# WP1: Systems for increased fuel flexibility

## Objectives

To develop **engines able to switch between fuels**, whilst operating in the most cost effective way and complying with the regulations in all sailing regions.

- **Development** of a **fuel injection system** for multi fuel purposes
- **Demonstration** of **fuel flexible** engine **operation**
- **Feasibility study** on rapid compression/expansion machine (**RCEM**)

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|---|
| 1.1 Fuel flexible engine<br>Identify, design, manufacture, test, and validate systems for flexible engine operation |

2-Stroke: Winterthur Gas & Diesel Ltd.

4-Stroke: Wärtsilä Finland Oy

| |
|---|
| 1.2 Feasibility study (RCEM)<br>Assessment, identification and reporting of existing systems |

WP Leader: Andreas Schmid

DWP leader: Kaj Portin

WÄRTSILÄ · Vaasan yliopisto UNIVERSITY OF VAASA · Aalto-yliopisto · PAUL SCHERRER INSTITUT PSI · n|w · OMT · WIN GD Simply a better different

WP Leader: Andreas Schmid

## Structure: Partners, roles

### PSI
Paul Scherrer Institute
- Support laser optical measurements at the SCC (SP 1.1)
- Concept study on RCEM (SP 1.2)

### FHNW
University of Applied Sciences and Arts Northwestern Switzerland
- Support during the literature research (SP 1.1)
- Feasibility study on RCEM (SP 1.2)

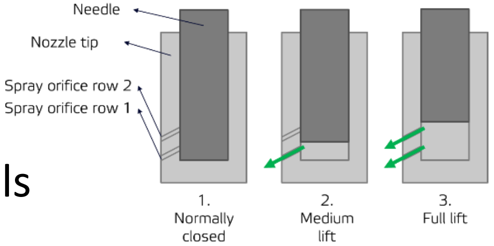
### OMT
O.M.T. OFFICINE MECCANICHE TORINO S.p.A.
- Manufacturing of injection system (SP 1.1)
- Functionality tests of injectors (SP 1.1)

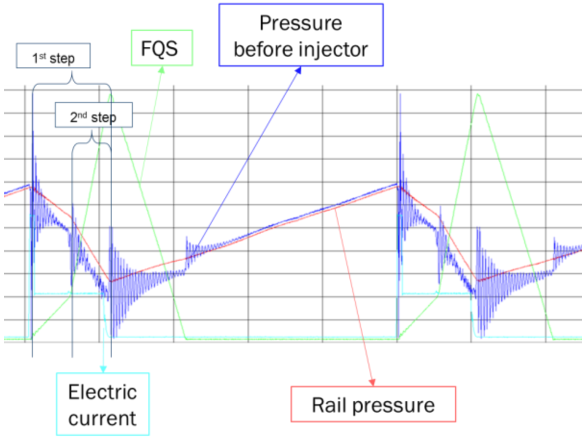
### WinGD
Winterthur Gas & Diesel Ltd.
- WP-lead
- Investigate fuel properties (literature study & experiments)
- Design of injection system
- Demonstrate fuel flexible engine

WP Leader: Andreas Schmid

# Outline of work performed

- Literature review to identify the possible fuel candidates.
  - There is not a single fuel which could replace HFO
  - Several possible solutions, depending on the individual case. => A high fuel flexibility is expected.
  - ETHANOL and Diesel were chosen to **represent** this broad fuel spectra
- A system was developed able to switch between fuels
  - Common Rail system with activation close to the nozzle
  - Made of stainless steel to withstand ethanol and other fuels
  - Variable flow area (two step FAST)
- The system was tested on the injection rig to understand the hydraulic behaviour

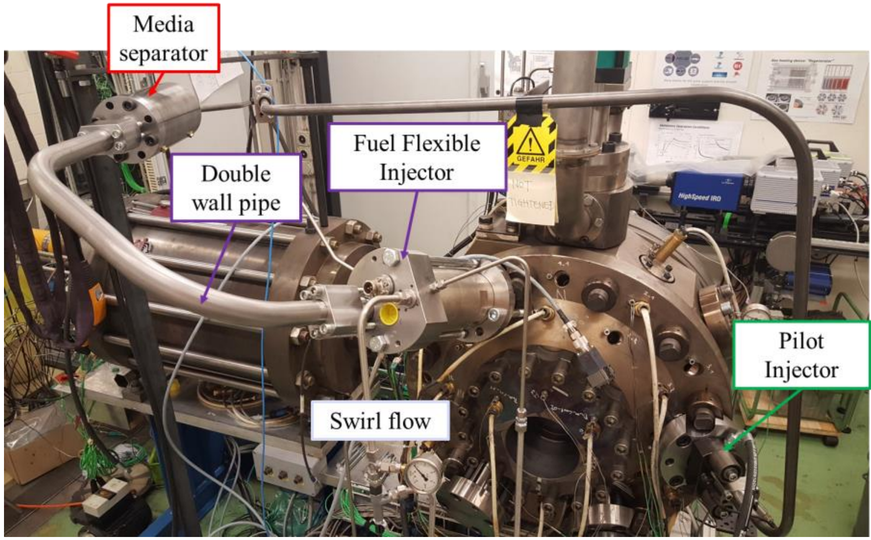


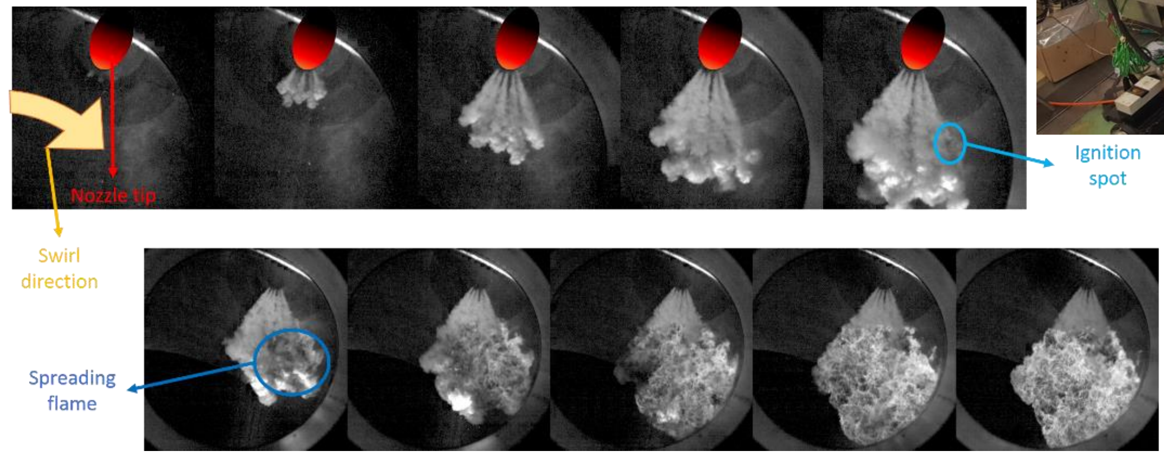



WP Leader: Andreas Schmid

# Outline of work performed

- Injector was taken to the Spray Combustion Chamber to understand spray, ignition and combustion of the injector

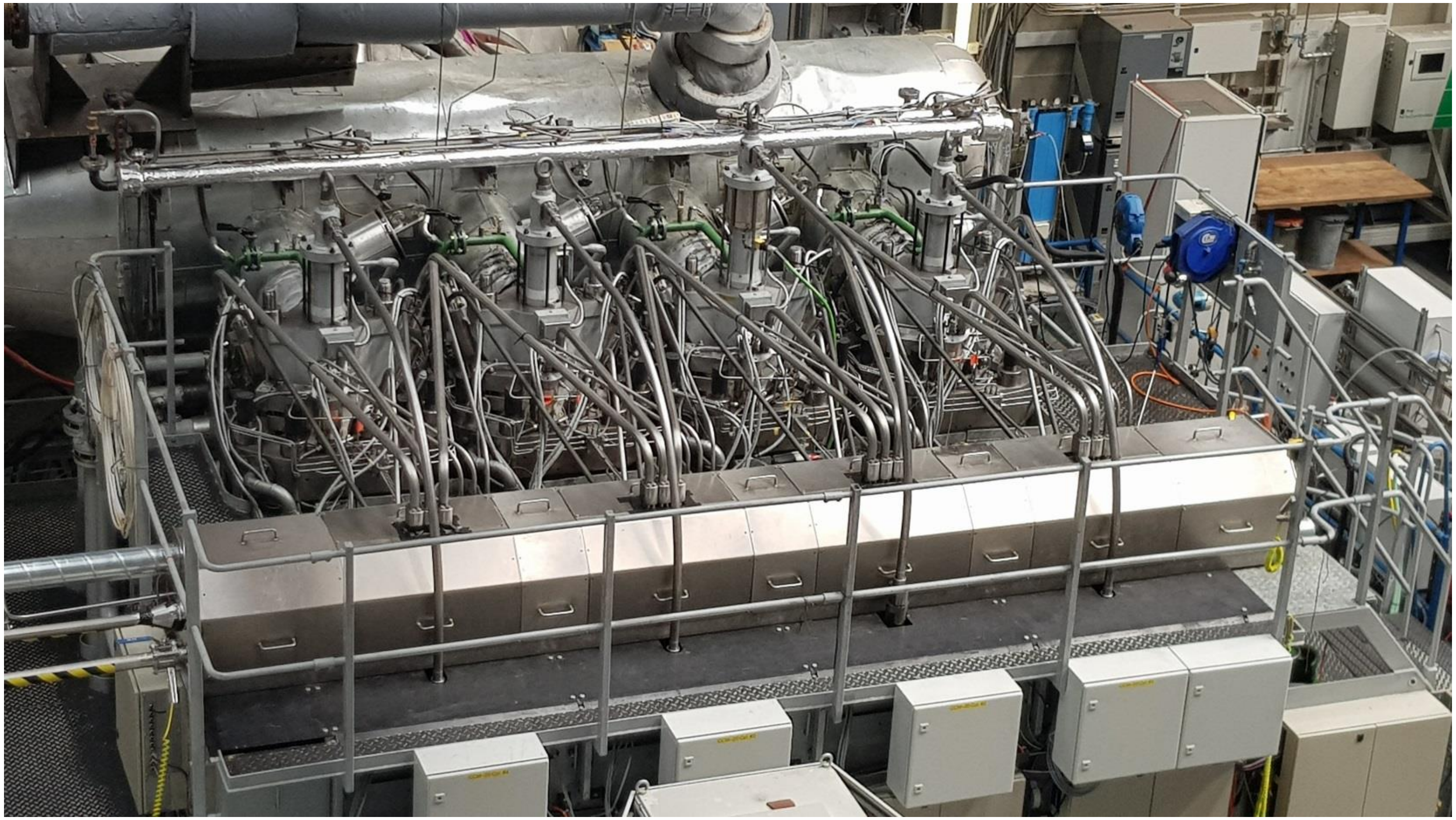


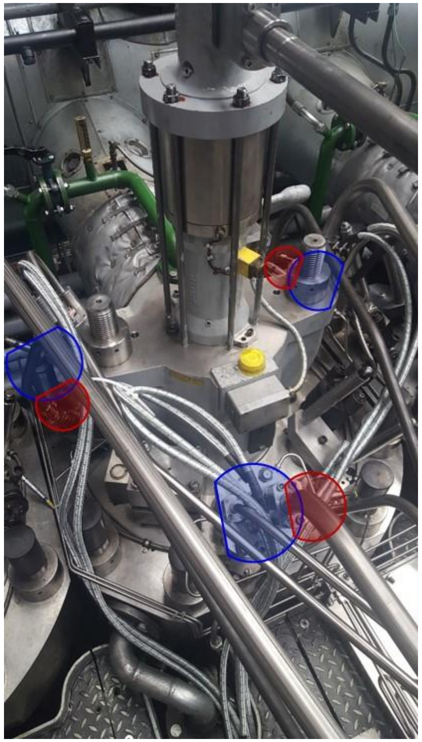



WP Leader: Andreas Schmid

# Outline of work performed

- The system was then taken to the RTX-6 test engine

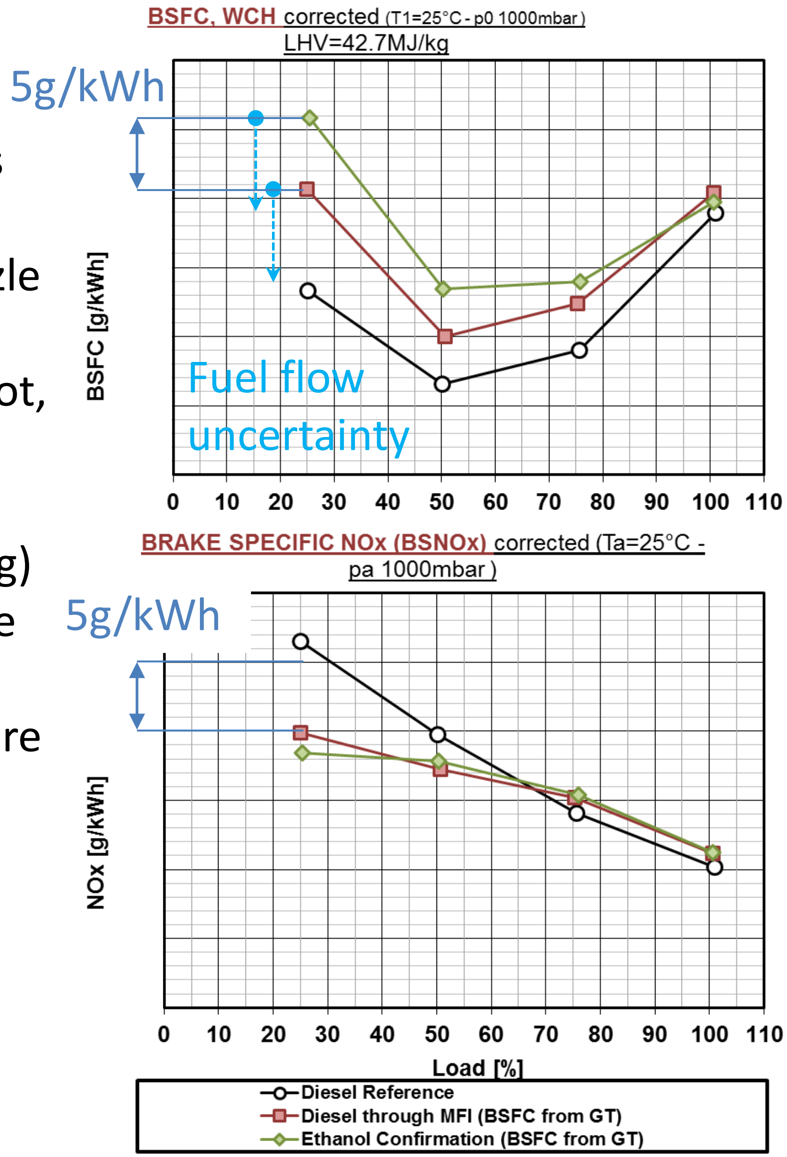




WP Leader: Andreas Schmid

## Final results & Achievements

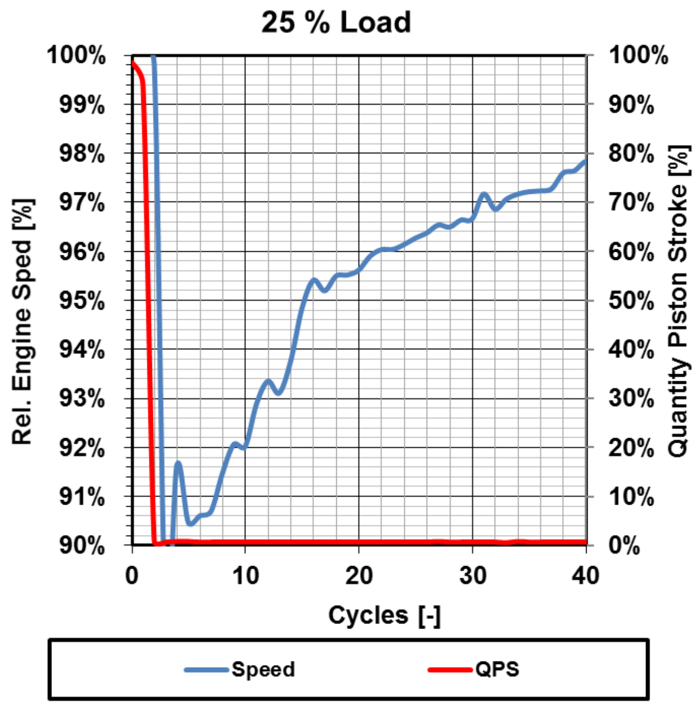
- The system was tested with diesel and ethanol as fuel.
  - Due to budget and time constraints the nozzle tips could not be optimised, yet.
  - The RT-Flex injectors which were used to pilot, could not be operated with their optimum performance
- The consumption (including the non-ideal piloting) was higher compared to the standard system. The reason for this is still investigated as there was a problem with a flow sensor. The values shown here are the values from the problematic sensor (conservative)
- NOx shows a similar trend for the new system, whereas the ethanol doesn't seem to reduce the NOx emissions

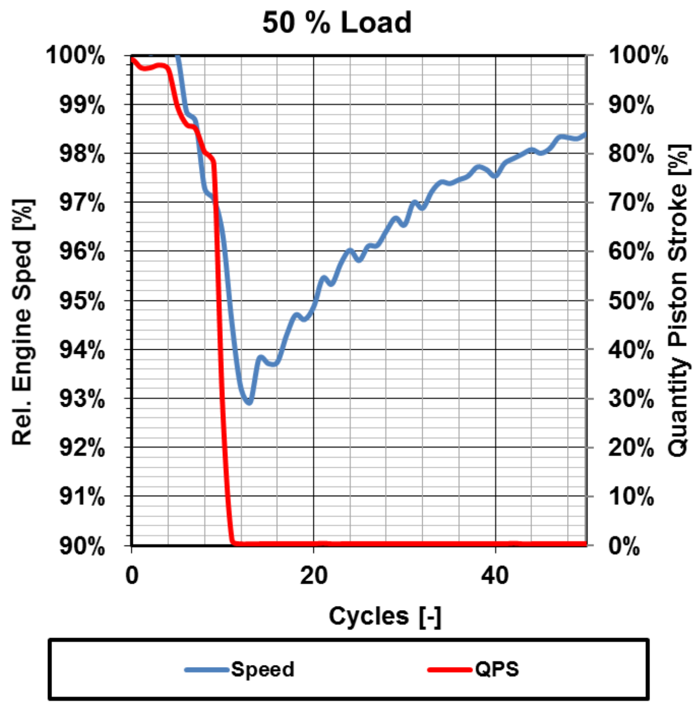


WP Leader: Andreas Schmid

# Final results & Achievements

- In case of problems with the fuel supply, the system would automatically trip to diesel mode
- The loss in engine speed caused by the "hard" changeover from alternative fuel to diesel was within reasonable limits

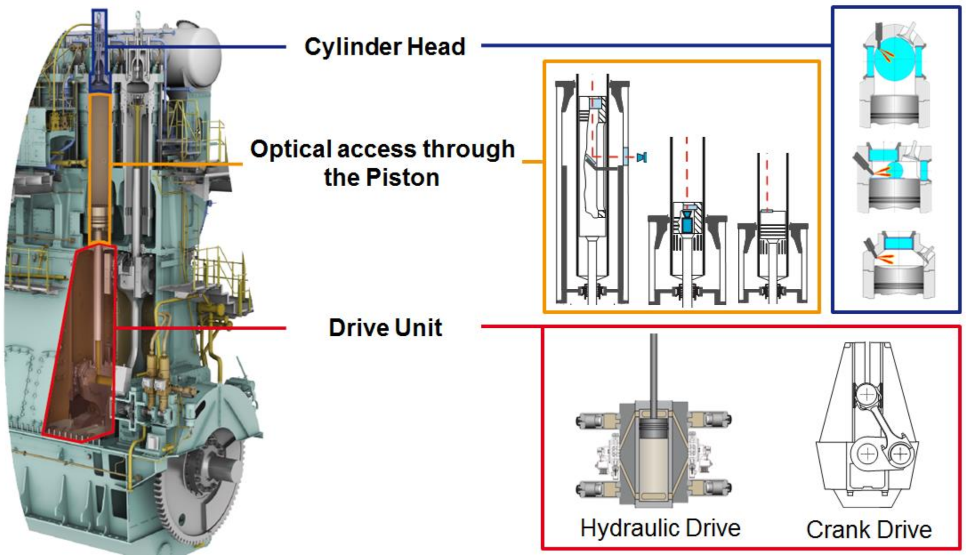


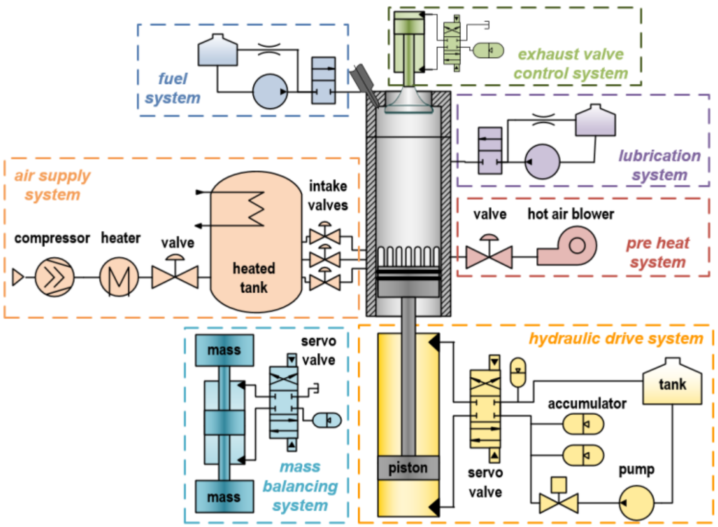



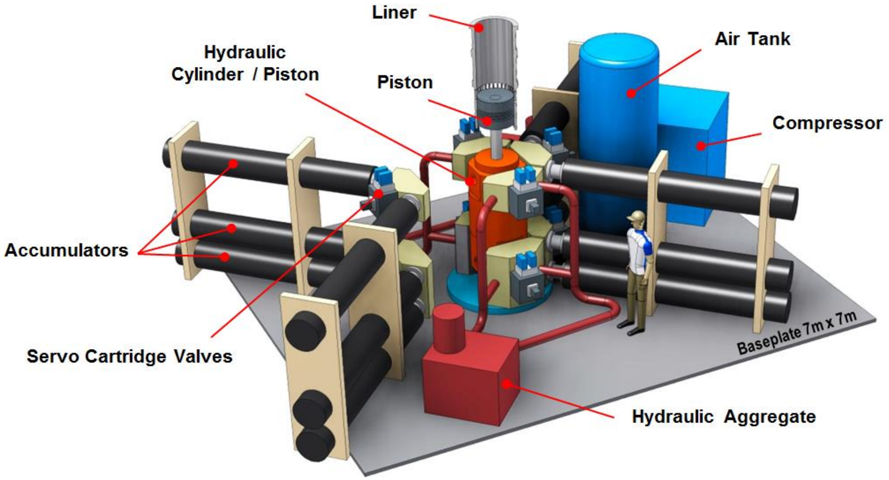
WP Leader: Andreas Schmid

# Final results & Achievements

For the feasibility study an extensive investigation was made with very good results: Such a system would be possible to build. It would allow for very good optical accessibility and could run on both, Otto and Diesel cycle



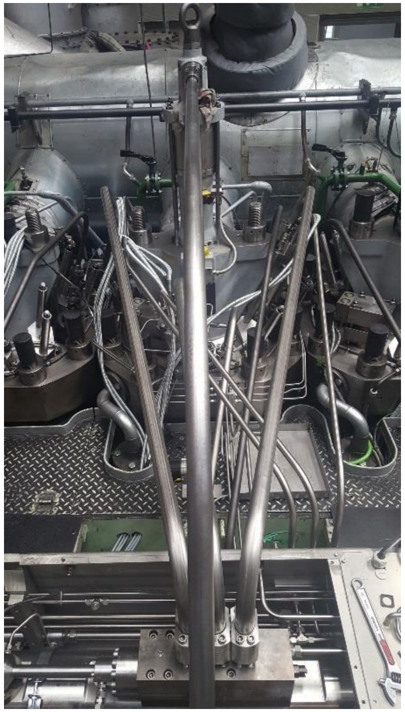



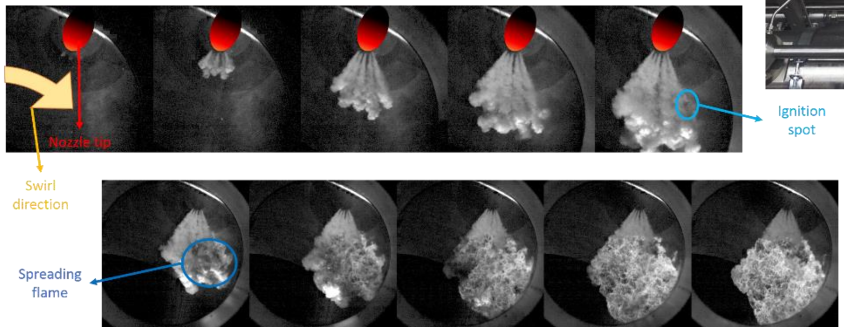

Cost roughly 2-3 M€

WP Leader: Andreas Schmid

## Conclusions



- During the past 3.5 years a complete new injection system could be designed, manufactured and tested.
- The results are promising, that such a system could be used in the future to operate a variety of fuels.
- The prototype built during the HERCULES-2 project allows the investigation of a broad spectrum of fuels and fuel qualities.
- WinGD will use it in the near future to learn more from different fuels.


MANY THANKS TO ALL PARTNERS, CONTRIBUTERS AND THE EC AND SWISS GOVERNMENT FOR THE FINANCIAL SUPPORT DURING ALL THE HERCULES PROJECTS

# WP1: Sub project 1.1 Fuel flexible engine (4-stroke)

## Objectives of Work Package

- To develop **engines able to switch between fuels**, whilst operating in the most cost effective way and complying with the regulations in all sailing regions.

DWP Leader: Kaj Portin

## How

Measurement technology for intermediate combustion products formed inside the combustion chamber will be developed and tested.

The impact of switching between different fuels on possible after-treatment devices and engine components will be part of the investigations.

## Expected Results

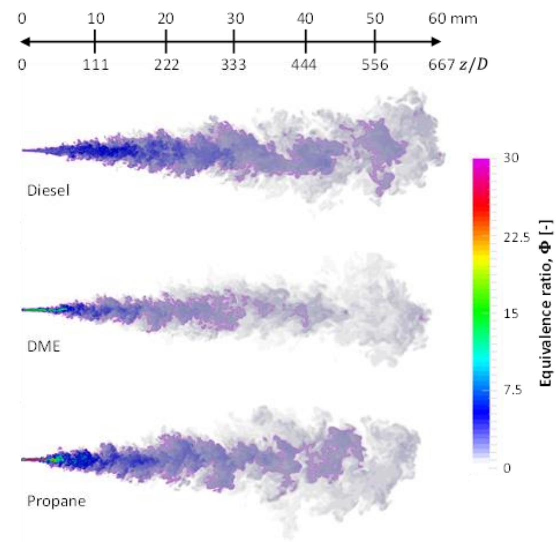
A fully fuel flexible optical injection and ignition test platform for low-speed Diesel engines will also be produced. A fully optical medium-speed multi-fuel engine will be developed and tested for the first time.

Partners: WÄRTSILÄ, Vaasan yliopisto UNIVERSITY OF VAASA, Aalto-yliopisto

DWP Leader: Kaj Portin

## Structure: subprojects, partners, roles

- At Aalto University Large Eddy Simulations (LES) has been Large Eddy Simulation (LES)of evaporating fuels: Diesel, dimethyl ether (dme), and propane and optical Dual-Fuel (DF) combustion characterization of methane-diesel combustion
- At the University of Vaasa, various liquid fuels were studied in a combustion research unit, high-speed and medium-speed diesel engines, e.g., renewable naphtha, circulation-origin MGO, and kerosene.
- At Wärtsilä gas online measurement and control was studied in order to optimize engine performance with gas quality variations

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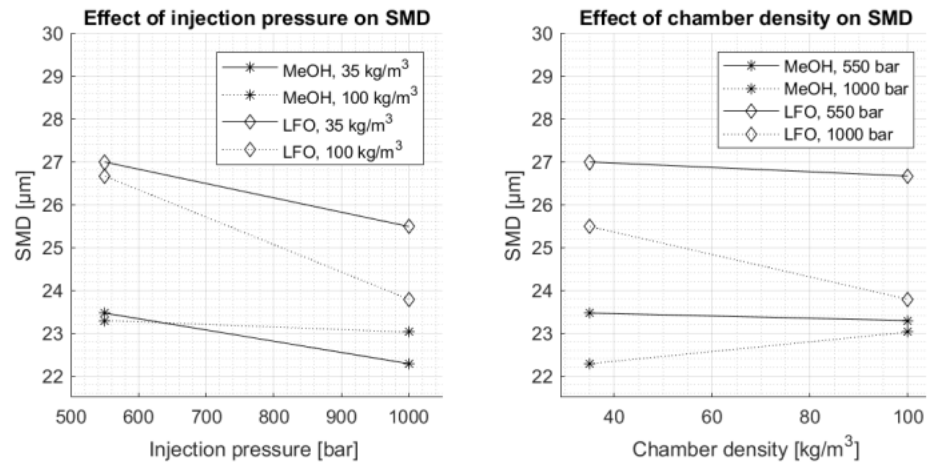
UNIVERSITY OF VAASA
Aalto-yliopisto

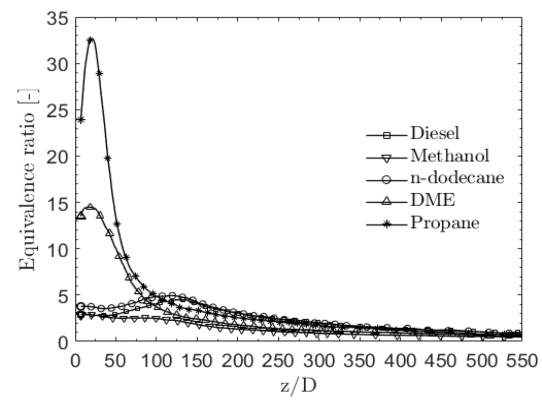
DWP Leader: Kaj Portin

## Final results & Achievements

- Aalto University
- For the first time ever, we measured the droplet sizes (SMD) of methanol sprays.
- LES simulations of various fuels indicated significant differences in the local equivalence ratio fields within the fuel sprays. This could have fundamental effects on e.g. emission during combustion.




Experiments: Effect of injection pressure and chamber density on SMD between Diesel and Methanol.

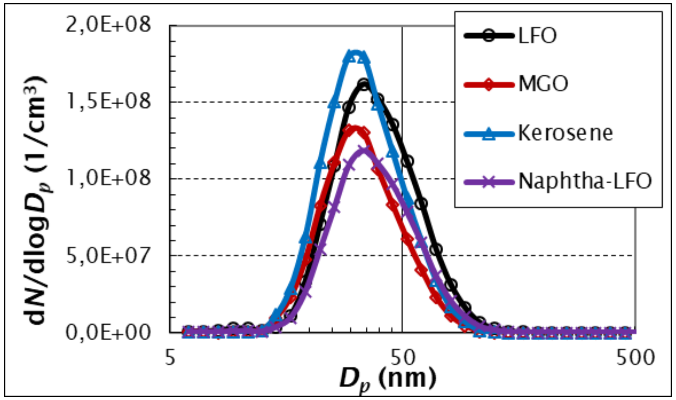



Simulation: Effect of fuel on the spray centerline equivalence ratio (z/D=500 is about 4.5cm from the nozzle)

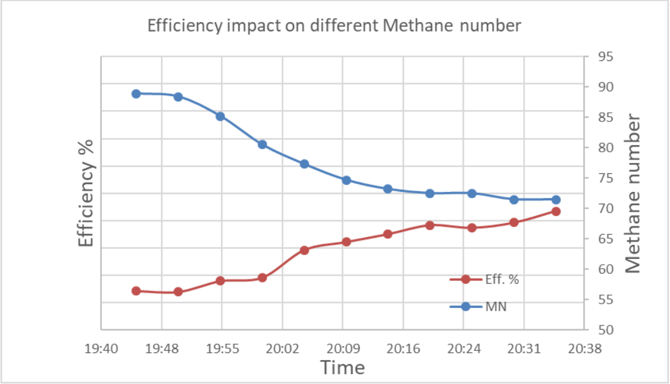
DWP Leader: Kaj Portin

## Final results & Achievements

- MGO and naphtha-LFO blend usually showed more favourable results of particle number emissions than neat LFO and Kerosene

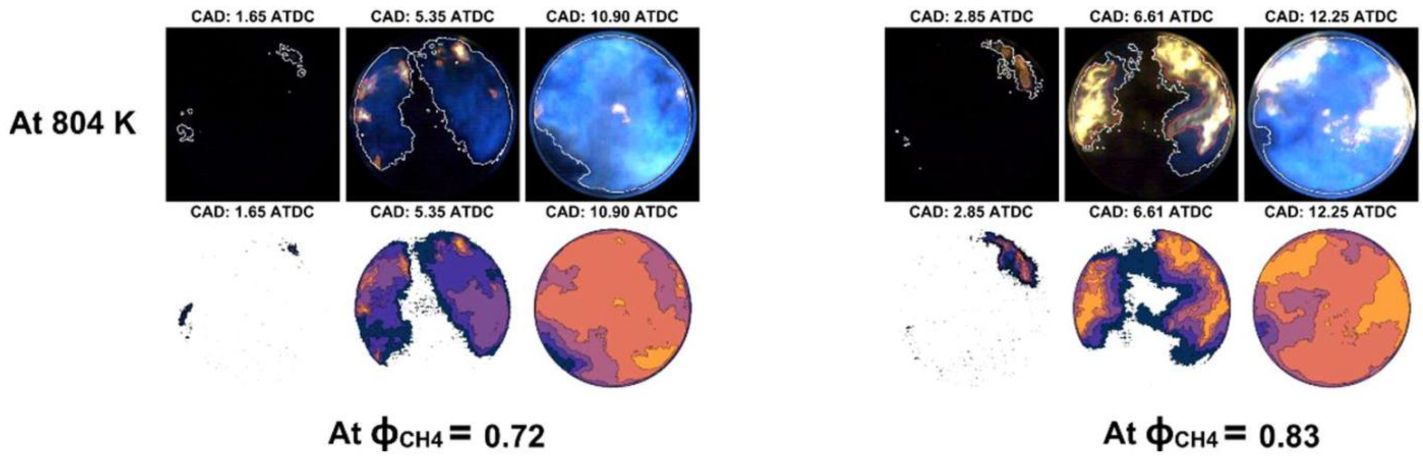



- A variation in gas quality is having a clear impact on the engine performance. This should and can be controlled with online gas measurement and control



DWP Leader: Kaj Portin

## Conclusions




*DF combustion characterization*

- Aalto University
- We characterized DF combustion in an optical engine using various methane lambda's and intake temperatures. Large differences can be observed in the flame propagation between the different intake conditions.
- Diesel, methanol, hexane, kerosene, DME, and propane were analysed numerical and experimentally yielding groundbreaking new picture of their behavior.

DWP Leader: Kaj Portin

## Conclusions

- Almost equal efficiency with all fuels.
  - Kerosene: slightly higher NOx emissions.
  - PM emissions very similar for all fuels.
- The low flash point of the naphtha-LFO blend is a security issue.
- Online gas quality measurement and control can have a significant influence on engine performance when the gas quality is variating.