AGRITECH DAY BY AXEMA

2026

FROM DIESEL TO BIOCNG AND HYDROGEN

TRANSFORMING AGRICULTURAL MOBILE MACHINERY WITH INTERNAL COMBUSTION ENGINE

OLIVIER MARCHAND – DIRECTOR OF INNOVATION, CRMT

WWW.AGRITECHDAY.COM



Generated with IA (Copilot)

WHO AM I ?



Olivier MARCHAND

Director Innovation & Development – CRMT

30+ years developing internal combustion engines for sustainable mobility and machines - ENSAM (1990)

1993	**2000**	**2005 → Today**
Wärtsilä	**Cummins**	**CRMT**
⬇	⬇	⬇
Diesel	Natural Gas	Diesel
Natural Gas	(biogas)	bioNGV
(biogas)	…	Hydrogen

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WHO IS CRMT ?



CRMT

CORE EXPERTISE

Powertrains, from design to testing.

Both at the engine test benches and in real usage.

A strong focus on low-carbon fuels, on-road vehicles, special-purpose machinery.



AGCO 4.9 in CRMT's test laboratory in bioCNG and H2 configuration

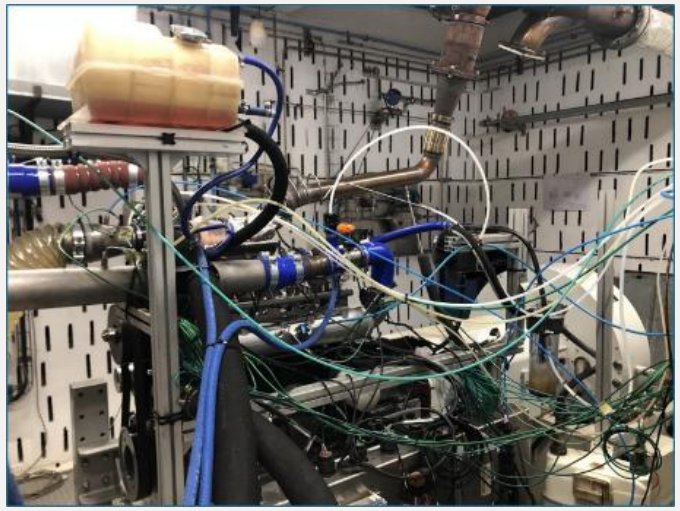
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CONTEXT (STAGE V) & GASEOUS FUELS PROPERTIES

Agricultural machinery needs low-carbon fuels without sacrificing field productivity, continuous-load capability or operational flexibility



bioCNG:

-80% C02 (LCA)

Hydrogen:

carbon-free fuel

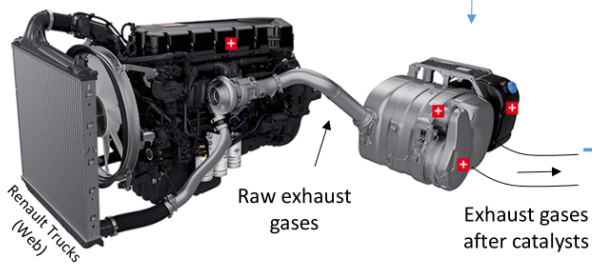
Diesel : 1 liter → 2.7 kg CO2 (exhaust emission)

STAGE V ENGINE (EU)

EXHAUST AFTERTREAMENT CONSIDERATION

Stage V Engines (same as Euro VI)

Internal Combustion Engine + Exhaust Aftertreatment System = **Compliancy with the regulation EU 2016/1628 for exhaust emission**



Pollutants in g/kWh (2020)

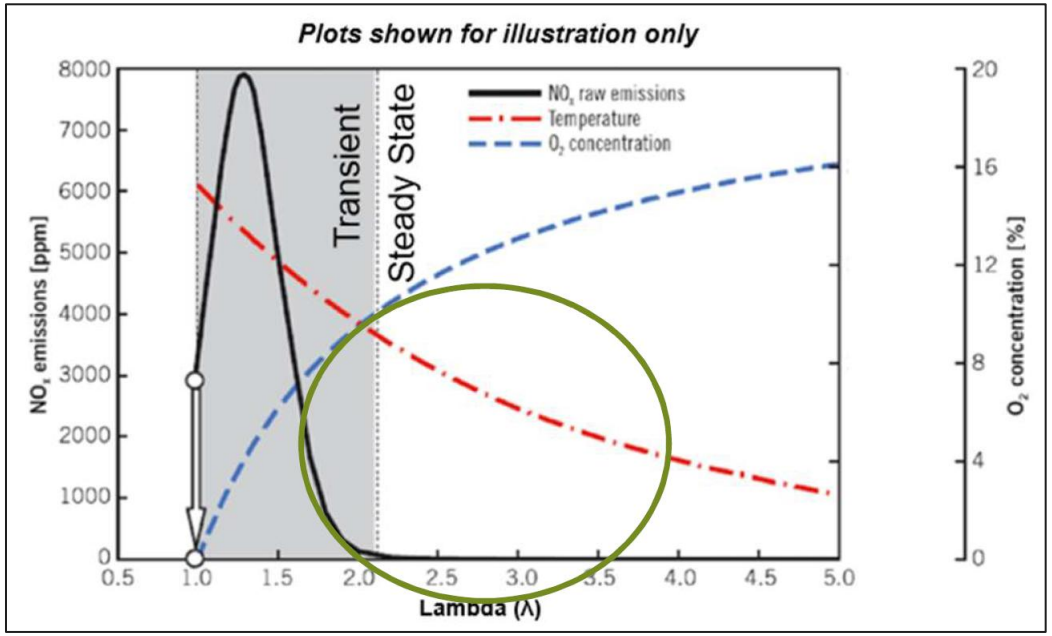
Pollutants	Limits
CO	5
HC	0.19
HC (CH4)	1.84
NOx	0.4
PM	0.015
PN	# 1x10^{12}

Natural Gas engine

All with the best efficiency (low CO2) !

CRMT Powertrain R&D 22 novembre 2016

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High lambda requires a high-performance air system.

NOx compliance is not a fuel property. It is the result of combustion, calibration, transients and aftertreatment working together.

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GASEOUS FUELS PROPERTIES IMPOSE DESIGN CONSTRAINTS

BIOCNG (CNG / METHANE) AND HYDROGEN FLAME PROPERTIES REQUIRE DISTINCT ENGINE-DESIGN APPROACHES.

LOW VOLUMETRIC ENERGY DENSITY MEANS LARGER TANKS, ADDED MASS AND REDUCED PACKAGING FREEDOM

		Gasoline	Diesel	H2 (700b)	CNG (200b)	NH3 (10b)
Density	kg/m3	737	830	40	435	603
LHV	kJ/g	43	43	120	50	19
Relative Vol. Energy Density	-	1.0000	1.1166	0.1502	0.6805	0.3547
Stiochiometric Air-Fuel Ratio	m/m	14.6	14.7	34.1	13.7	6.1
Cetane Number	-	11	>46	-	-	-
Octane Number	-	92	-	115	120-130	110
Adiabetic Flame Temperature	K	2274	2104	2254	1963	1800
Ignition Energy at Stoichiometric & NTP	µJ	~250	-	18	280	14000
Laminar Flame Speed	m/s	0.34	-	1.4	0.35	0.05
Flammability Range	% (vol/vol)	1.3/7.6	-	4/75	5/15	15/28

Figure 4: Fuel Physical Properties – NOTE: Indicative values taken for component mass fractions to illustrate a typical variation in concentration and properties **Table from a PHINIA paper**

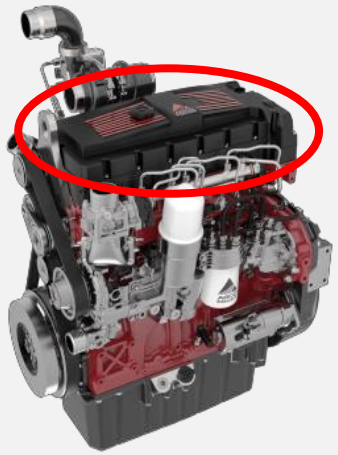
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AGCO 4.9 ENGINE FOR BIOCNG & H2 AND INSTRUMENTATION

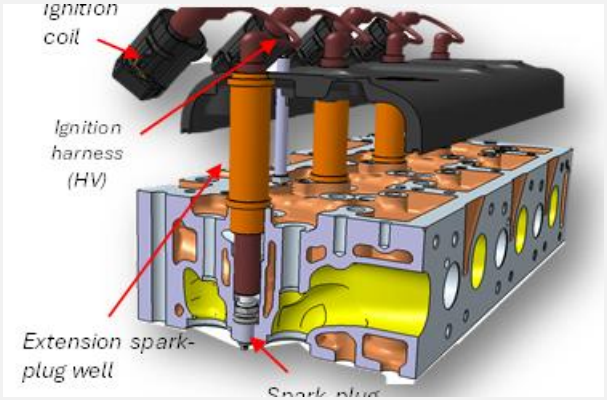
1. **Retain**
2. **Modify**
3. **Add**

Diesel



Simple & Reliable

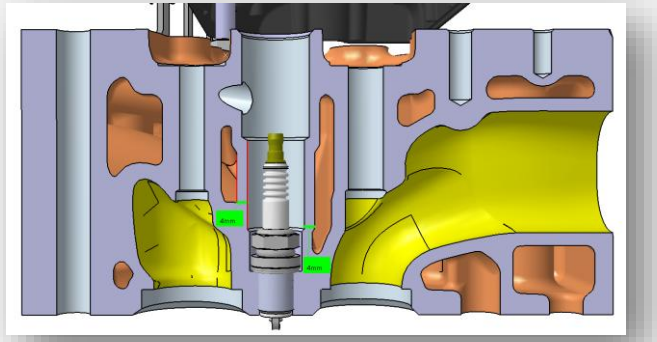
bioCNG & H2



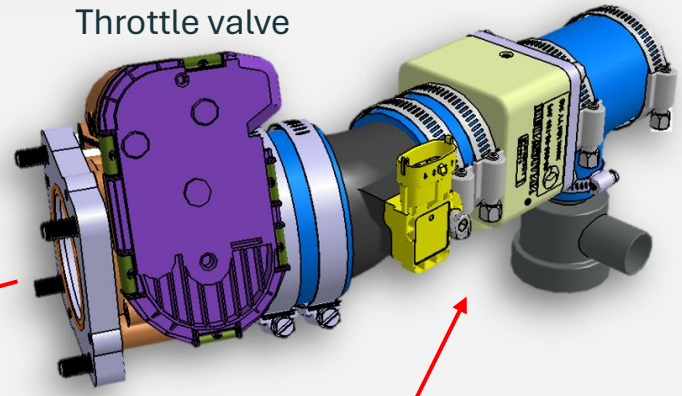
Shared blocks

Modified cylinder head
Spark plugs and coils
Re-machined pistons
CRMT ECU and control
Original single turbo retained

Tested on bench over a wide operating range, with combustion, performance and emissions measurements.



Air & Gas mixture
To the engine



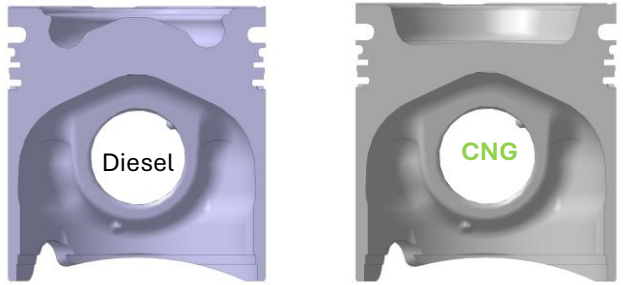
Single-point gas injection (SPI)

BIOCNG CONVERSION

SIMPLE HARDWARE, THERMAL CHALLENGE

Key choices

- **Single-point gas injection (SPI)**
- Stoichiometric operation, λ = 1
- Compression ratio ≈ 12:1
- Original turbocharger retained
- No EGR in the tested configuration

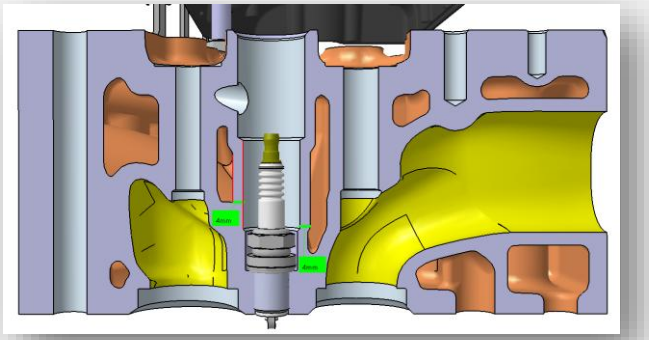


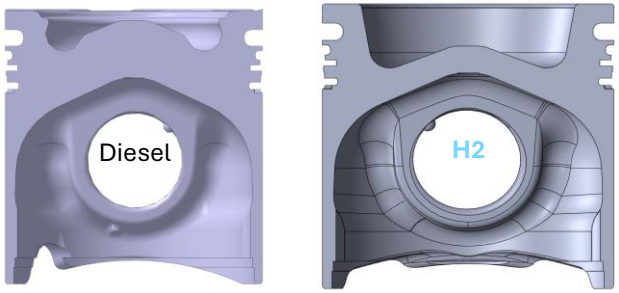
H2 CONVERSION

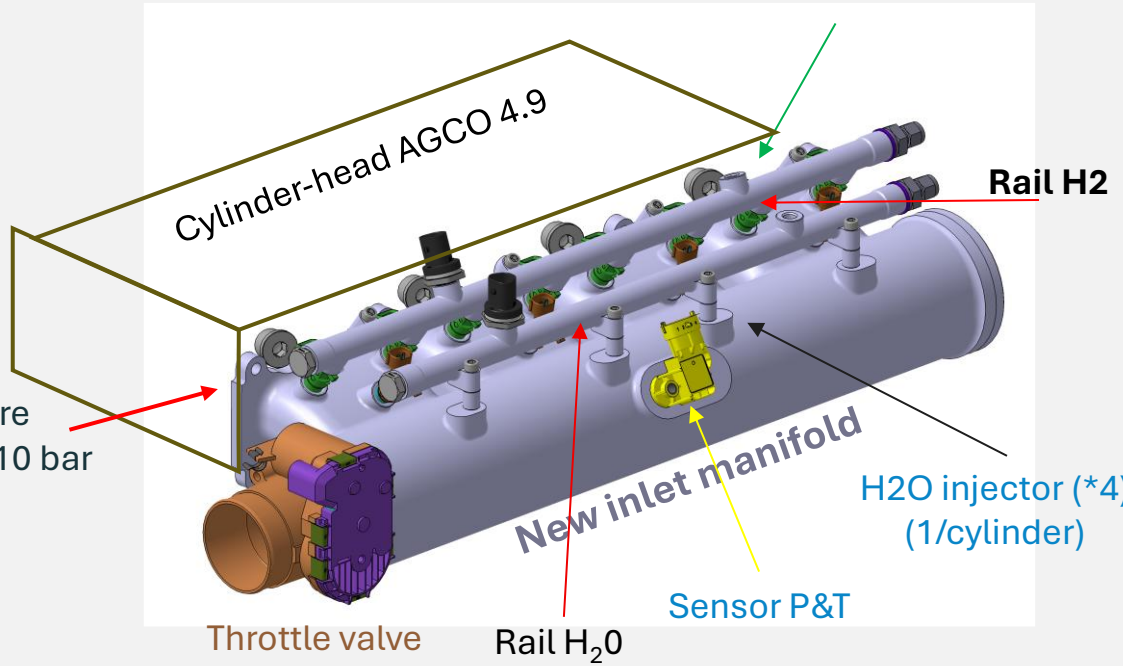
SPECIFIC CYLINDER-PER-CYLINDER H2 DELIVERY (AS PORT-FUEL-INJECTION - PFI)

Key choices

- **Multi-point port fuel injection (MPI and PFI)**
- Phased H2 injection (critical)
- Lean-burn operation, λ > 1 (as much as possible)
- Start with the bioCNG compression ratio ≈ 12:1 (later 13:1)
- Original turbocharger retained





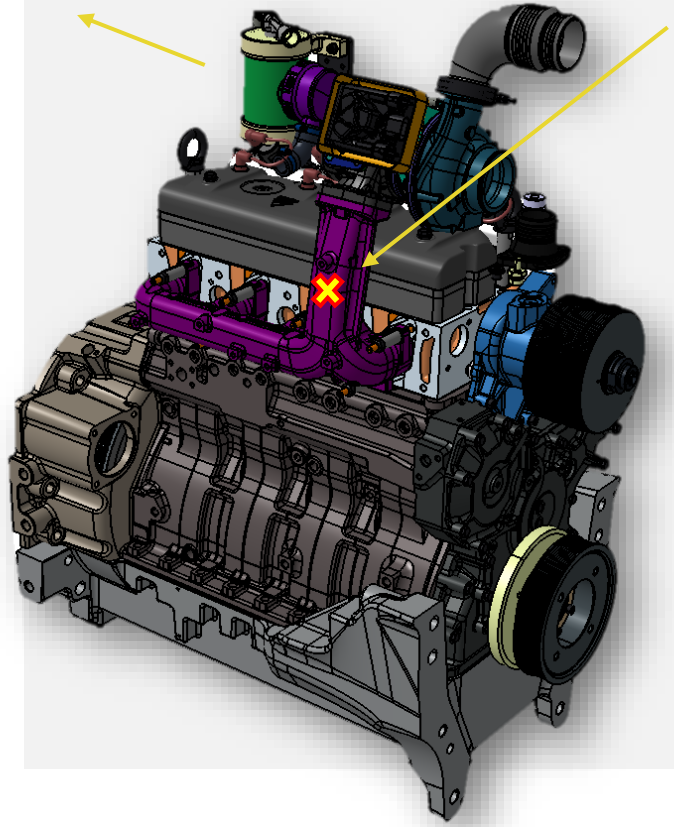


INSTRUMENTATION

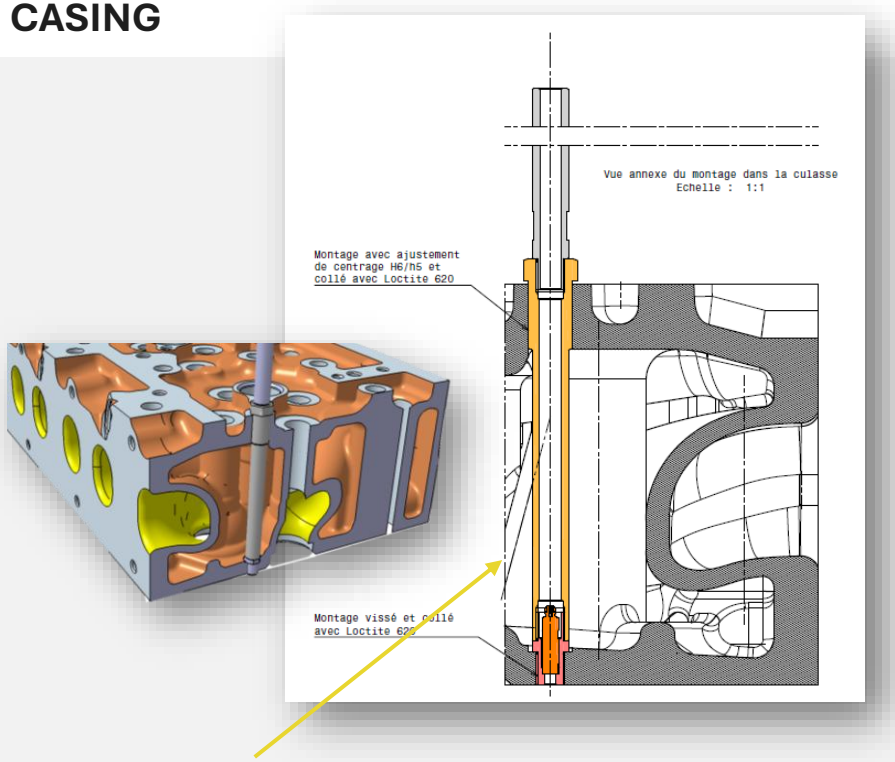
IMPLEMENTATION OF AN IN-CYLINDER PRESSURE SENSOR (PCYL) FOR COMBUSTION ANALYSIS

INSTALLATION OF A TEMPERATURE SENSOR BEFORE THE TURBINE CASING

Emissions:
HORIBA analyzers



Thermal load:
Monitor turbine-inlet temperature to protect the turbocharger and exhaust components.



Combustion behavior:
A custom three-piece sensor holder, developed and machined to install the Pcyl sensor flush with the cylinder head combustion surface to eliminate signal delays associated with recessed sensor mounting, thereby improving the accuracy of combustion analysis.

03

RESULTS

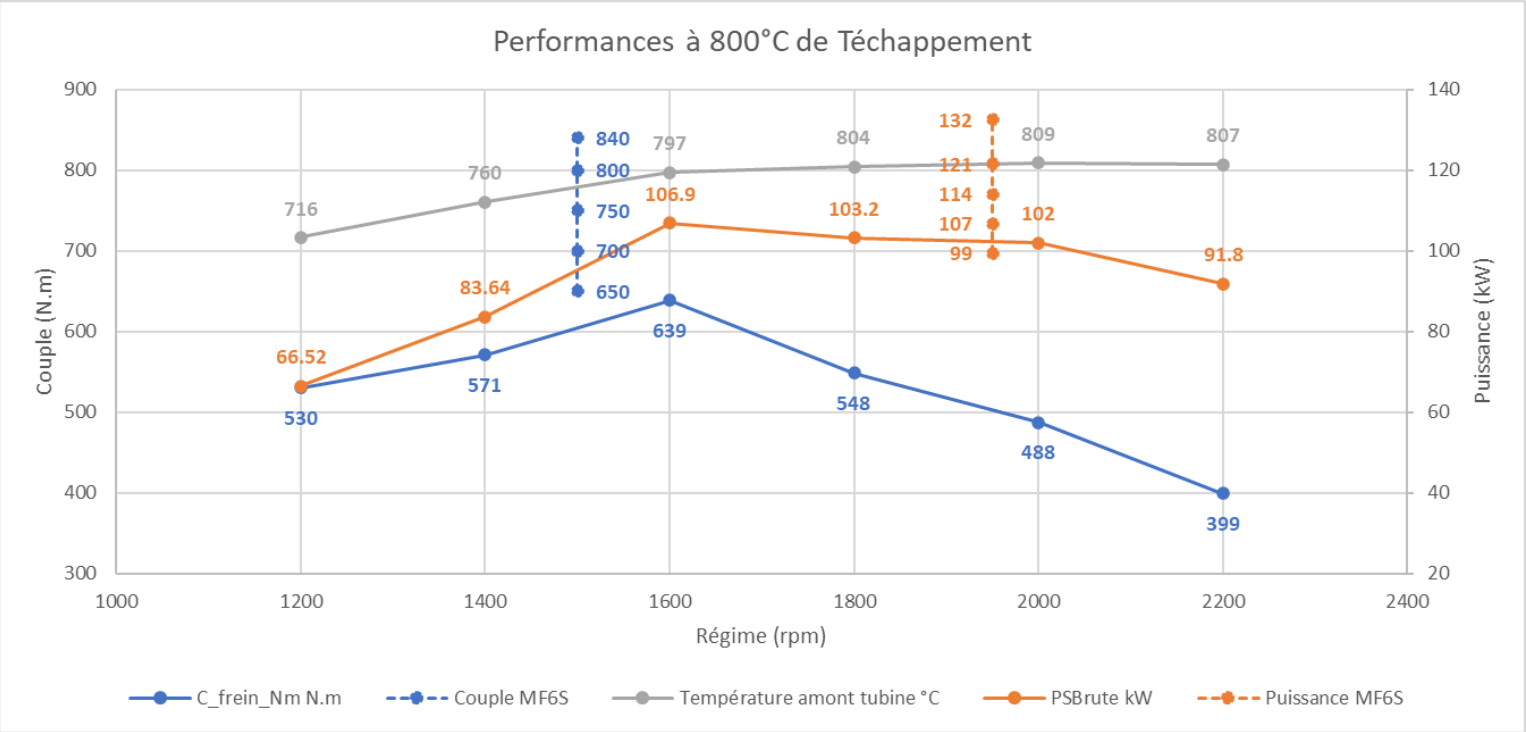
110–115 kW achieved with largely shared hardware

A robust conversion architecture has been demonstrated

Each fuel reveals a fundamentally different high-load limitation

BIOCNG MAXIMUM POWER AND EFFICIENCY

THE LIMITING FACTOR IS THE EXHAUST TEMPERATURE (NOT THE BIOCNG SUPPLY)



115 kW achieved near 800°C turbine inlet

At 700°C, maximum brake power was limited to 93 kW (700°C = selected limit).

Typical continuous Diesel turbine-inlet temperature: 500–600°C

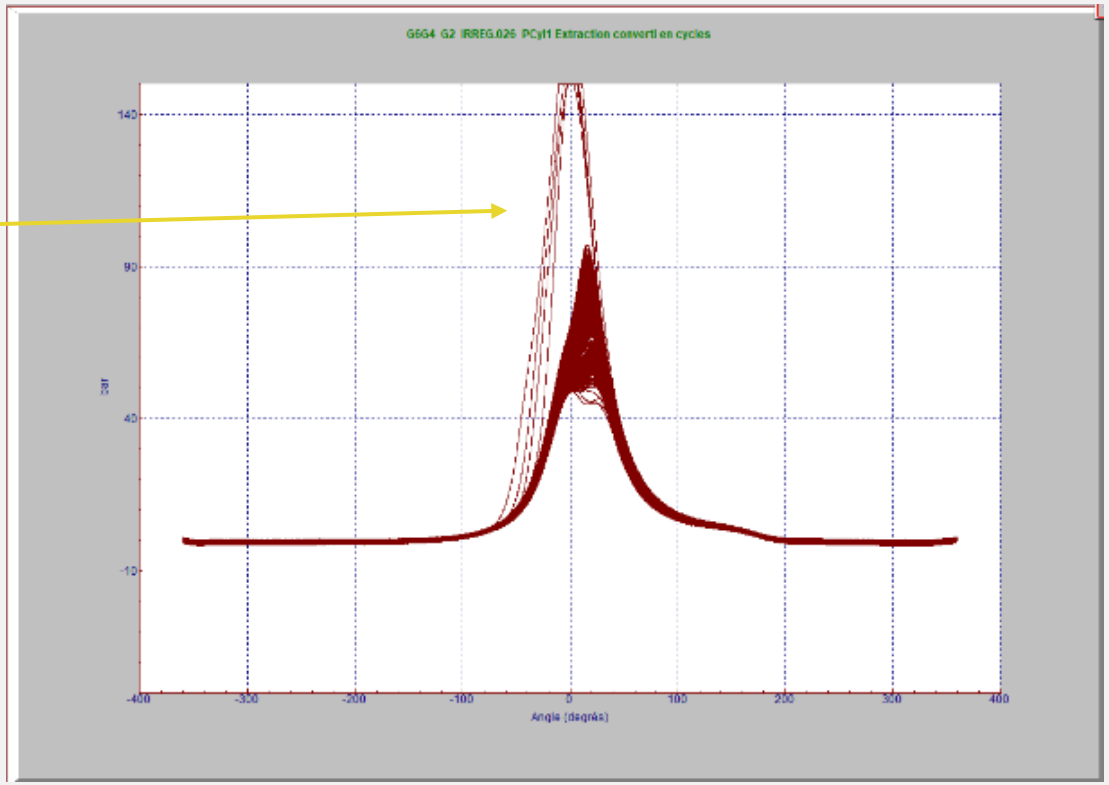
HYDROGEN MAXIMUM POWER AND EFFICIENCY

ABNORMAL COMBUSTION (MISFIRE OR PRE-IGNITION) DEFINE THE HIGH-LOAD BOUNDARY

Large cycle-to-cycle variations and pressure saturation up to the 150-bar acquisition limit.

Pre-ignition may arise from several mechanisms: Lubricant droplets or deposits are possible contributors, alongside hot spots, residual gases and mixture inhomogeneity.

Cylinder-pressure cycles during pre-ignition events

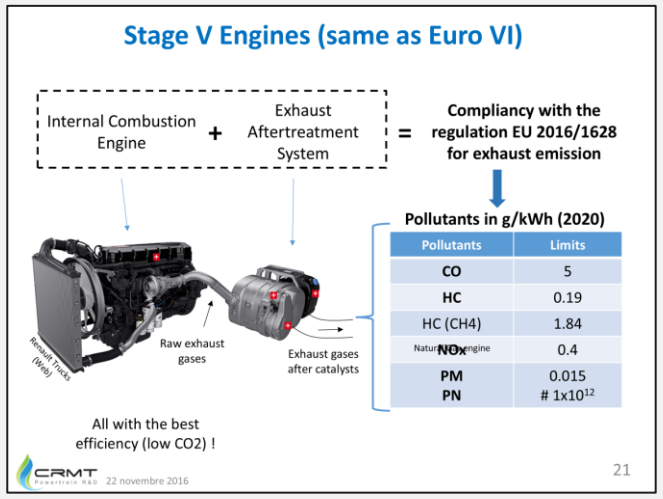


STAGE V IN HYDROGEN MODE

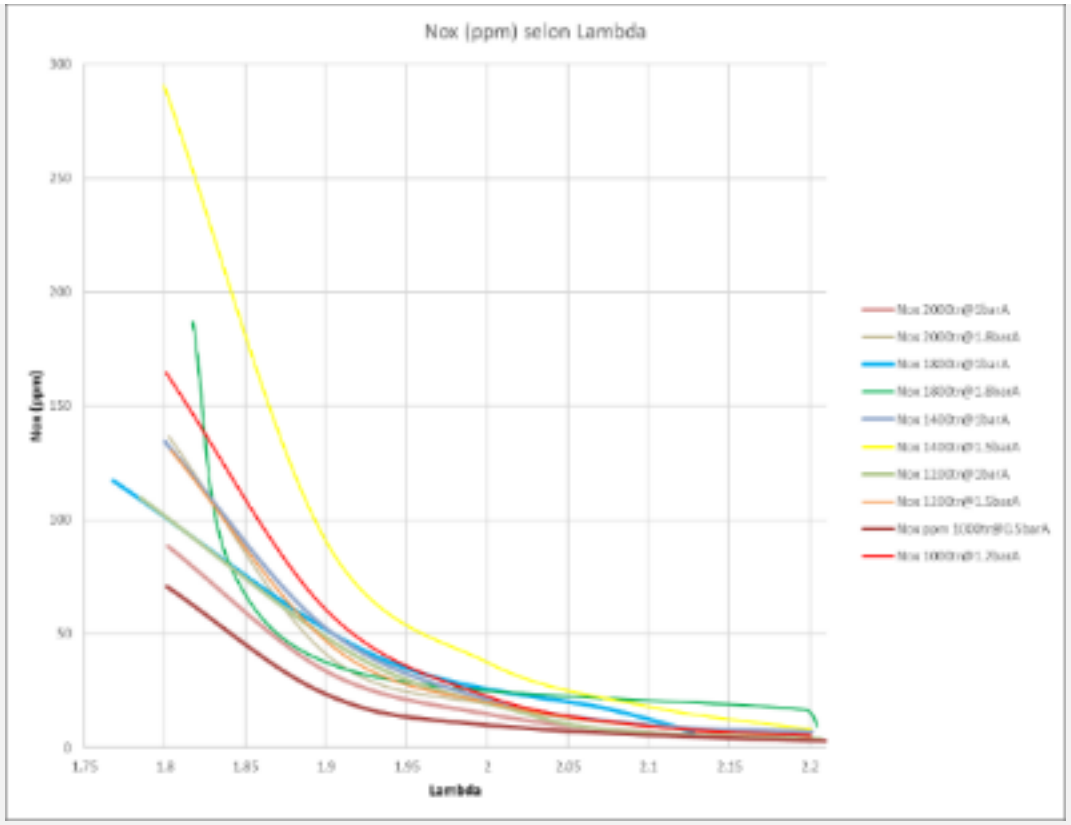
BELOW λ ≈ 1.95, NOX RISES RAPIDLY

NOx falls sharply when the mixture stays ultra-lean (<25ppm measured over part of the stabilized mid-load range).

Ultra-lean combustion is effective, but Stage V compliance must still be demonstrated over a complete transient cycle. A small SCR may remain necessary.



NOx engine out vs lambda in H2 combustion (AGCO 4.9 in H2)

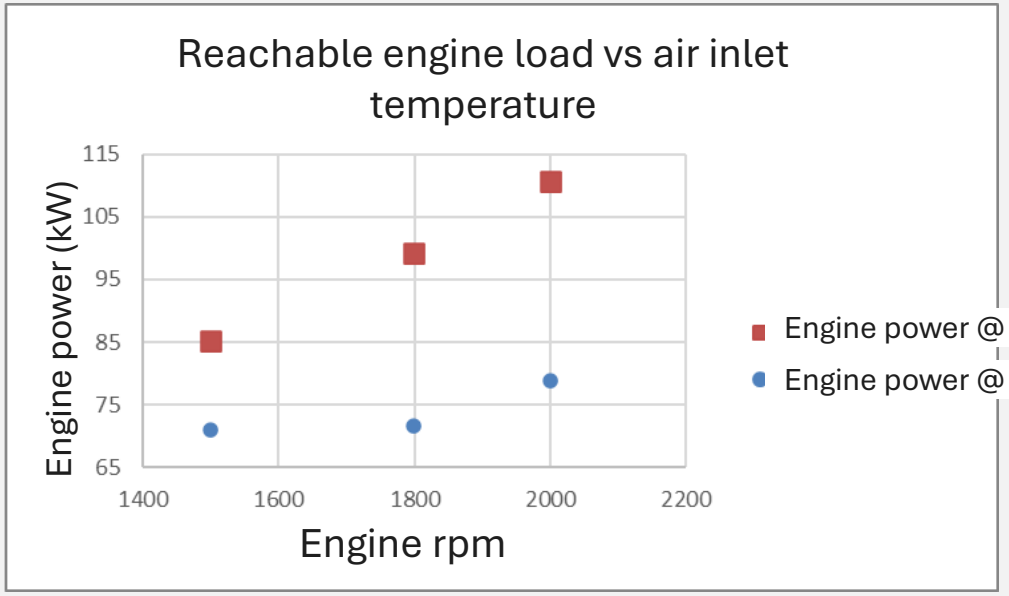


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INLET AIR TEMPERATURE (BIOCNG & H2) & INJECTION PHASING (H2)

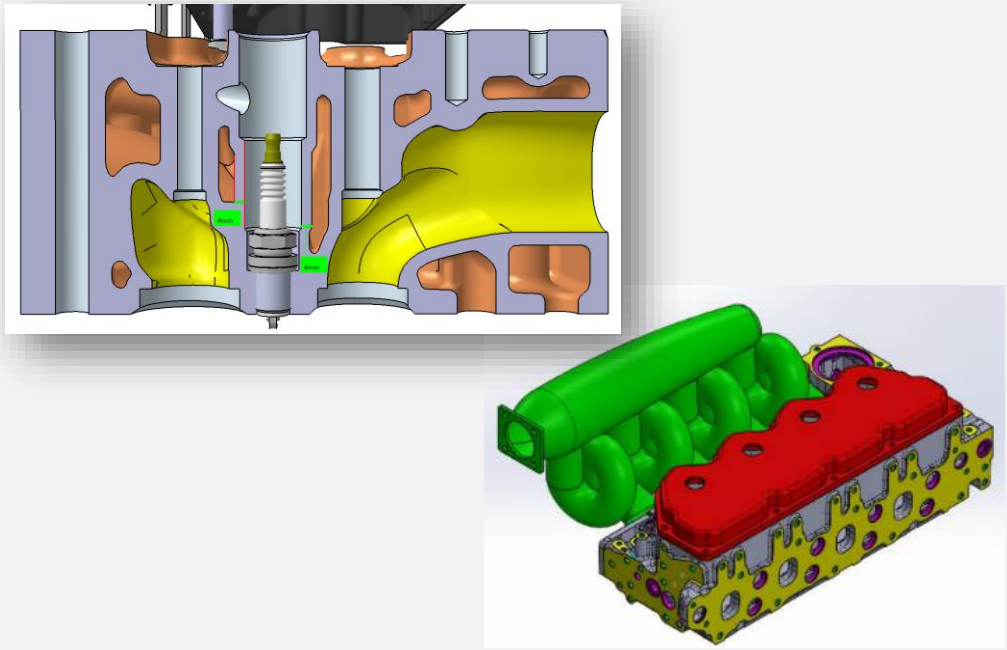
DECISIVE FOR HIGH LOAD PERFORMANCES

Intake temperature: At 40–45°C, pre-ignition and backfire increased near the high-boost boundary, reducing the stable torque envelope



Engine power versus inlet-manifold temperature

Injection phasing: Backfire increased when end of injection was delayed toward ≈470°CA. A start-of-injection ~ 390–400°CA improved behavior.



Potential inlet-manifold with longer runners

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BIOCNG AND H2 COMPARISON TO DIESEL

Items	Diesel	bioCNG	Hydrogen
Main issue	CO2 emission (fossil)	Exhaust temperature	Combustion control: pre-ignition/backfire
Combustion	Diffusive: Lean burn	Premixed: Stoichiometric	Premixed: Ultra-lean burn (ideally > 2)
Torque / Power	Baseline (150kW and 800Nm)	115 kW demonstrated; higher power requires further thermal optimisation	110 kW demonstrated; further combustion and air-system optimisation required
Engine efficiency	> 42%	37% (lower than H2)	Closer to Diesel - 39%
Exhaust aftertreatment system	SCR (deNOx) + DOC + DPF + ASC	Three-Way-Catalyst	None to light SCR (deNOx)
NOx (raw from engine outlet)	High	High	Very low
NOx	Stage V compliant	Stage V compliant	Stage V or more stringent limits (to be demonstrated on certification cycles)

04

CONCLUSIONS

1/ Engine demonstration

2/ To field-ready machine (tractors ...)

3/ Further engine optimisation

ENGINE DEMONSTRATION

THE CONVERSION TO BIOCNG AND H2 OF A DIESEL 4.9 AGCO ENGINE WAS DEMONSTRATED

- Useful power and torque are achievable while using most of the original architecture (including the turbocharger).
- Well-identified operating limits, with approximately 110 kW achieved on the AGCO 4.9-litre engine (respectively 37% and 39% efficiency for bioCNG and H2). Diesel max power & torque 150kW & 800Nm.
- A converted machine can be designed. Considering Stage V, NOx limits in H2 still to be demonstrated.

<u>A proposed homologation approach for low-volume retrofits</u>

In our view, homologation for low-volume retrofit machinery should retain essential test-bench certification while introducing proportionate requirements and more representative in-use validation with PEMS.
ISM: In-Service-Monitoring ; PEMS: Portable Emissions Measuring System

FIELD READY AGRICULTURAL MACHINE (TRACTORS ...)

THE ENGINE IS NOT THE ONLY QUESTION ...

- Storage, operating range, safety, maintenance, certification and TCO will decide the transformation viability.
- Machine control integration and validation remain to be performed

FURTHER ENGINE OPTIMISATION

FOR ADDITIONAL POWER

- The development pathways required to approach the Diesel power rating have been identified. Constraints differ:
  - bioCNG is thermally limited.
  - Hydrogen is limited by the air system and abnormal combustion at high load → GH-SAFE (H2)

QUESTIONS & ANSWERS

From Diesel to BioCNG and Hydrogen

Transforming Agricultural Mobile Machinery with Internal Combustion Engine

CRMT thanks **AGCO SAS** as part of the **ARHYSTOTE project** for the authorization to use real data.

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