FINDINGS FROM CONCLUDED METHANOL PROJECTS

Methanol Engine Technologies

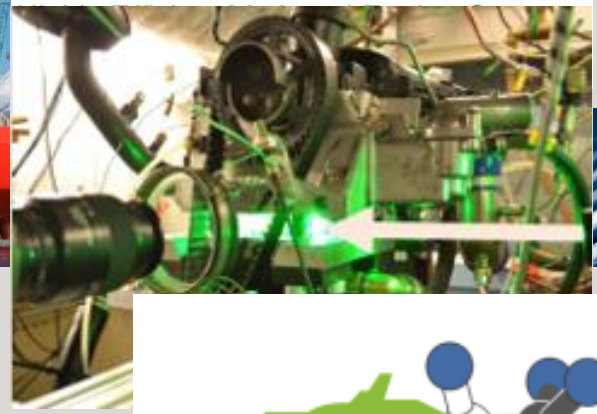
Martin Tunér, Energy Sciences, Lund University

Methanol: a sustainable, scalable, storable energy carrier, November 5th, 2020

Methanol projects

2010

2020



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Annex 56
A Report from the
Advanced Motor Fuels Technology Collaboration

FASTWATER
FAST Track to Clean and Carbon-Neutral WATERborne Transport

MethaShip

Methanol engines @ Ghent University

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Methanol projects

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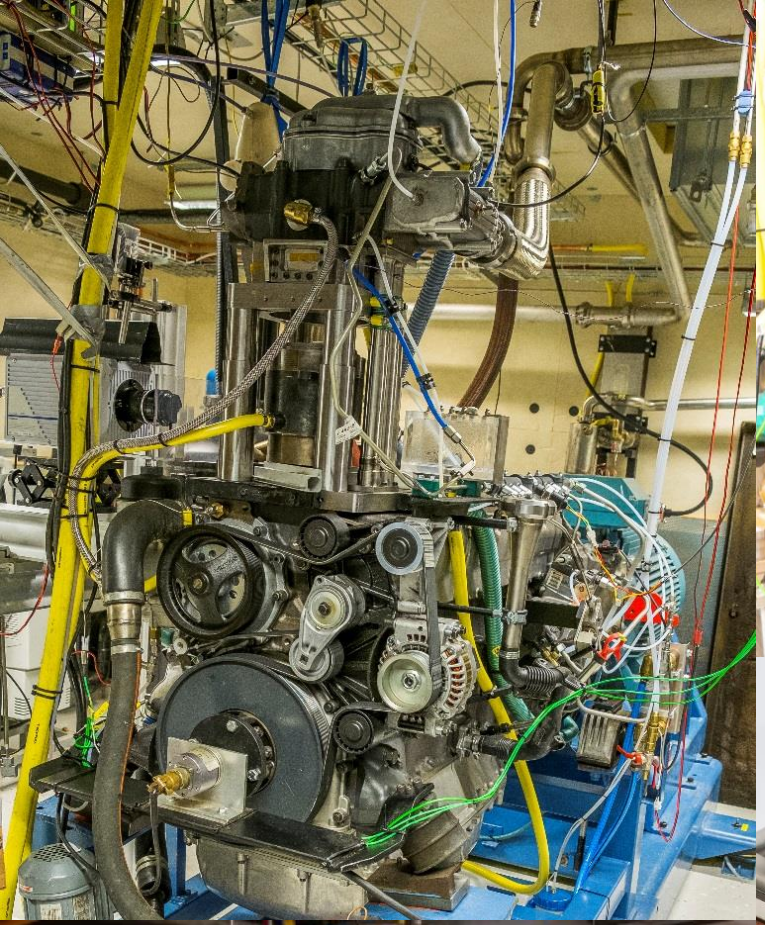



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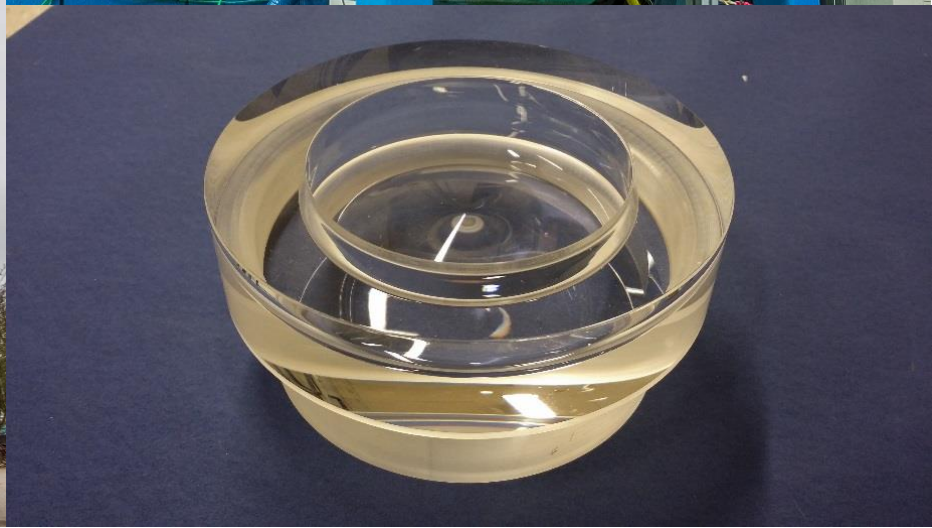
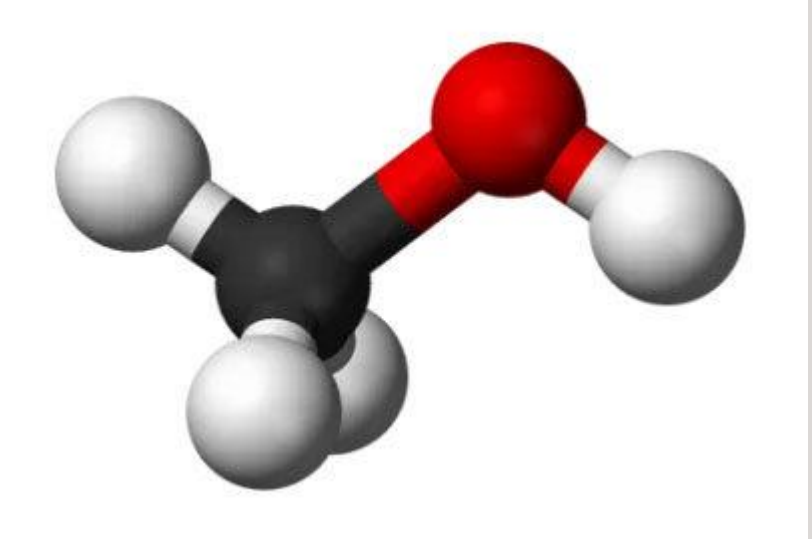


Five important methanol properties

Simple molecule

=> many feedstocks => realistic scalable & sustainable option to replace oil



Liquid

=> convenient storage, distribution, and engine fueling

High heat of vaporization & high ignition resistance

=> higher engine efficiency & power, reduced emissions

No carbon-carbon bonds + attached oxygen atom

=> no soot

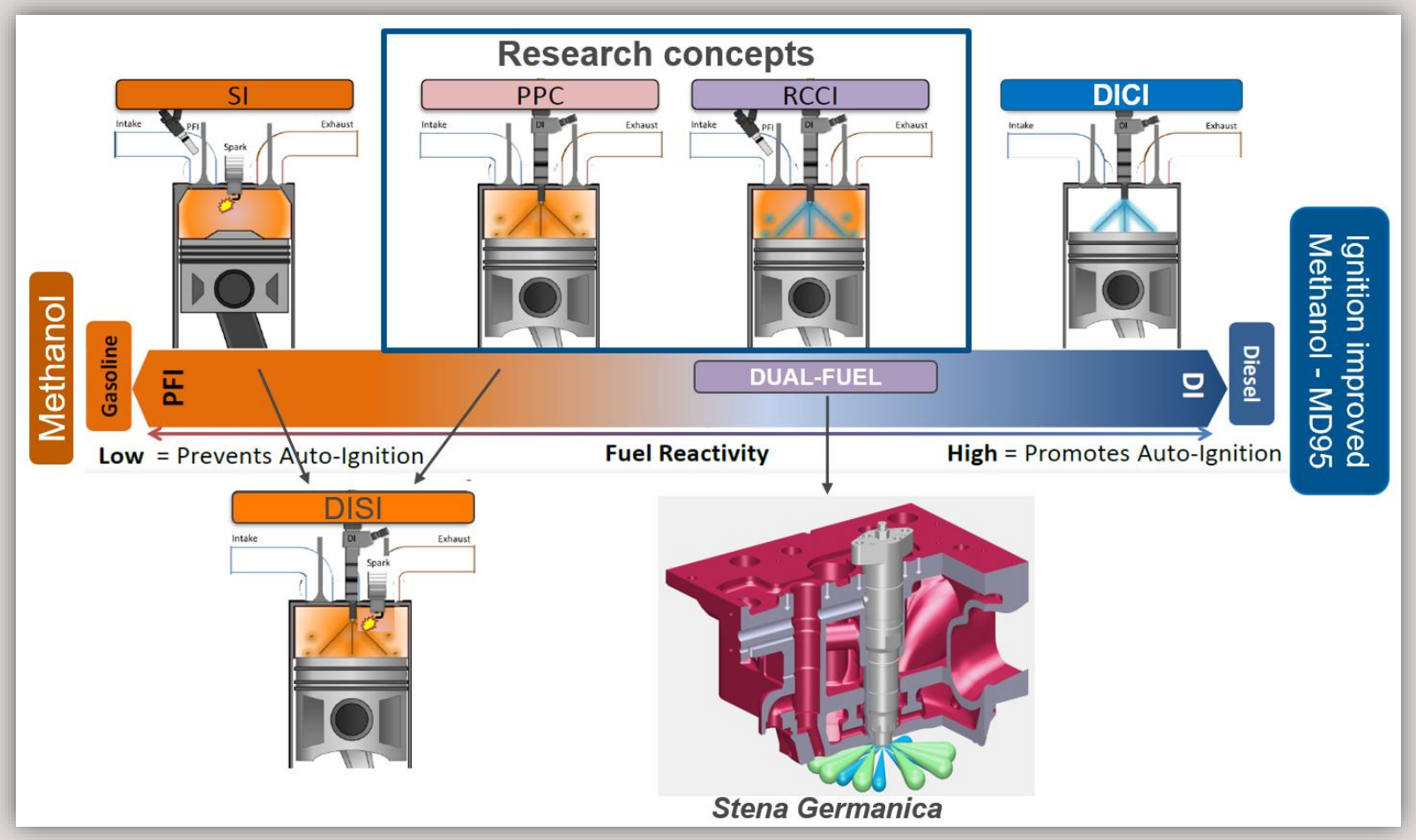
Stena Germanica – a milestone!

- Clever retrofit solution – dual direct injection (methanol and diesel)
- Commercial operation on methanol fuel since 2015
- Sulphur oxide reduction >90%
- NOx reduction >60%
- Soot reduction >50%
- Path for fully sustainable operation
- Strongly reduced risk for water life
- Cleaner and cooler engine rooms

Haraldson L., "Methanol as fuel", Methanol as Fuel & Energy Storage Workshop. Lund, Sweden, 2015, http://www.lth.se/fileadmin/mot2030/filer/12._Haraldsson_-_Methanol_as_fuel.pdf

Methanol engines – combustion strategies

Several options:



SI – Spark Ignition
CI – Compression Ignition
DI – Direct Injection
PFI – Port Fuel Injection

PPC – Partially Premixed Combustion
RCCI – Reactivity Controlled Compression Ignition

SUMMETH
Sustainable Marine Methanol

Project description
Work Packages
WP1
WP2
WP3
WP4
WP5
WP6
Partner Area
Final seminar
Contact
Reports

Financed by:
Swedish Maritime Administration
Methanol Institute
Region Västra Götaland
Oiltanking

Project partners
Lund University
Färjerederiet Trafikverket
Marine Benchmark
ScandiNAOS AB
Scania
Swedish Marinetechnology Forum
SSPA
VTT

http://summeth.marinemethanol.com/

https://www.sspa.se/how/research/greenpilot

Case study: Conversion of a Swedish Road Ferry to methanol operation

- M/S Jupiter road ferry – 86 metre length, capacity for 397 passengers and 60 cars
- Currently running on diesel fuel, bunkered by truck
- Developed a methanol conversion design with recommendations for fuel storage and supply, safety systems, and bunkering
- Emissions reduction potential compared to operation on diesel fuel

Conversion design developed by project partner ScandiNAOS

GreenPilot

- Conversion of a Swedish pilot boat to run on methanol
- Two engines tested on board with methanol – using spark-ignited port fuel technology
- Fossil-free methanol produced from pulp mill black liquor was used in the tests
- On board emissions measurements verified very low particulate emissions and low NOx

Co-financed by
Swedish Maritime Administration
Trafikverket Swedish Transport Administration
Methanol Institute

Lund University

SUMMETH WP3: DICI on MD95

VTT MD95 study with Scania ED95 alcohol engine (market). CR 28:1

MD95 blends were clean burning. Low aldehyde emissions. Particles are “liquid”-type originating from additives and assumedly removable by oxidation catalyst.

Similar performance for MD95 and ED95 fuels.

MD95 fuels:

- Methanol, dry (80-85 wt%)
- Water (5.5 wt%)
- Ignition improvers
- Lubricity improver
- Stability additive

Scania commercial ED95 (ethanol) truck

 Päivi Aakko-Saksa et al. Energy&Fuels. 2020, 34, 379-388

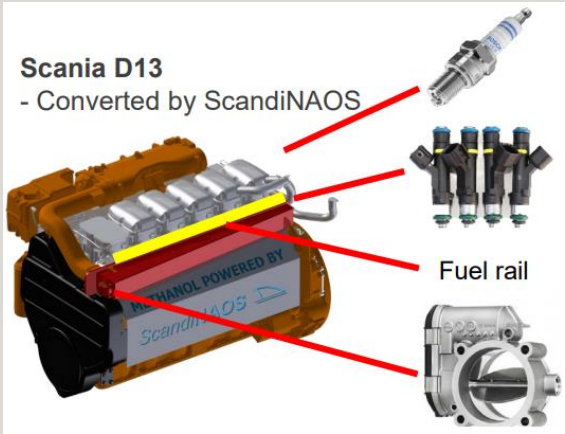
SUMMETH WP3: PFI-SI and DISI on 100% methanol

ScandiNAOS study on PFI-SI (Scania D13)

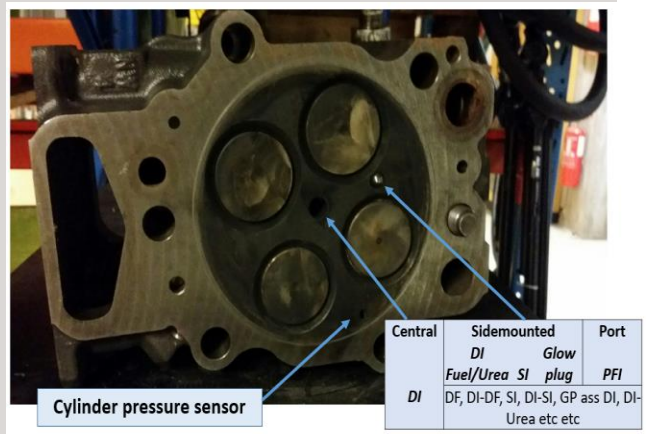
- Simple and well known technology
- Complies with present and upcoming EU and IMO regulations without aftertreatment
- Extremely low PM

Lund study on DISI (Scania D13)

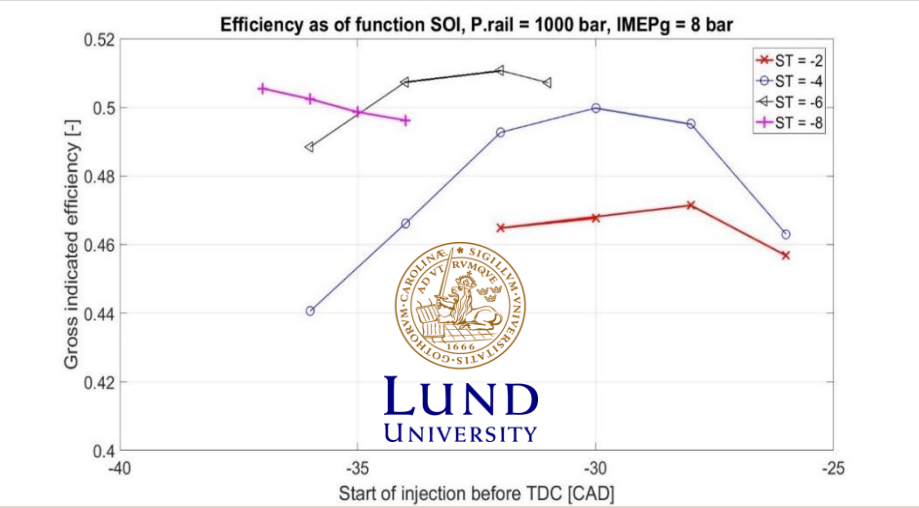
- High pressure direct injection – proof of concept
- Higher efficiency and lower emissions compared to PFI-SI
- Stratified = very high efficiency
- Stoichiometric operation possible = TWC = ultra-clean



ScandiNAOS PFI-SI conversion



LU bespoke DI-SI cylinder head



Efficiency versus start of injection and spark timing (ST) for DI-SI

Martin Tunér, Päivi Aakko-Saksa and Patrik Molander, Engine Technology, Research, and Development for Methanol in Internal Combustion Engines, http://summeth.marinemethanol.com/reports/SUMMETH-WP3_fnl.pdf

Björnestrand, L. "Efficiency and emissions analysis of a methanol fuelled direct injection spark ignition heavy duty engine". Master Thesis, Lund 2017.

SUNFUELS (KAUST)

Chalmers Univ.: RCCI (Methanol/diesel)

The importance of injector performance & placement

Aalto Univ.: DIDF (Methanol/diesel)

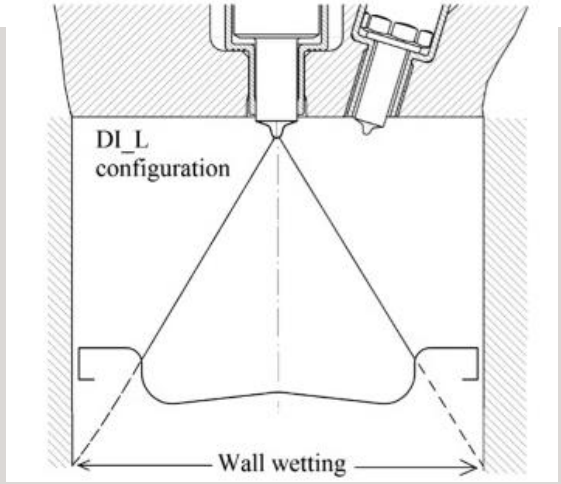
HP-DI methanol, non-premixed dual-fuel (DF) – inhouse design

Early fuel injection has advantages for high engine load, combustion stability and emissions

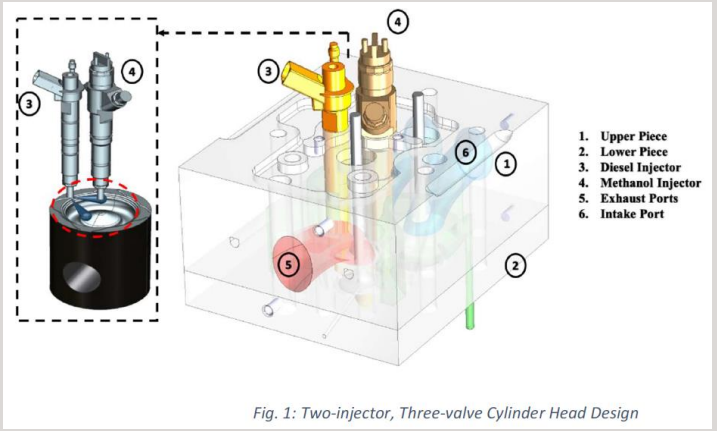
Lund Univ.: DISI (100% Methanol)

Strategies for low load operation (1 bar possible with split injection)

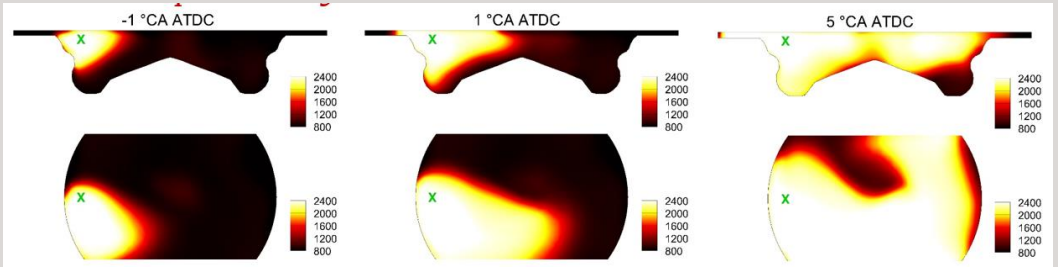
Advanced models for methanol DISI: Interaction between fuel spray, spark and flame propagation



Volvo TD13 RCCI concept



Aalto bespoke HP-DI cylinder head



Ignition site and flame propagation Scania D13 DISI

Zhiqin Jia, IngemarDenbratt, Chalmers University of Technology
Yabin Dong, Ossi Kaario, Martti Larmi, Aalto University
Burak Zincir, Yaopeng Li, Mateusz Pucilowski, Xue-Song Bai, Martin Tunér, Lund University
Bengt Johansson, KAUST

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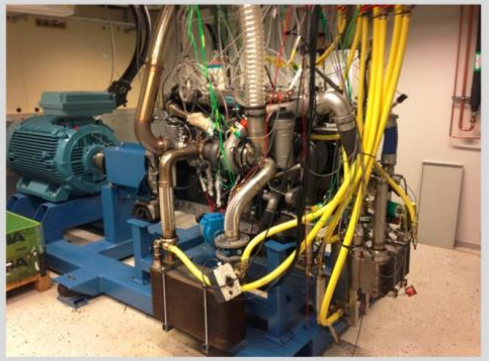
Highly Efficient Methanol Engine Systems for Fossil Free Transportation 2030

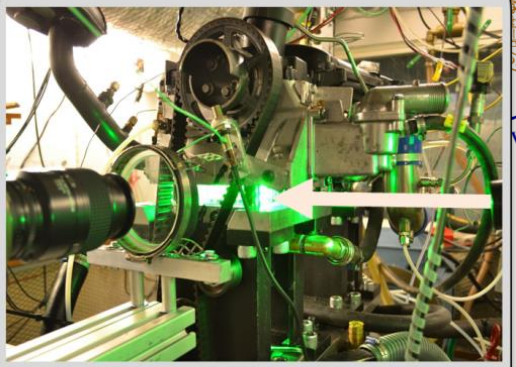
100% methanol in advanced combustion engines (2015-2018)

Engine experiments



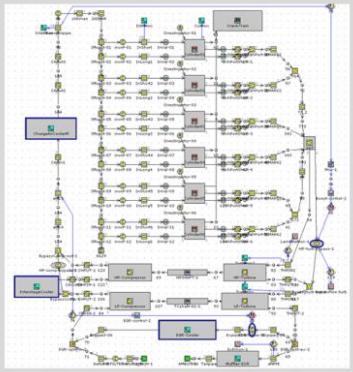
Investigate/explain emissions and efficiency performance of methanol in PPC engines

Optical diagnostics



Investigate/explain various phenomenon of methanol combustion inside the PPC engine

System analysis



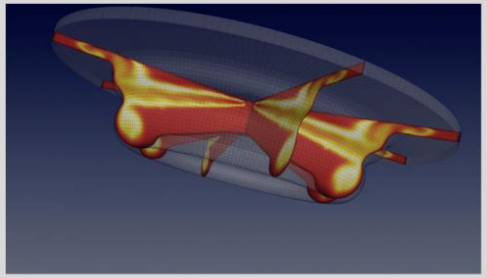
Investigate/explain overall Well-To-Wheel PPC engine performance with methanol

Swedish Energy Agency

Supporting companies

In-house tests and other experience of methanol fuel in engines

Advanced modeling

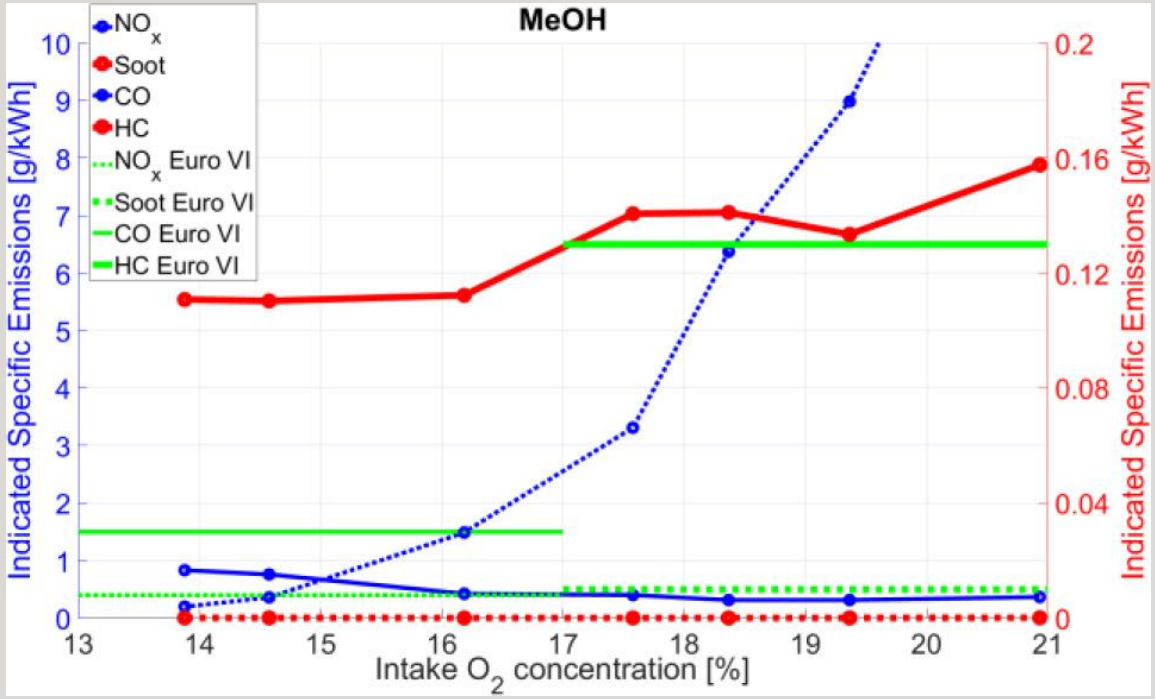


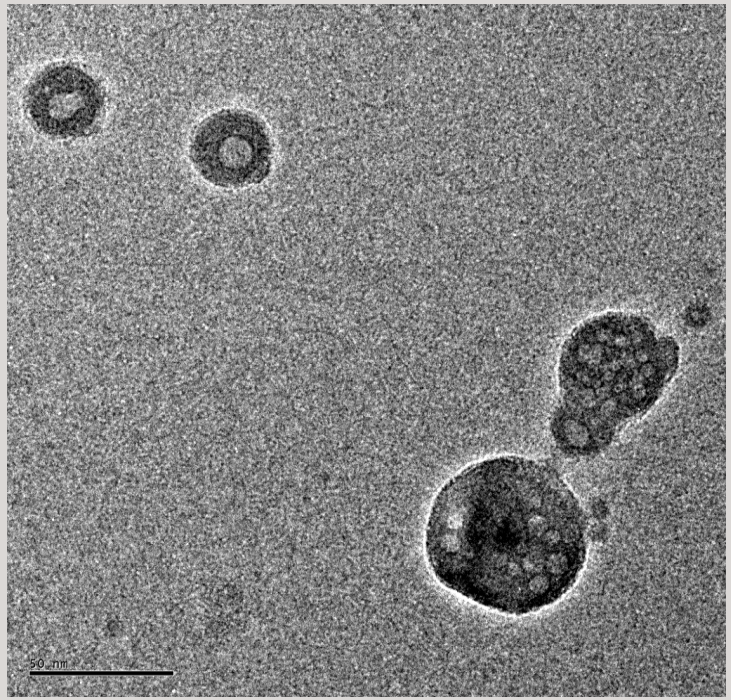
Investigate/explain relations between chemistry, heat release, heat transfer and engine physical parameters for methanol PPC

MOT-2030: Engine experiments

Methanol-PPC can meet EURO VI emissions regulations without aftertreatment!!!

PM exist (<20 nm). Liquid core & lubricant origin (oxides of Zn, Ca, P, S). There is no black carbon.





Sam Shamun, PhD Thesis.
Characterization of the Combustion of Light Alcohols in CI Engines : Performance, Combustion Characteristics and Emissions
http://lup.lub.lu.se/record/6dcc5cd6-a3c8-434c-acff-68ded6441c2b

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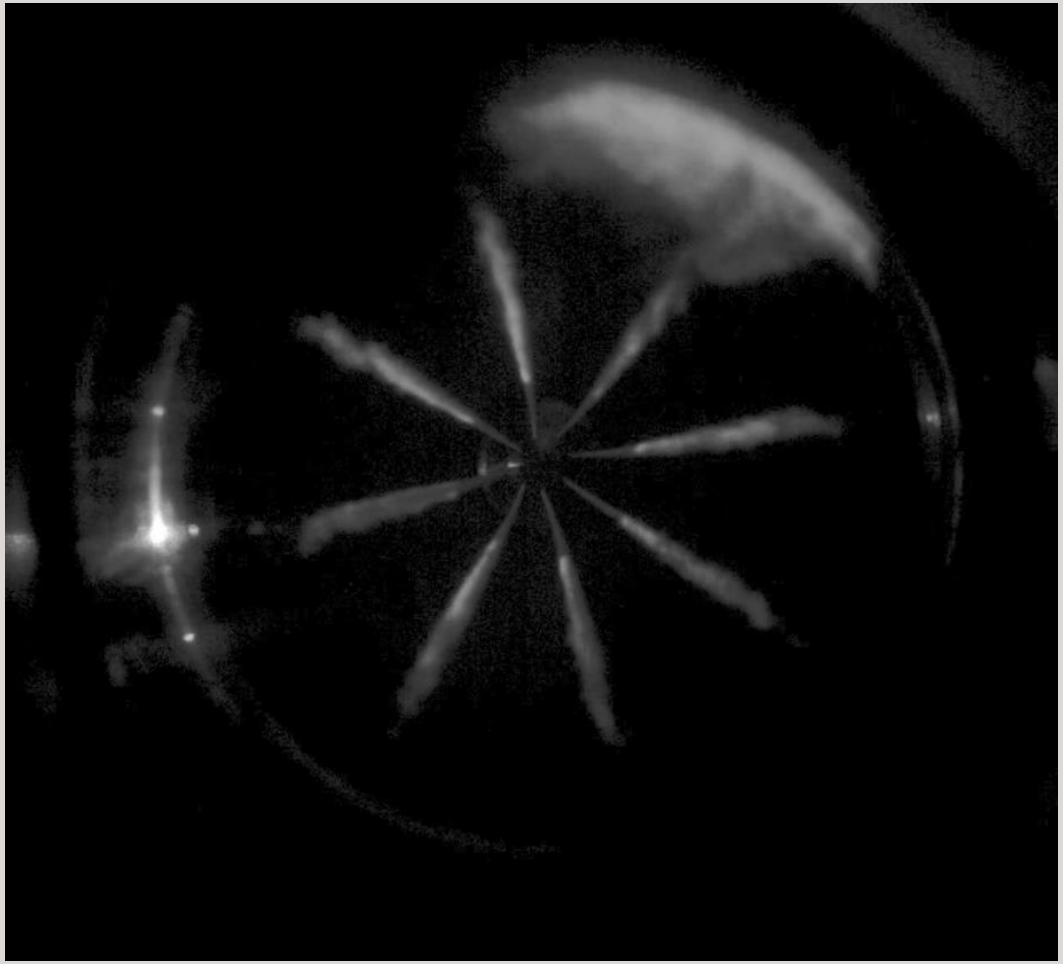
MOT-2030: Optical diagnostics

Explaining methanol-PPC combustion

- Spray details
- Surface ignition sensitivity
- Lean autoignition
- …and much more

Data for modell development!



Methanol PPC- Flat piston - triple injection case filmed from below

Alexios Matamis et al Optical characterization of methanol compression-ignition combustion in a heavy-duty engine, Proceedings of the Combustion Institute, http://dx.doi.org/10.1016/j.proci.2020.06.024

Sara Lönn, PhD Thesis.
Investigation of PPC in an Optical Engine : With focus on Fuel Distribution and Combustion Characterization.
http://lup.lub.lu.se/record/0d96ad72-32ee-415e-8243-10c4b82a714a

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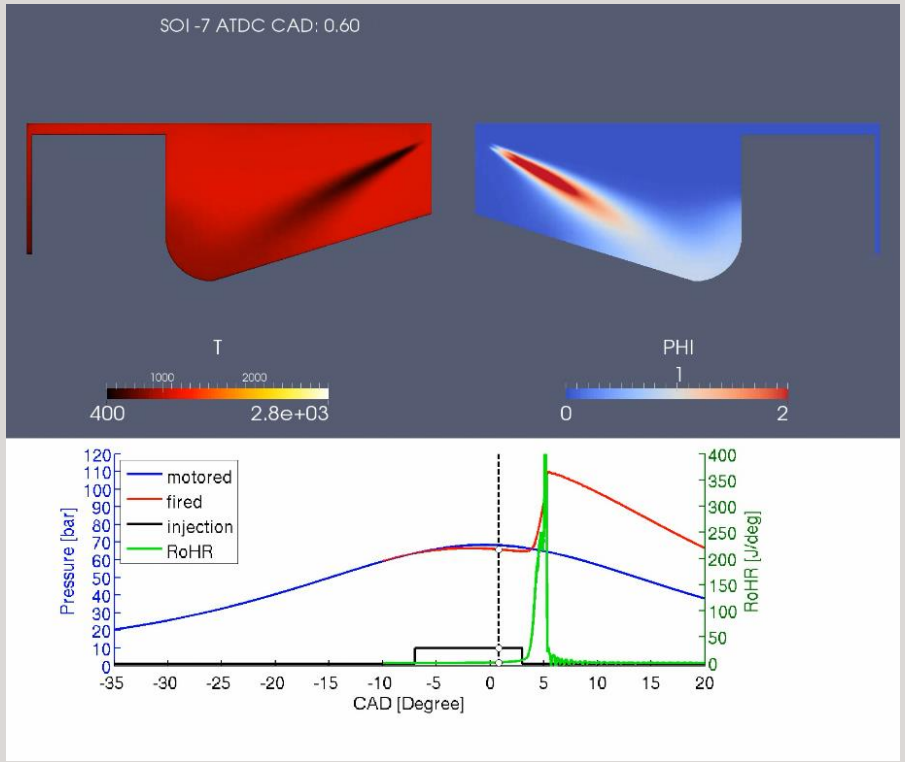
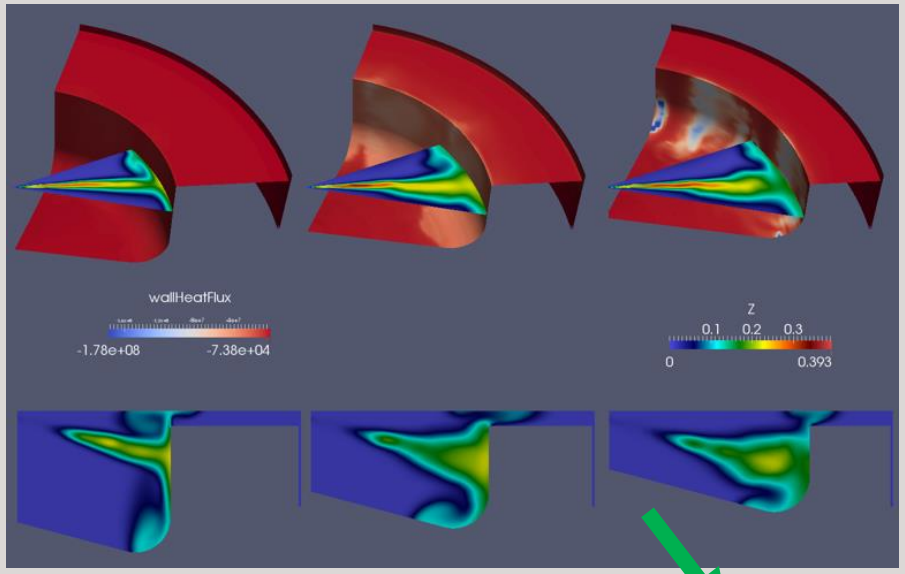
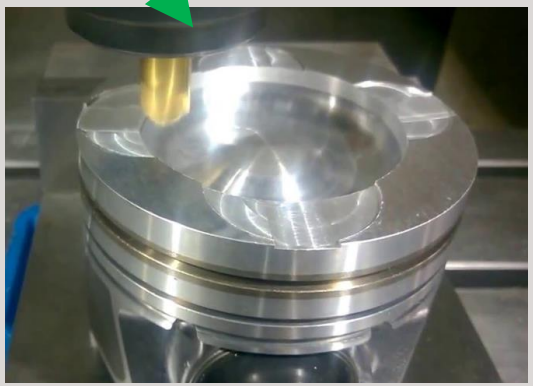
MOT-2030: Advanced modelling

Improved numerical models – further insights into methanol combustion

Virtual engine development (for even higher efficient) - guide the development of prototypes and new experiments







Methanol PPC- piston with bowl – side projection

Mateusz Pucilowski, PhD Thesis.
Numerical Studies of Methanol PPC Engines and Diesel Sprays
http://lup.lub.lu.se/record/30226188-5063-470f-aada-983c61a06186

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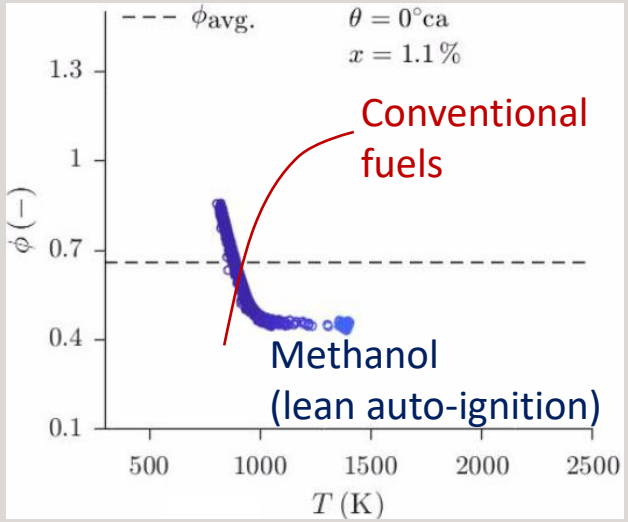
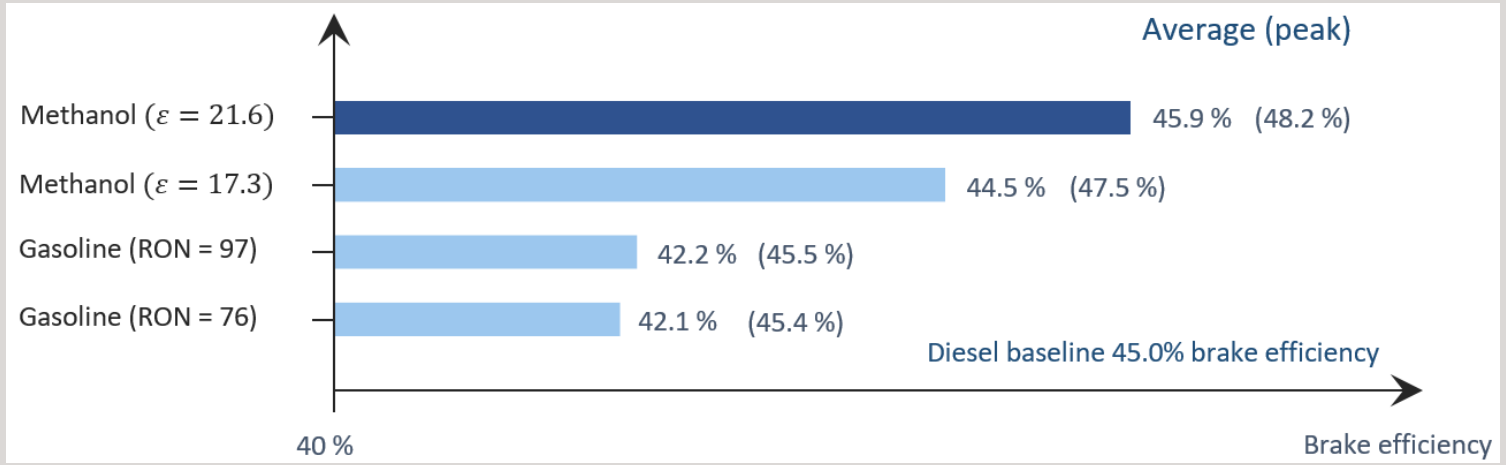
MOT-2030: System studies

Applying everything we learned – combining experiments and numerical studies

Unusual: lean auto-ignition for methanol in direct injected compression ignition (due to high Hvap and high RON)

Likely a dedicated methanol engine will have substantially higher efficiency than diesel engines





Modell of boosted Scania D13 diesel engine. Methanol versus gasolines and diesel fuel on average and peak efficiencies in the ESC13 cycle.

Erik Svensson, PhD Thesis.
System Simulation of Partially Premixed Combustion in Heavy-Duty Engines : Gas Exchange, Fuels and In-cylinder Analysis
http://lup.lub.lu.se/record/1e44b743-55b7-4ab7-ae96-270fe5dd080d

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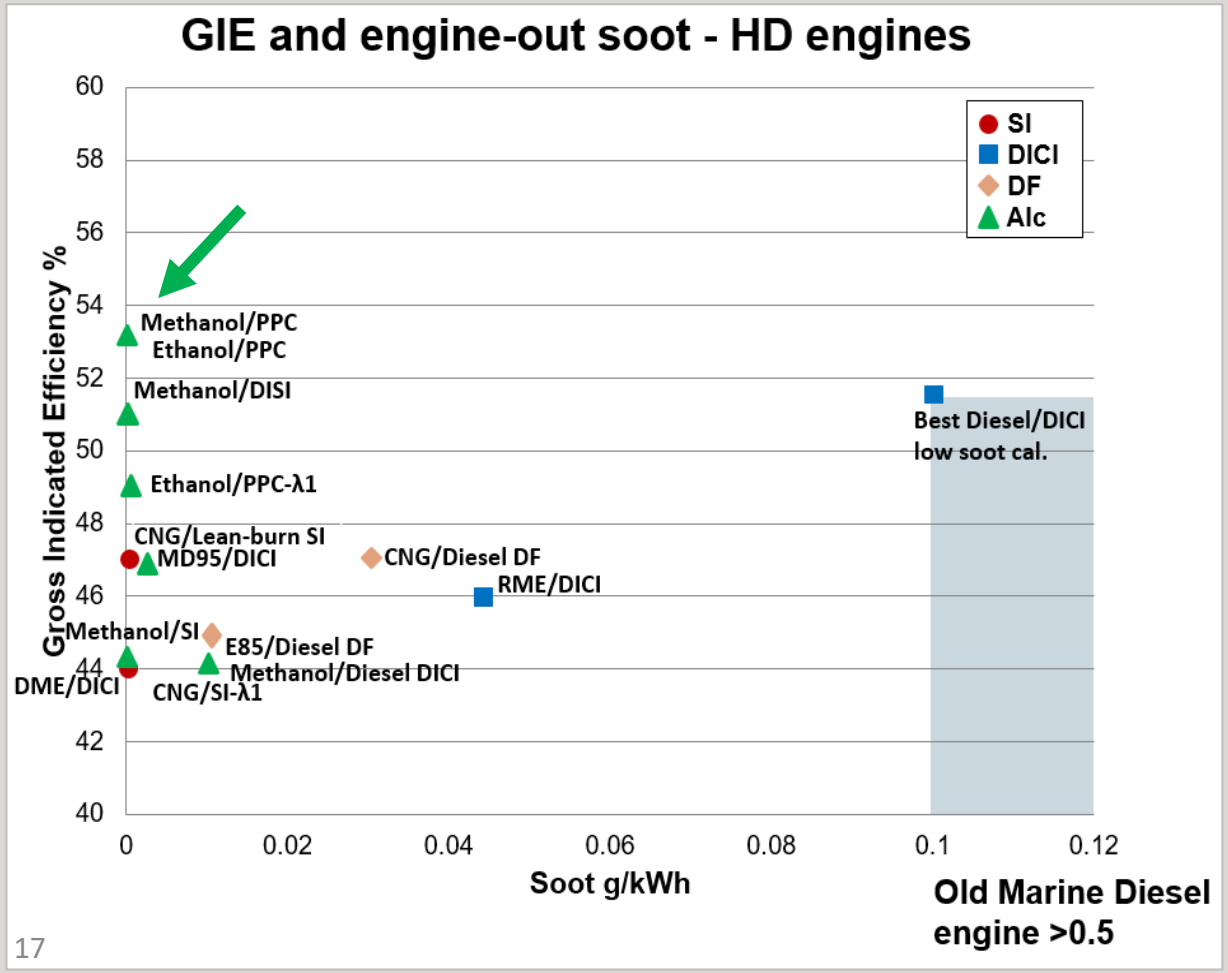
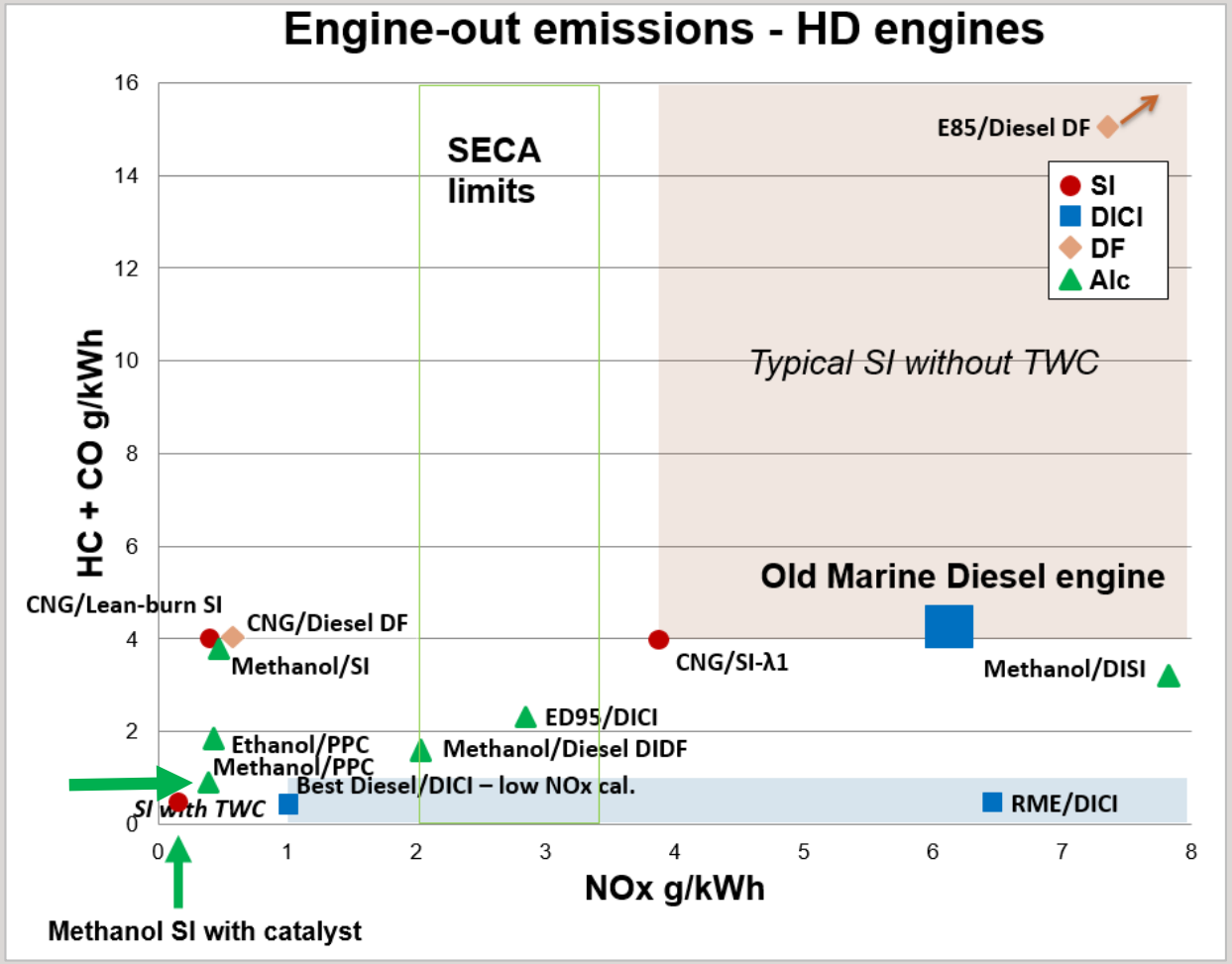
So far the cleanest & most efficient fuel we researched at the Lund laboratory

Methanols unique properties indicate a continued future advantage over diesel and gasoline engines





Summary, needs and opportunities

Methanol engines already in use and demonstrate high efficiency and low emissions

Potential for exceptional efficiencies – we hardly scratched the surface!

Needs:

- Robust fueling systems and dedicated injectors
- Further R&D (se below)

Opportunities:

- Dedicated methanol engines
- Flex fuel engines (GEM)
- Retrofit kits

Work machinery sector should run clean and efficienctly on it´s own fuels! Retrofit kits needed.

Thank you!

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