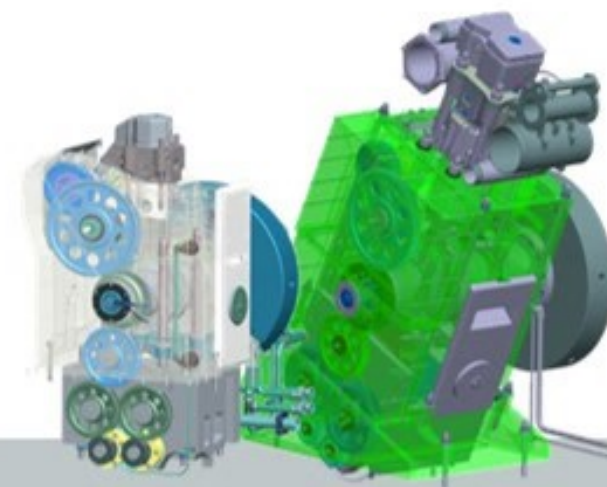
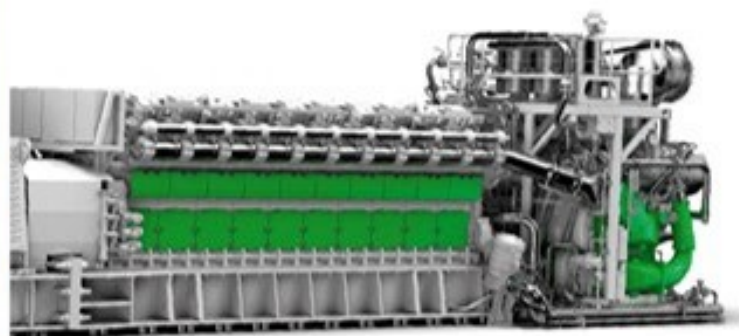




Large Engines Competence Center

CIMAC Cascades 2021, Graz

Zero Emission Shipping – from Vision to the HyMethShip Technology Demonstrator

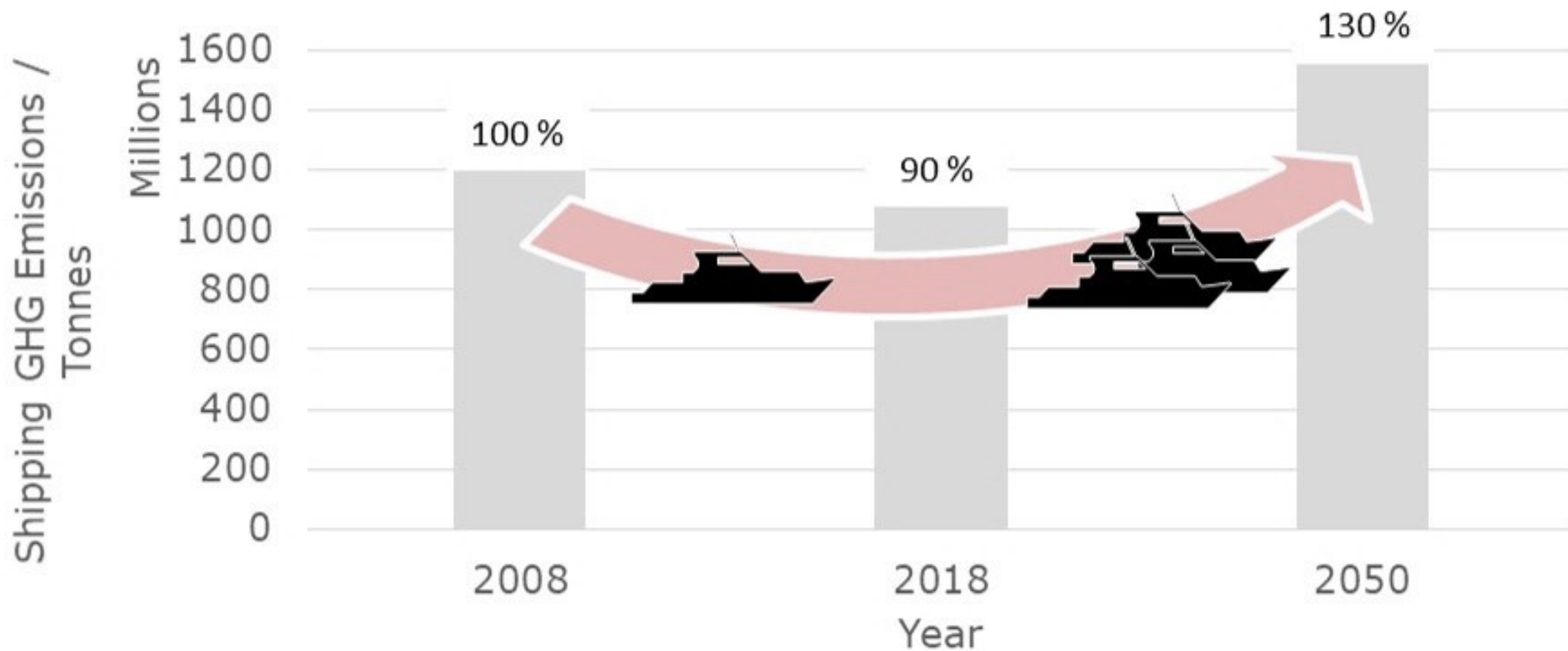


22 September 2021 • M. Lackner



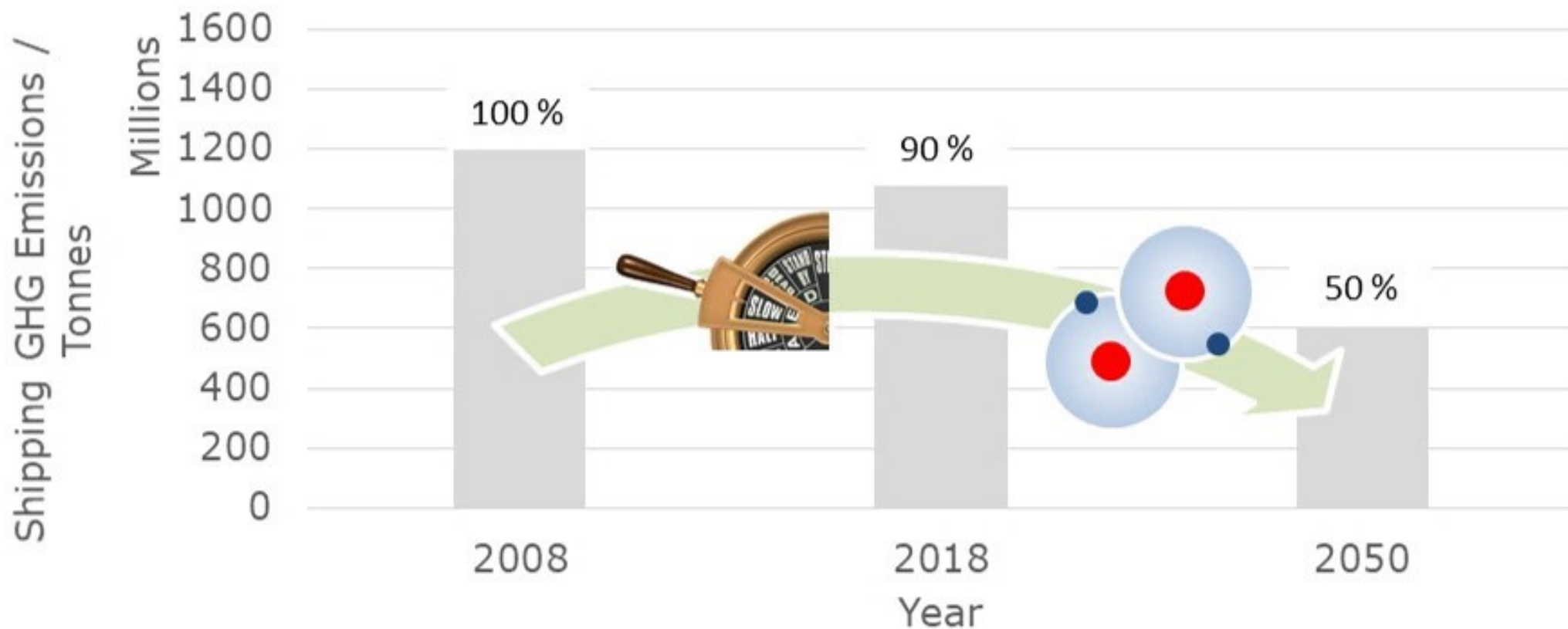
This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 768945

Introduction & motivation



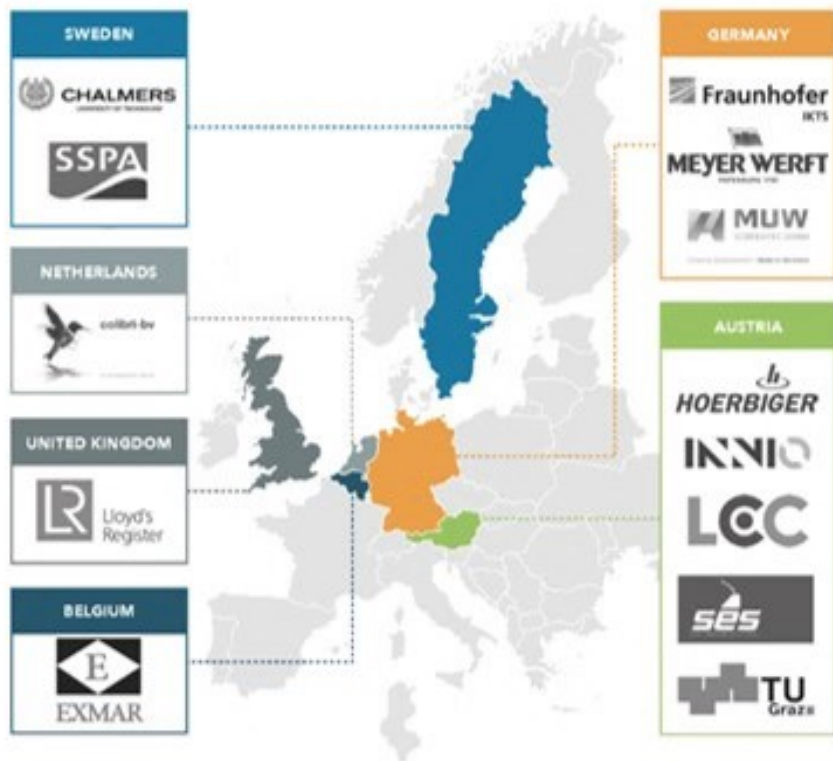
Source: Fourth IMO Greenhouse Gas Study 2020

Introduction & motivation



Source: Fourth IMO Greenhouse Gas Study 2020

Introduction & motivation

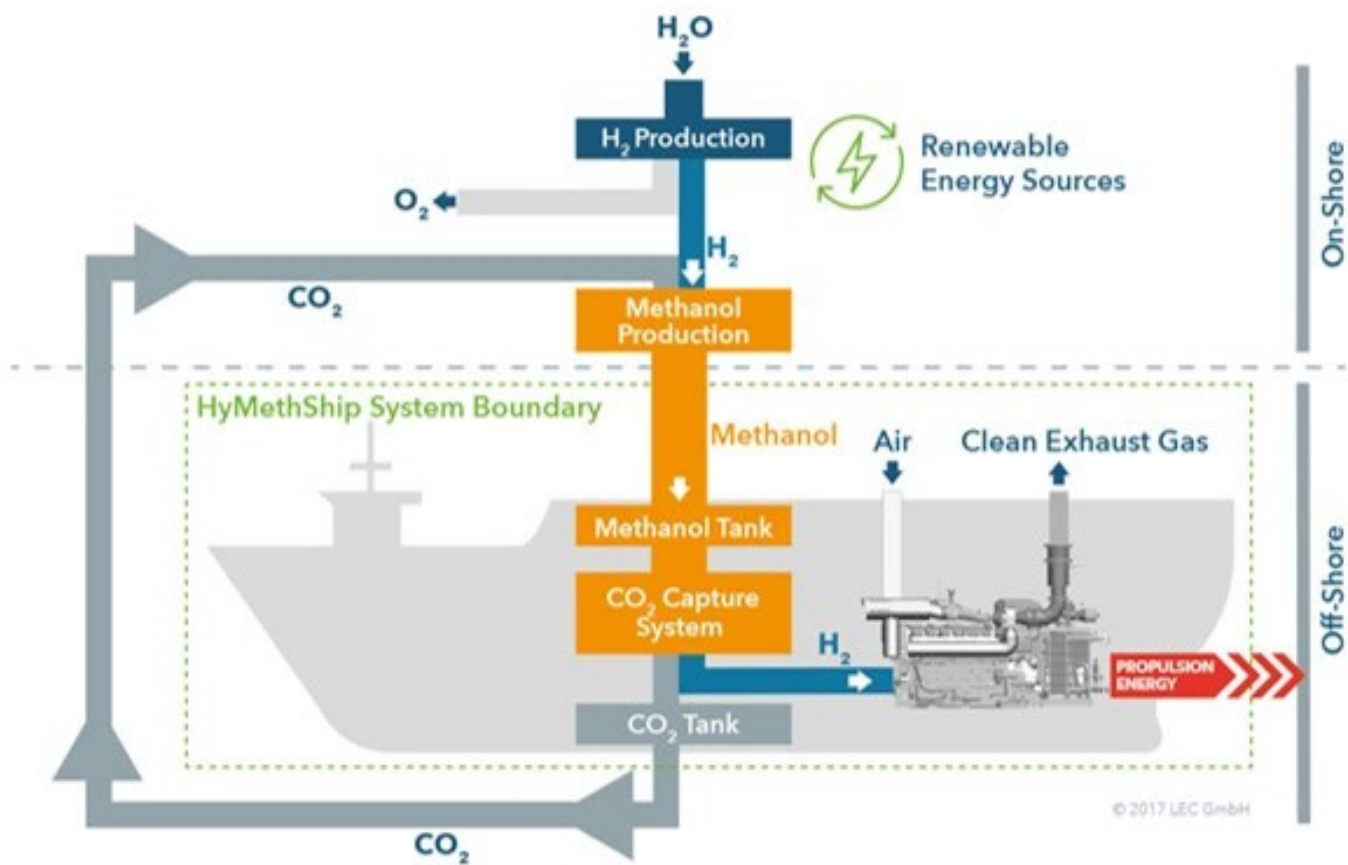


Agenda

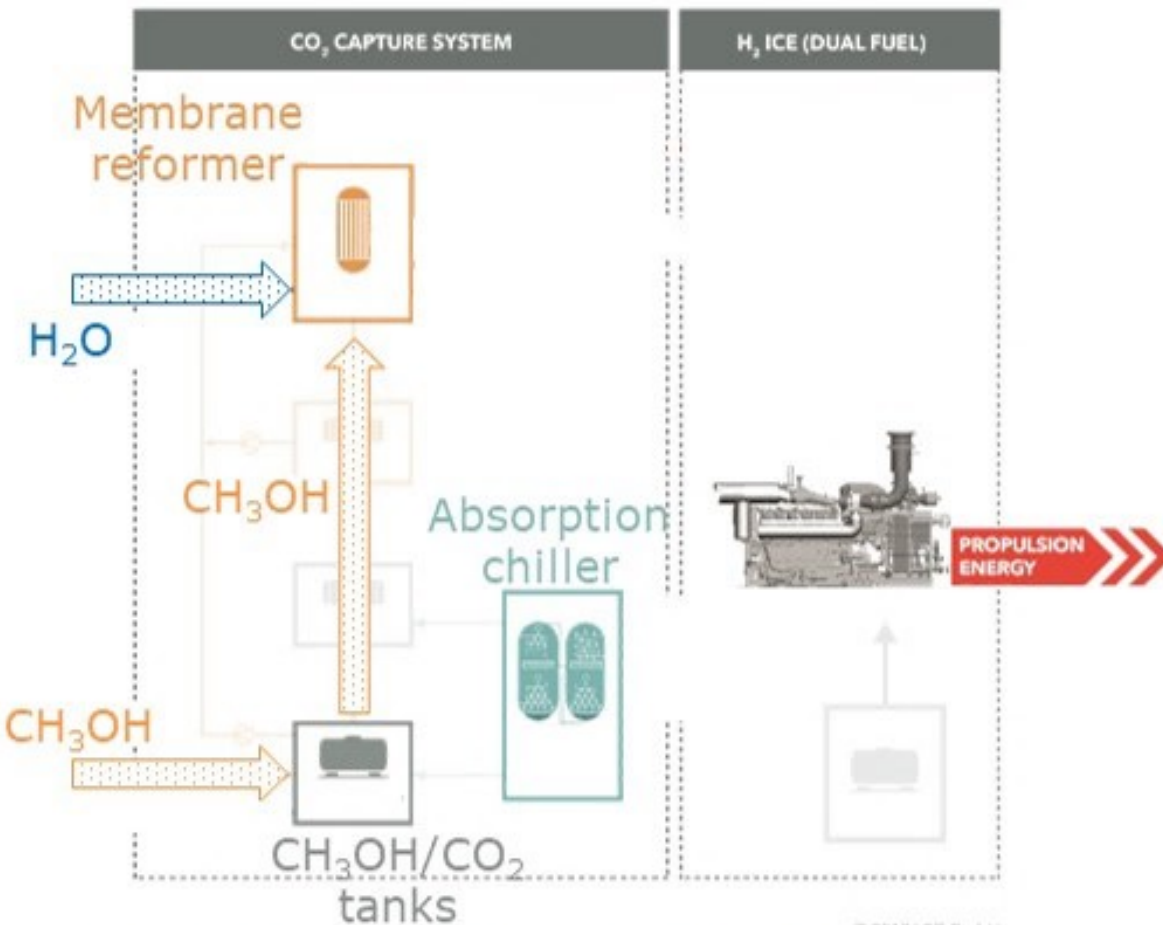
- HyMethShip concept
- Membrane methanol reformer
- Combustion system development
- Technology demonstrator
- Current status & outlook



HyMethShip concept



HyMethShip concept

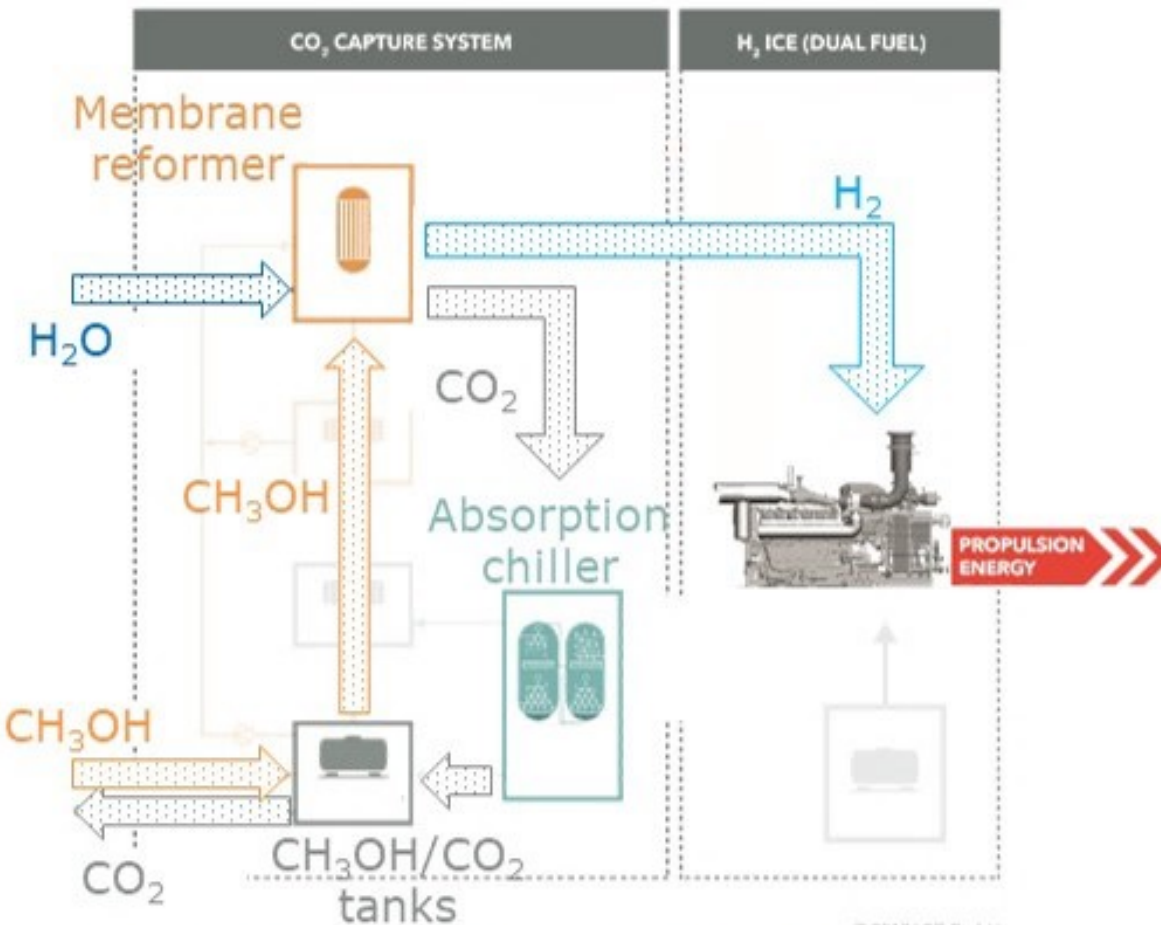


Pre-combustion carbon capture system

- Receiving liquid **methanol** and **water**

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HyMethShip concept

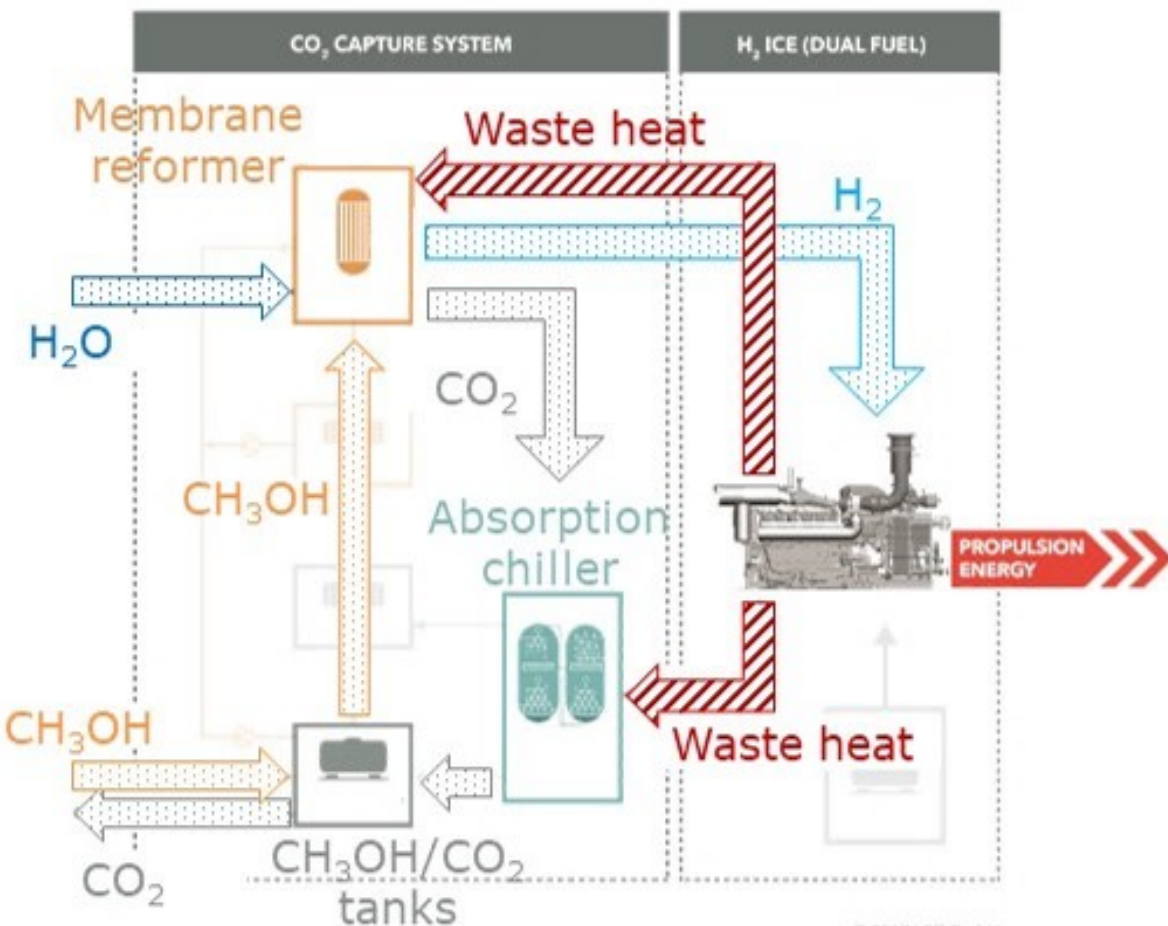


Pre-combustion carbon capture system

- Receiving liquid **methanol** and **water**
- Producing **hydrogen** fuel and carbon dioxide (fed back in liquid form to tank)

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HyMethShip concept



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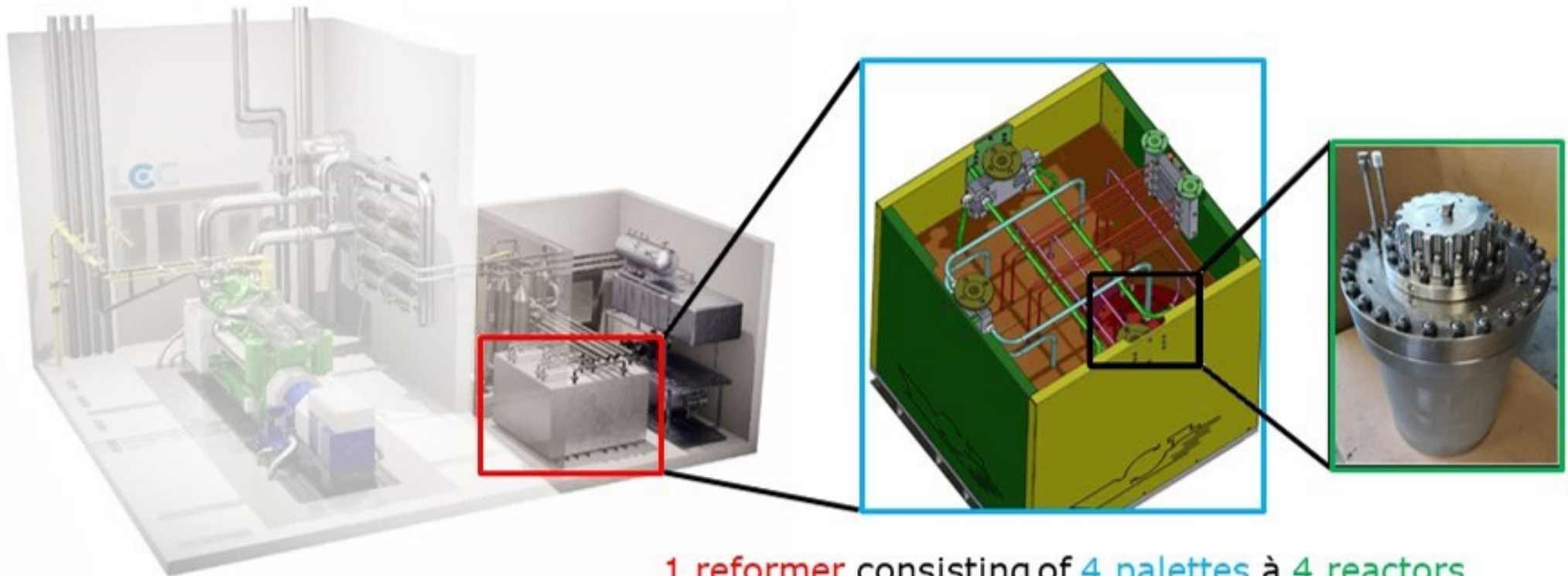
Pre-combustion carbon capture system

- Receiving liquid **methanol** and **water**
- Producing **hydrogen** fuel and carbon dioxide (fed back in liquid form to tank)

Propulsion engine

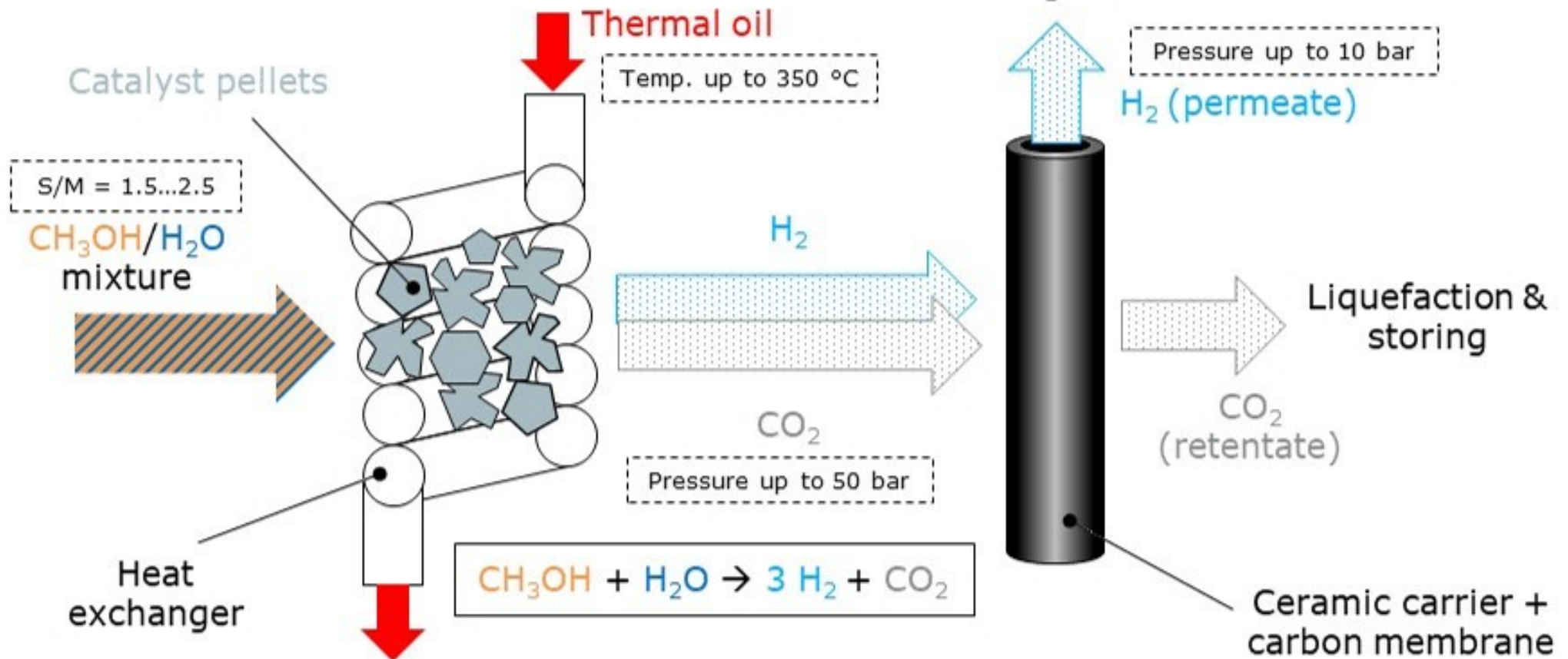
- Consuming **hydrogen** fuel
- Supplying **waste heat** for CCS

Membrane methanol reformer



1 reformer consisting of **4 palettes** à **4 reactors**

Membrane methanol reformer



Combustion system development



Jenbacher J612-J engine „Standard“

Configuration	V 60°
Bore	190 mm
Stroke	220 mm
Rated speed	1500 rpm
Rated power	~ 2 MW (el)
Fuel	Natural gas
Mixture preparation	Low pressure gas mixer
Combustion concept	Gas scavenged pre-chamber

Combustion system development



Hydrogen rail
PFI valve
PFI cylinder head
Spark plug sleeve & spark plug (not visible)

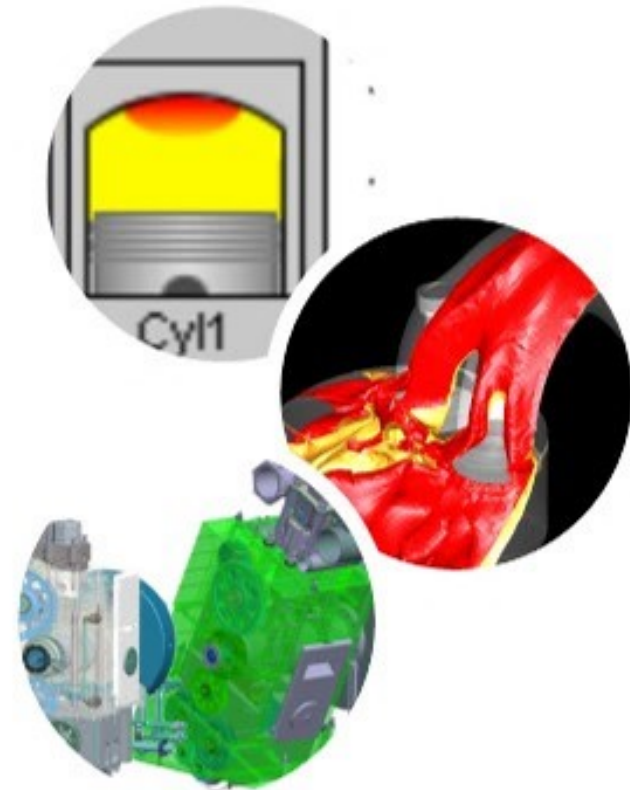


Jenbacher J612-J engine „HyMethShip“

Configuration	V 60°
Bore	190 mm
Stroke	220 mm
Rated speed	1500 rpm
Rated power	~ 1 MW (el)
Fuel	Hydrogen
Mixture preparation	Port fuel injection
Combustion concept	Open chamber spark ignition

Combustion system development

- Combustion system development
 - 1D engine simulations
 - **3D CFD simulations**
 - Single-cylinder evaluation

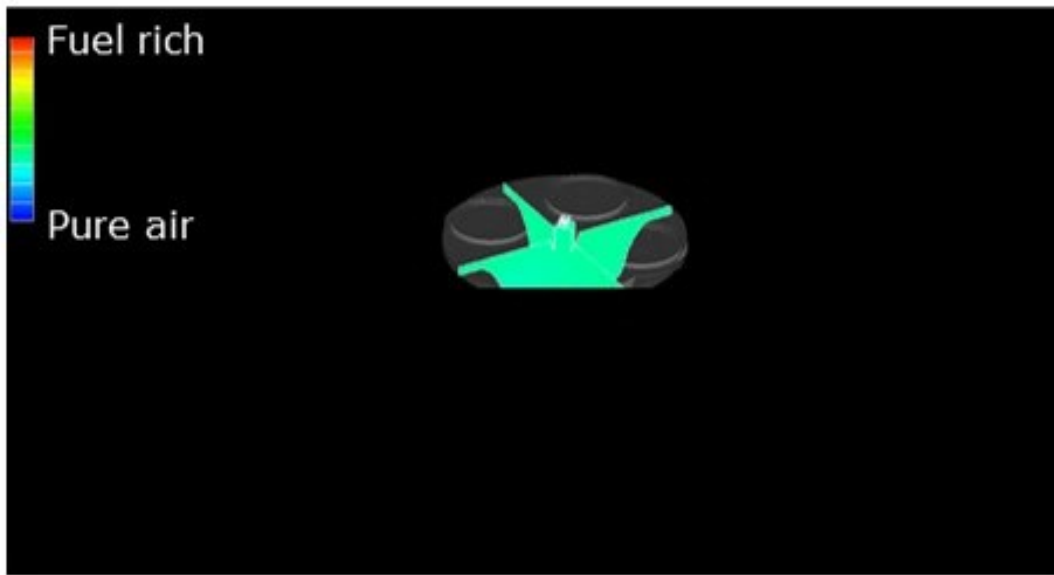


Combustion system development

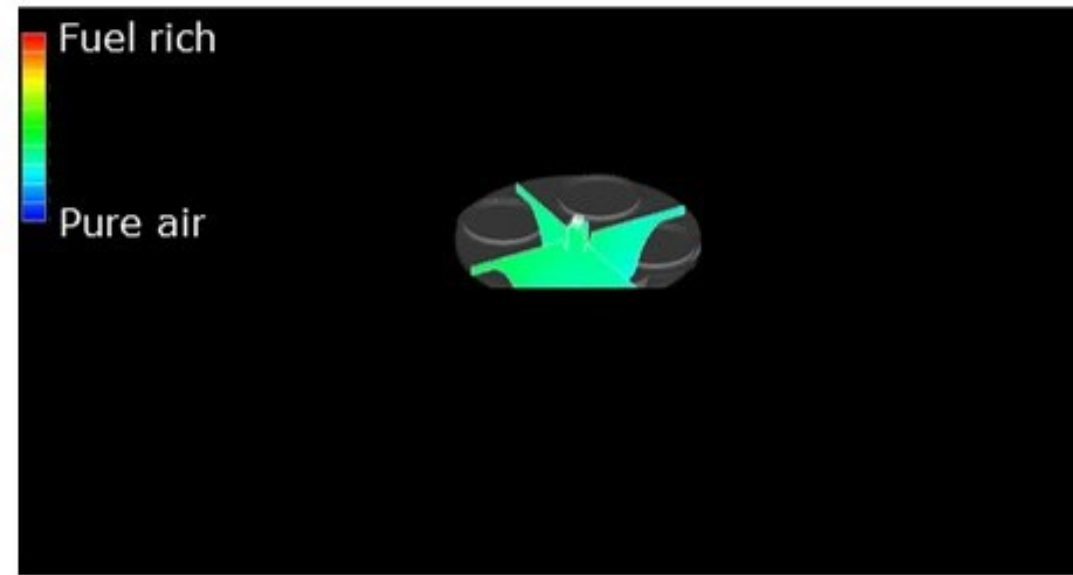
- Mixture formation optimization for different injection sleeve geometries
- Design variant selection based on achievable in-cylinder homogeneity and low fuel retention in the intake port
- Impact of injection timing on in-cylinder homogeneity



Combustion system development



Start of injection (SOI) = early

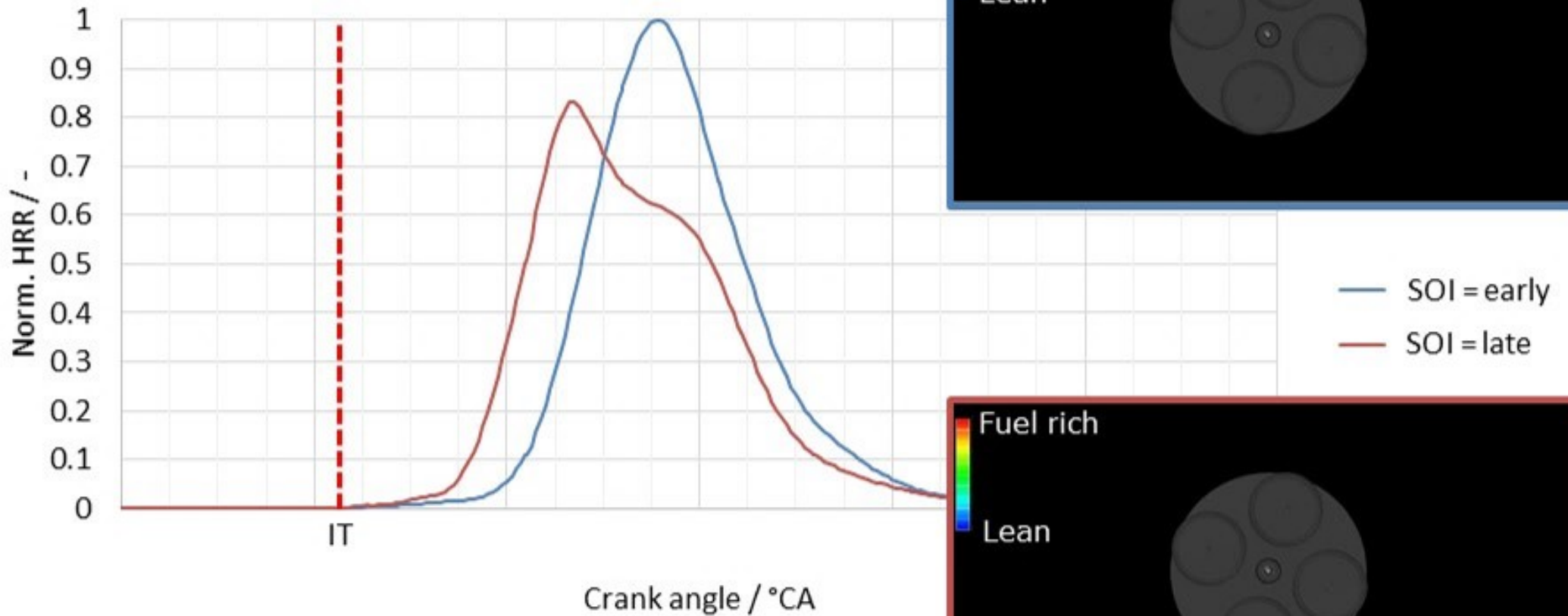


SOI = late

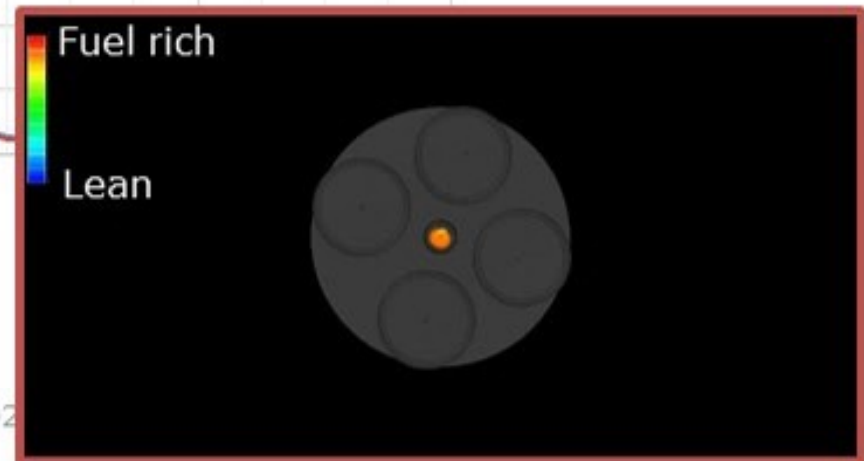
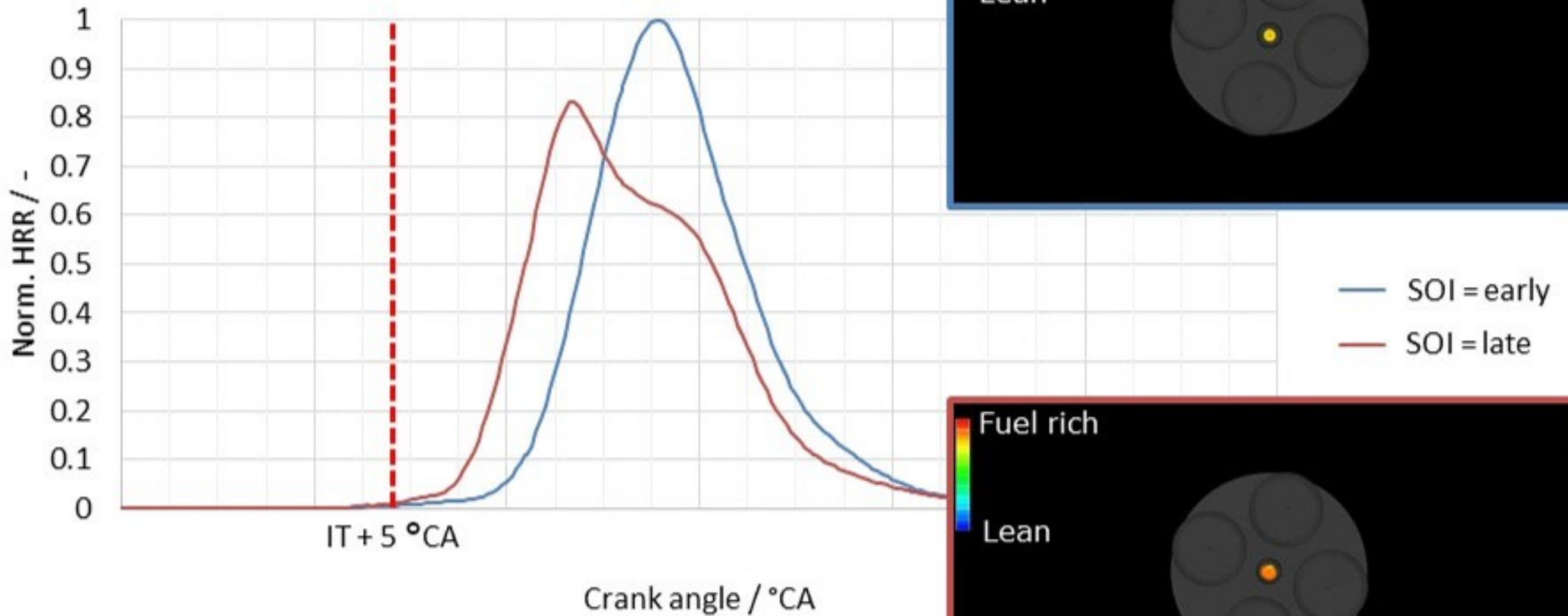
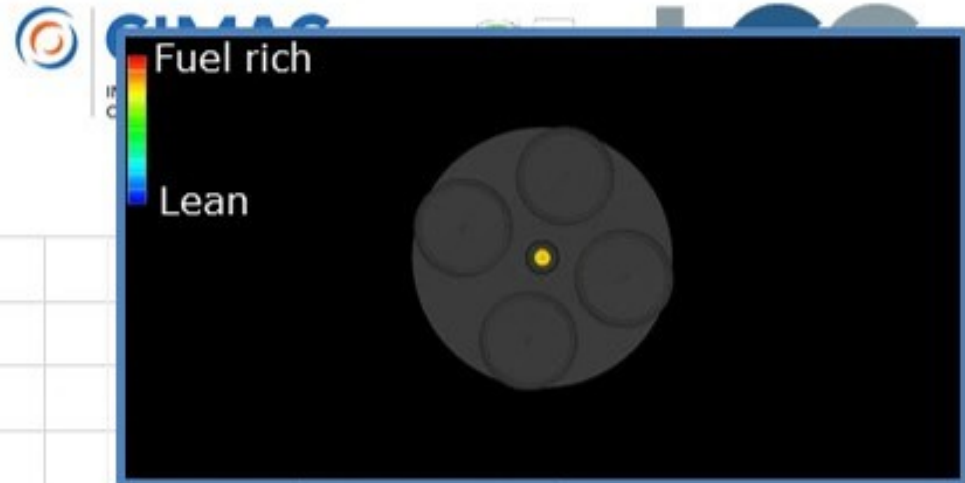
Combustion system development



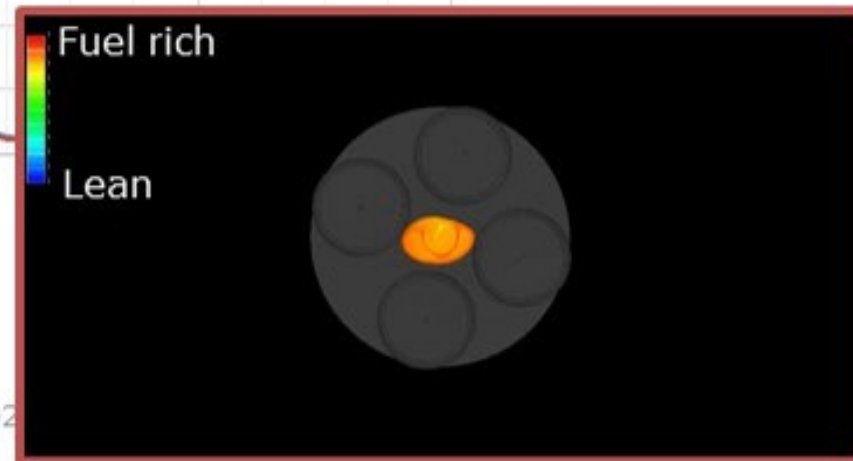
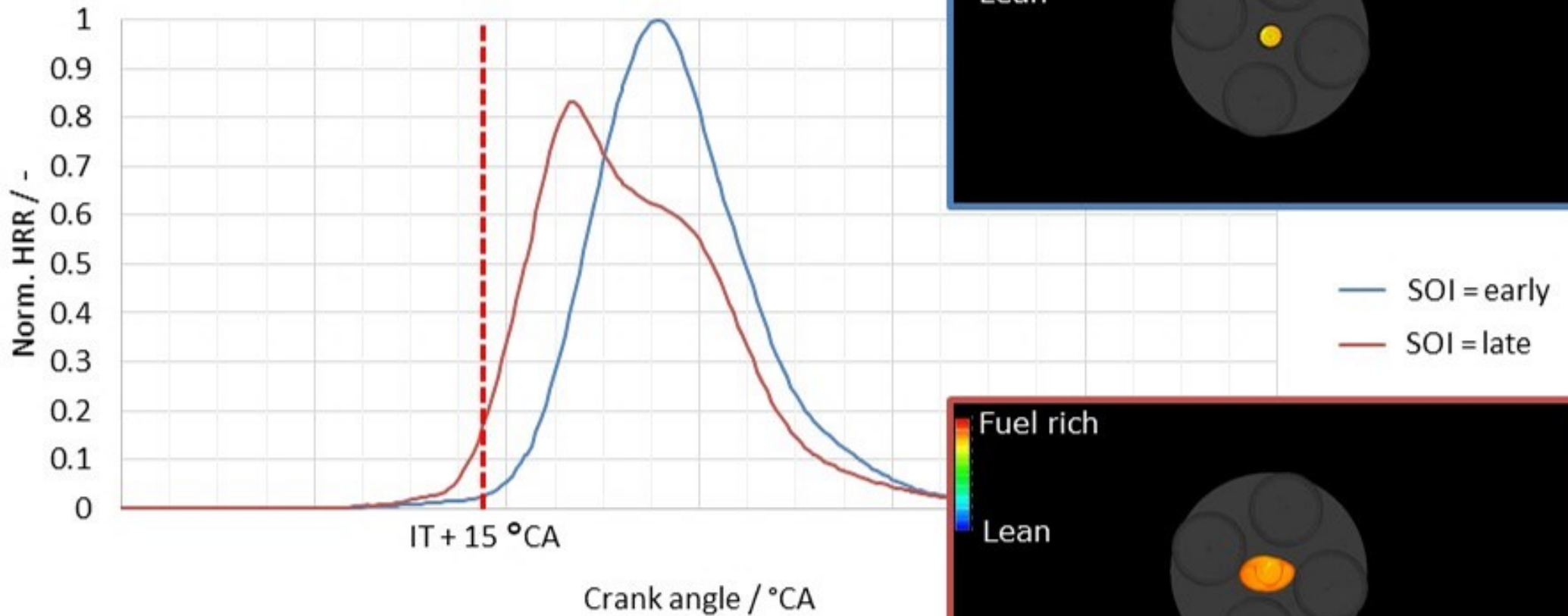
CEMTE



Combustion system development



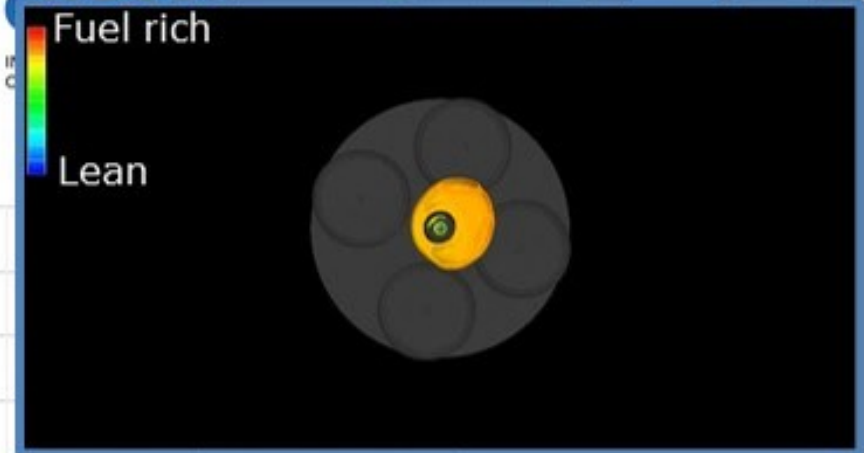
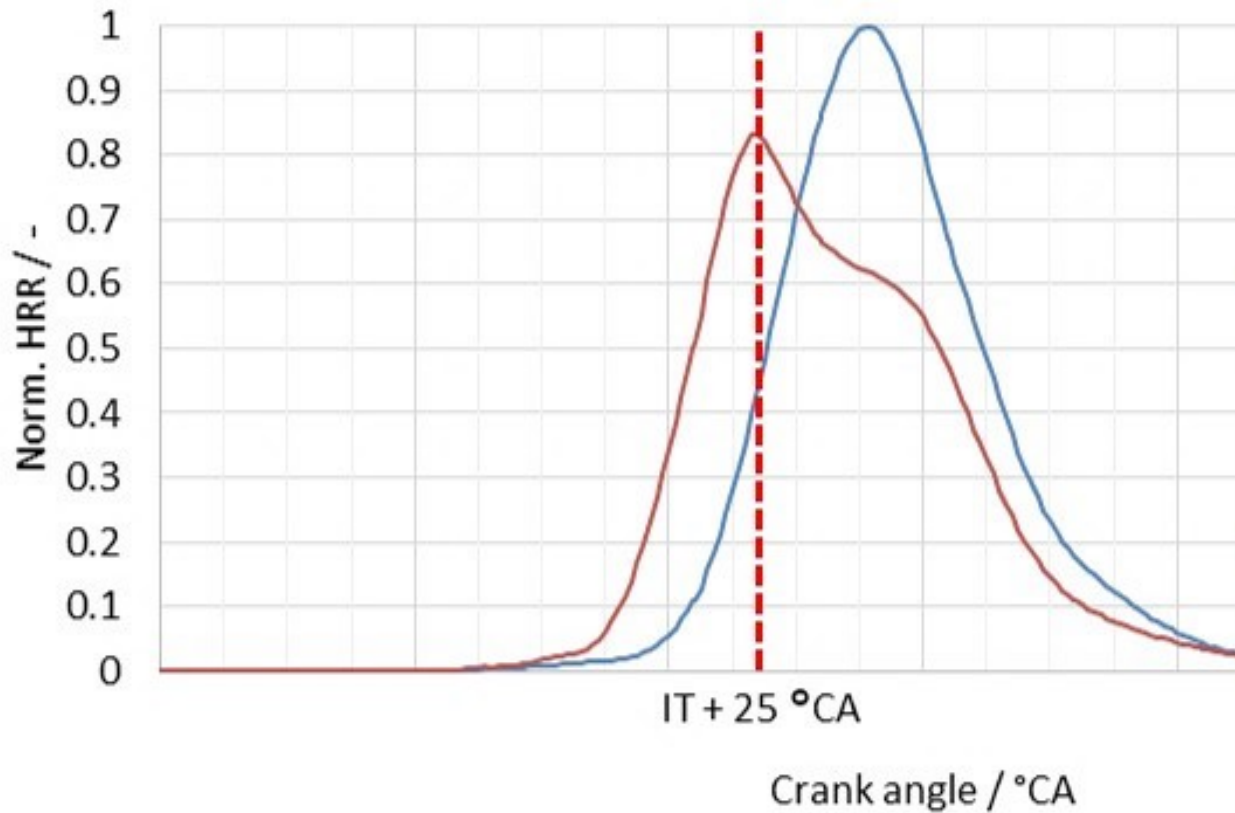
Combustion system development



Combustion system development



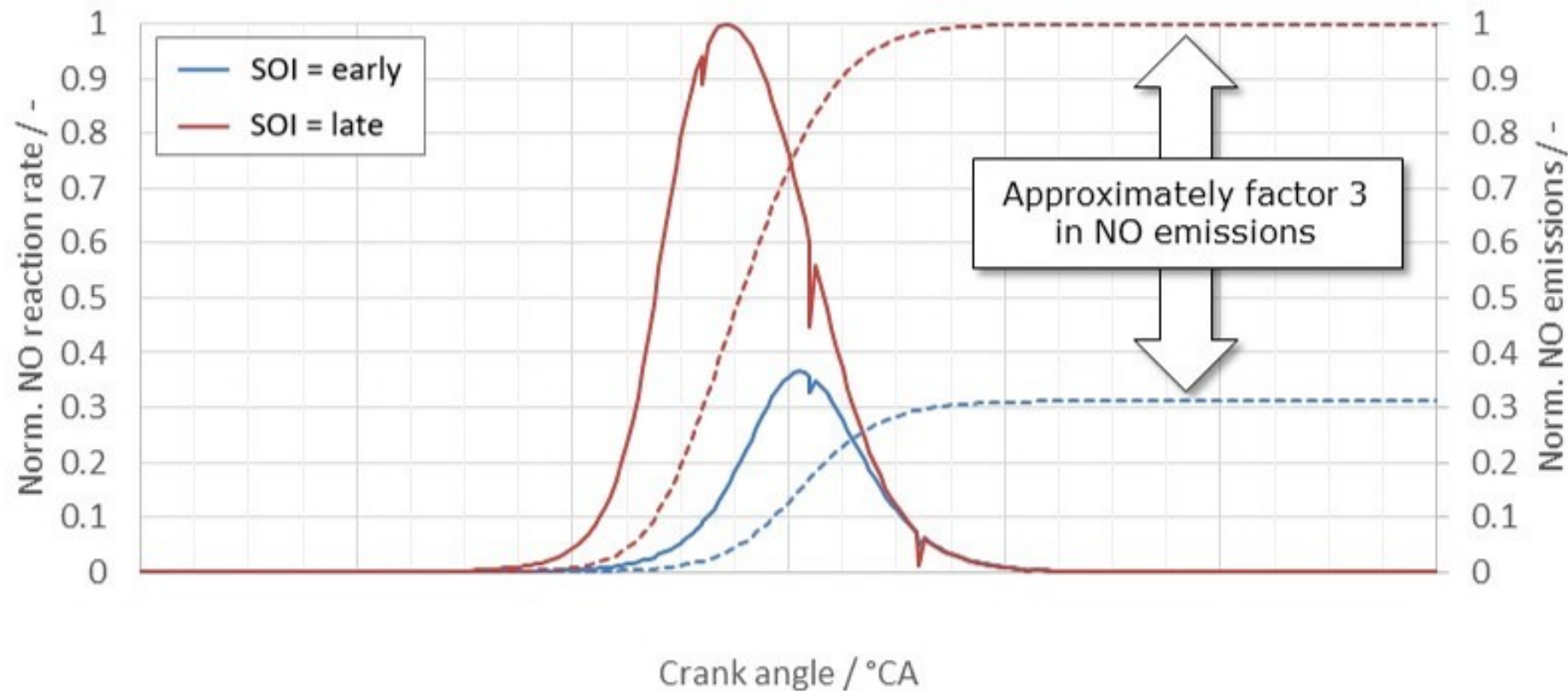
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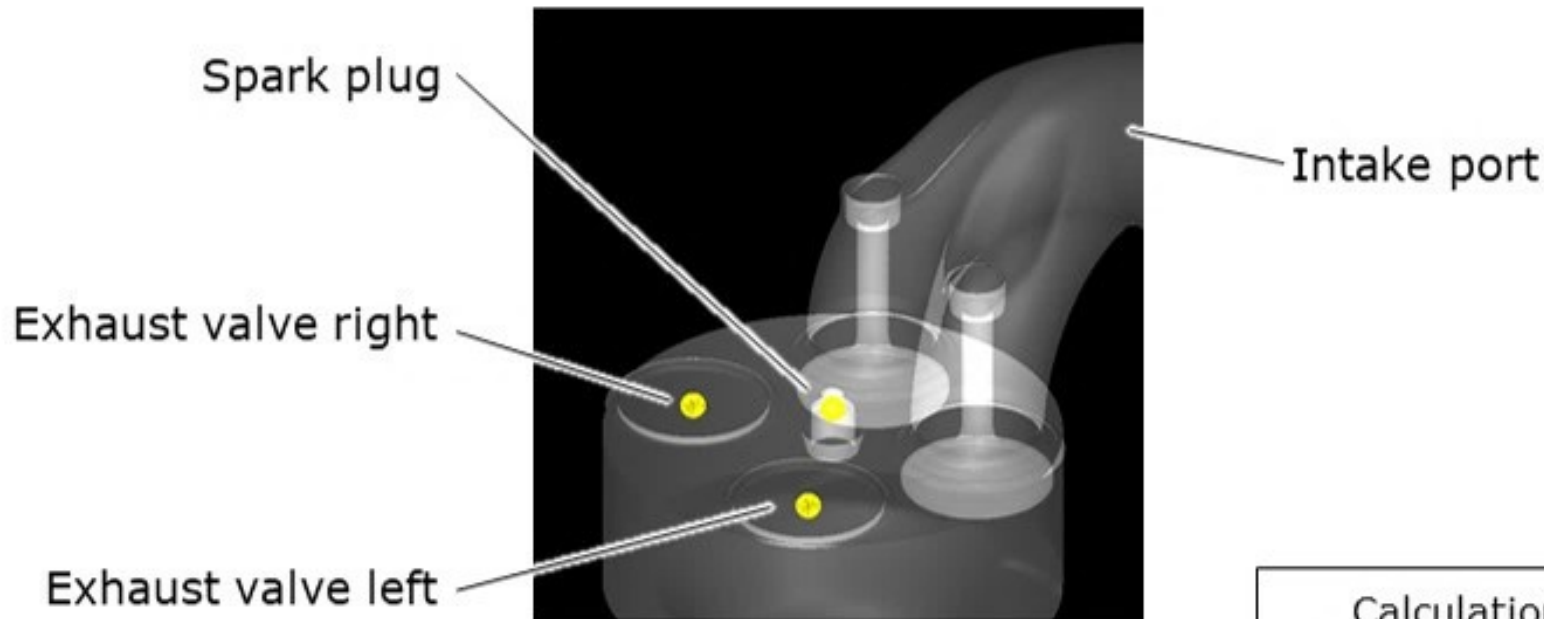
— SOI = early
— SOI = late



Combustion system development

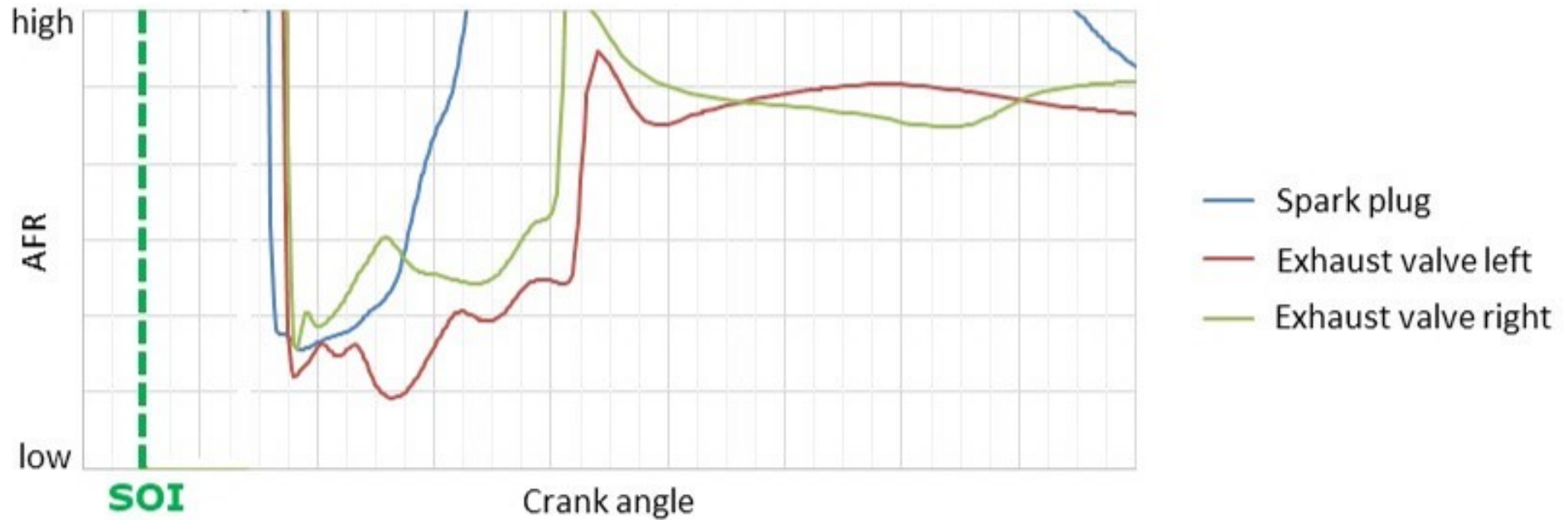


Combustion system development

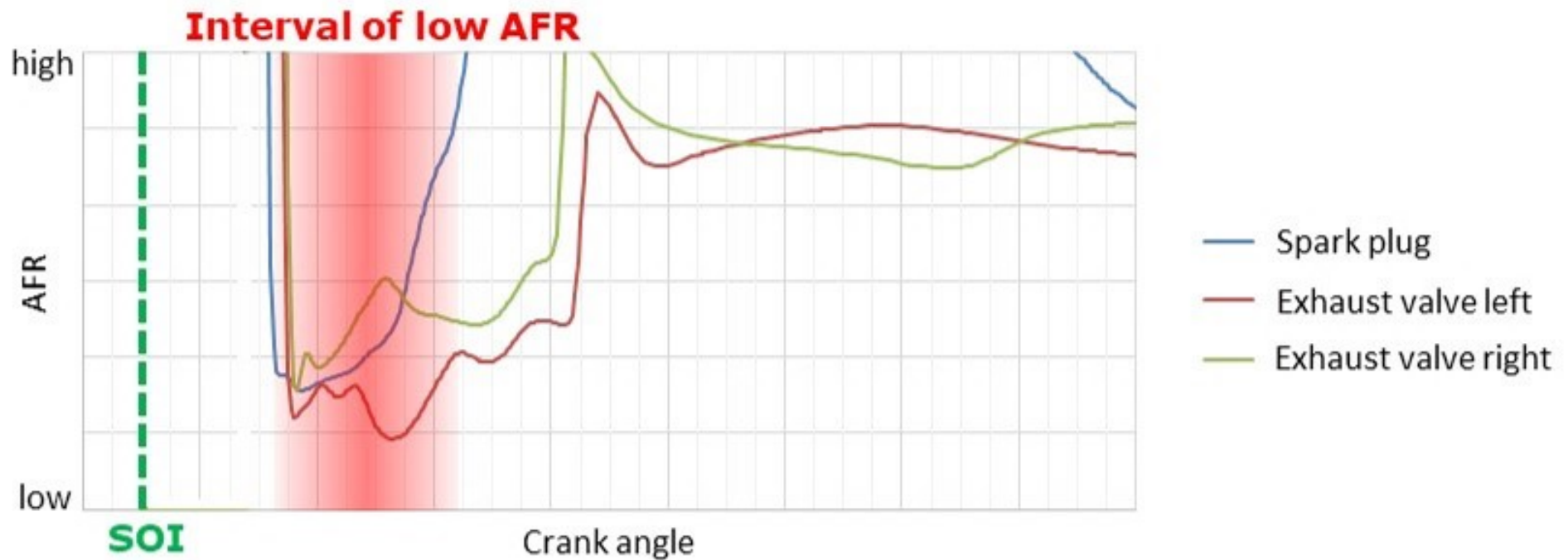


Calculation of mean AFR inside of spheres ($r=5$ mm) located at regions of interest in relevant crank angle interval

Combustion system development

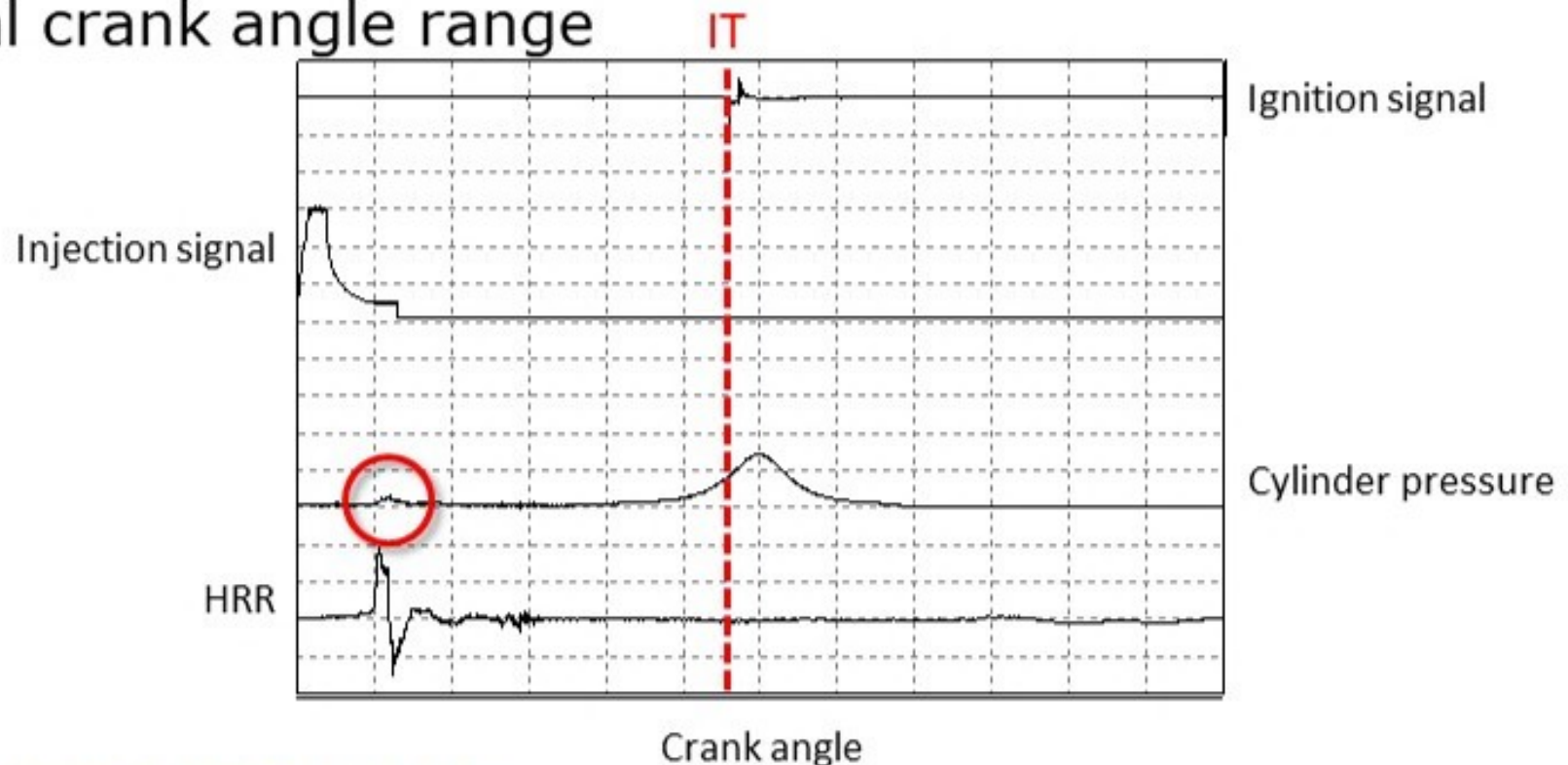


Combustion system development

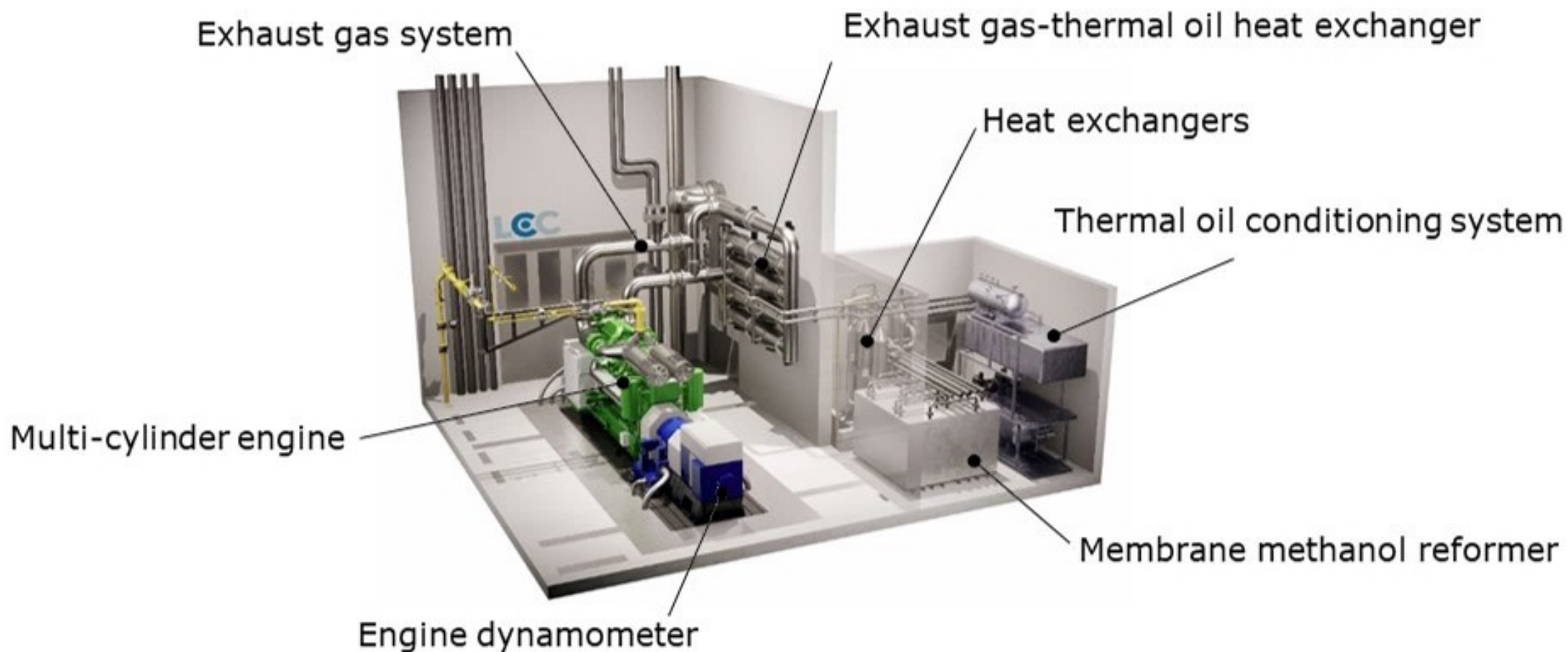


Combustion system development

- Most pre-ignitions observed during measurements happen in a typical crank angle range



Technology demonstrator



Technology demonstrator



Engine
Hydraulic brake
Engine dynamometer



Exhaust gas-thermal oil heat exchanger

Technology demonstrator



Heat exchanger-
chimney connection

Engine-
heat exchanger
connection



Exhaust gas-
thermal oil
heat exchanger

Thermal oil
(return flow)

Thermal oil
(feed-in)

Technology demonstrator



Current status & outlook



- ✓ Reformer commissioning and hydrogen production

Current status & outlook



- ✓ Reformer commissioning and hydrogen production
- Improvement measures of hydrogen/carbon dioxide selectivity

Current status & outlook



- ✓ Reformer commissioning and hydrogen production
- Improvement measures of hydrogen/carbon dioxide selectivity
- ✓ Engine operation at part load with 100 % hydrogen

Current status & outlook



- ✓ Reformer commissioning and hydrogen production
- Improvement measures of hydrogen/carbon dioxide selectivity
- ✓ Engine operation at part load with 100 % hydrogen
- Operation with increased engine load

Current status & outlook



- ✓ Reformer commissioning and hydrogen production
- Improvement measures of hydrogen/carbon dioxide selectivity
- ✓ Engine operation at part load with 100 % hydrogen
- Operation with increased engine load
- Combined operation/interaction of sub-systems



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