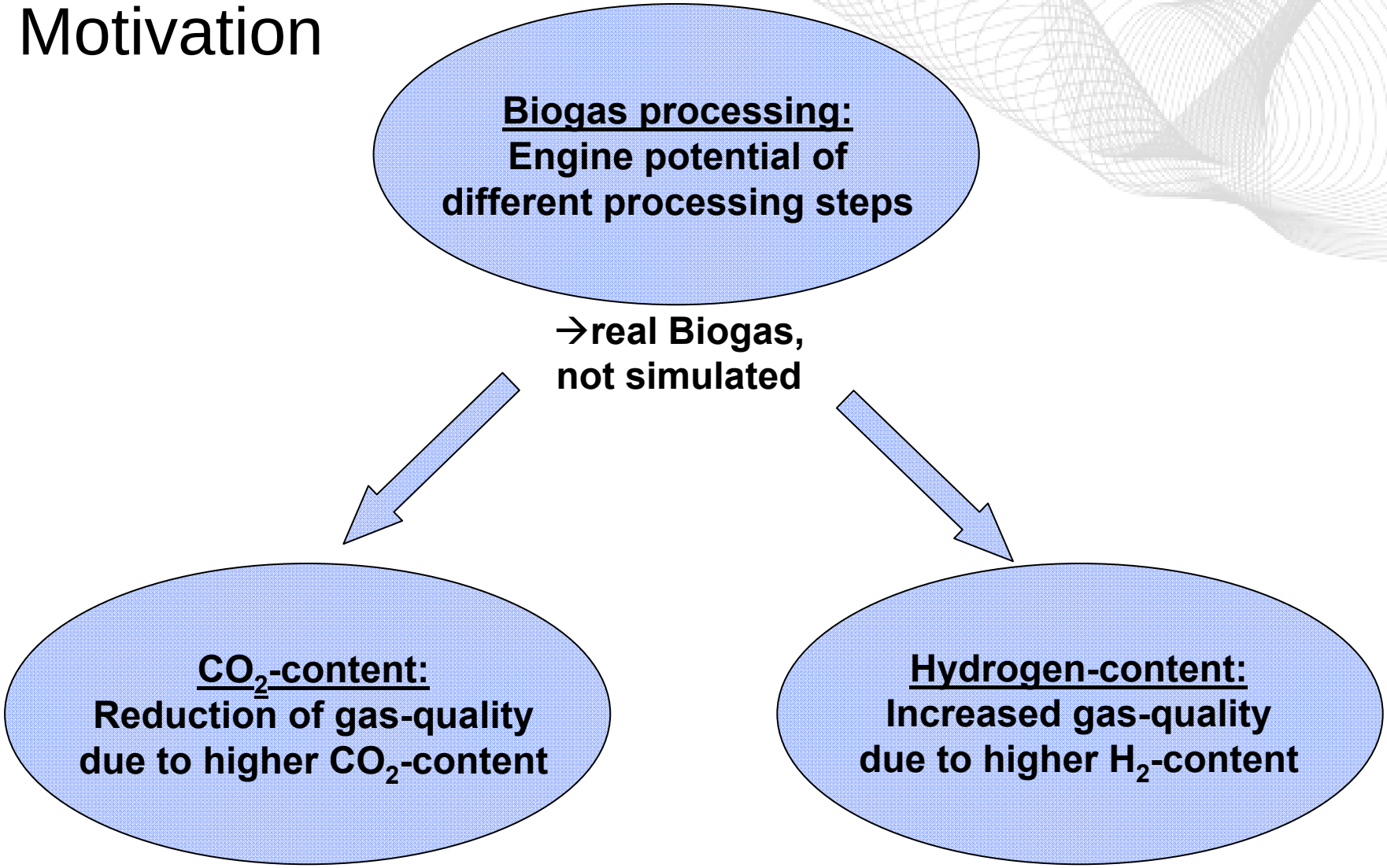
EU Legislation:
CO_2-reduction emission standards independence of fossil fuels

High Knock Resistance:
advantage at full load conditions

Almost Closed CO_2-Cycle:
further reduction of CO_2-emissions

Lower C/H-Ratio:
reduction of CO_2-emissions

Motivation


Biogas processing:
Engine potential of
different processing steps
→real Biogas,
not simulated
CO2-content:
Reduction of gas-quality
due to higher CO2-content
Hydrogen-content:
Increased gas-quality
due to higher H2-content

Composition of raw Biogas

component	Einheit	Gehalt
Methane	**Vol%**	**40 – 80**
Carbon dioxide	**Vol%**	**14 – 55**
Nitrogen	Vol%	0 – 20
Hydrogen	Vol%	0 – 1
Oxygen	Vol%	0 – 2
Sulfide	Vol%	0 – 2
Ammoniac	Vol%	0 – 1
CFC	mg/m^3	<3

Composition for recovery from fermentative processes

Methane enrichment by separation of CO_2
→ Natural gas quality: **CH_4 ≥ 96%** (AUT)

Separation during Biogas processing

Source: Mayer, T., Hofbauer, H., Vienna University of Technology 2008

Content

Test engine and experimentation

cylinder / alignment		**4 cylinder /in-line, 4 valves per cylinder**
displacement	**cm^3**	**1598**
bore x stroke	**mm**	**79 x 81,5**
effective power / rpm	**kW / rpm**	**71 / 6200**
max. torque / rpm	**Nm / rpm**	**135 / 4200**
Compression ratio		**12,5 : 1**
mixture preparation		**Intake-manifold fuel injection**

1,6 l engine, natural aspirated

high compression ratio for gas operation

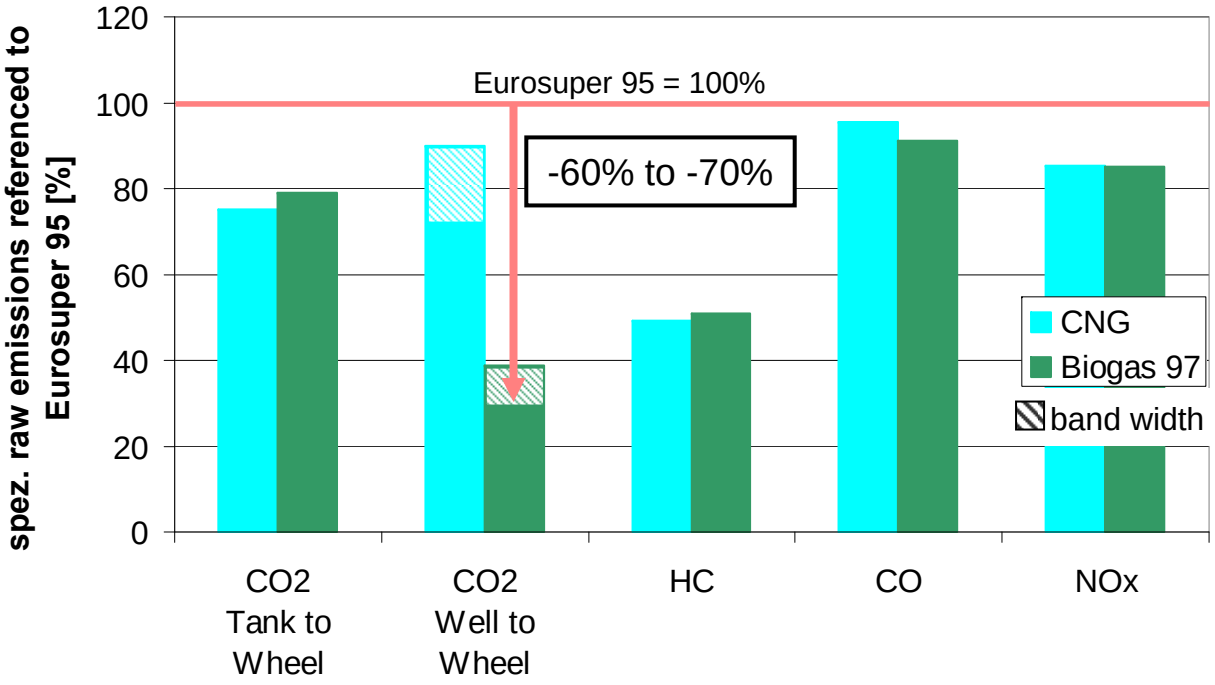
Separated injection valves for gas- and liquid fuel operation

All experiments carried out with stoichiometric air ratio (except assembly protection with Eurosuper 95)

All measurements of exhaust emissions in raw exhaust before oxidation catalyst

Content

Results for Eurosuper 95, CNG and Biogas, load point 2000 rpm – 2 bar BMEP



engine operation

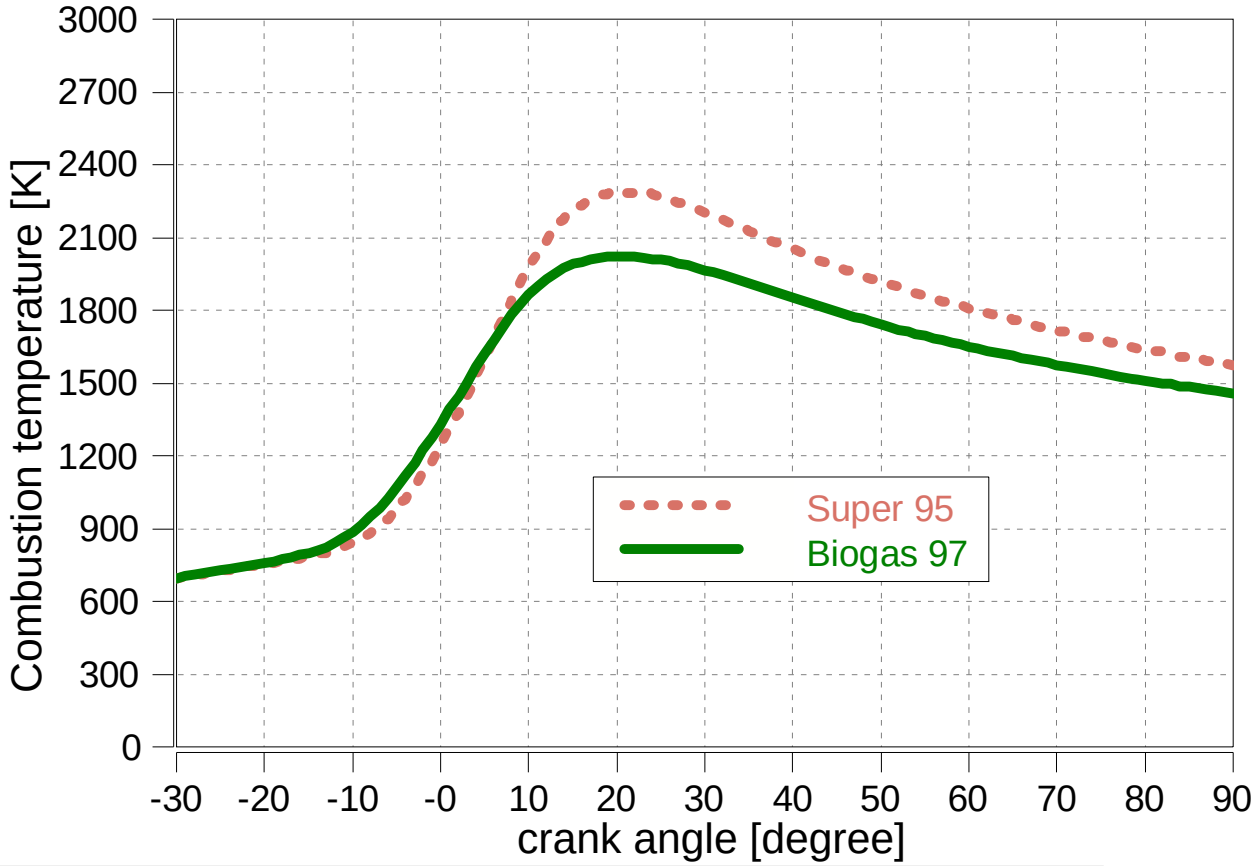
path of life*

CNG: Rest C_xH_y
Biogas: Rest CO_2

*Quelle: Edwards, R. et al, November 2008

Results for Eurosuper 95, CNG and Biogas, load point 2000 rpm – 2 bar BMEP

Higher hydrogen content in gaseous fuels
→ more H_2O as combustion product
→ reduced combustion temperatures



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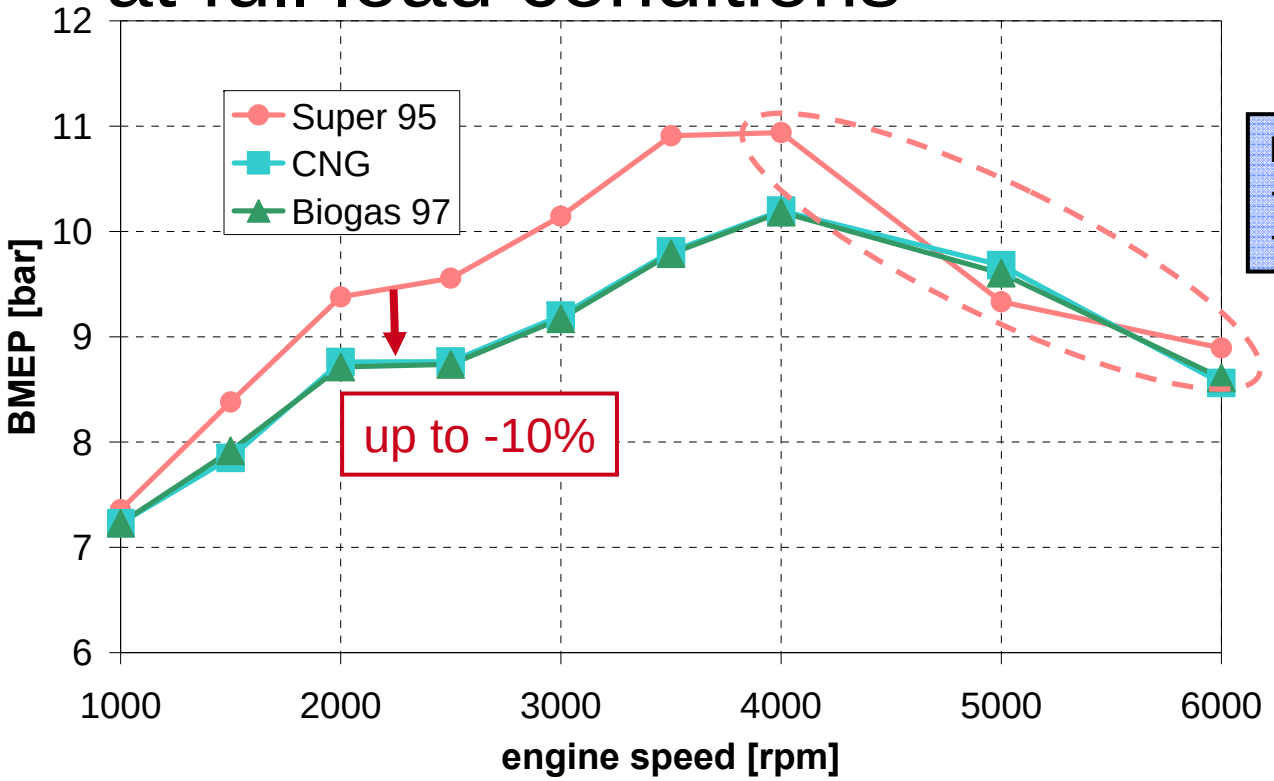
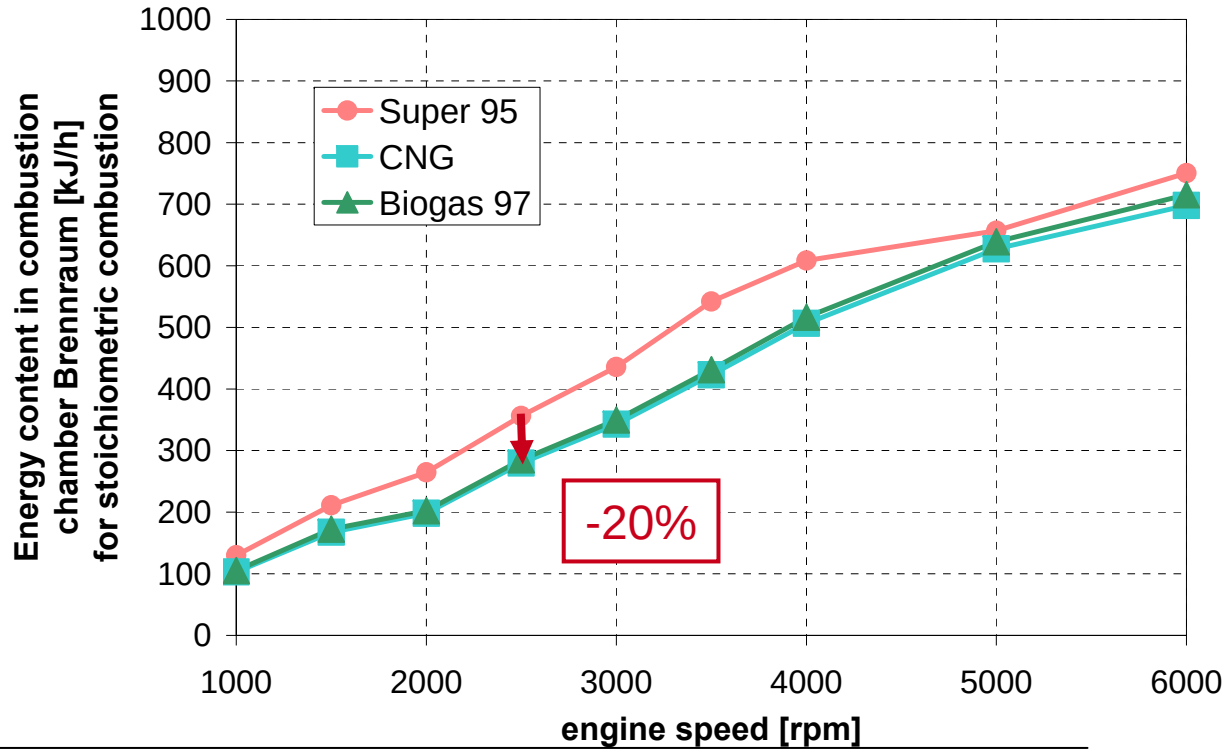
Results for Eurosuper 95, CNG and Biogas at full load conditions



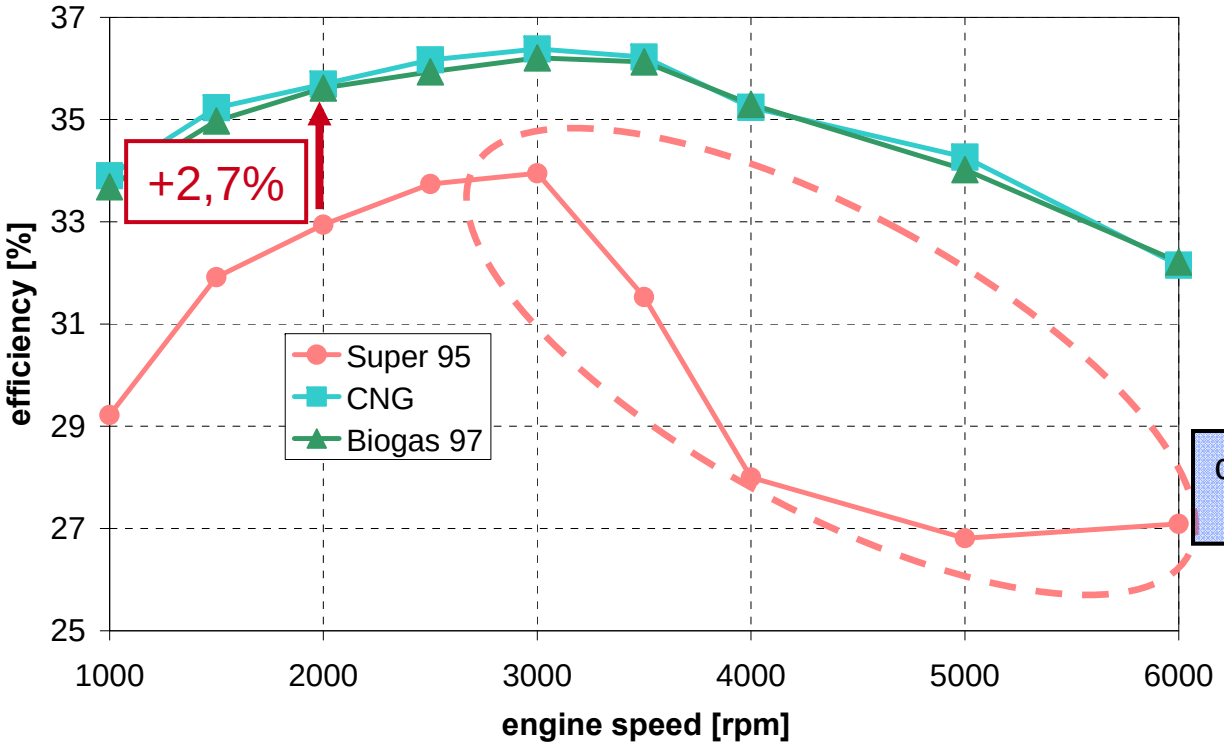
Late combustion for Eurosuper 95
→ High exhaust gas temperatures
→ catalyst overheating protection

Results for Eurosuper 95, CNG and Biogas at full load conditions

Reduced mixture heat value with gas operation:
→ reduction of full load torque of up to 10%



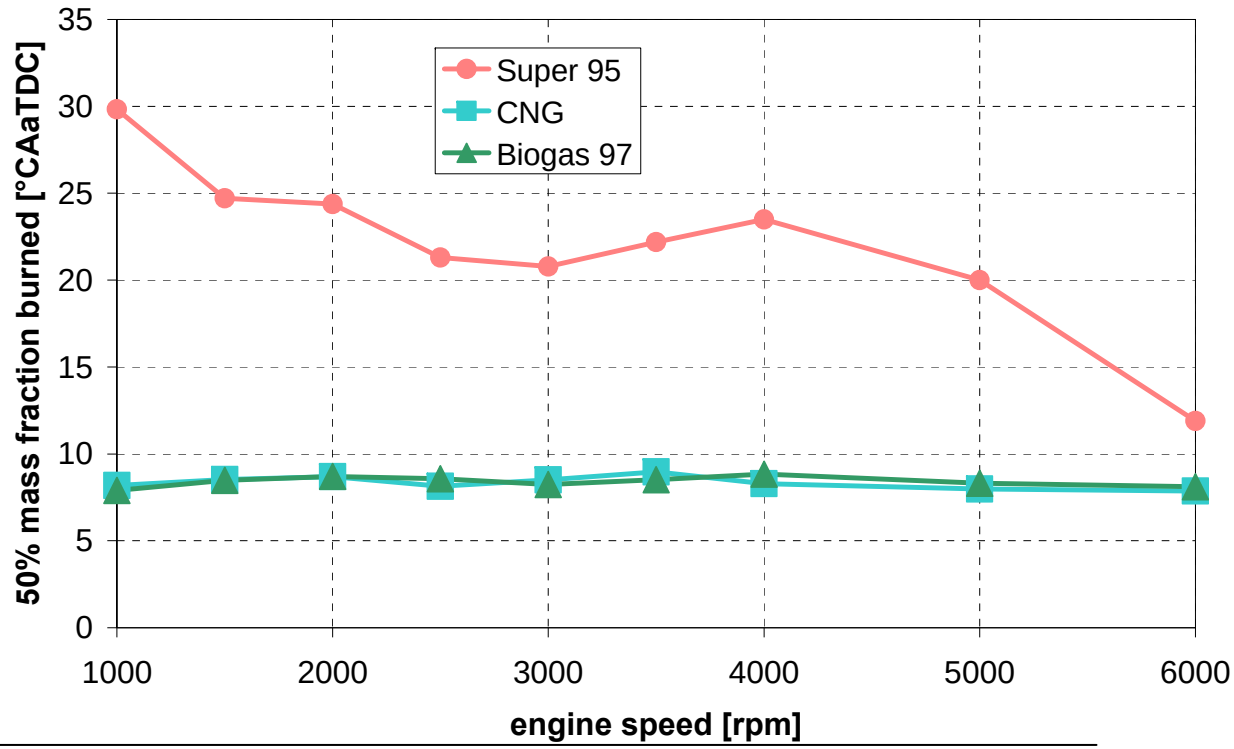
Results for Eurosuper 95, CNG and Biogas at full load conditions



catalyst overheating protection for Eurosuper 95

Results for Eurosuper 95, CNG and Biogas at full load conditions

Late combustion necessary to prevent knocking with ROZ 95

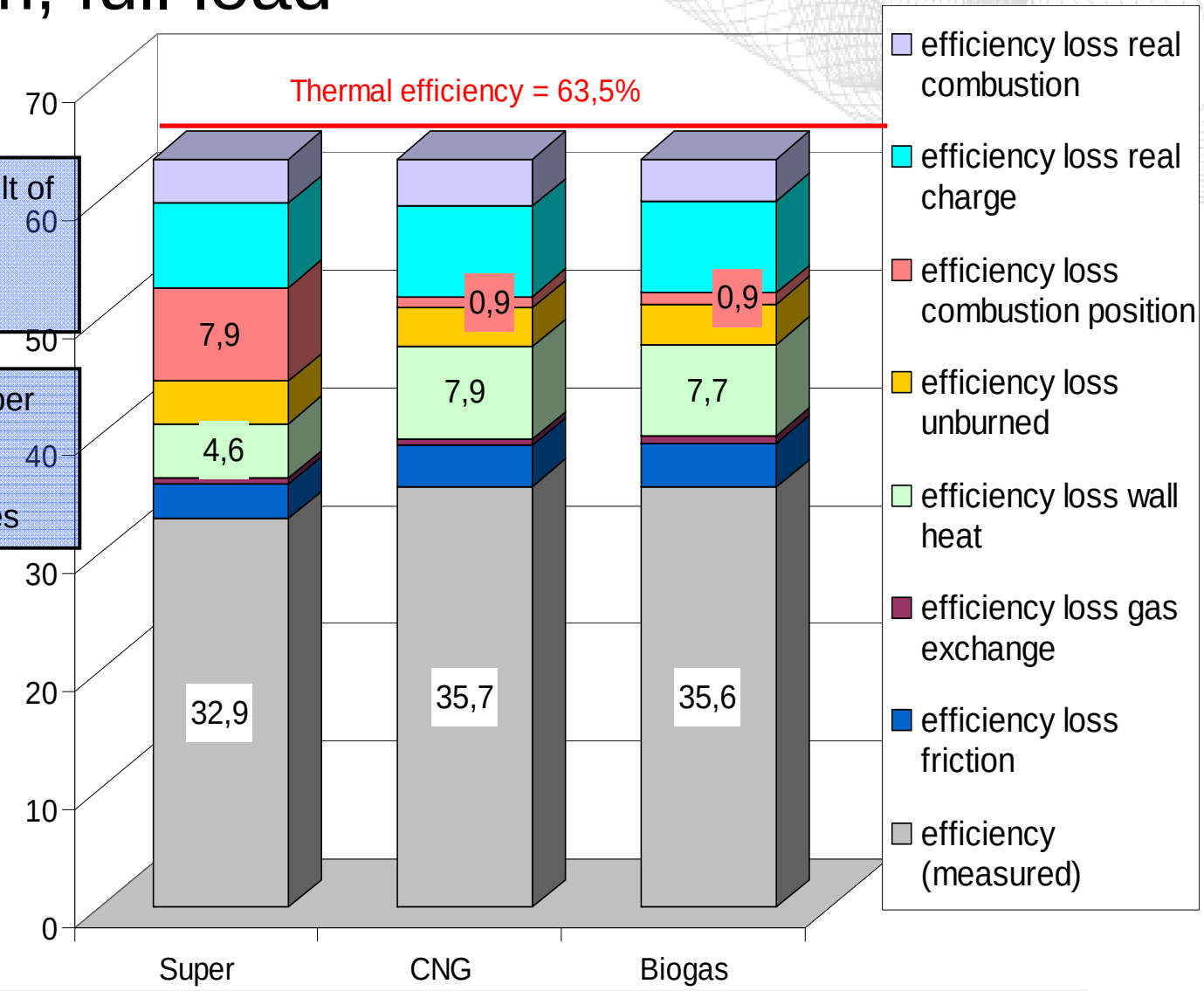


Results for Eurosuper 95, CNG and Biogas at 2000 rpm, full load

7% advantage for gas as result of optimum combustion timing
→ advantage of high octane number

Late combustion with Eurosuper
Results in low gas temperatures (p_{max} drops)
→ reduction of wall heat losses

Higher efficiency with gaseous fuels



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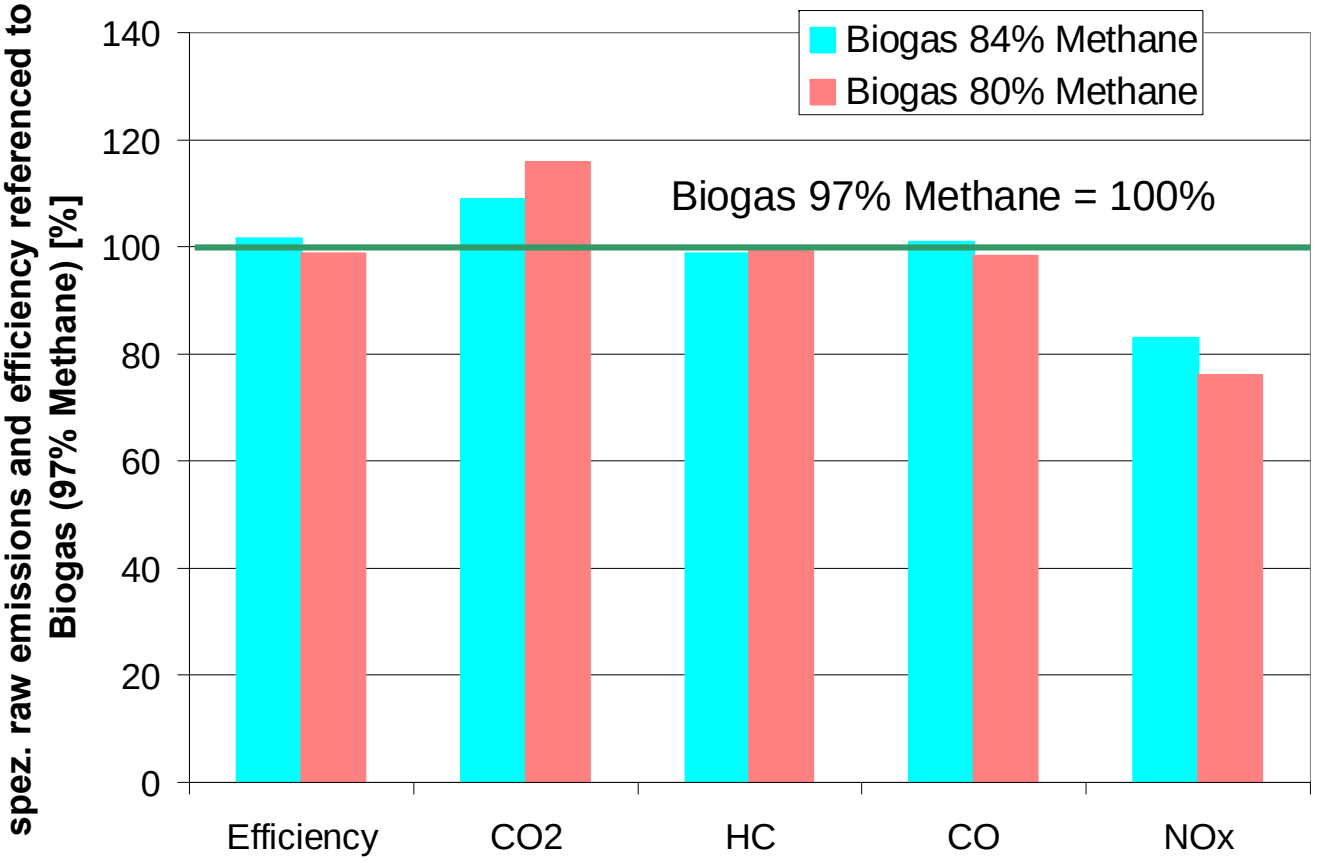
Results for different Biogas qualities (CO_2-content), load point 2000 rpm – 2 bar BMEP



CO_2 contained in fuel is emitted in the exhaust gas

Reduction of NO_x-emissions due to higher CO_2 content → reduction of Temperature

Content

Conclusions

- Biogas proofed equal potential as CNG in the engine operation
- life cycle → Biogas reduces CO_2 emissions by 60% to 70% compared to Eurosuper
- increased efficiency at full load conditions as result of high knock resistance of Biogas
- decreased full load torque for naturally aspirated engine, but same for turbocharged engine
- Same or even better emission level for lower Biogas qualities (CO_2-content)
  - Requires changed logistic

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Thank you for your attention !

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