HCCI collaborative task

MONDAY, September 21, 2009

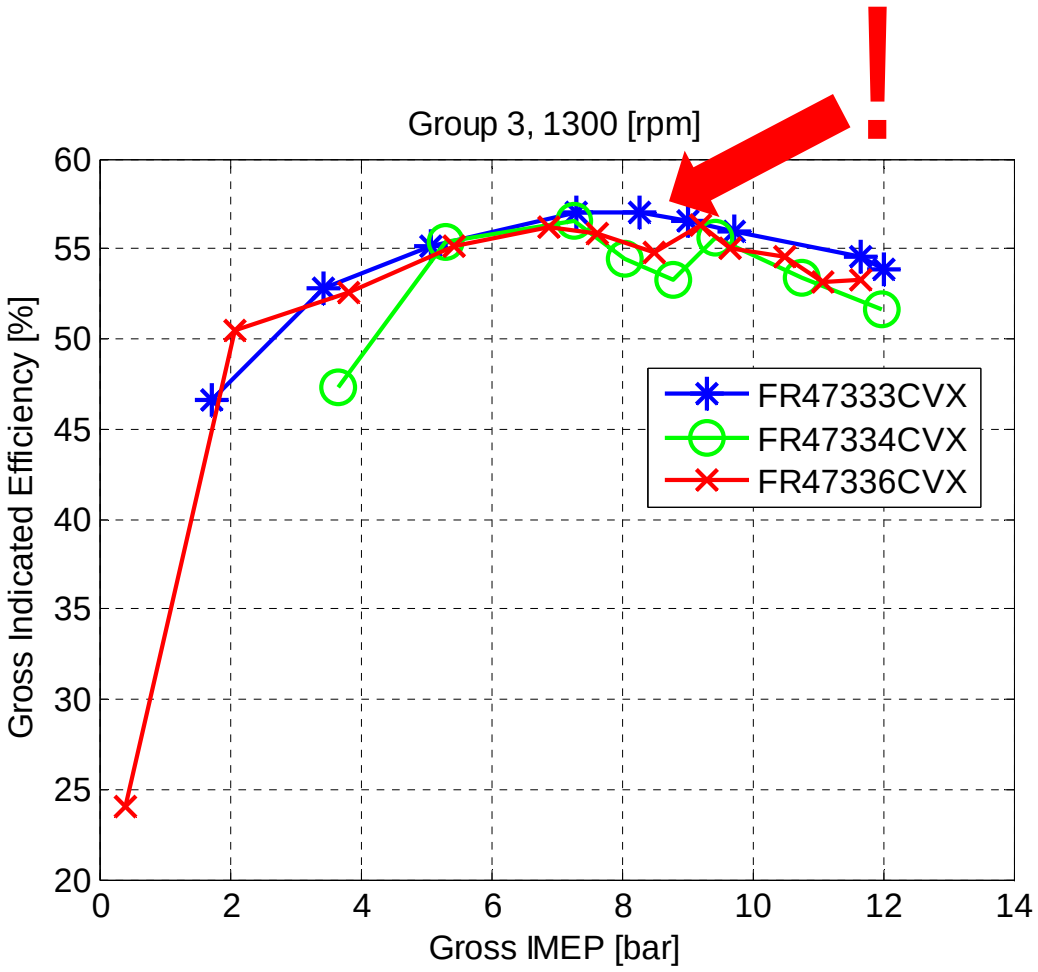
07:00 – 08:40		Breakfast
08:40		Opening remarks
08: 50	HCCI Fuels Collaborative Task	PPC for high fuel efficiency engine operation, *Bengt Johansson, Lund University, Sweden*
09:10		Research into the fuel properties for HCCI, *Hongming Xu, University of Birmingham, UK*
09:30		Dual fueled HCCI operation with DME/LPG/gasoline/hydrogen, *Choongsik Bae, Korea Advanced Institute of Science and Technology (KAIST), Korea*
09:50		Effect of cetane number on HCCI combustion efficiency and emissions, *Vahid Hosseini, W Stuart Neill, Hongsheng Guo, Wallace L. Chippior, National Research Council Canada, Craig Fairbridge, Natural Resources Canada, and Ken Mitchell, Shell Canada Limited, Canada*
10:10		Utilization of HCCI concept - behavior of autoignition of end gas without knock in an engine, *Eiji Tomita and Nobuyuki Kawahara, Okayama University, Japan*
10:30 – 10:50		Break
10:50		Active fuel design and management for homogeneous charge compression ignition (HCCI), *Huang Zhen, Shanghai Jiao Tong University, China*
11:10		Preliminary results on HCCI implementation with high cetane number fuel, *Martti Larmi, Helsinki University of Technology, Finland*
11:30		Study of advanced combustion mechanisms for clean engines at Istituto Motori, *Felice E. Corcione, Istituto Motori CNR, Italy*

Partially Premixed Combustion, PPC, for high fuel efficiency engine operation

Prof. Bengt Johansson

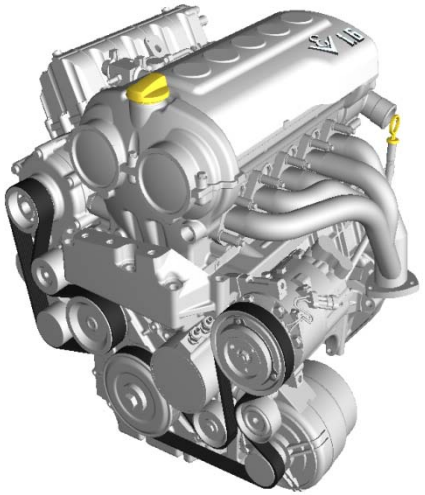
Division of Combustion Engines
Department of Energy Sciences
Lund University

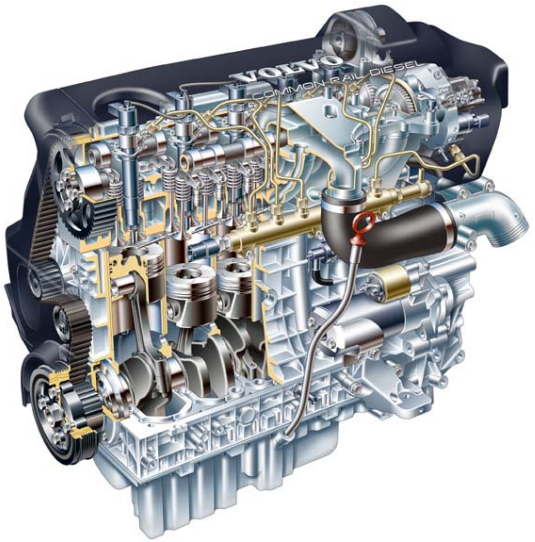
Scania diesel engine running on gasoline



Path to high efficiency gasoline engine

SI → HCCI → PPC





Prof. Bengt Johansson

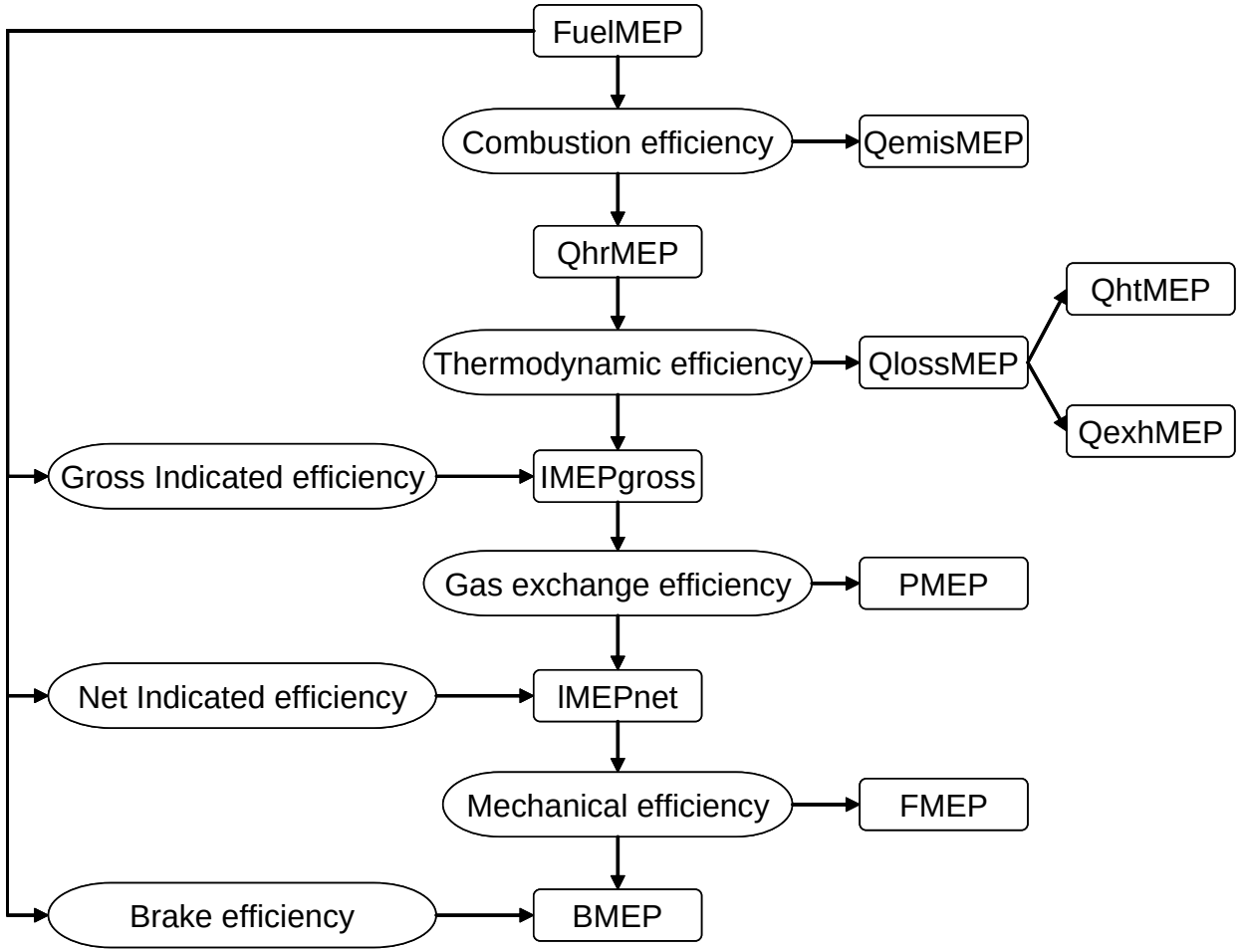
Division of Combustion Engines
Department of Energy Sciences
Lund University

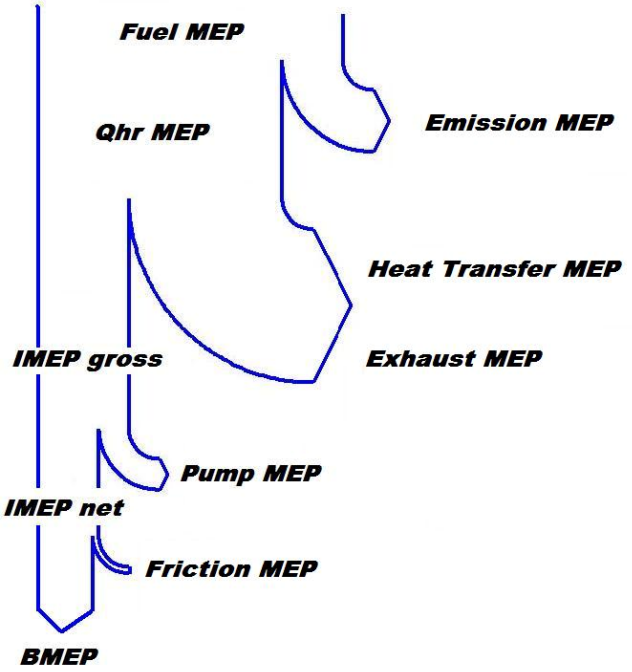
Path to high efficiency gasoline engine

- Lean HCCI in three engines, 0.3-2 l/cyl
  - 50-54% thermal efficiency
- PPC in Volvo Cars diesel engine, 0.5l/cyl
  - 56% thermal efficiency, 51% indicated
- PPC in Scania, 2 l/cyl, 17:1
  - 57% indicated efficiency
- PPC in Scania 2 l/cyl, 14.3:1
  - 55% indicated efficiency with high load

Efficiencies?

Energy flow in an IC engine

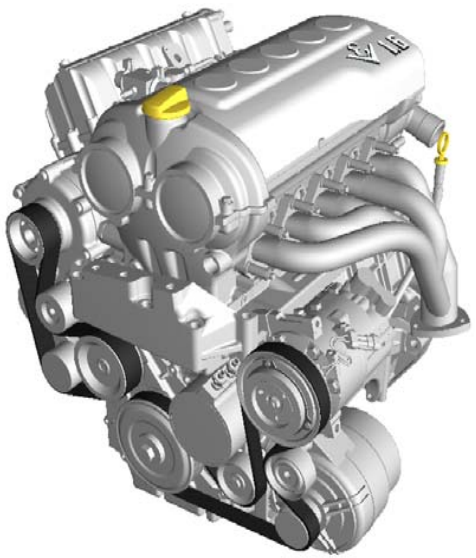




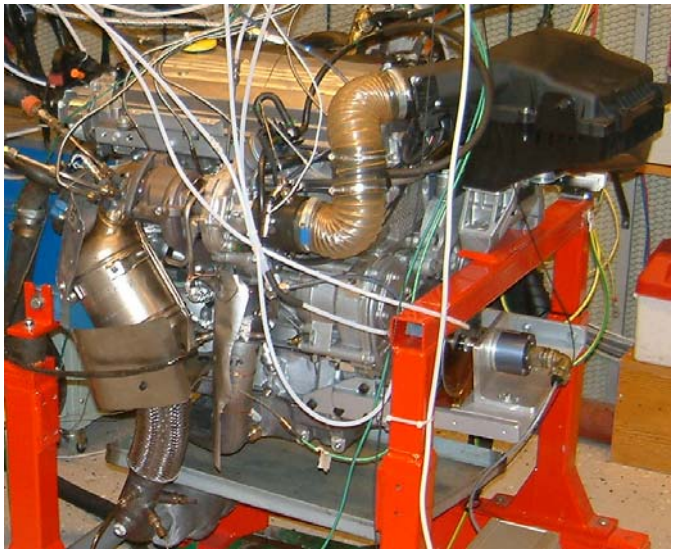
$$\eta_{Brake} = \eta_{Combustion} * \eta_{Thermodynamic} * \eta_{GasExchange} * \eta_{Mechanical}$$

HCCI benchmark tests

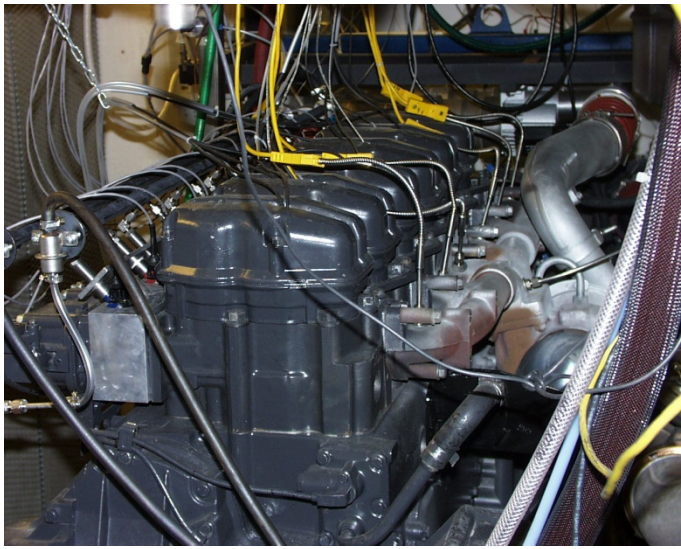
Three test engines; five cases:



5 cyl of 0.32 l



4 cyl of 0.5 l



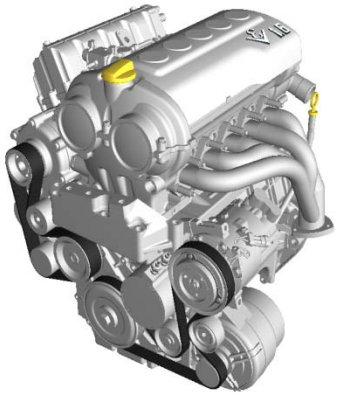
6 cyl of 1.95 l

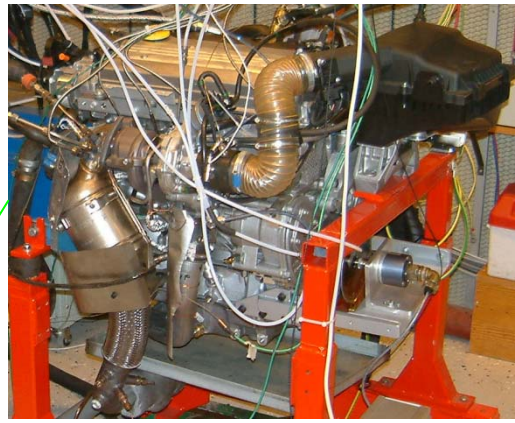
- Saab SVC variable compression ratio, VCR,
  1. HCCI, Rc=10:1-30:1;
- General Motors L850 “World engine”
  2. HCCI, Rc=18:1
  3. SI, Rc=18:1
  4. SI, Rc=9.5:1 (std)
- Scania D12 Heavy duty diesel engine,
  5. HCCI, Rc=18:1;

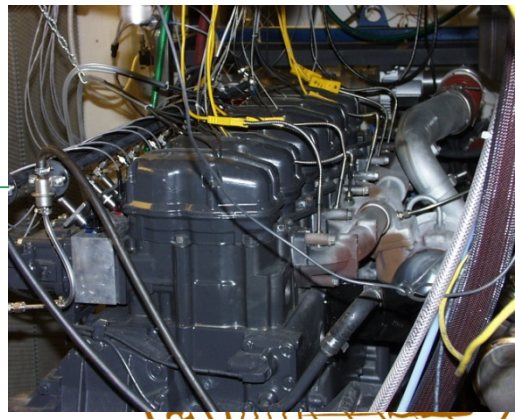
Thermodynamic efficiency

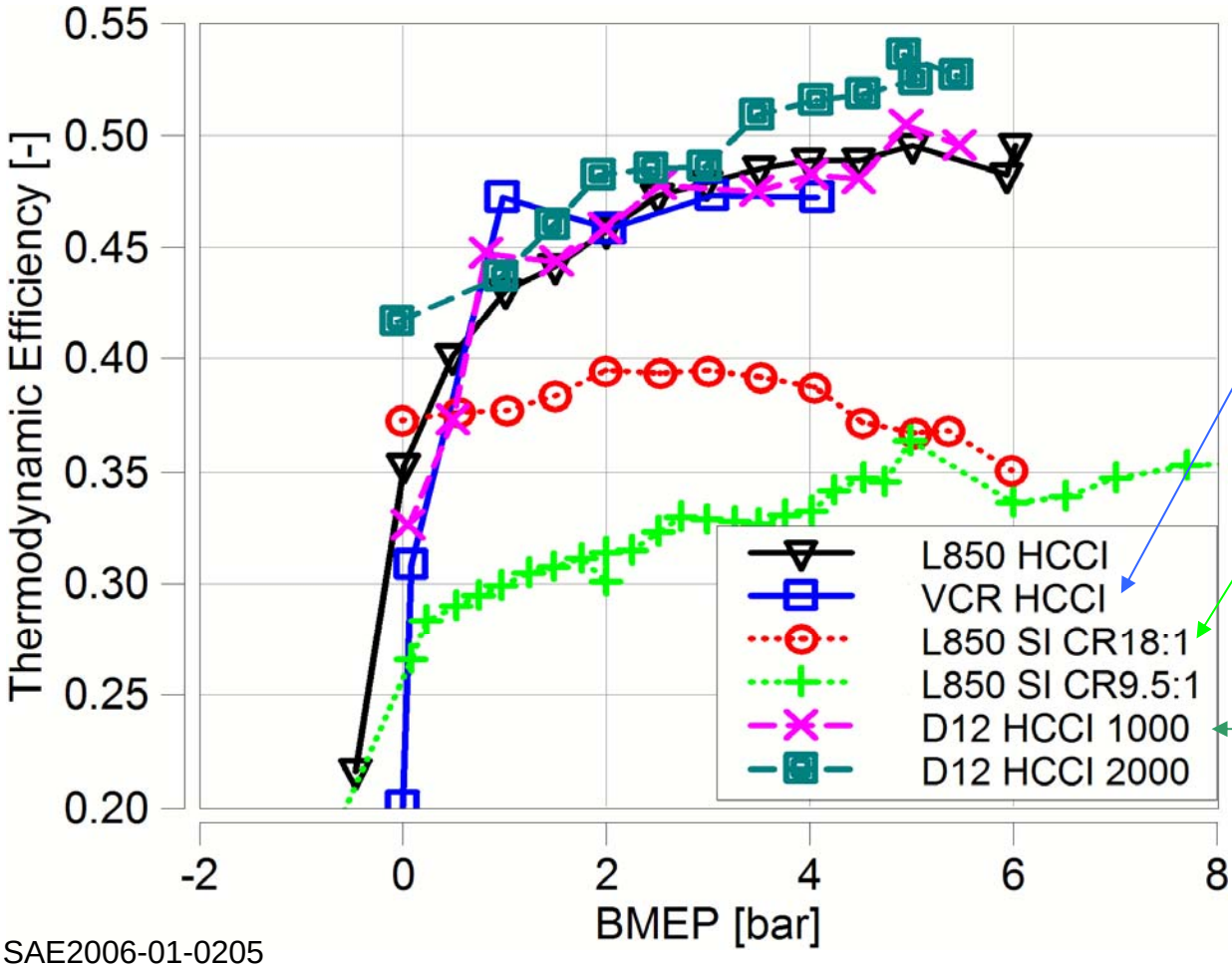
Saab SVC variable compression ratio, VCR, HCCI, Rc=10:1-30:1;
General Motors L850 "World engine", HCCI, Rc=18:1, SI, Rc=18:1, SI, Rc=9.5:1 (std)
Scania D12 Heavy duty diesel engine, HCCI, Rc=18:1;

Fuel: US regular Gasoline



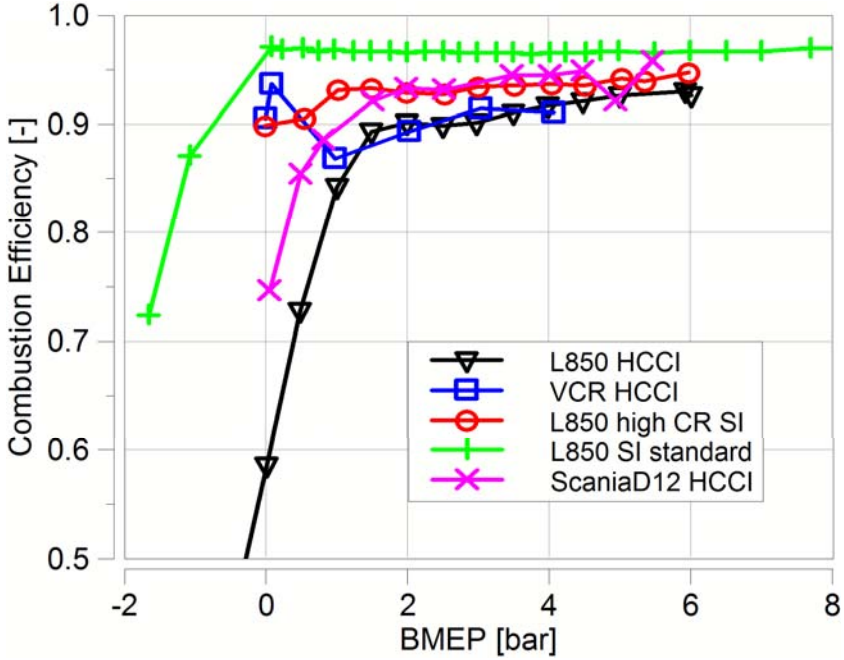


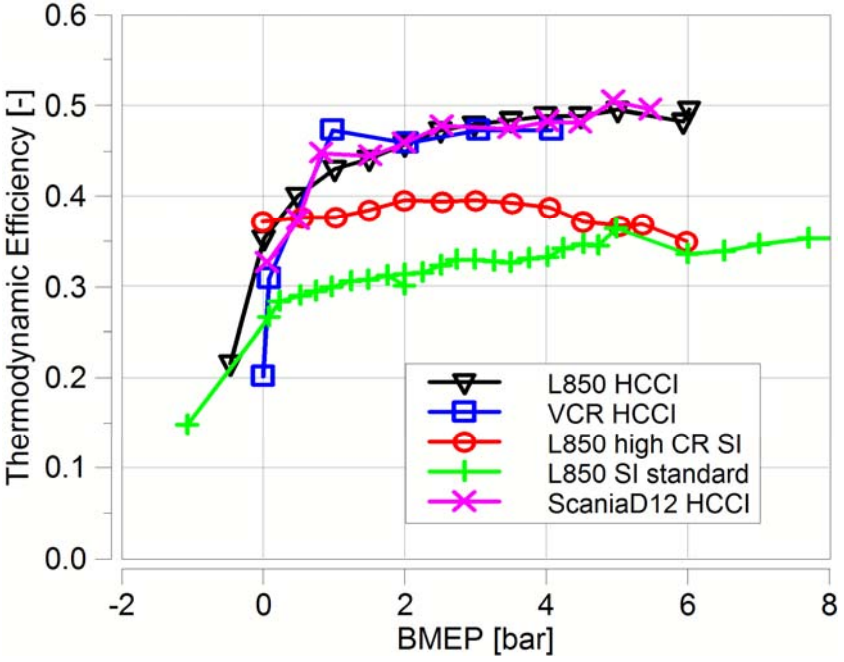


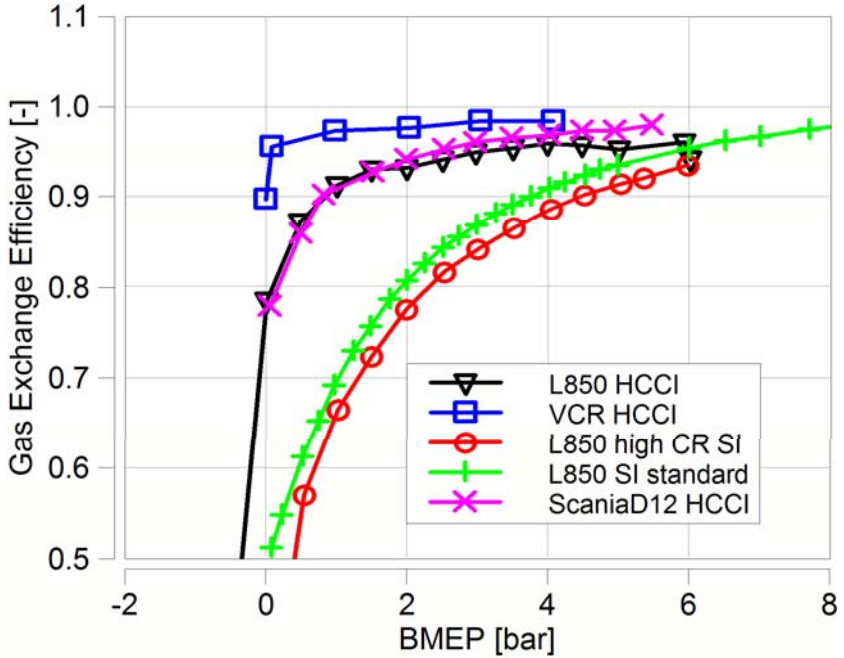


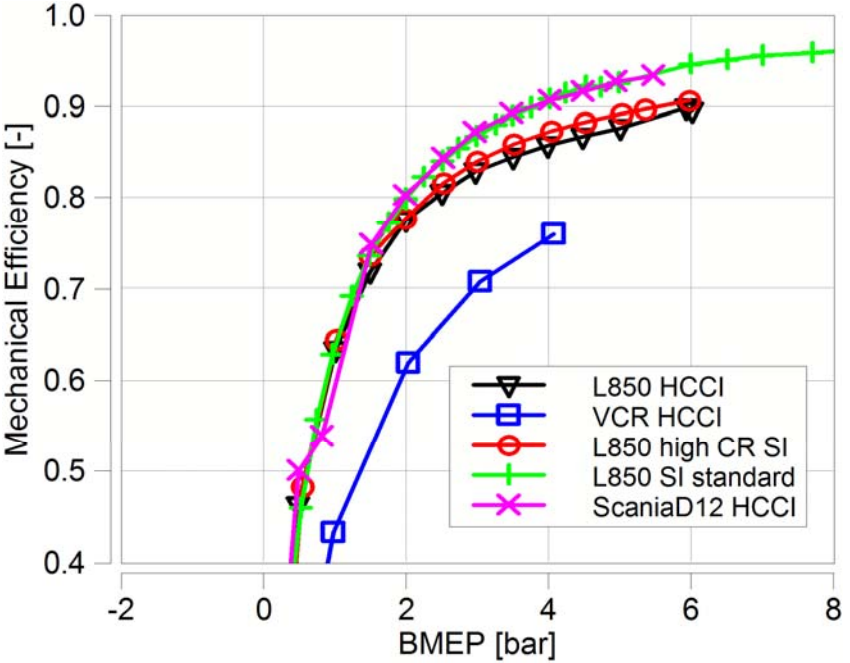
SAE2006-01-0205

All four efficiencies

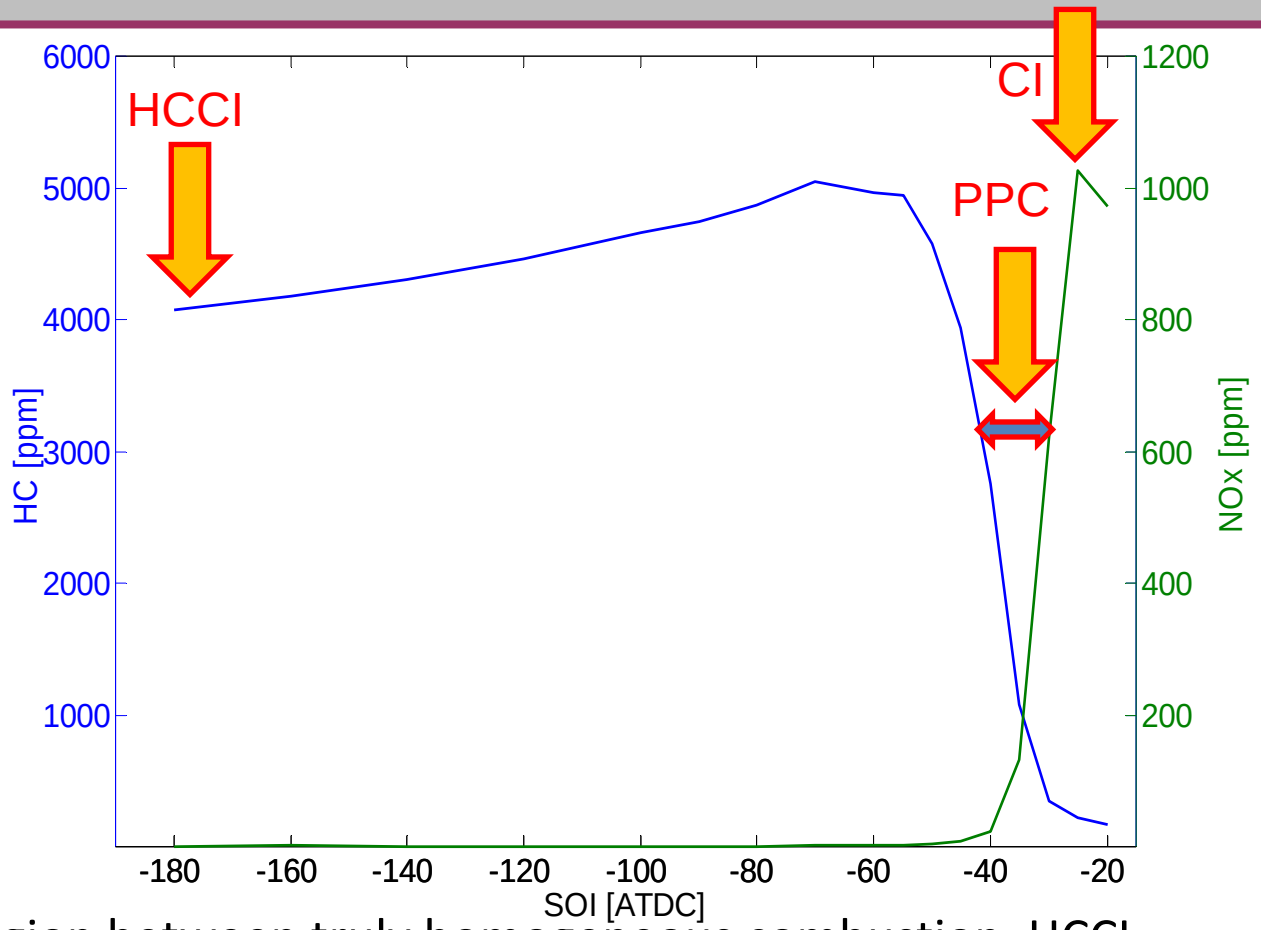








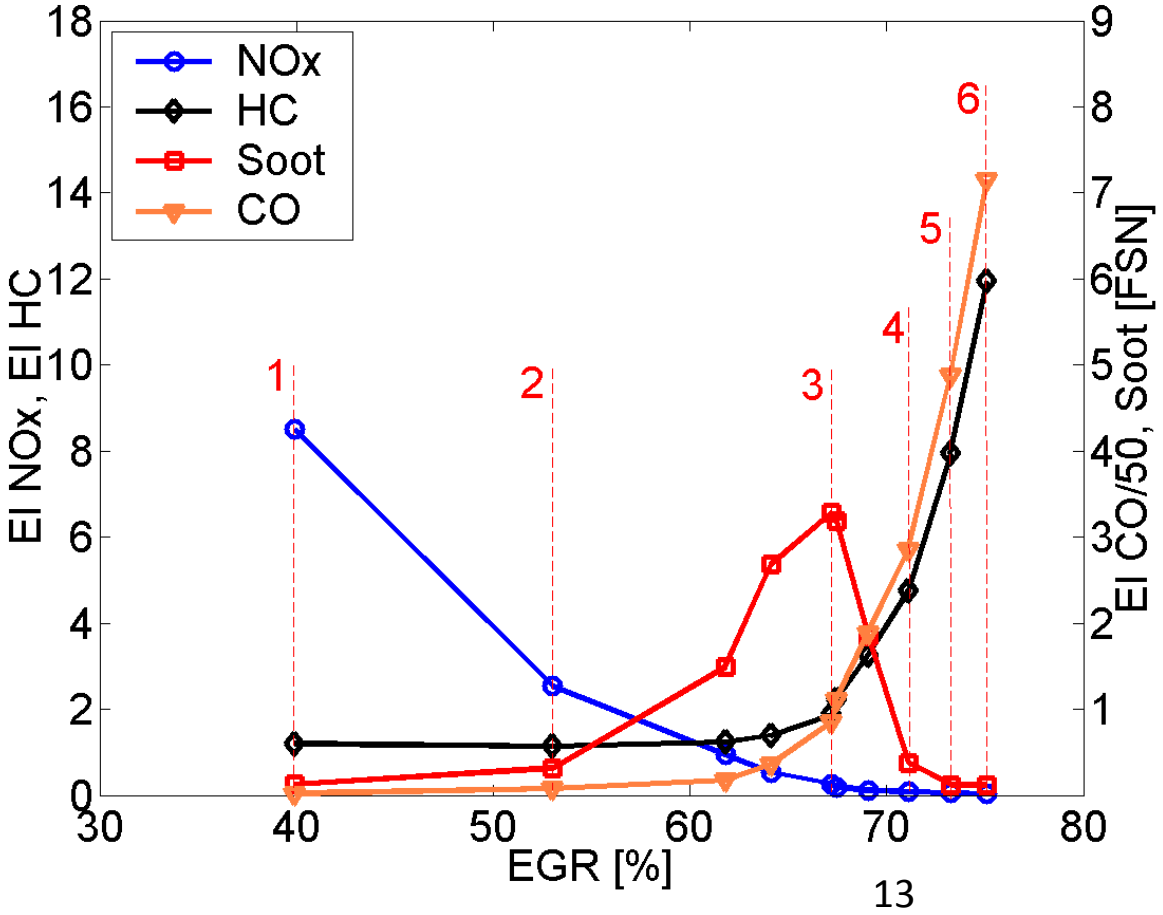
Partially Premixed Combustion, PPC

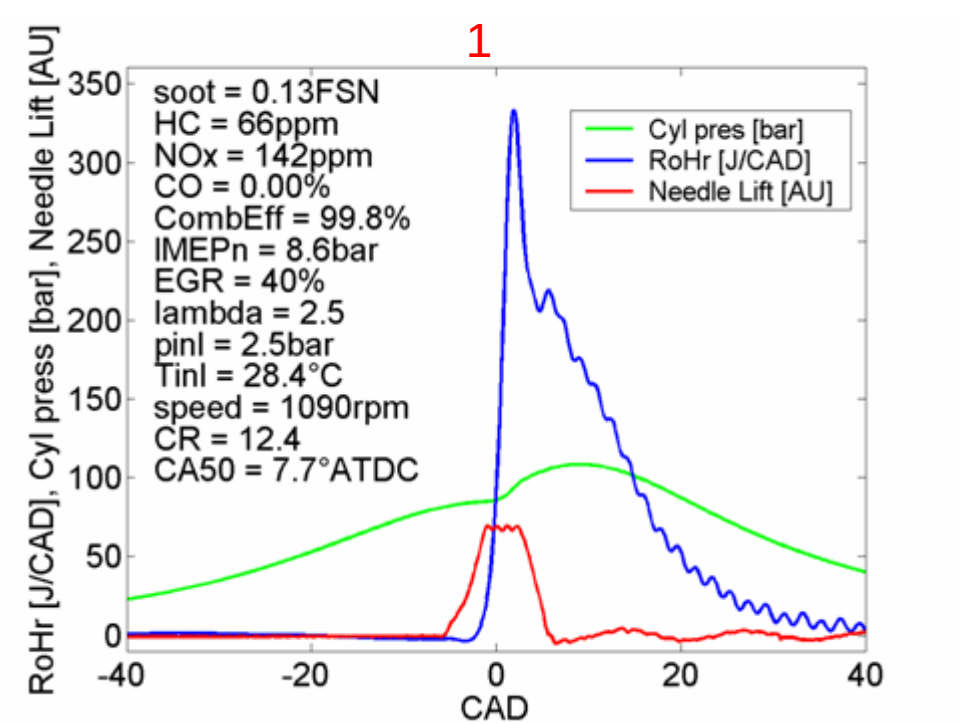


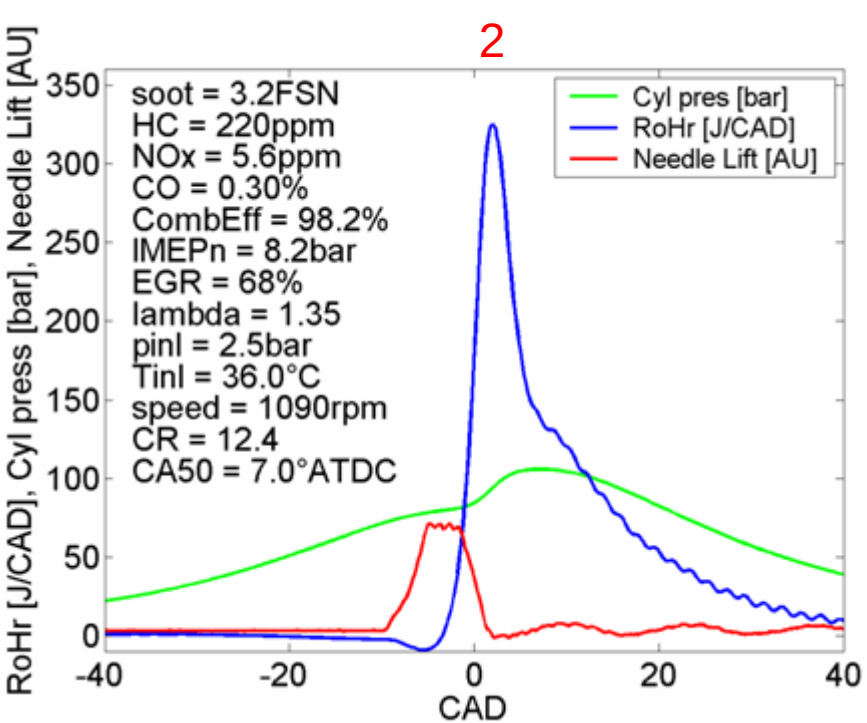
- Def: region between truly homogeneous combustion, HCCI, and diffusion controlled combustion, diesel
- Trade-off between NOx and HC, soot typical
- Combustion process not well known
- Soot a key feature

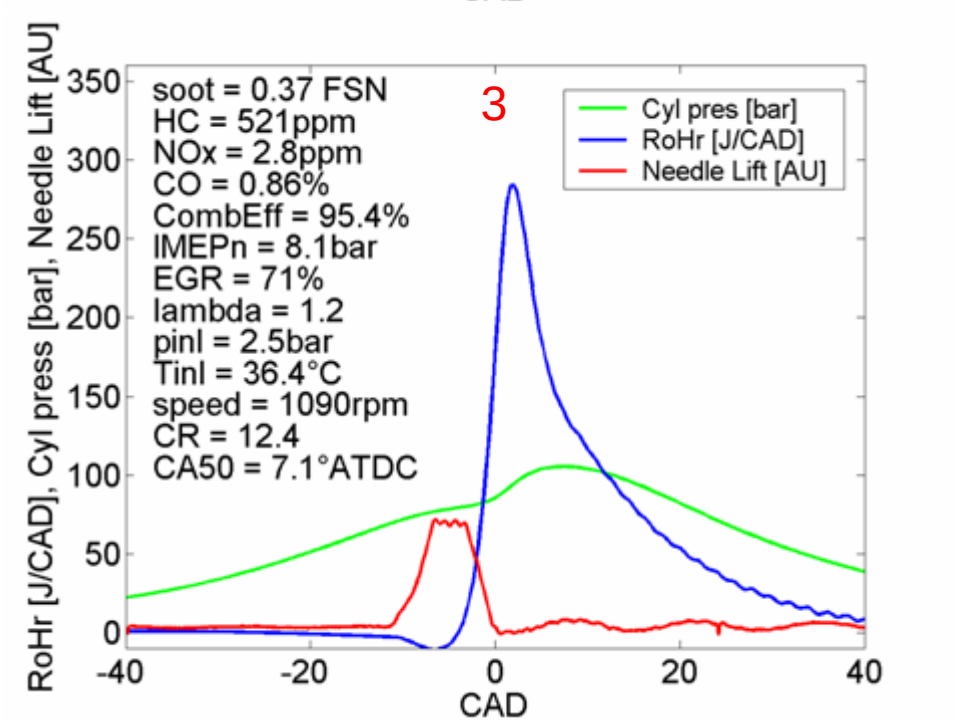
Effect of EGR with diesel fuel

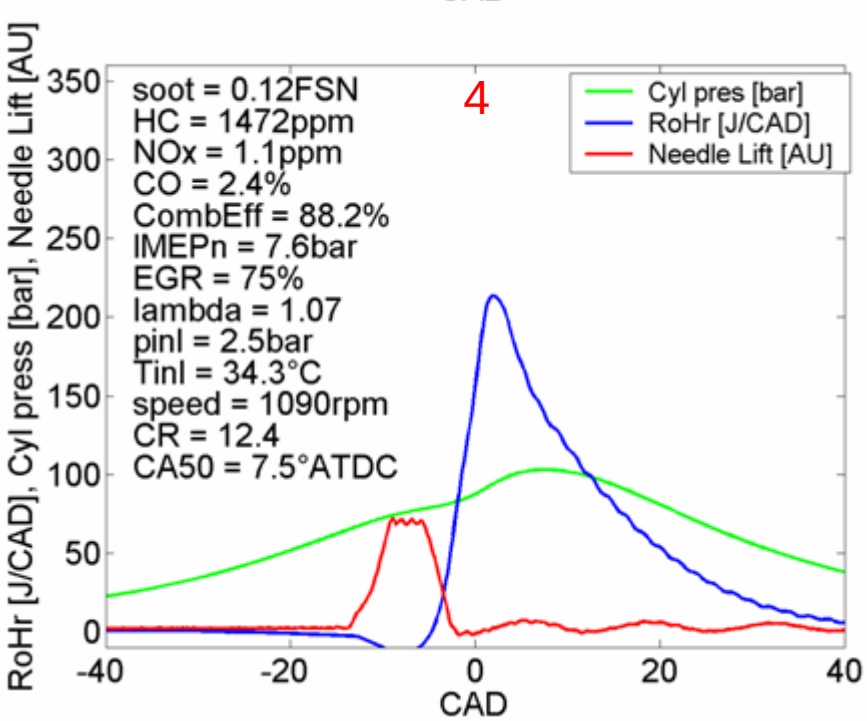
Load	8 bar IMEP
Abs. Inlet Pressure	2.5 bar
Engine Speed	1090 rpm
Swirl Ratio	1.7
Compression Ratio	**12.4:1 (Low)**



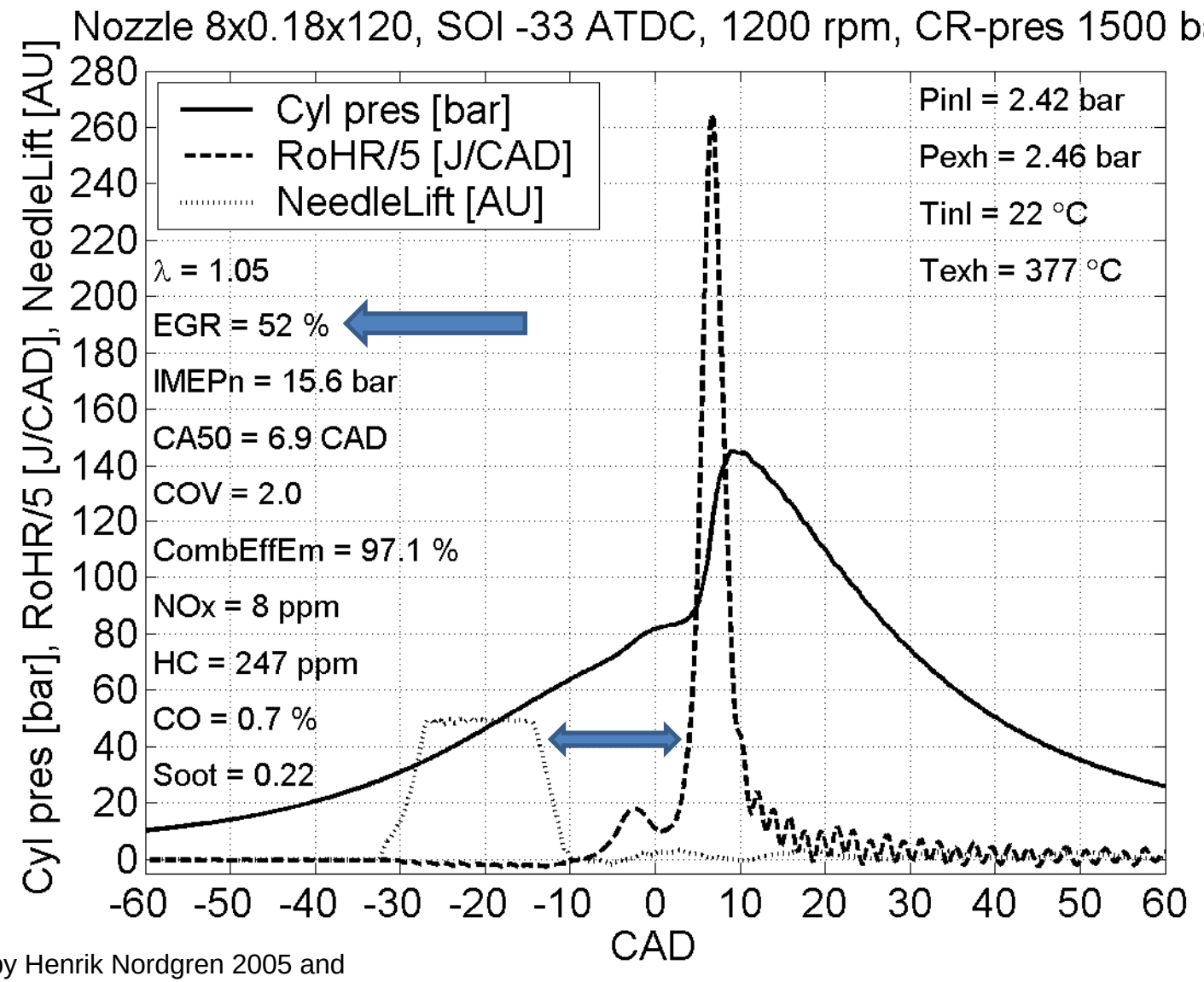

1
soot = 0.13FSN
HC = 66ppm
NOx = 142ppm
CO = 0.00%
CombEff = 99.8%
IMEPn = 8.6bar
EGR = 40%
lambda = 2.5
pinl = 2.5bar
Tinl = 28.4°C
speed = 1090rpm
CR = 12.4
CA50 = 7.7°ATDC
Cyl pres [bar]
RoHr [J/CAD]
Needle Lift [AU]
RoHr [J/CAD], Cyl press [bar], Needle Lift [AU]
CAD


2
soot = 3.2FSN
HC = 220ppm
NOx = 5.6ppm
CO = 0.30%
CombEff = 98.2%
IMEPn = 8.2bar
EGR = 68%
lambda = 1.35
pinl = 2.5bar
Tinl = 36.0°C
speed = 1090rpm
CR = 12.4
CA50 = 7.0°ATDC
Cyl pres [bar]
RoHr [J/CAD]
Needle Lift [AU]
RoHr [J/CAD], Cyl press [bar], Needle Lift [AU]
CAD


3
soot = 0.37 FSN
HC = 521ppm
NOx = 2.8ppm
CO = 0.86%
CombEff = 95.4%
IMEPn = 8.1bar
EGR = 71%
lambda = 1.2
pinl = 2.5bar
Tinl = 36.4°C
speed = 1090rpm
CR = 12.4
CA50 = 7.1°ATDC
Cyl pres [bar]
RoHr [J/CAD]
Needle Lift [AU]
RoHr [J/CAD], Cyl press [bar], Needle Lift [AU]
CAD

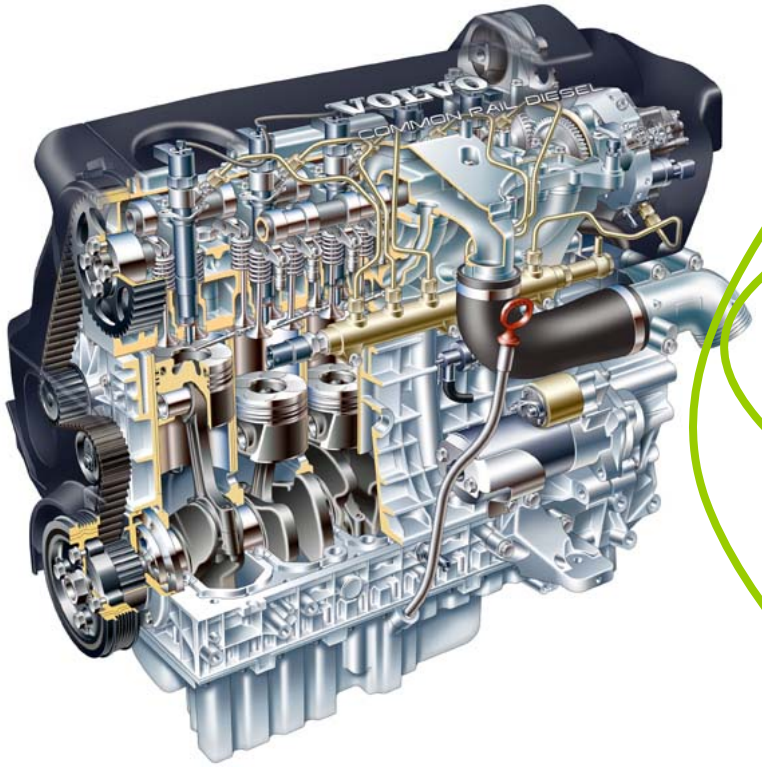

4
soot = 0.12FSN
HC = 1472ppm
NOx = 1.1ppm
CO = 2.4%
CombEff = 88.2%
IMEPn = 7.6bar
EGR = 75%
lambda = 1.07
pinl = 2.5bar
Tinl = 34.3°C
speed = 1090rpm
CR = 12.4
CA50 = 7.5°ATDC
Cyl pres [bar]
RoHr [J/CAD]
Needle Lift [AU]
RoHr [J/CAD], Cyl press [bar], Needle Lift [AU]
CAD

PPC with low cetane diesel



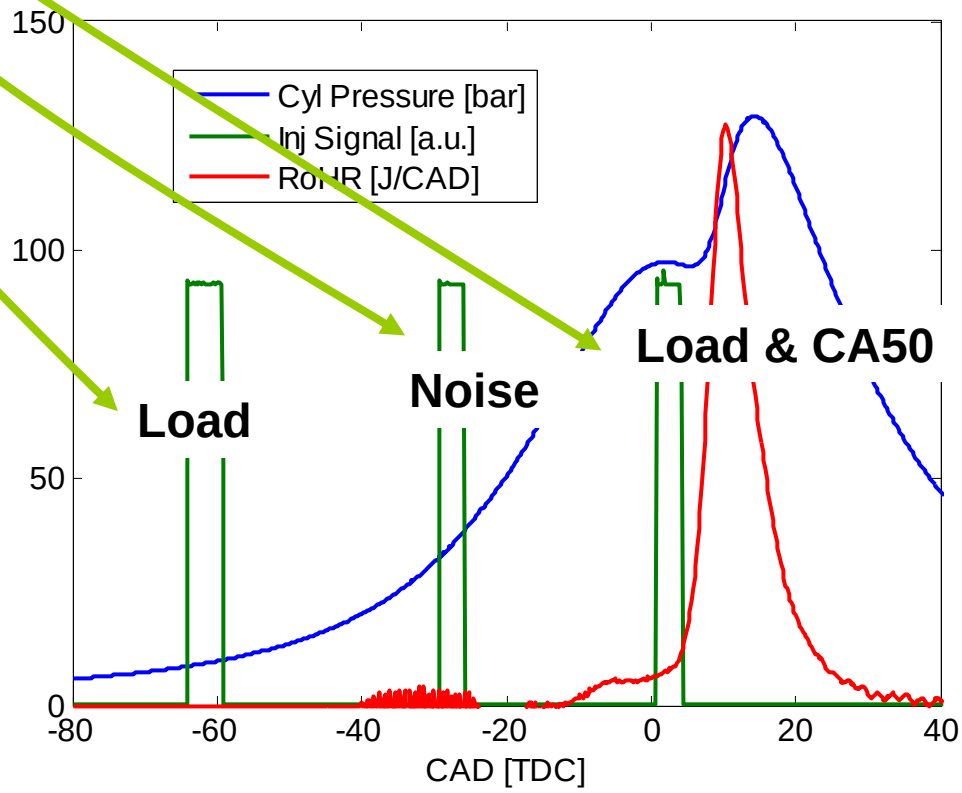
Lic. Thesis by Henrik Nordgren 2005 and presented at DEER2005

VOLVO D5 with Gasoline

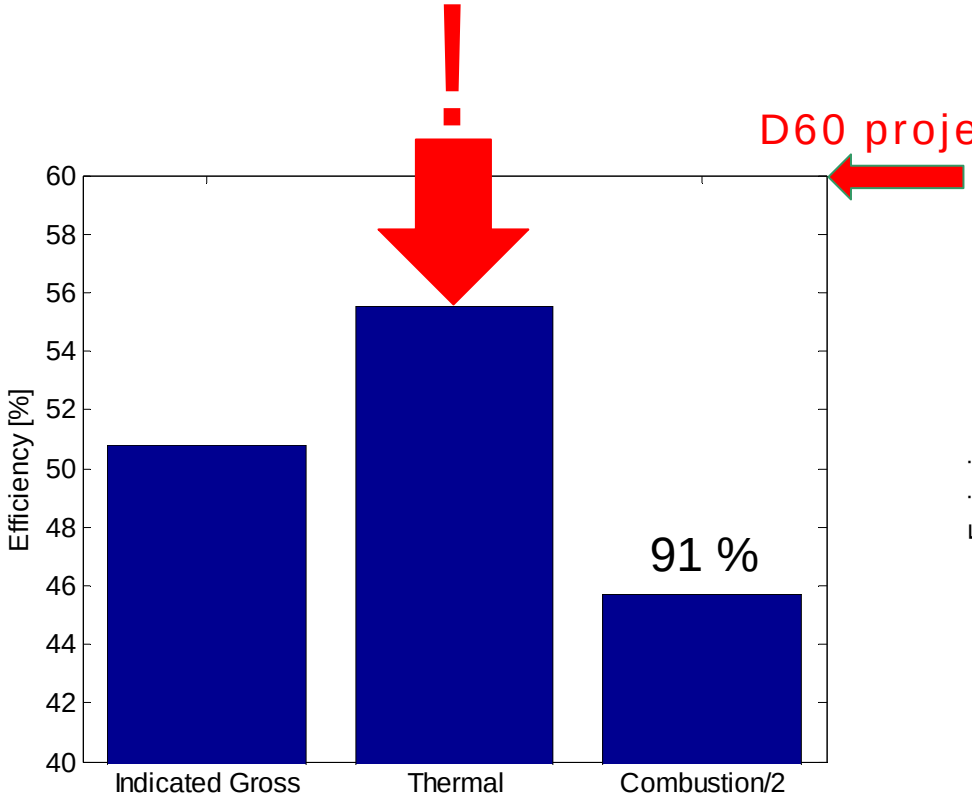


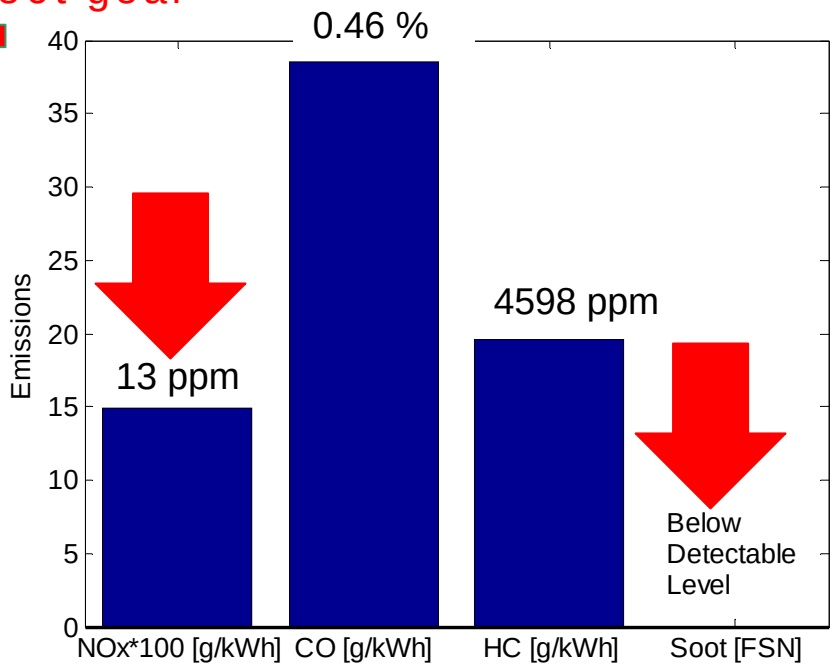
Injection	SOI [TDC]	Fuel MEP [bar]	Percentage [%]
1	-64.00	10.88	41.28
2	-29.20	7.74	29.36
3	0.80	7.74	29.36

N	2000	[rpm]
IMEPg	13.38	[bar]
Pin	2.57	[bar]
Tin	354	[K]
EGR	39	[%]
lambda	1.75	[-]



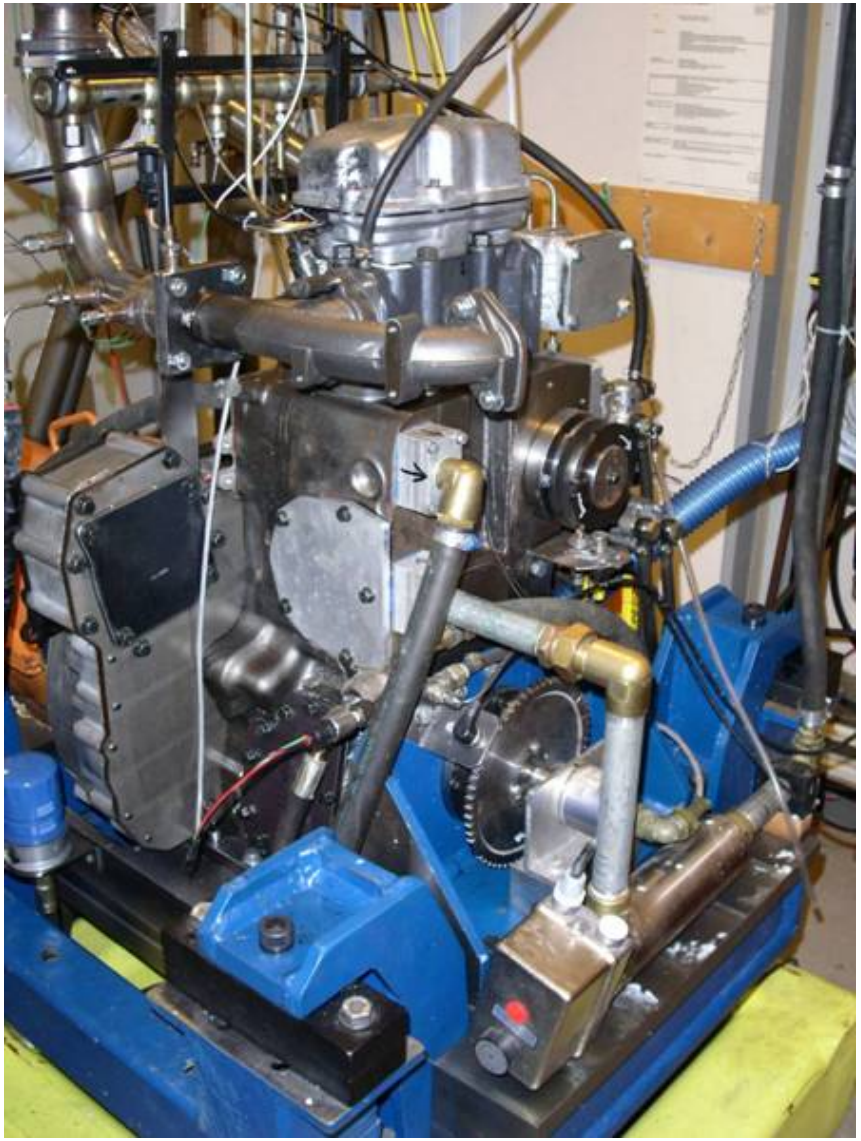
Efficiencies & Emissions





dPmax	7.20	[bar/CAD]
CA5	3.40	[TDC]
ID	-1.00	[CAD]
CA50	11.35	[TDC]
CA90-10	13.00	[CAD]

Experimental setup, Scania D12



Bosch Common Rail		
$Prail_{max}$	1600	[bar]
Orifices	8	[-]
Orifice Diameter	0.18	[mm]
Umbrella Angle	120	[deg]
Engine / Dyno Spec		
BMEPmax	15	[bar]
Vd	1951	[cm3]
Swirl ratio	2.9	[-]

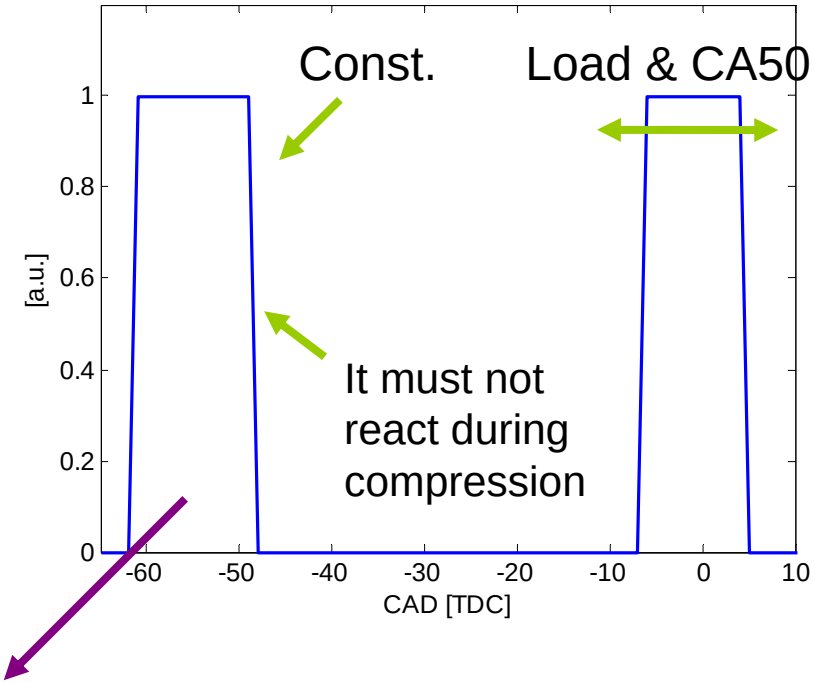
Two test series, high and low compression ratio

Low Compression Ratio PPC

High Compression Ratio PPC

Injection Strategy

It consists of two injections. The first one is placed @ -60 TDC to create a homogeneous mixture while the second around TDC. The stratification created by the second injection triggers the combustion. The first injection must not react during the compression stroke, this is achieved by using EGR.



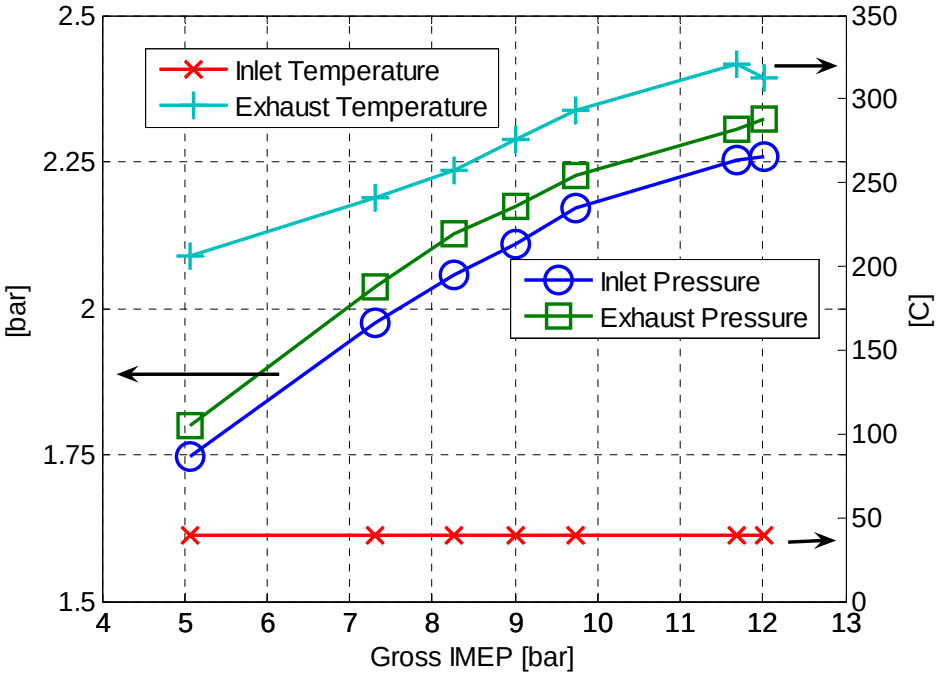
Fuel amount in the pilot is a function of:

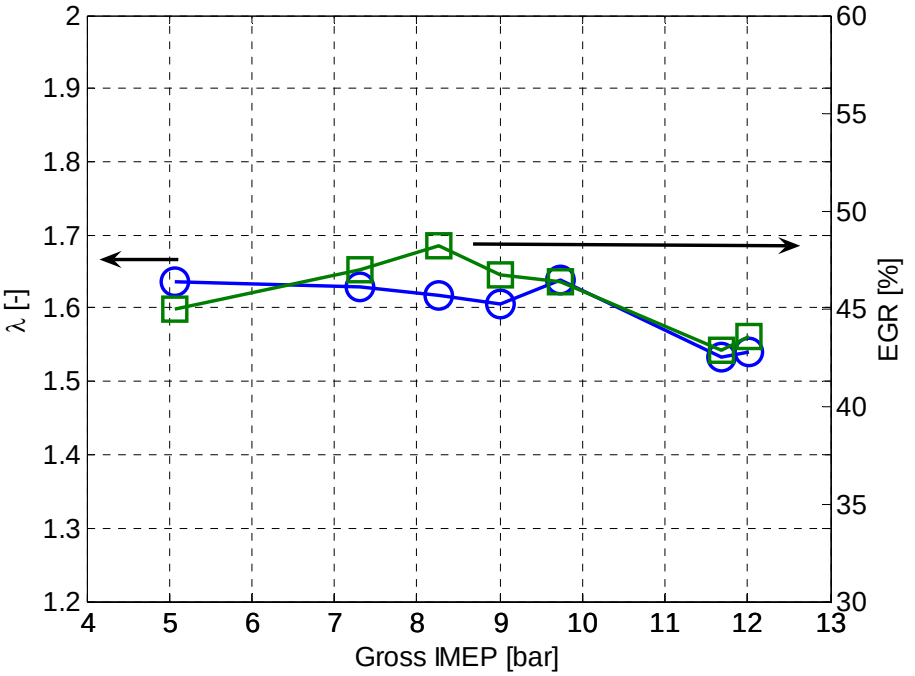
1.Rc

2.RON/MON

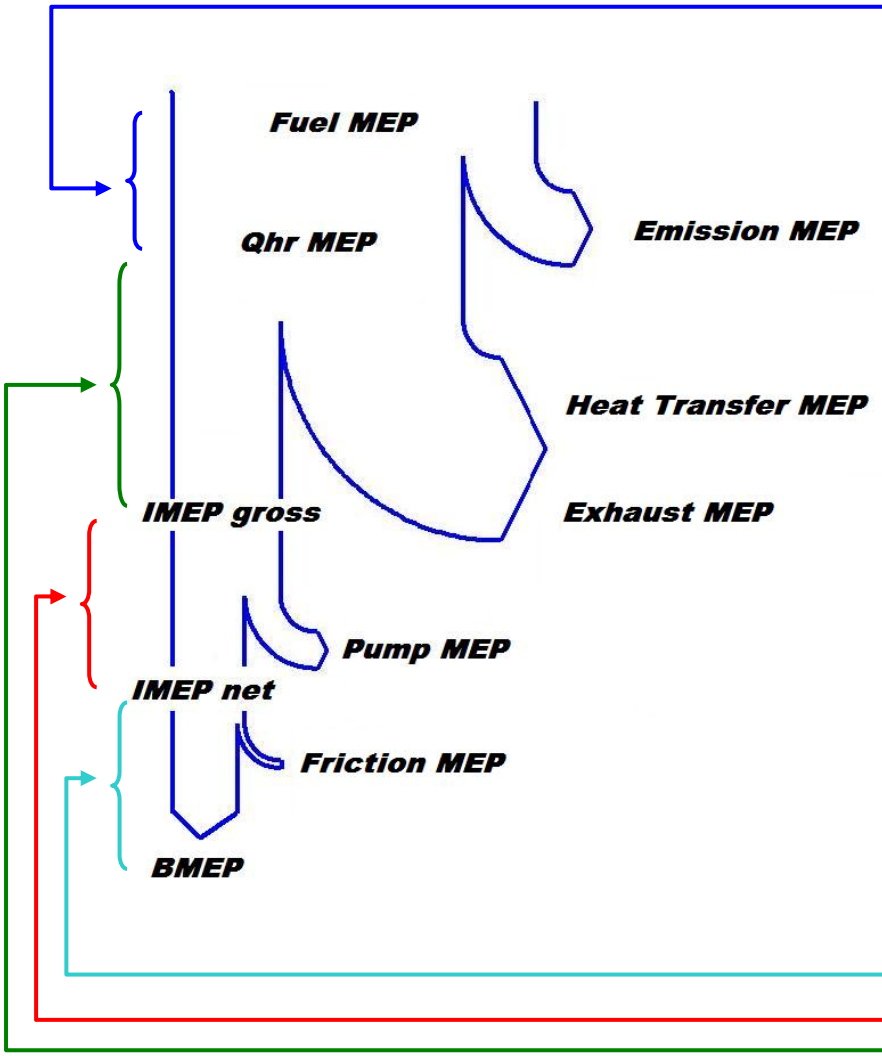
3.EGR

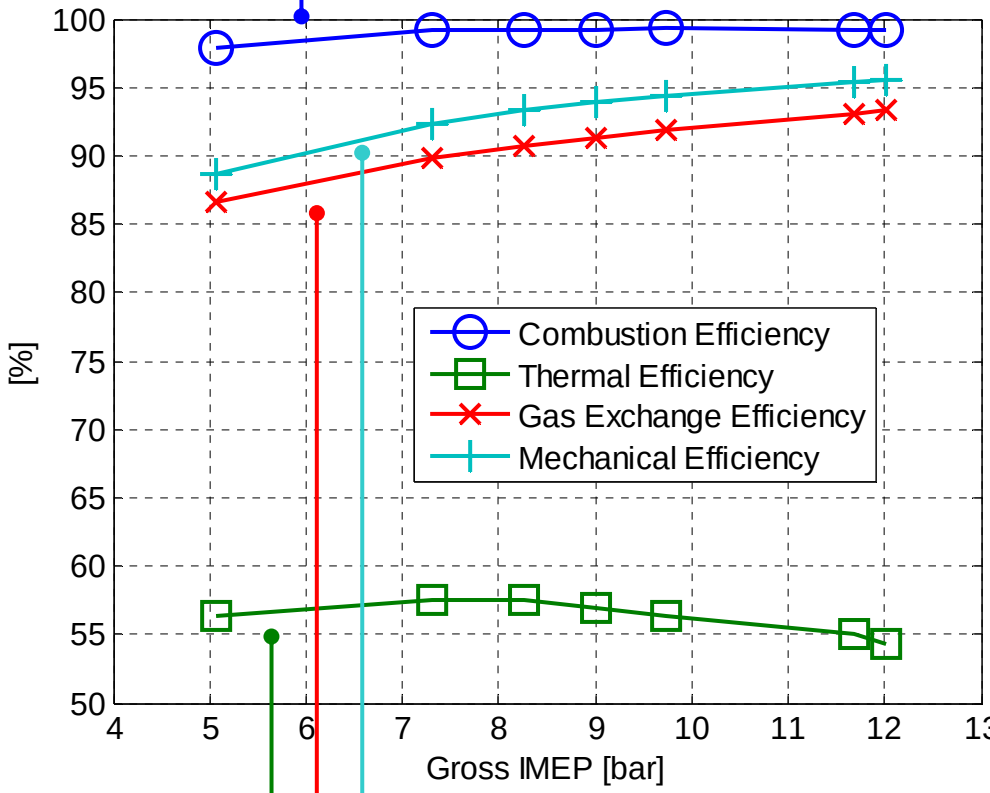
Running Conditions



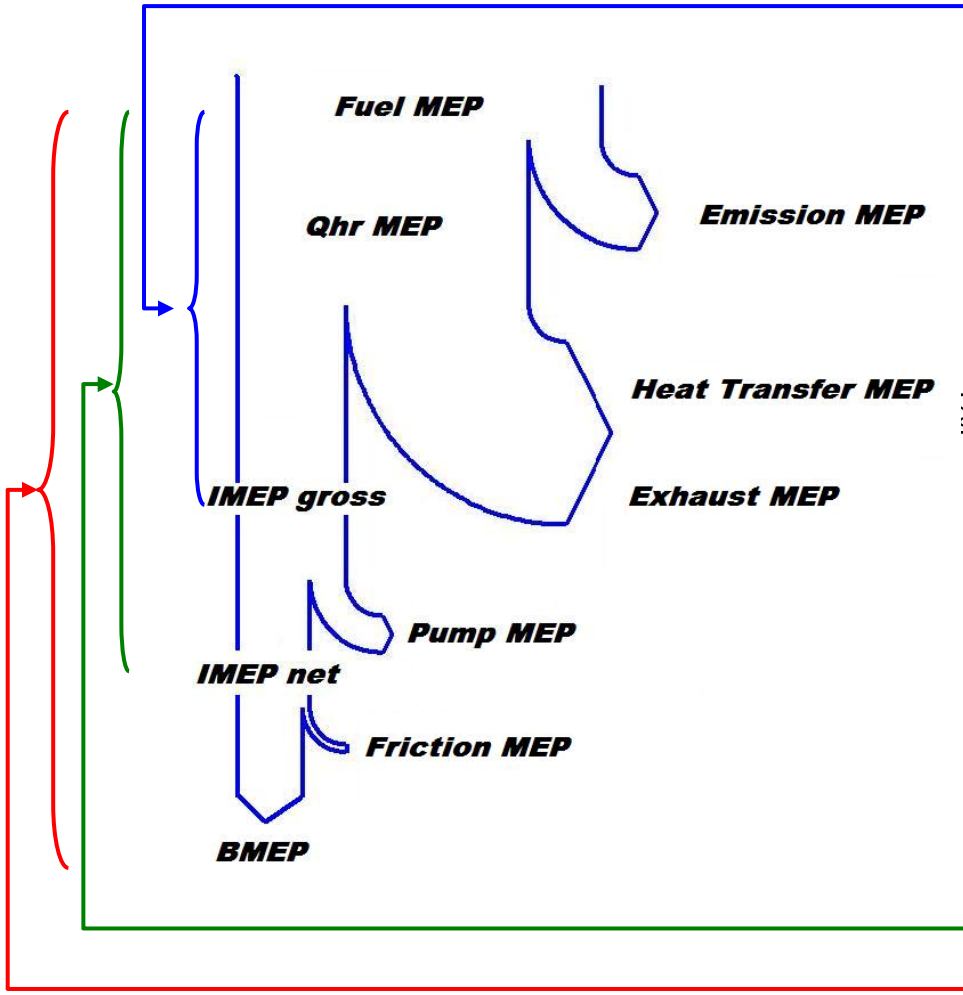


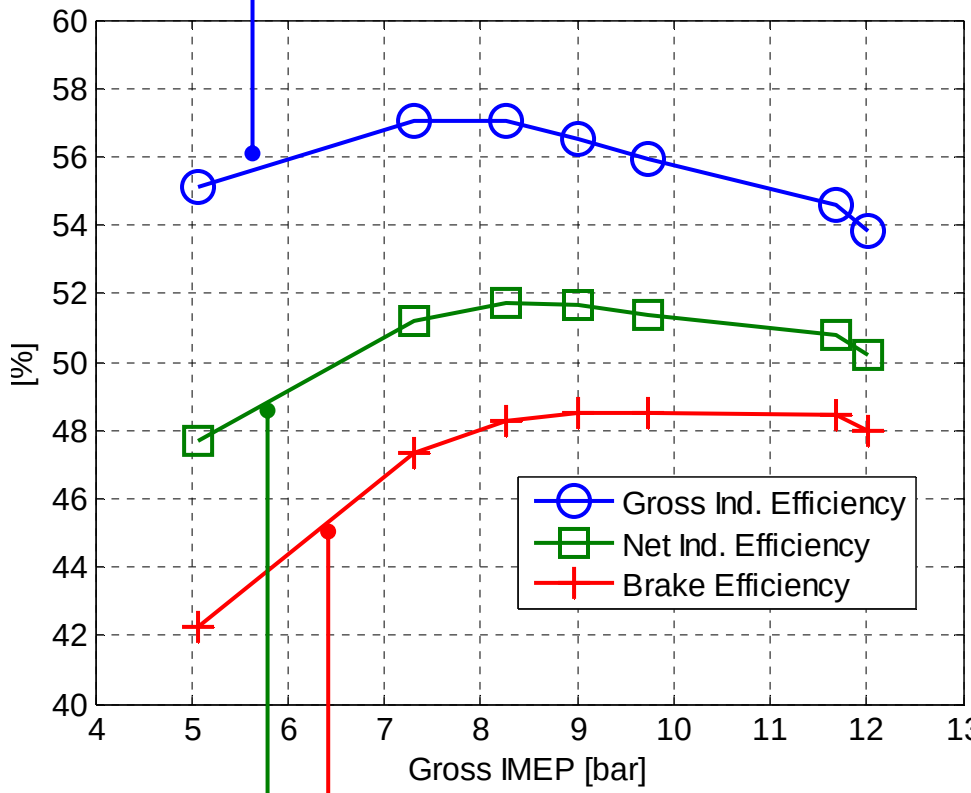
Efficiencies



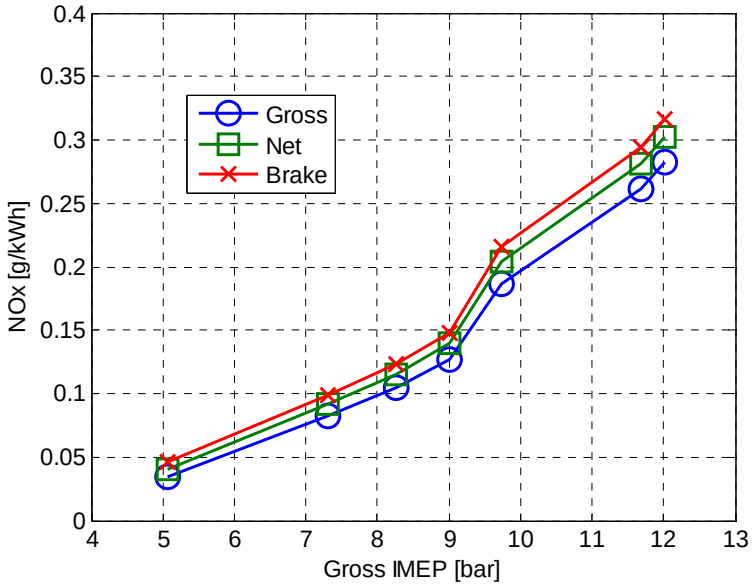


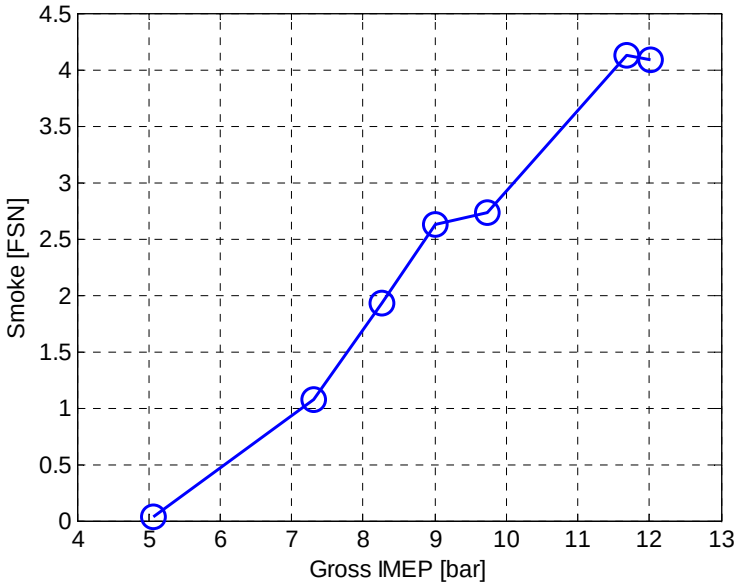
Efficiencies

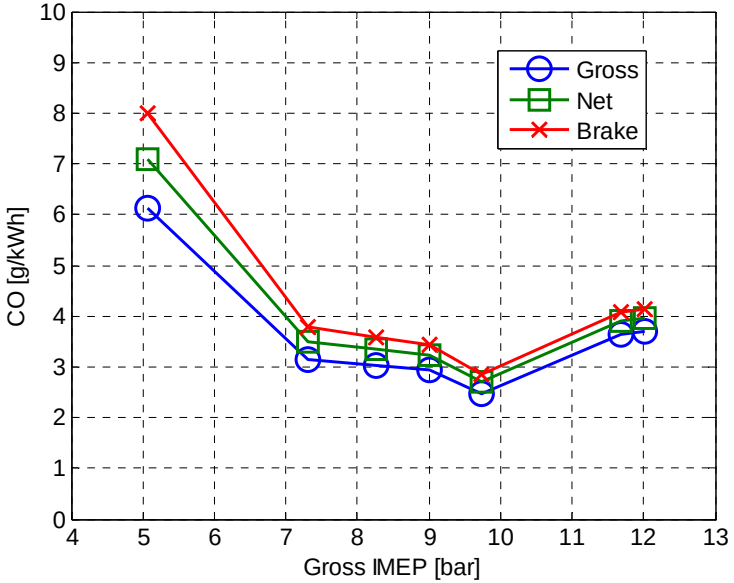


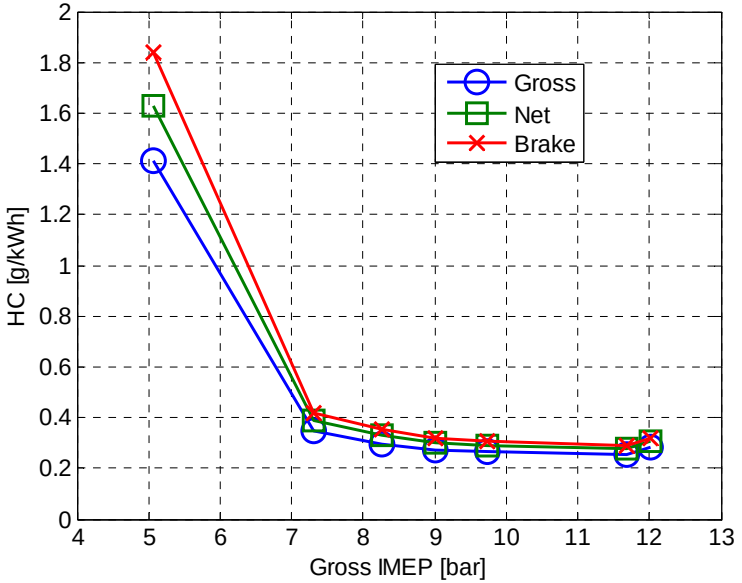


Emissions


Gross
Net
Brake
NOx [g/kWh]
Gross IMEP [bar]


Smoke [FSN]
Gross IMEP [bar]

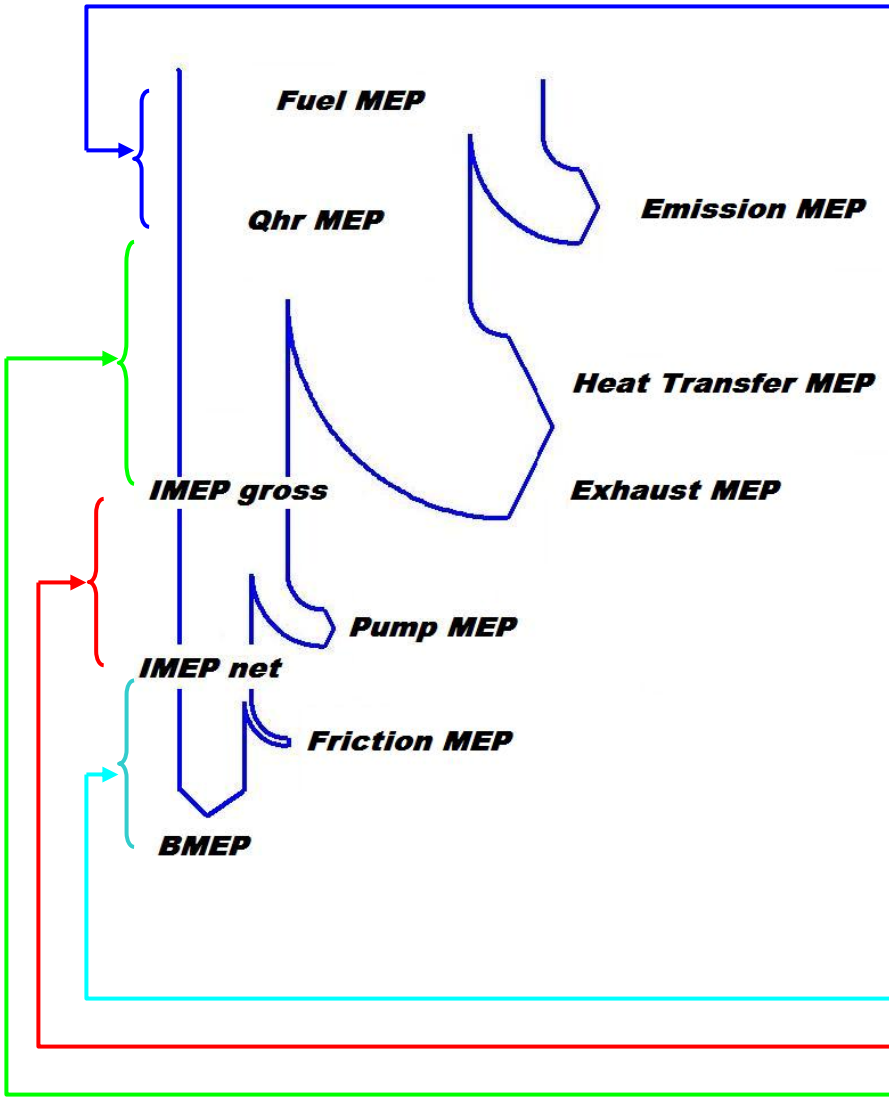

Gross
Net
Brake
CO [g/kWh]
Gross IMEP [bar]

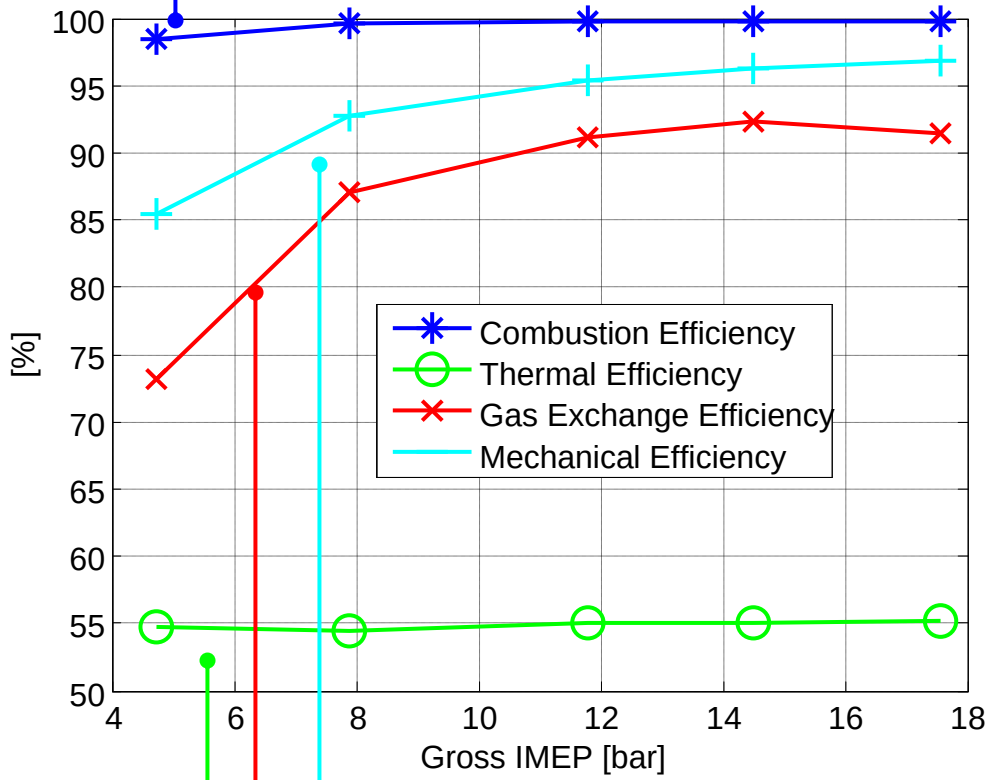

Gross
Net
Brake
HC [g/kWh]
Gross IMEP [bar]

Low Compression Ratio PPC

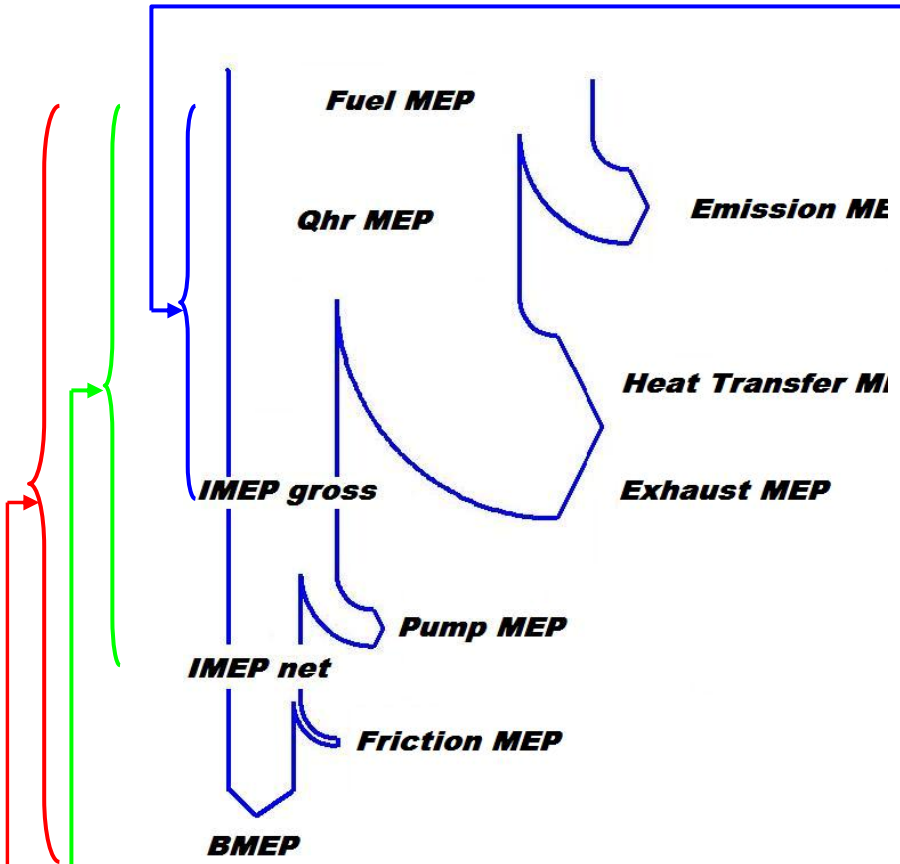
IMEP Sweep @ 1300 [rpm]

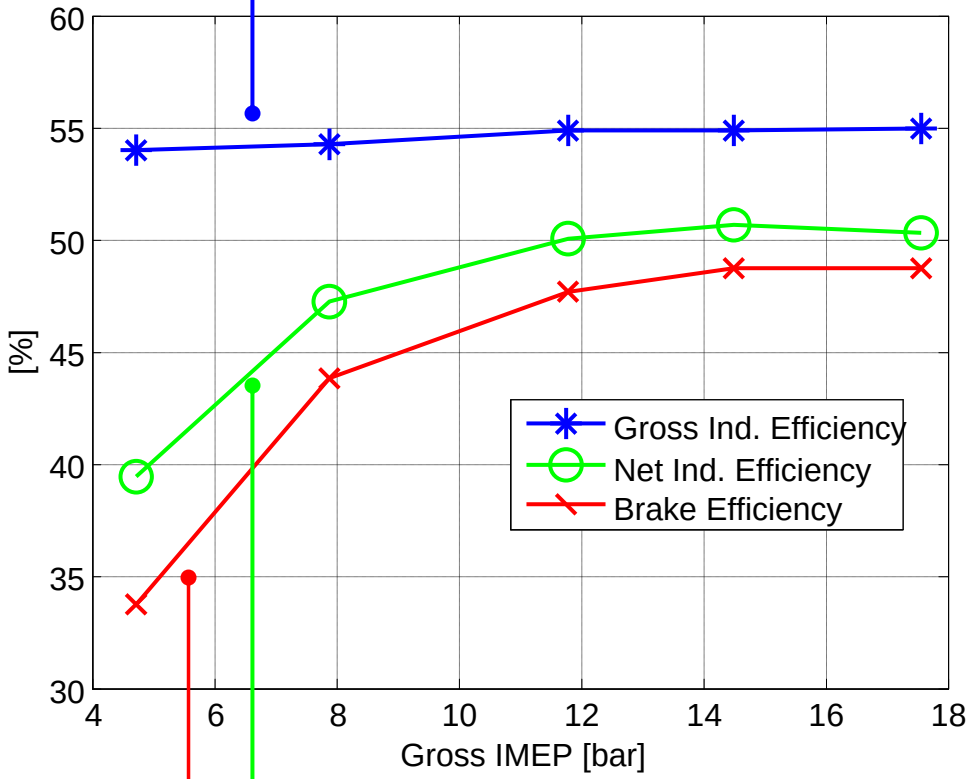
Efficiencies



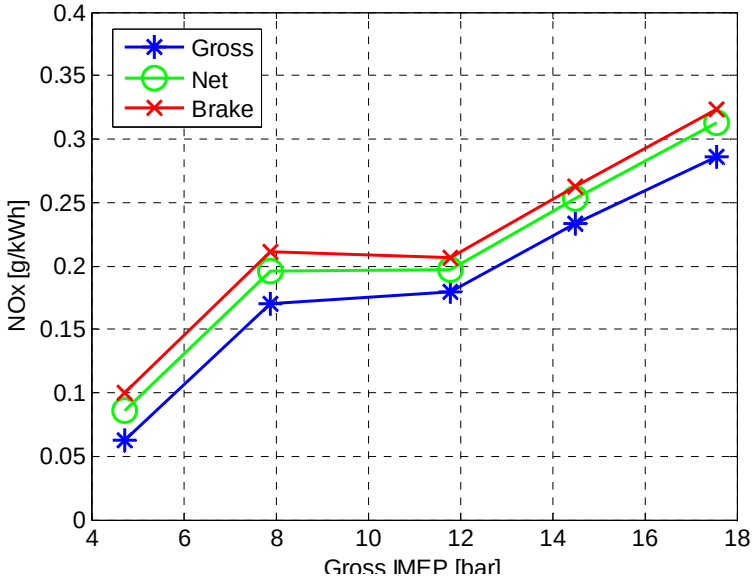


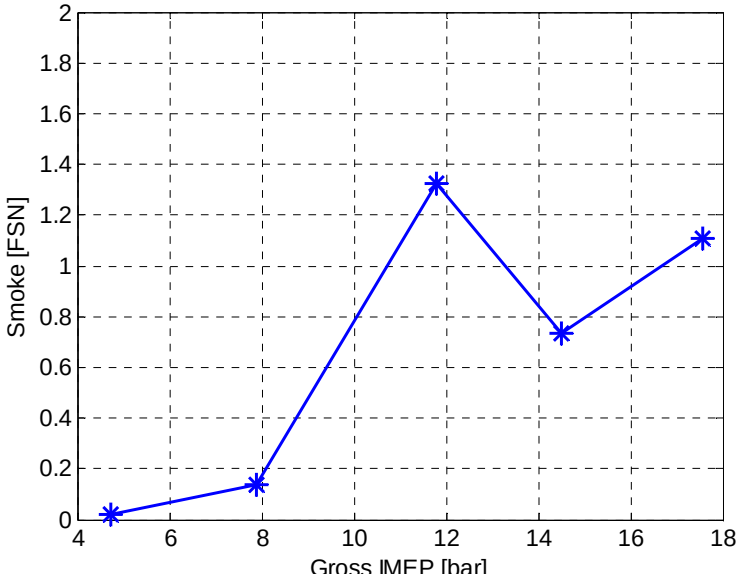
Efficiencies

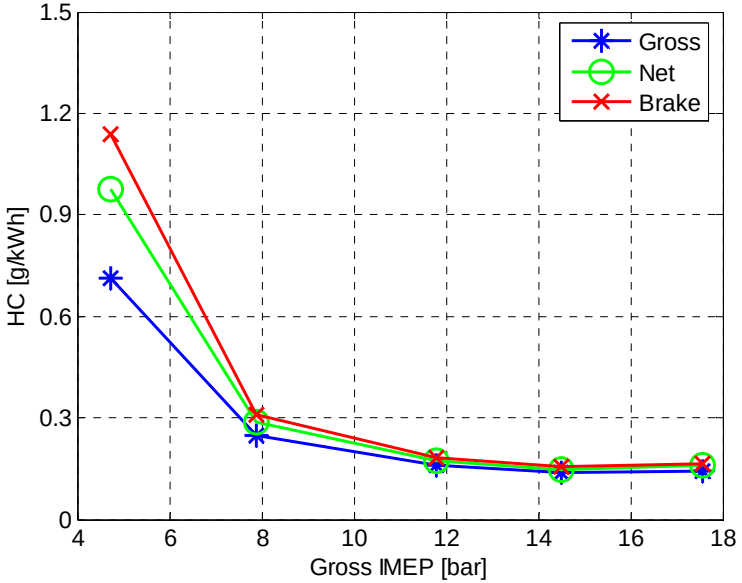


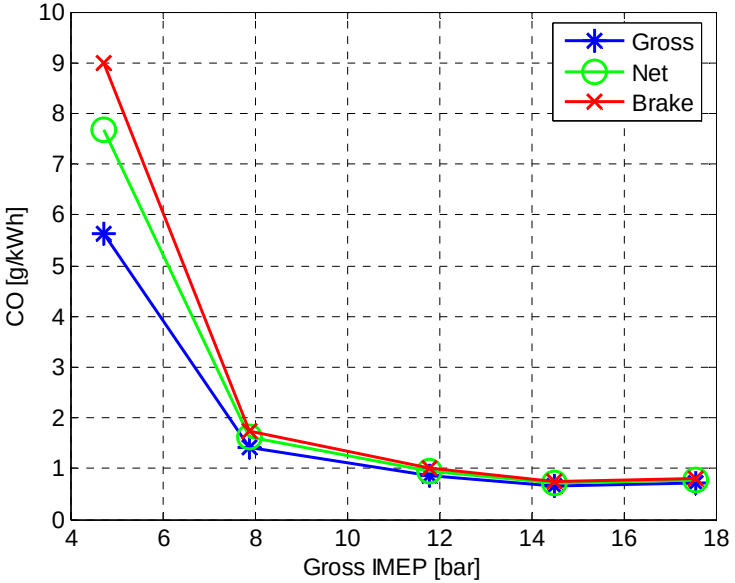


Emissions


Gross
Net
Brake
NOx [g/kWh]
Gross IMEP [bar]


Smoke [FSN]
Gross IMEP [bar]


Gross
Net
Brake
HC [g/kWh]
Gross IMEP [bar]


Gross
Net
Brake
CO [g/kWh]
Gross IMEP [bar]

Summary:
Path to high efficiency gasoline engine

- Lean HCCI in three engines, 0.3-2 l/cyl
  - 50-54% thermal efficiency
- PPC in Volvo Cars diesel engine, 0.5l/cyl
  - 56% thermal efficiency, 51% indicated
- PPC in Scania, 2 l/cyl, 17:1
  - 57% indicated efficiency
- PPC in Scania 2 l/cyl, 14.3:1
  - 55% indicated efficiency with high load