IEA Collaborative Task

HCCI – Fuel

Prof. Bengt Johansson

Agenda

12h00 Homogeneous Charge Compression Ignition (HCCI) I

13h30 Lunch

15h00 Homogeneous Charge Compression Ignition (HCCI) II

17h00 Coffee break

Agenda

12h00 Homogeneous Charge Compression Ignition (HCCI) I –
Prof. B. Johansson

12h10 Partially Premixed Combustion, PCCI, with gasoline and/or ethanol
Bengt Johansson Lund University, Sweden

12h30 The Effect of Mixture Conditions on HCCI Engine Combustion Fuelled with Gasoline/LPG/DME
Choongsik Bae, Department of Mechanical Engineering, KAIST, Republic of Korea

12h50 Combustion and Emissions of Diesel in a Direct Injection HCCI Engine
Hongming Xu, University of Birmingham, UK

13h30 Lunch

Agenda

15h00 **Development of Gasoline HCCI Using Exhaust Gas Blow Down Boosting**

T. Kuboyama,Y. Moryoshi Chiba University, Japan, K. Hatamura HERO, Japan, T,Yamada, CDAJ, Japan, Y. Urata, J. Takanashi, Honda R&D, Japan

15h20 **Introducing New Combustion Technologies Research Project for the HCCI Fuels**

Ossi Kaario, University of Helsinki, Finland

15h40 **Multipoint auto-ignition of end gas region in a natural gas engine without knock**

Eiji Tomita and Nobuyuki Kawahara, Okayama University, Japan

16h00 **Compression Ratio Reduction effect on LD Diesel Engine running in PCCI Combustion**

Carlo Beatrice, Nicola Del Giacomo, Chiara Guido, Istituto Motori, CNR, Napoli, Italy

16h20 **Investigation of Controlling PCCI Combustion Process in Consideration of Heterogeneity of Mixture**

H. Gen Fujimoto, Doshisha University, Japan

16h40 **Effects of Jet-Bowl and Jet-Jet Interactions on Late-Injection Low-Temperature Heavy-Duty Diesel Combustion**

C.L. Genzale, R.D. Reitz, M. Musculus, University of Wisconsin, Engine Research Center, Madison, USA

Background

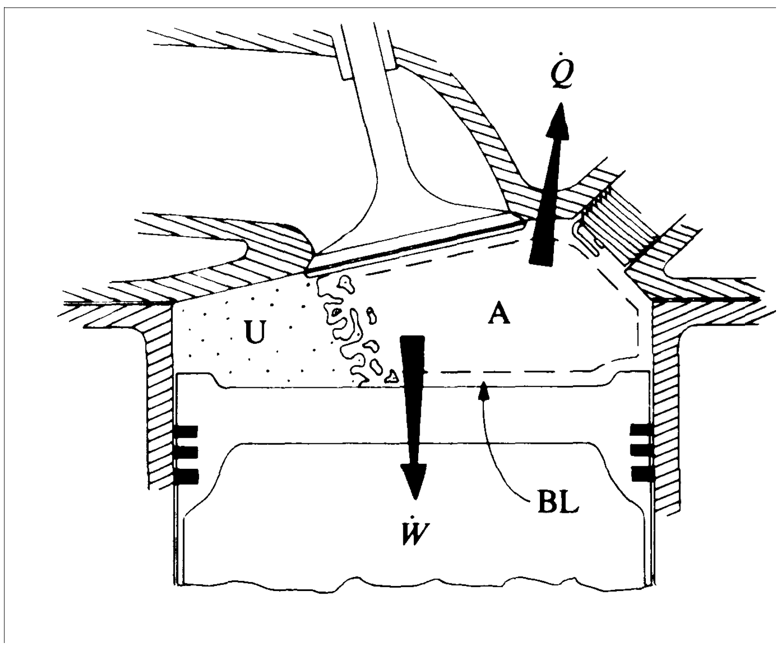
Combustion concepts

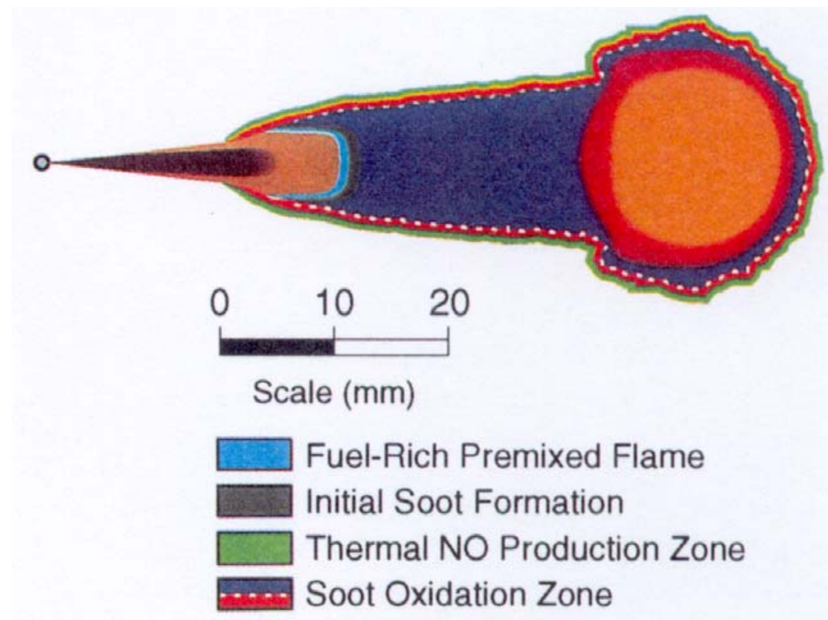
- \+ Clean with 3-way Catalyst
- \- Poor low & part load efficiency

Spark Ignition (SI) engine (Gasoline, Otto)

- \+ High efficiency
- \- Emissions of NO_x and soot

Compression Ignition (CI) engine (Diesel)





Clean locally or globally?

Local emissions:

NOx

HC

CO

PM

Global emission (Greenhouse effect):

CO2 i.e. fuel consumption

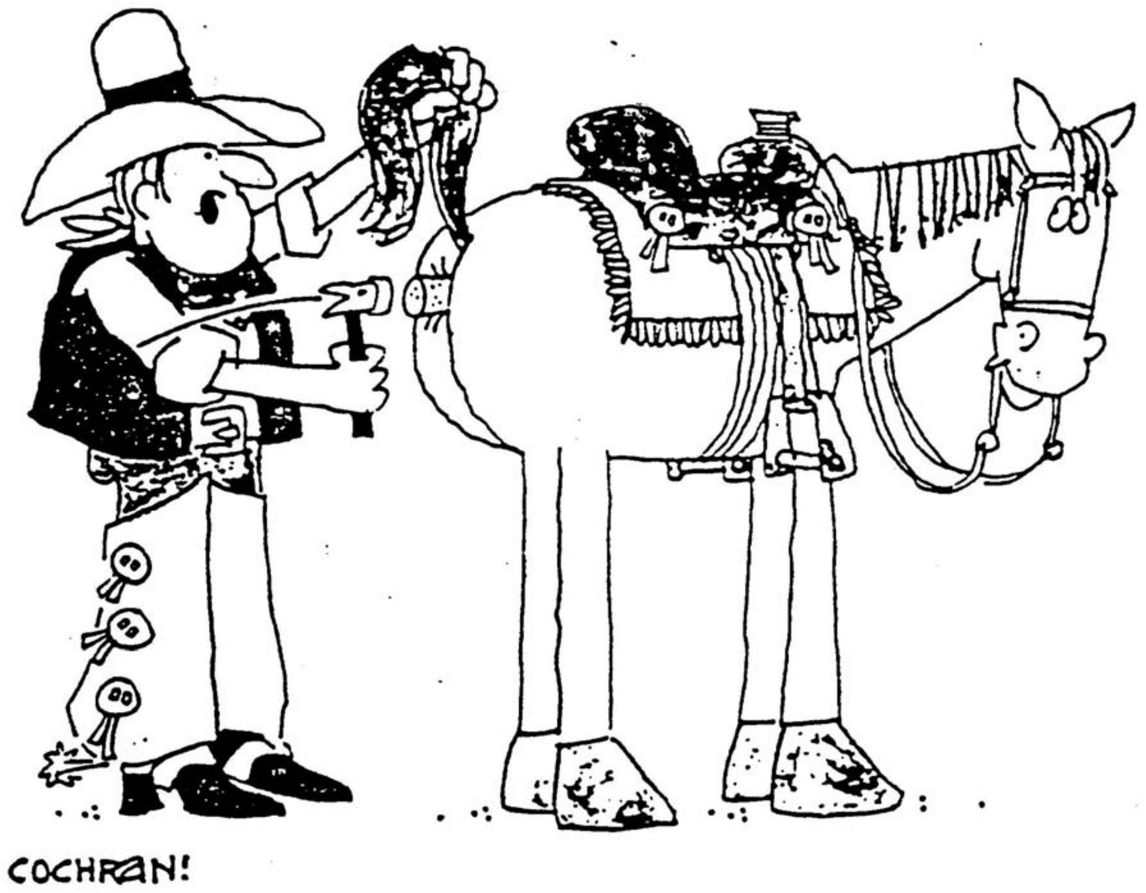
Environmentally friendly
≡ no CO2?

The CO2 neutral alternative…

Some emission statistics from New York by the turn of the century…

- 200 m^3 liquid emissions per day
- 1000 ton solid emissions per day
- An army of tenths of thousands worked with transporting the emissions out from the city

The first IC engine driven car was thus welcomed as a significant enviromental improver



"'Tut mir leid, alter Junge . . . neue Abgasvorschriften"

100 years later - Smog

Clean locally or globally?

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Compression Ignition (CI) engine (Diesel)

+ High efficiency
+ Ultra low NO_x

Homogeneous Charge Compression Ignition (HCCI)

-Combustion control

-Power density

Spark Assisted Compression Ignition (SACI)
Gasoline HCCI

Partially premixed combustion (PPC)
Diesel HCCI

+ Injection controlled
- Less emissions advantage

HCCI, CAI, PCCI, pHCCI, PPC, LTC…?

- HCCI is normally a set-up with port fuel injection and high compression ratio.
- CAI is normally a set-up with low compression ratio and high residual gas concentration with negative valve overlap
- PCCI is normally a set-up with early direct injection forming a rather homogeneous charge
- pHCCI=PCCI
- PPC, partially premixed combustion is an bit less homogeneous than PCCI i.e. later injection
- LTC is any combustion process giving low NOx due to low temperature combustion.

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HCCI?

Spark Assisted Compression Ignition (SACI) Gasoline HCCI

Partially premixed combustion (PPC) Diesel HCCI

+ Injection controlled
- Less emissions advantage

Partially Premixed Combustion, PPC, with gasoline or ethanol

Bengt Johansson, Vittorio Manente

Department of Energy Sciences
Division of Combustion Engines
Lund University

Outline

- Experimental Set-Up
- Newly developed combustion concept
- Chronological steps towards this target
- Conclusions

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- **Experimental Set-Up**
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Experimental setup

Specifications of single cylinder engine:

Displacement Volume	1951 cm^3
Swirl Ratio (standard)	1.7
Swirl Ratio (if modified)	2.9
Number of injector holes	8
Injector hole diameter	0.18 mm
Spray umbrella angle	120°
Compression ratio	17.1:1

Outline

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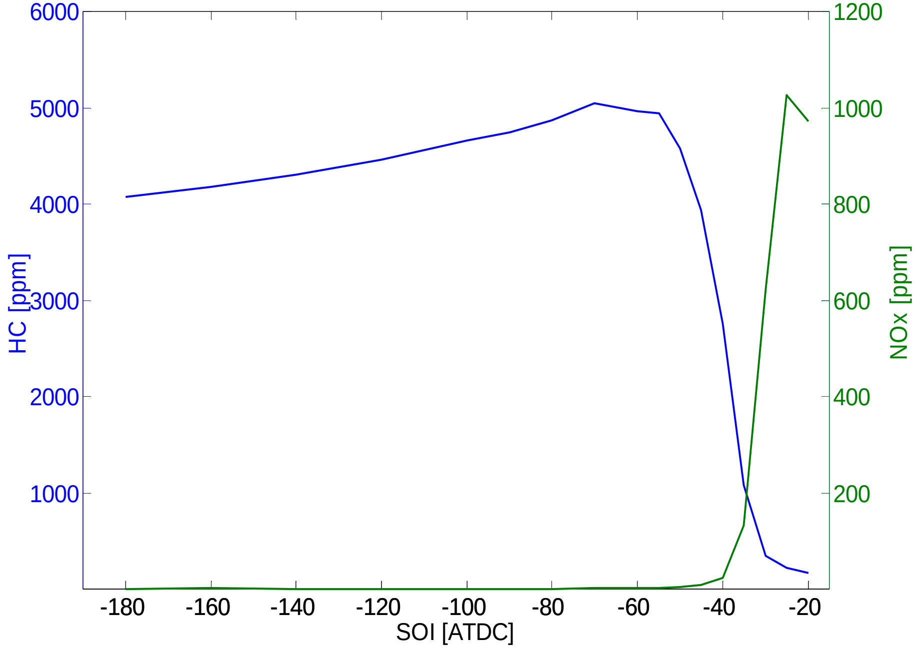
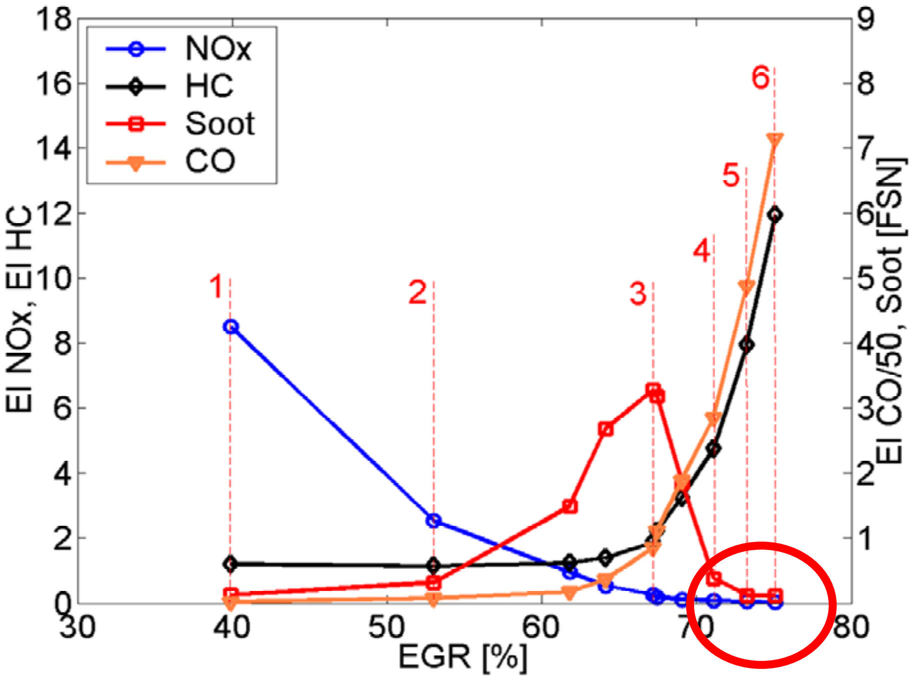
Partially Premixed Combustion, PPC

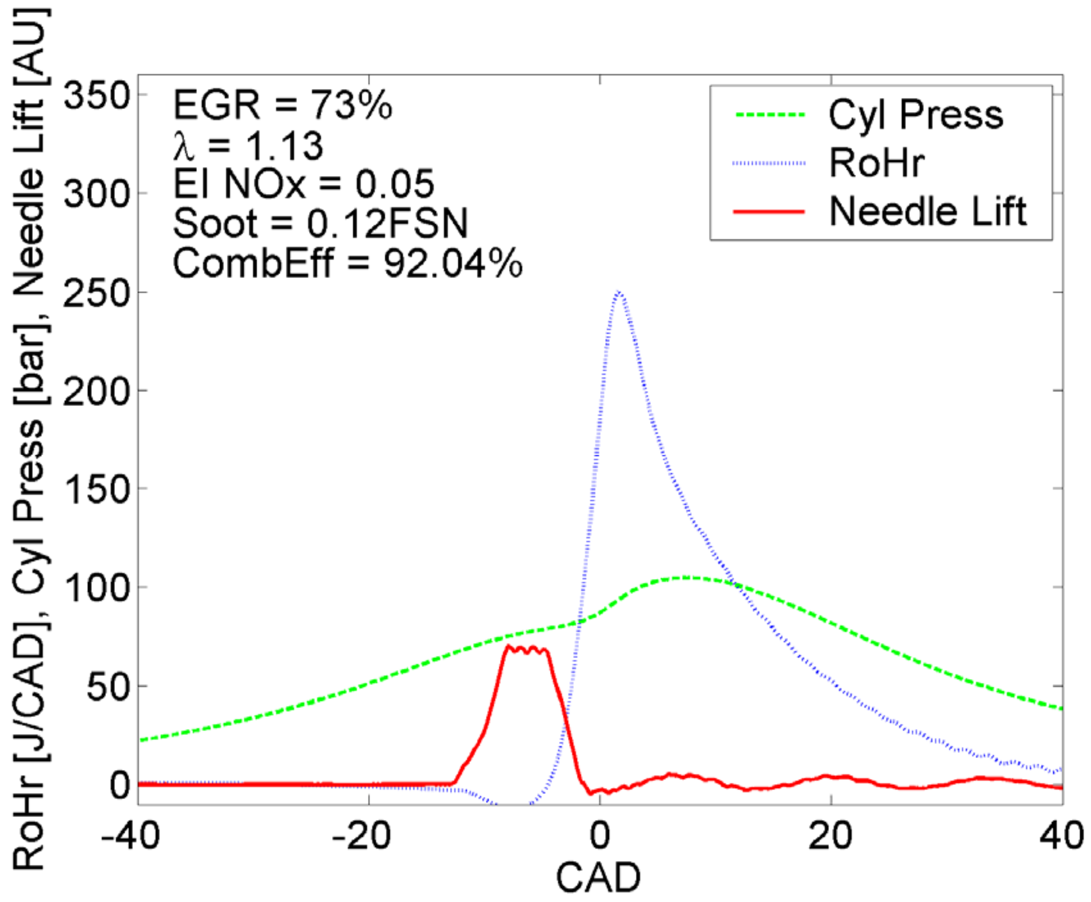
Reduction of NOx and Soot at same time!





PPC @ IMEP 8 [bar]

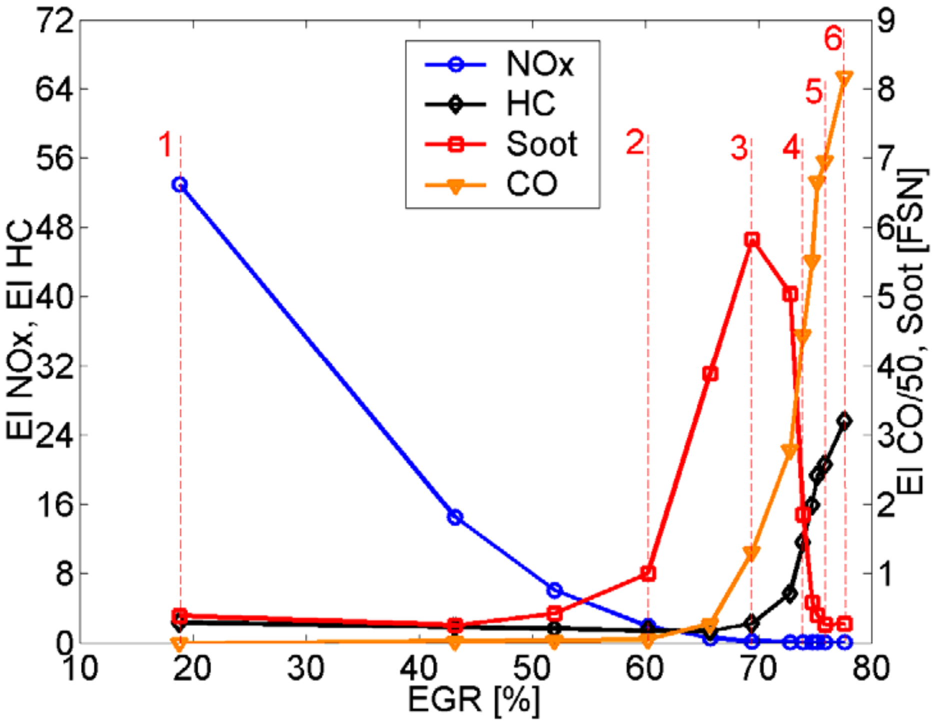
Swedish MK 1: 54 CN

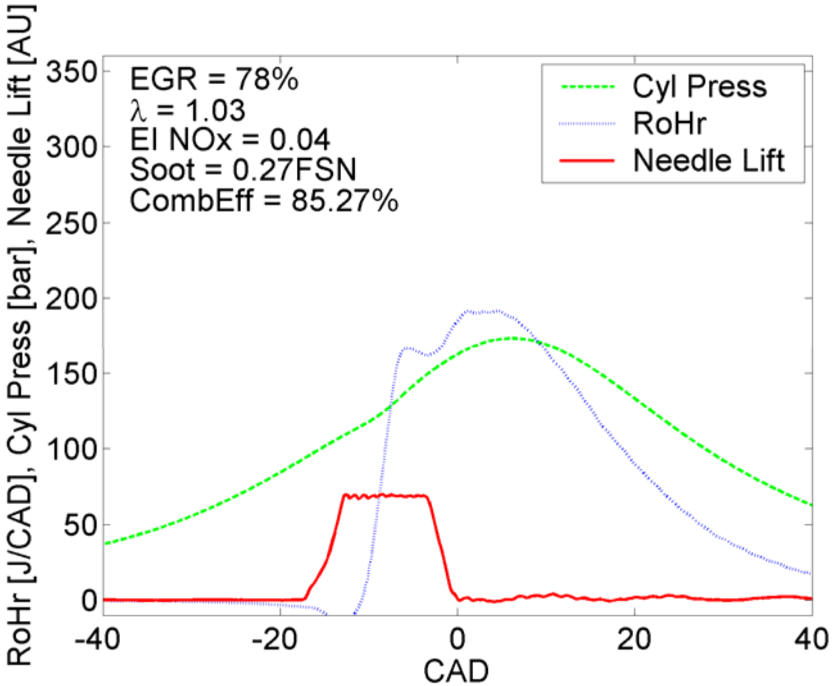


Load	8 bar IMEP
Abs. Inlet Pressure	2.5 bar
Engine Speed	1090 rpm

PPC @ IMEP 15 [bar]

Swedish MK 1: 54 CN





Load	15 bar IMEP
Abs. Inlet Pressure	2.5 bar
Engine Speed	1090 rpm

PPC

Advantages:

- Contemporary reduction of soot and NOx
- High efficiency
- Combustion control

Disadvantages:

- CO, HC increases
- Lower power density because of EGR

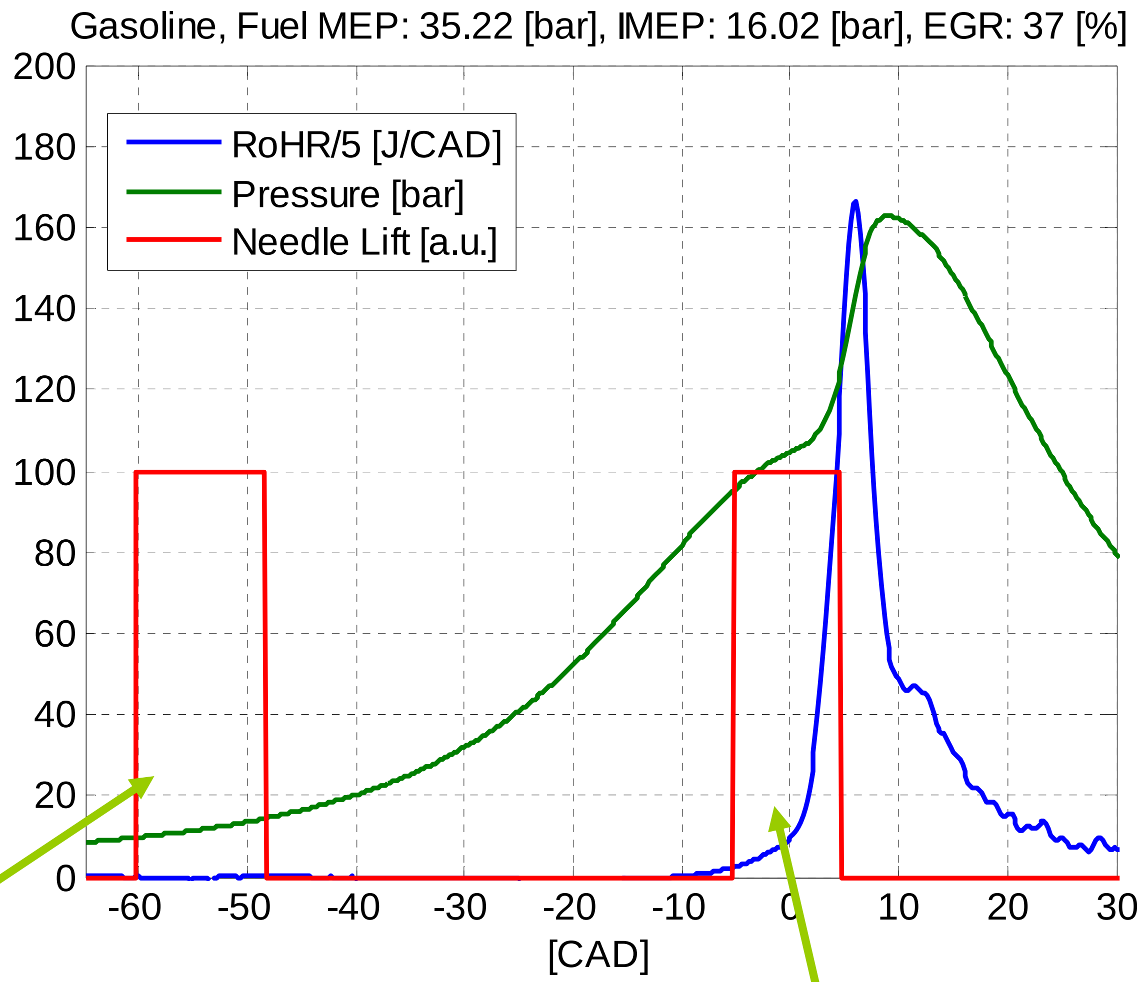
Need:

- Fuel with higher ignition delay

Gasoline

High Load Gasoline

Gasoline: 98 ON

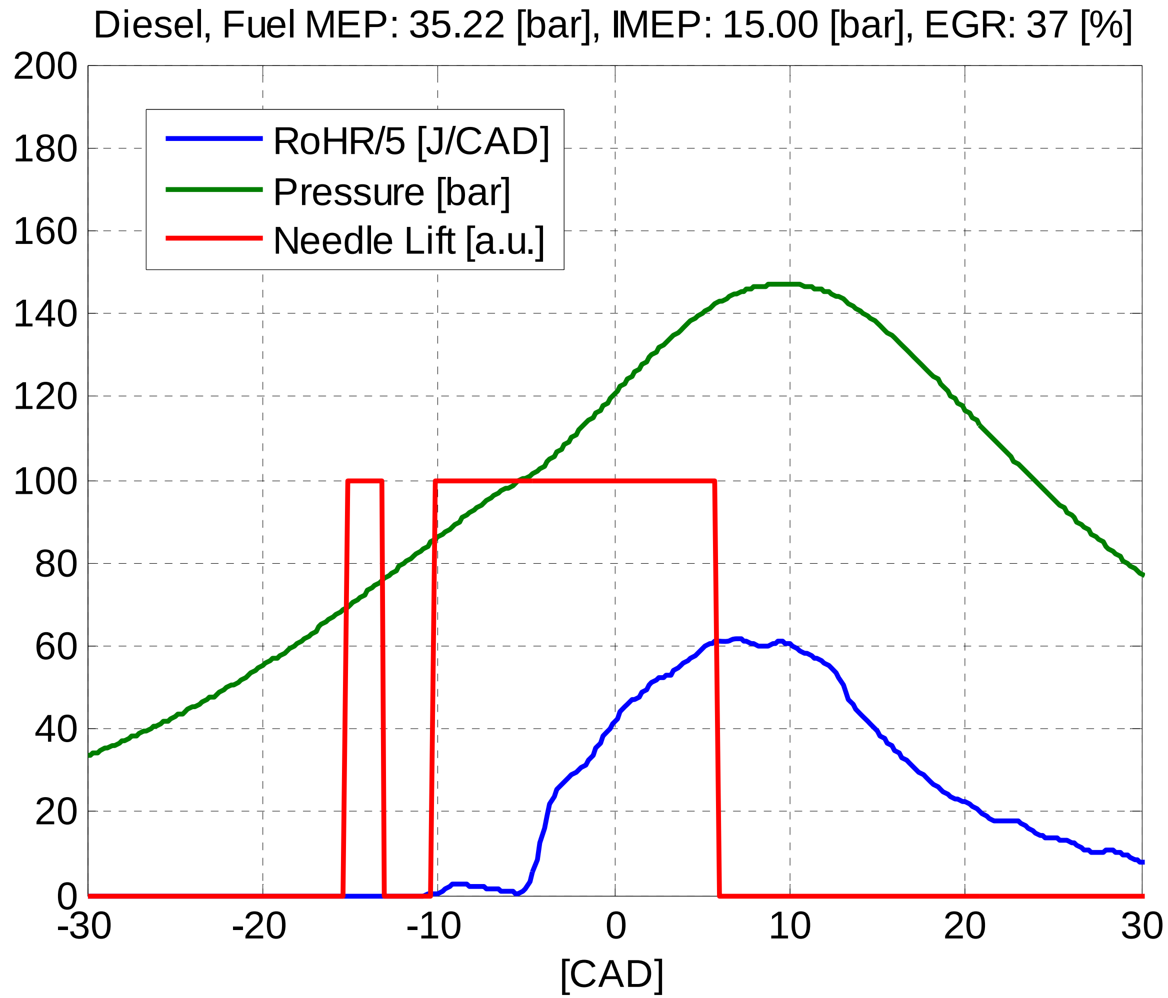


Homogeneous Mixture

Stratification for autoignition

High Load Diesel

Swedish MK 1: 54 CN



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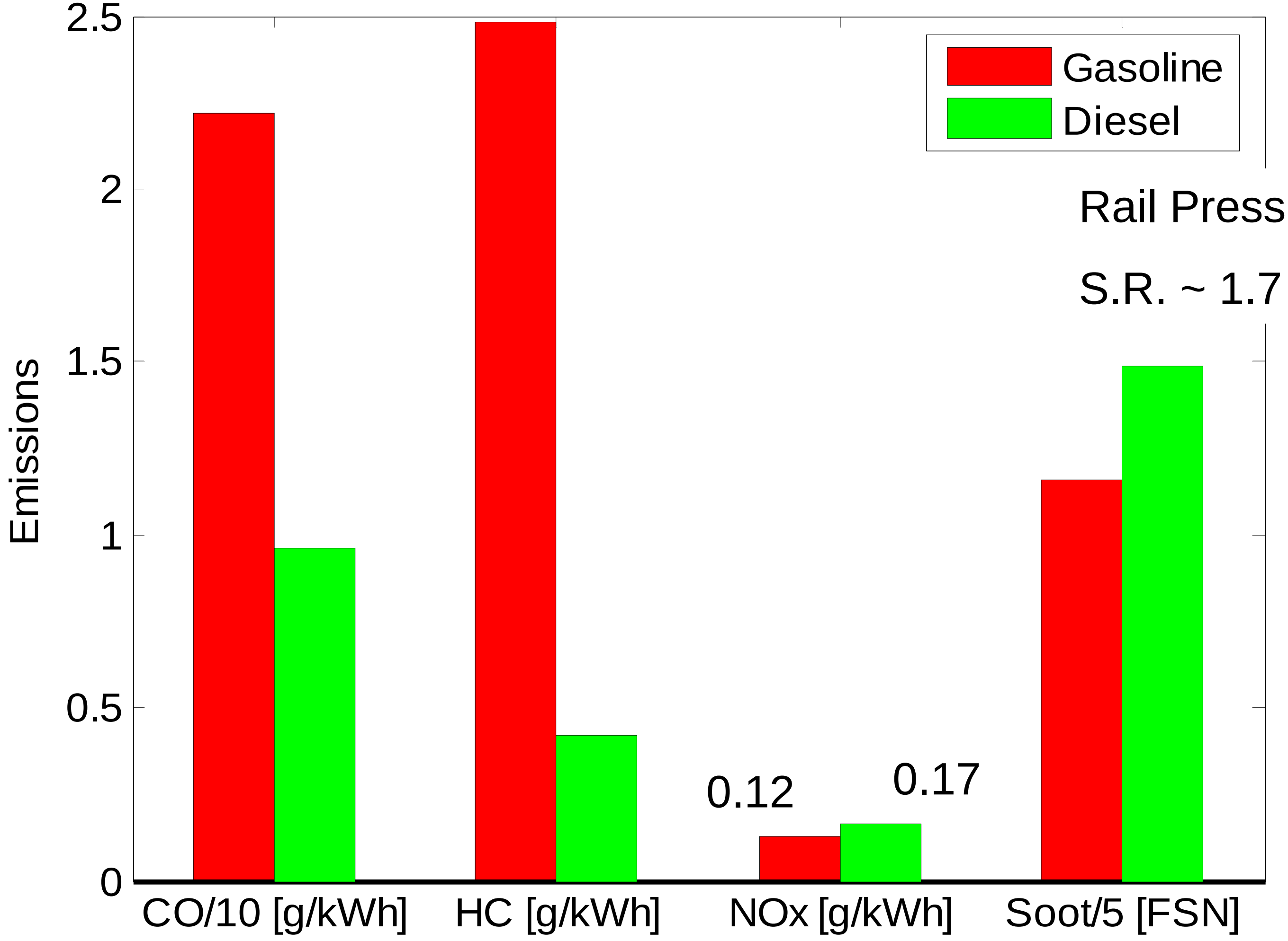
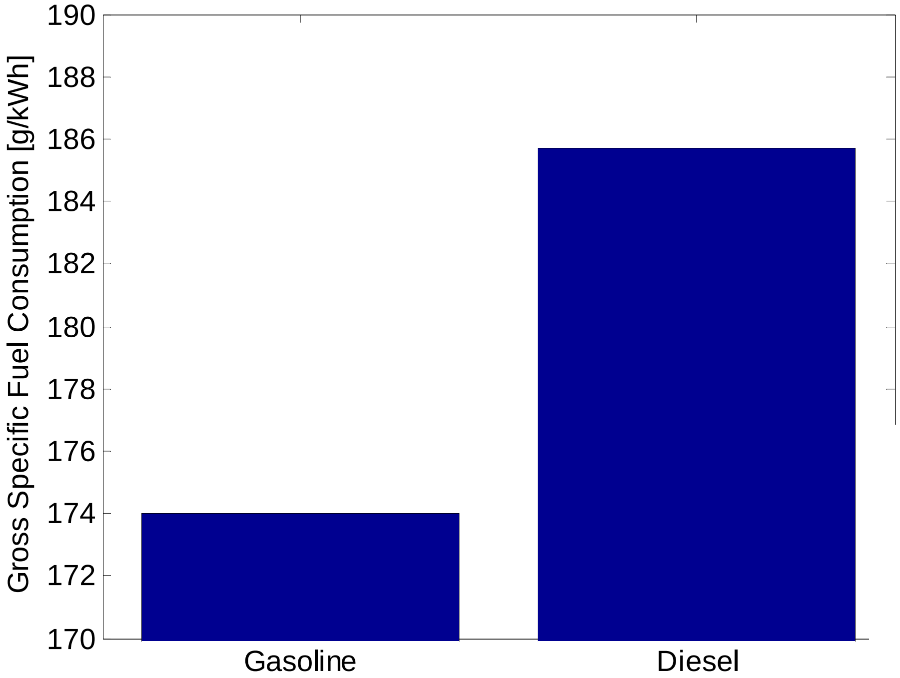
Emissions

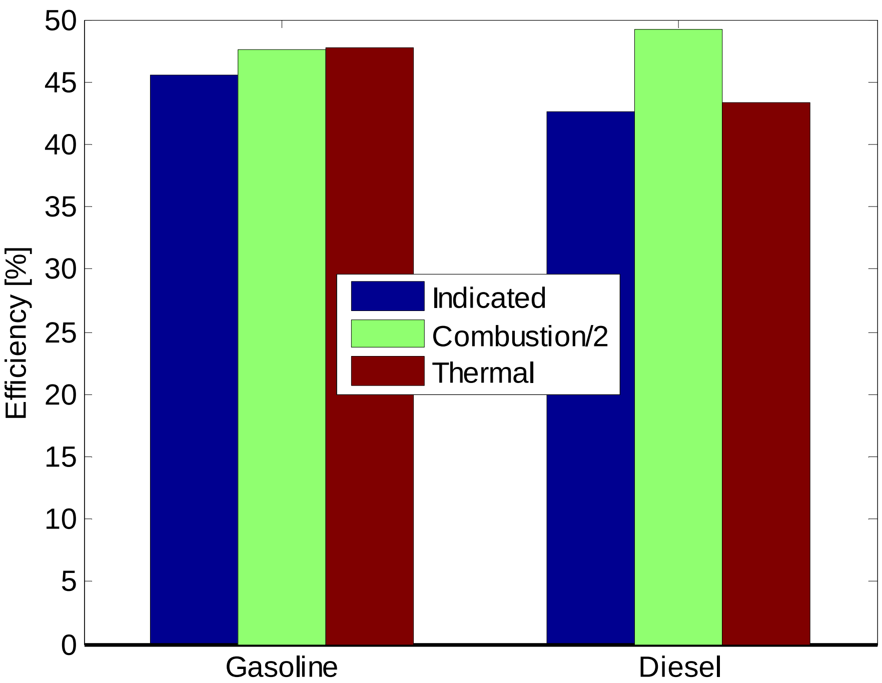


Rail Pressure:1000 [bar]

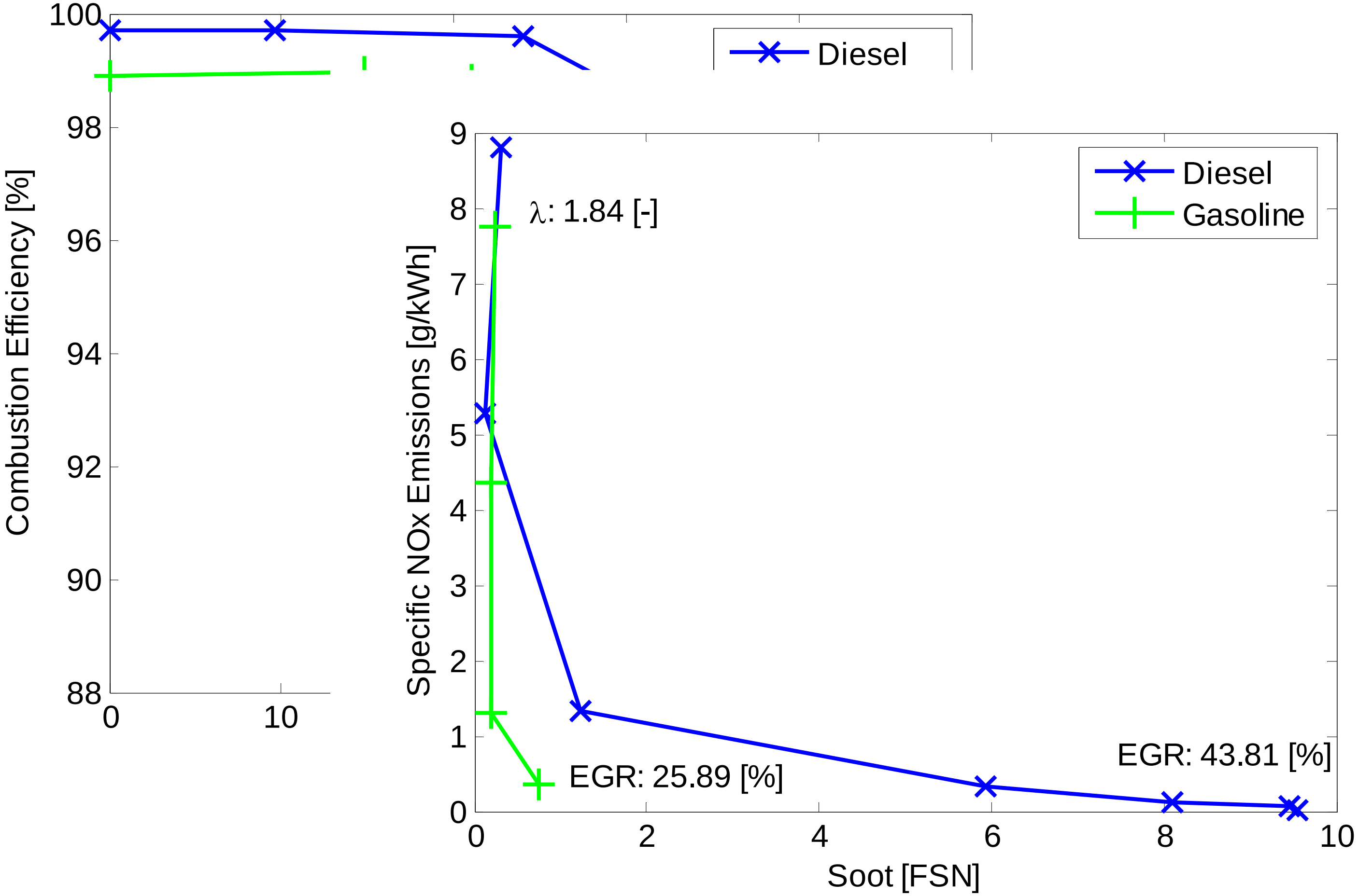
S.R. ~ 1.7 [-]

Efficiency & Fuel Consumption





EGR Sweep @ 12 bar IMEP



Advantages of the concept

Gasoline Type of Fuels

More mixing trough longer natural ignition delay

↓

Very high boost ⟷ Mostly kinetically controlled combustion (fast) ⟷ High rc

↓

Low specific fuel consumption

<u>NO_x</u> reduction with EGR

<u>Soot</u> reduction with injection pressure + swirl + relative homogeneity of the mixture

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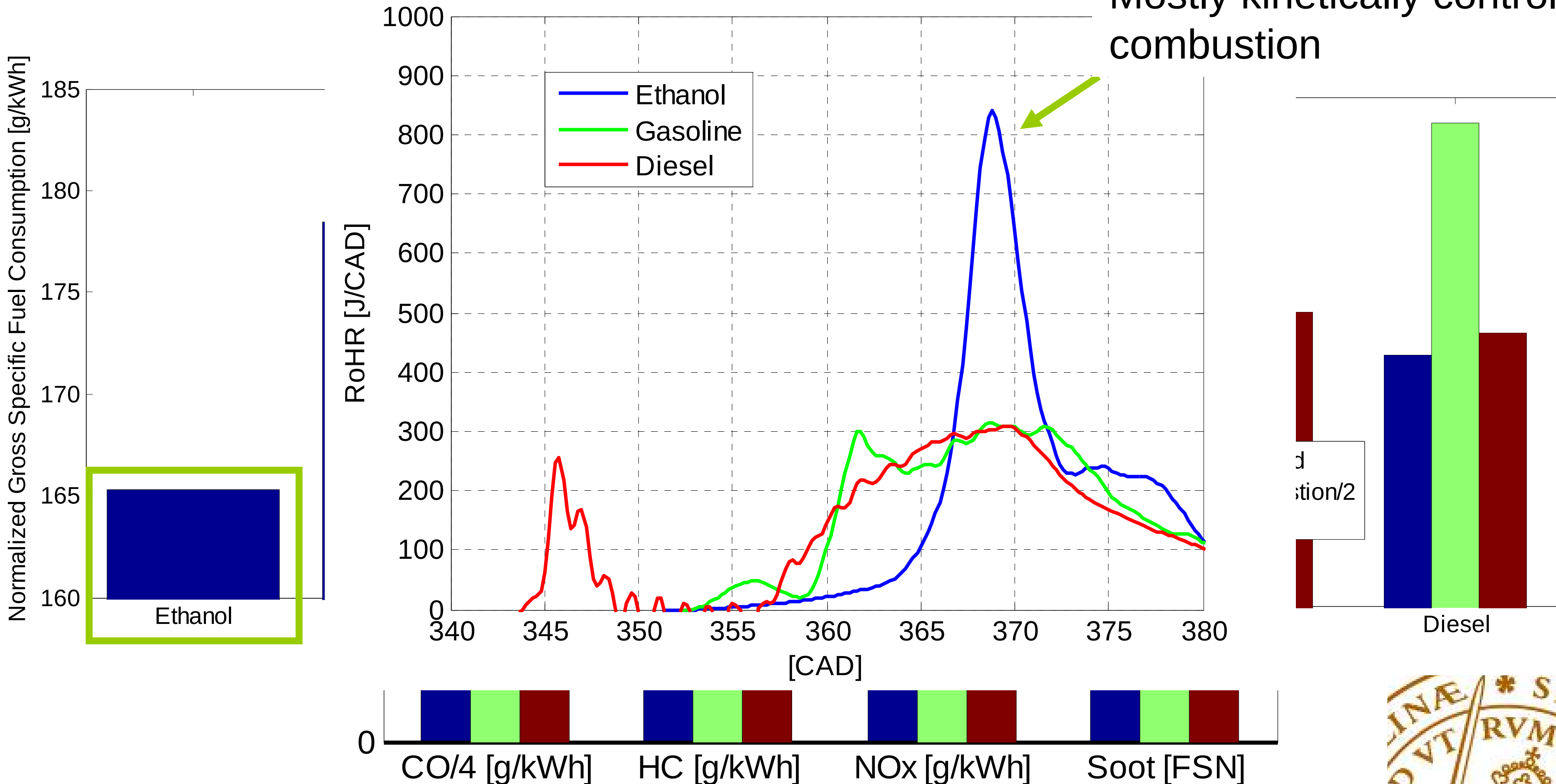
Double Injection @ 14 bar IMEP

- Gasoline & Diesel:
  - Pilot: -20 [TDC], 0.45 [ms]
  - Main: 1.8 [ms]
- Ethanol:
  - Pilot: -20 [TDC], 1 [ms]
  - Main: -1 [TDC], 1.8 [ms]

Emissions & Fuel Consumption

IMEP: 14 bar

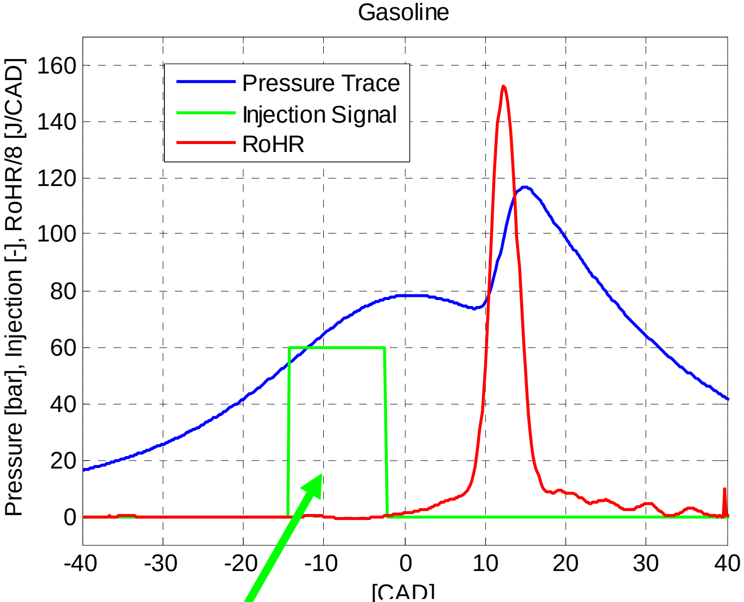
Mostly kinetically controlled combustion

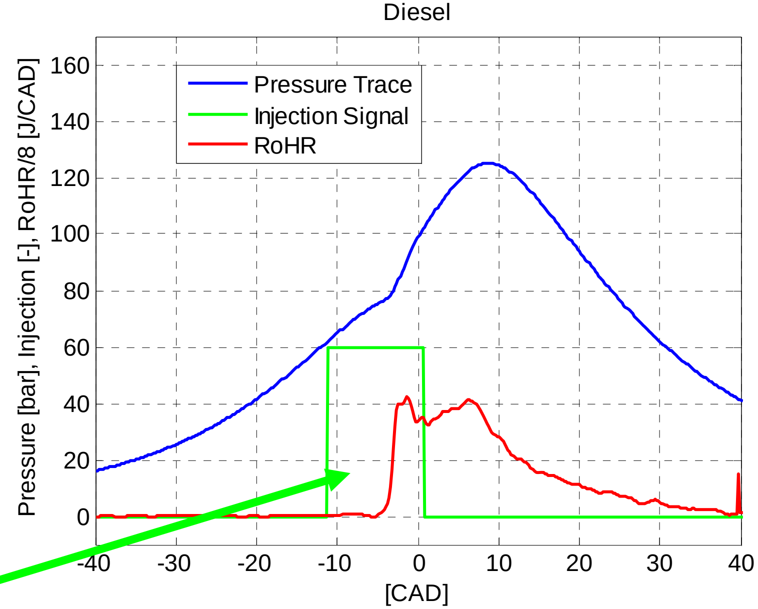


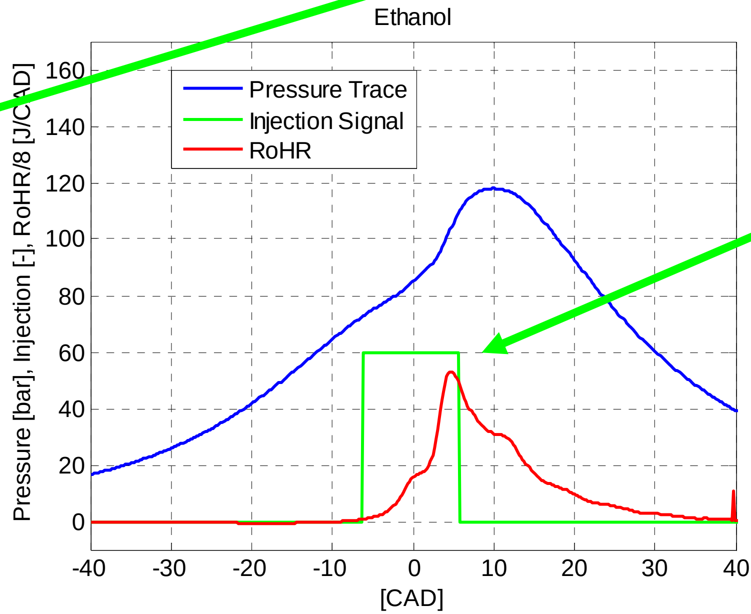
EGR: 25% ➔ λ~1.56

Why double injection?

Pressure, RoHR & Injection Traces



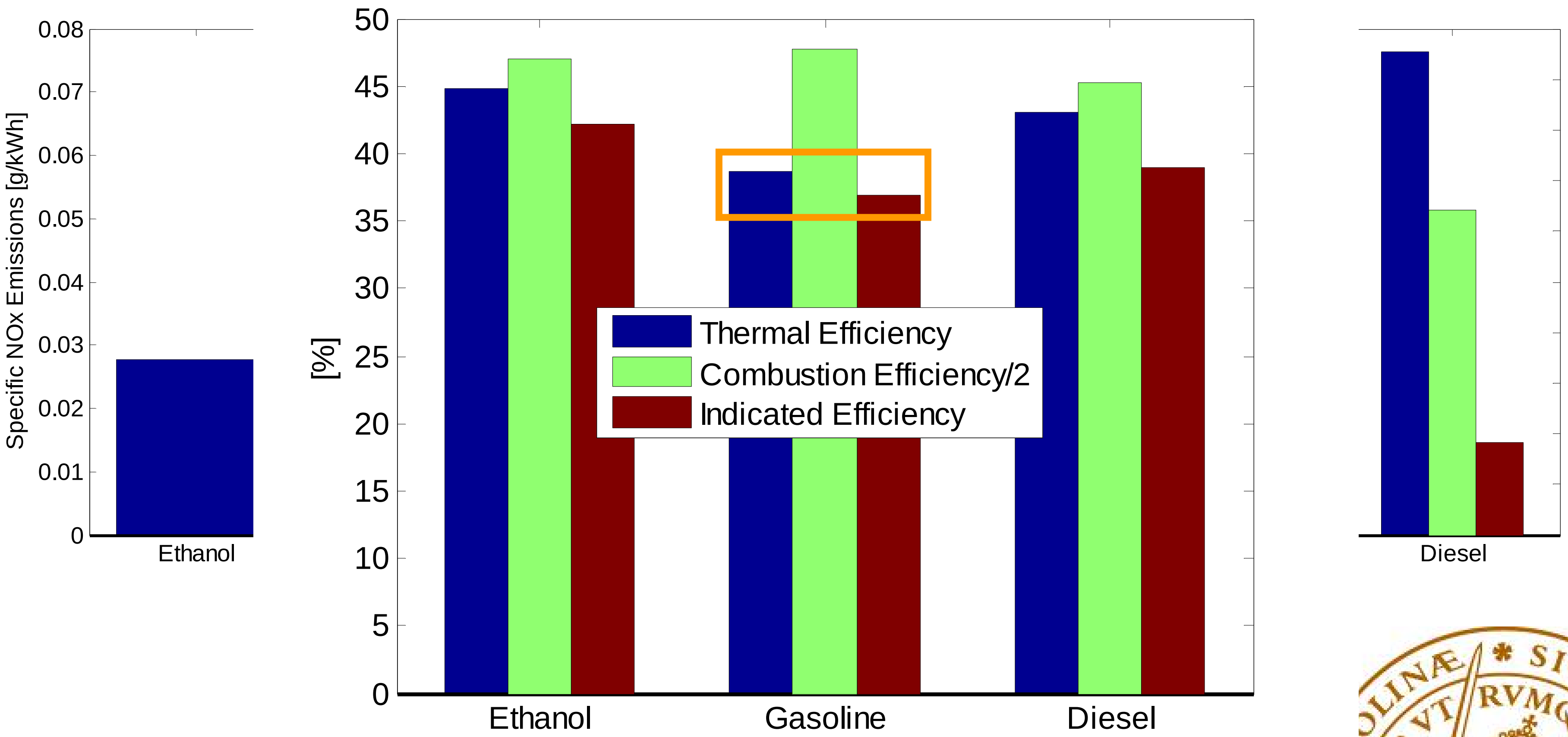




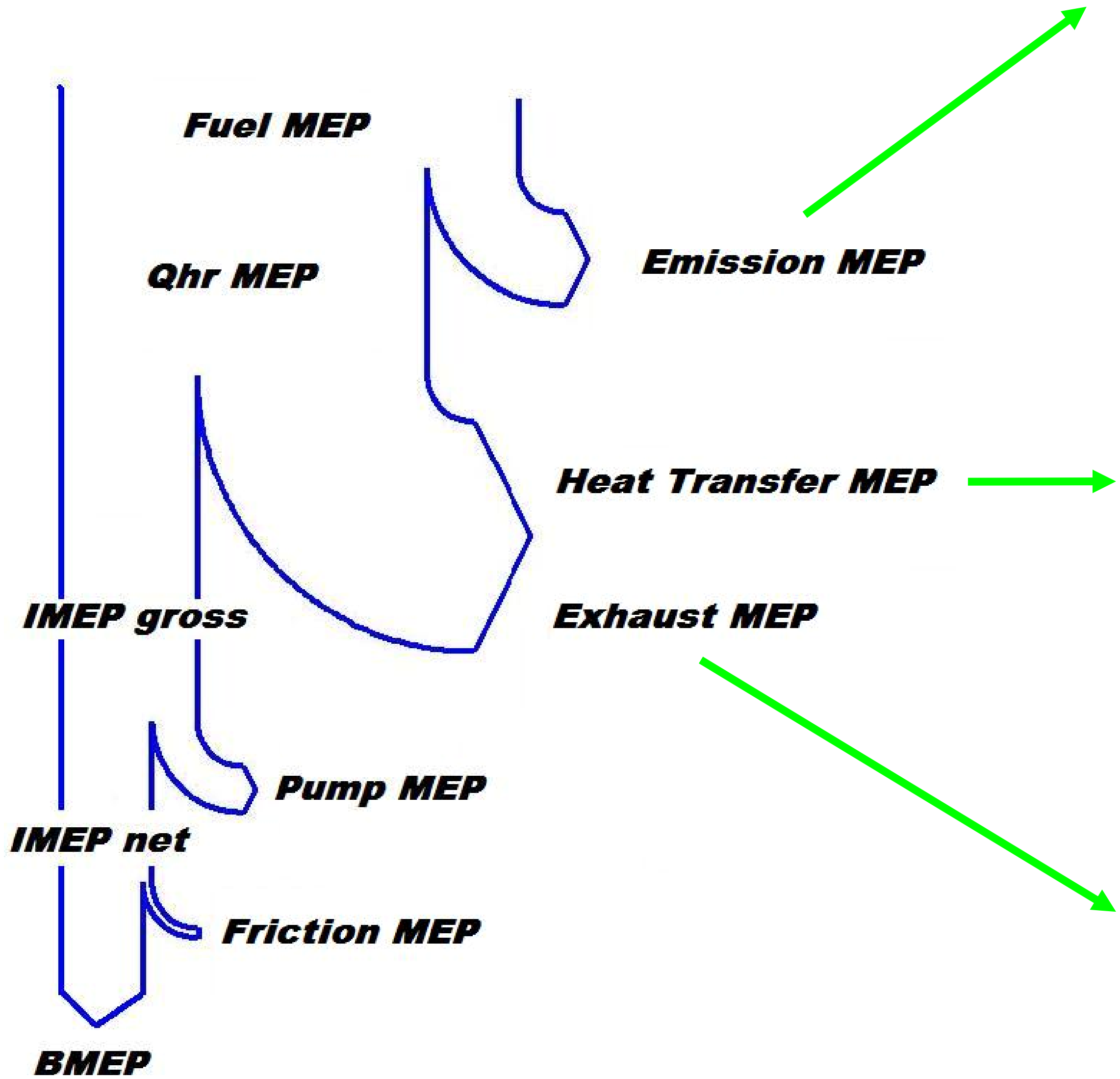
Single Injection,
1.8 [ms]

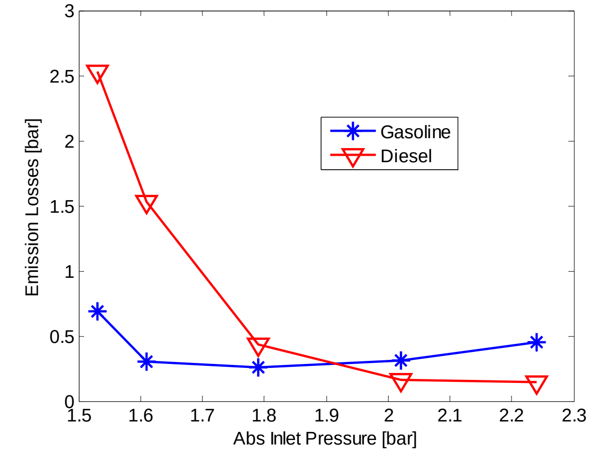
Double Injection

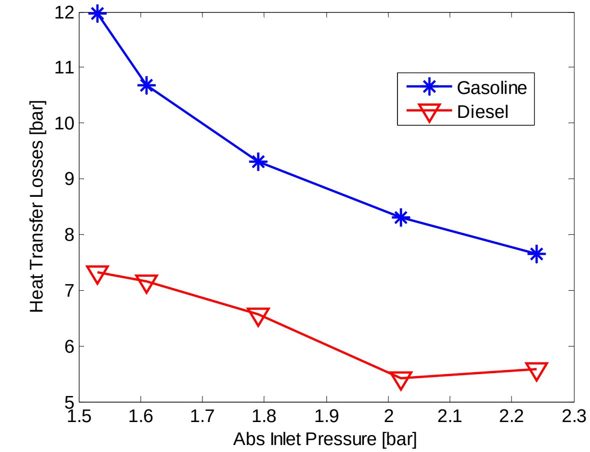
Emissions & Efficiency

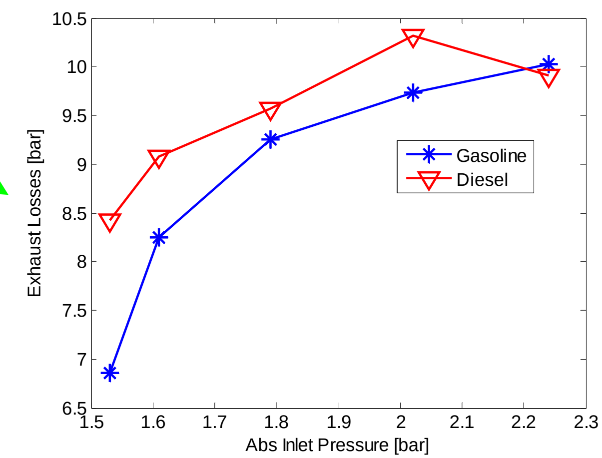


Losses Analysis









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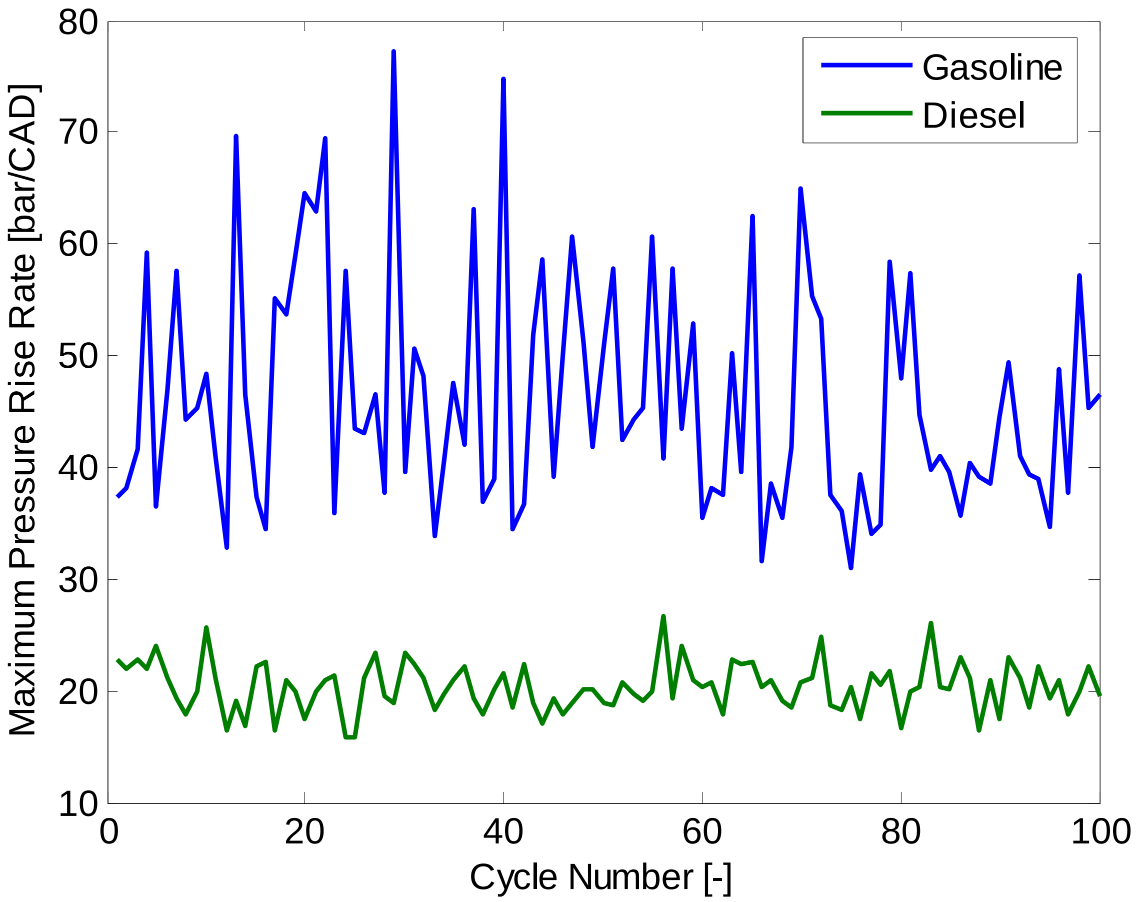
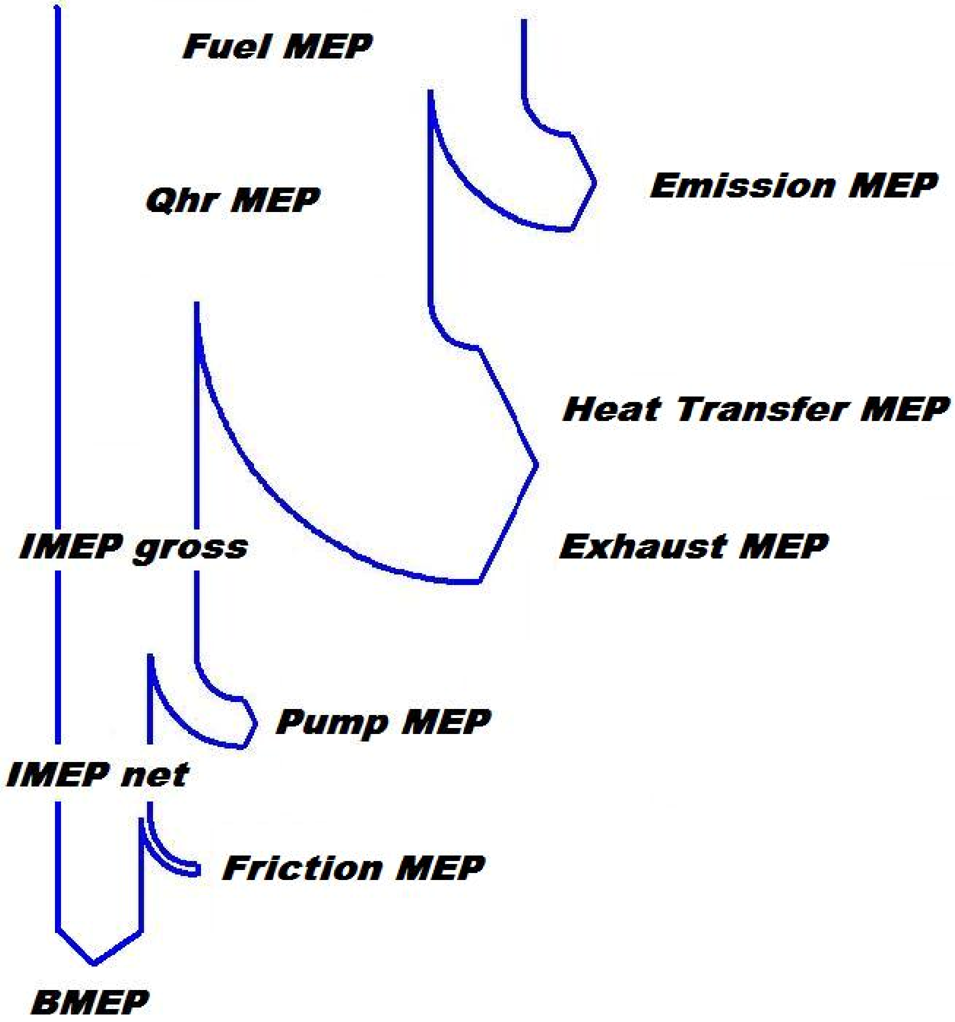
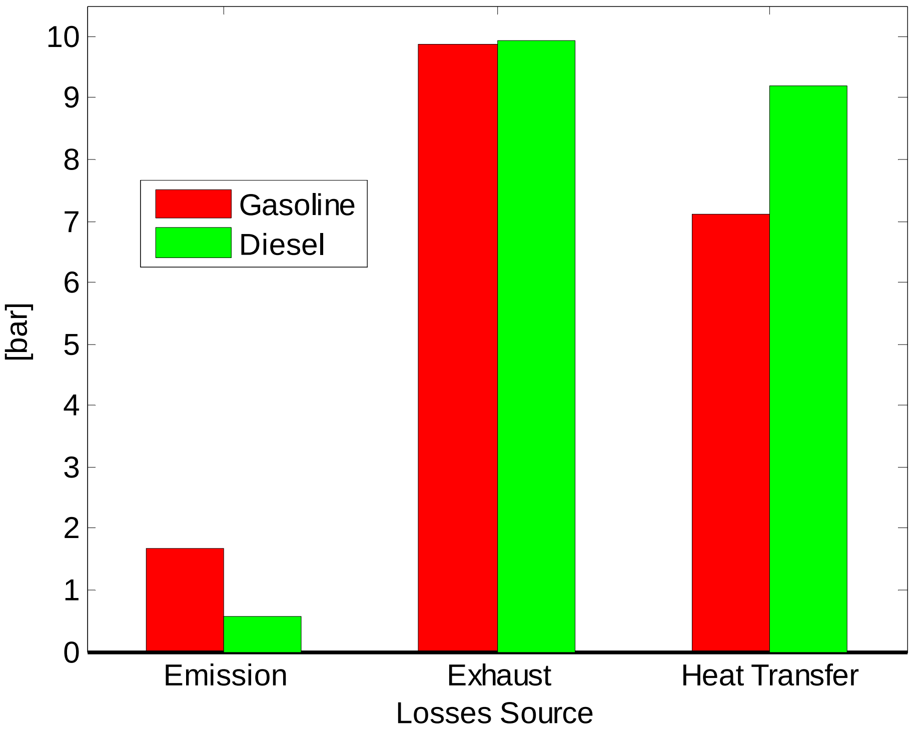


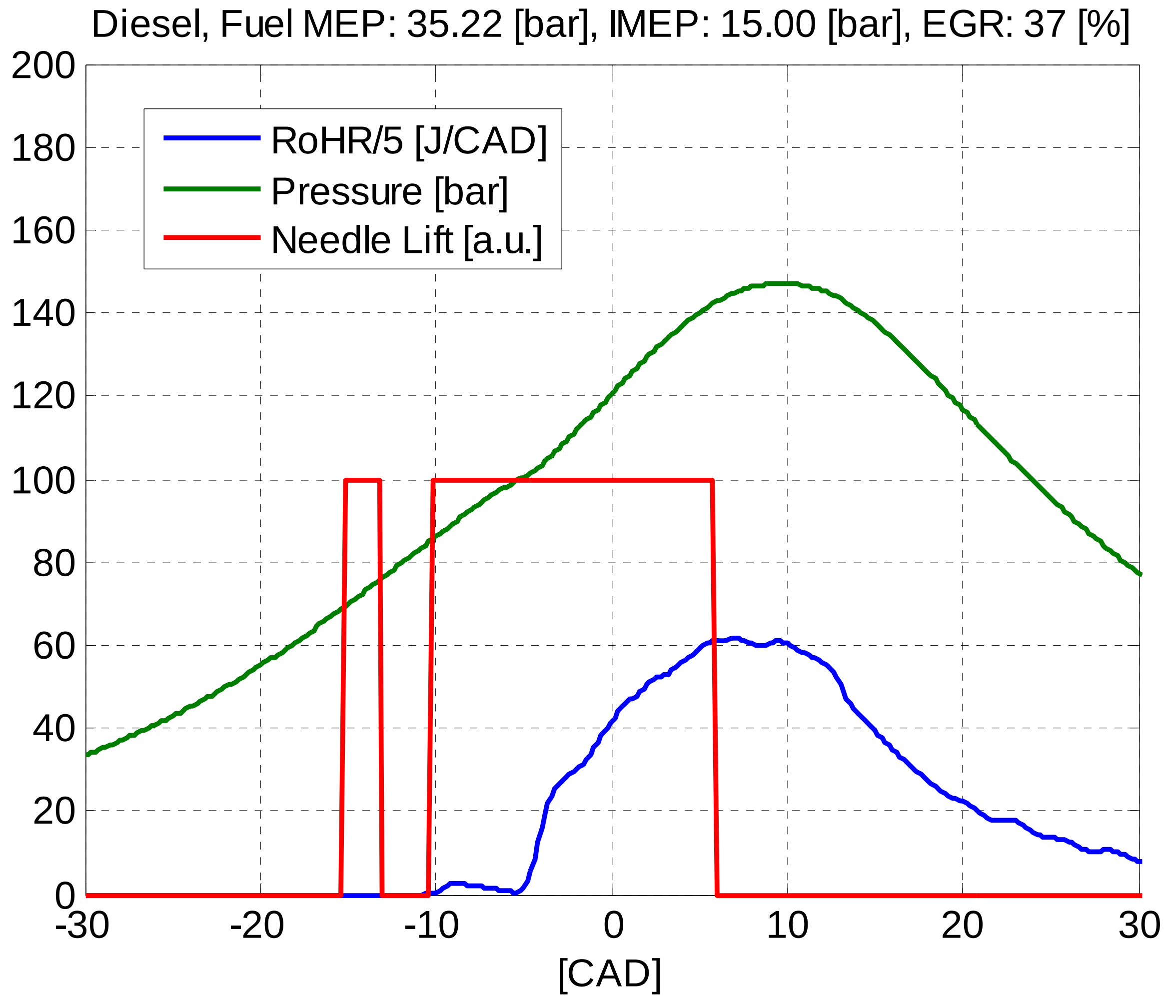
Thermal Boundary Layer breaks ➔ Higher Heat Losses

Energy Losses Analysis – split injection





New combustion concept



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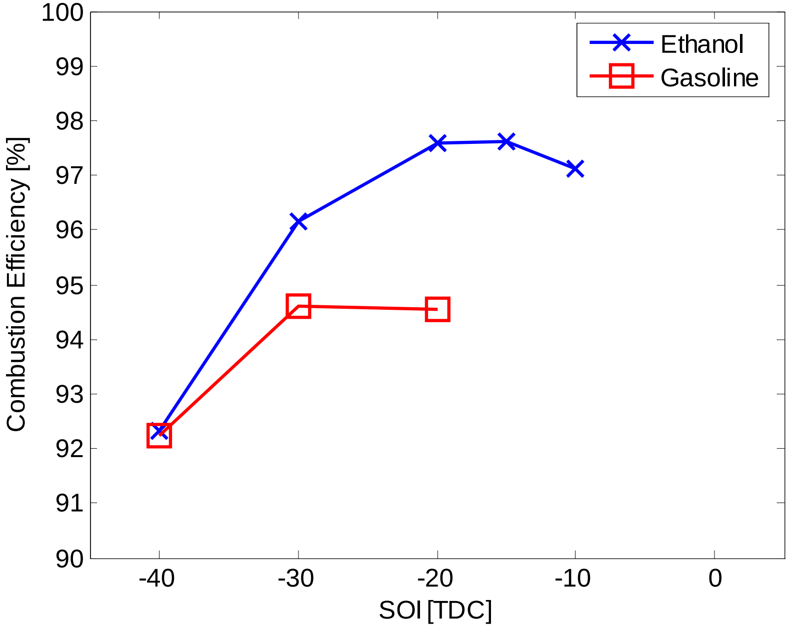
Conclusions

- **PPC with high ON fuels is a feasible concept but the logic on how to operate the engine is different.**
- **Low fuel consumption, low emissions and low noise can be achieved at the same time.**
- **Gasoline PPC is able to run at much higher loads than Diesel and its power density is not penalyzed by a large amount of EGR.**

Thanks for the Attention!

Idle



IMEP ~ 1.5 bar

T_{inlet}: Gasoline 105 [C], Ethanol 135 [C]

P_{inlet}: atm