

JOINT FINAL EVENT 12 & 13TH NOVEMBER 2019, SANTA OLIVA, SPAIN



Efficient additivated gasoline lean engine

Project overview and preliminary results

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*This project has received funding from
the European Union's Horizon 2020
research and innovation programme
under grant agreement no 724084*

Context and objectives

► GV-02-2016: Technologies for low emission light duty powertrains

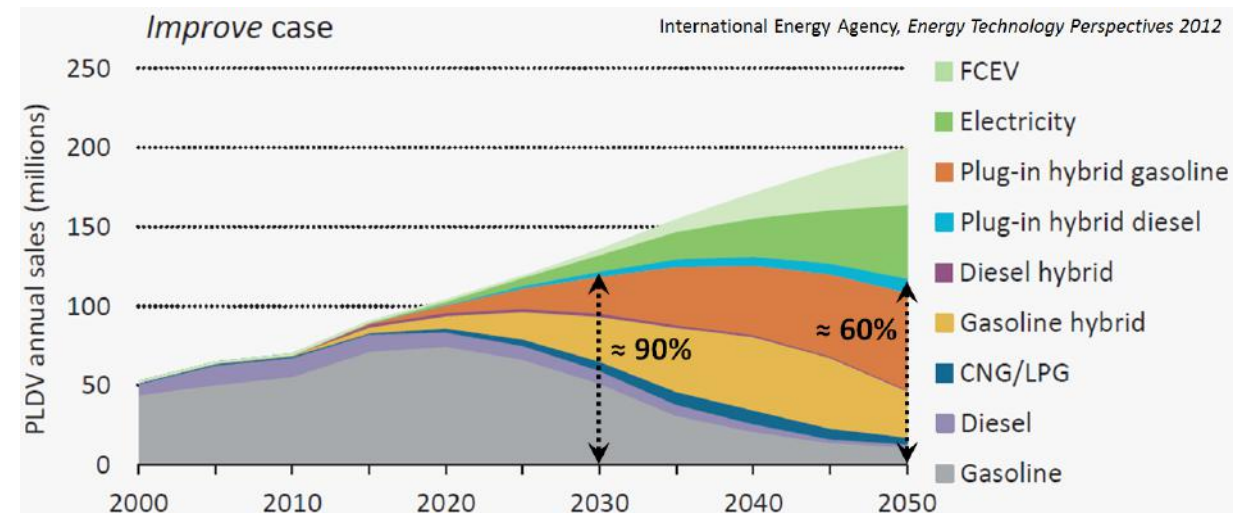
- Scope: future combustion engines for electrified powertrains
 - New combustion processes, sensing, control and after treatment systems
 - Future ambitious energy and emission targets
 - Special attention should be given to the assessment and reduction of particle emissions below 23 nm



► Research and Innovation Action

► Objectives

- Long term fleet target of **50 g/km CO₂** (WLTP)
- Peak brake thermal efficiency of **50%**
- Real driving €6 values with no conformity factor



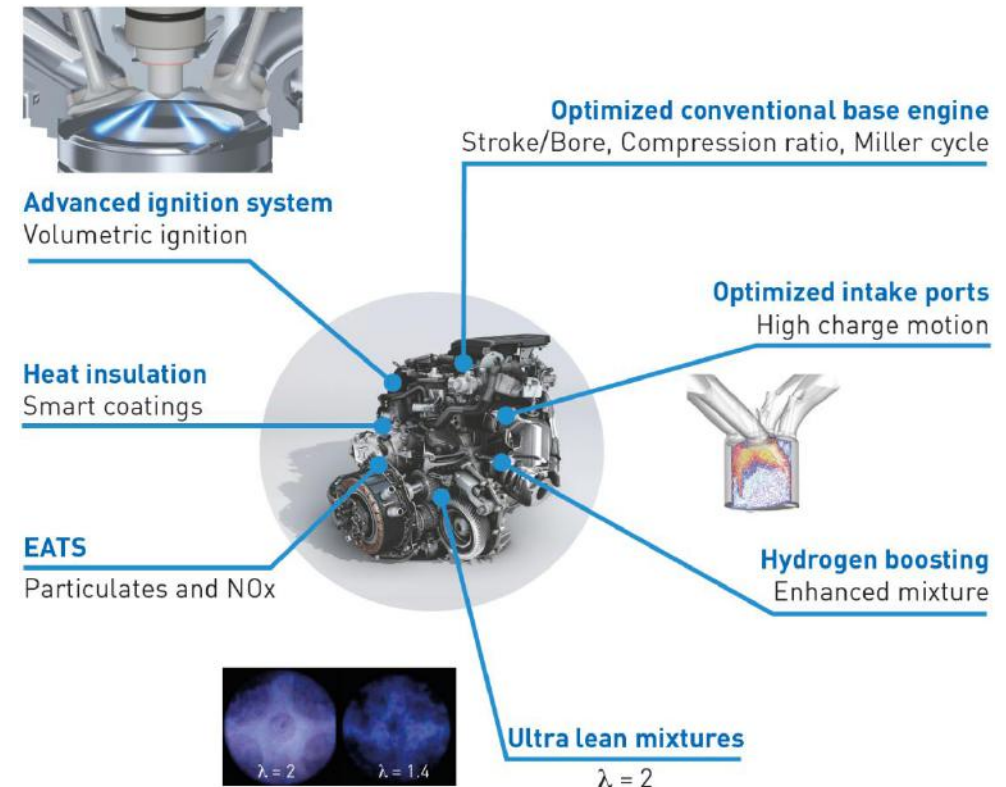
EAGLE Consortium

- ▶ 9 Partners from 4 countries
 - ▶ IFP Energies nouvelles (coordinator)
 - ▶ FEV Europe GmbH
 - ▶ Università degli Studi di Napoli Federico II
 - ▶ Renault SAS
 - ▶ Universitat Politècnica de València
 - ▶ RWTH Aachen
 - ▶ Saint-Gobain CREE
 - ▶ CPT Group GmbH (ex Continental)
 - ▶ CPT France SAS (ex Continental)
- ▶ Funding ≈ 6M€
- ▶ October 2016 - March 2020



Engine concept

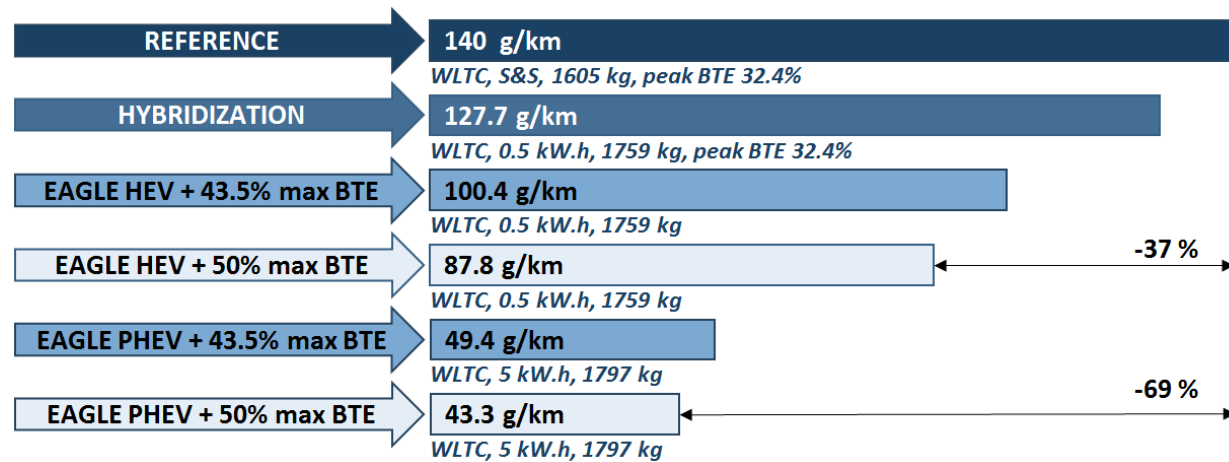
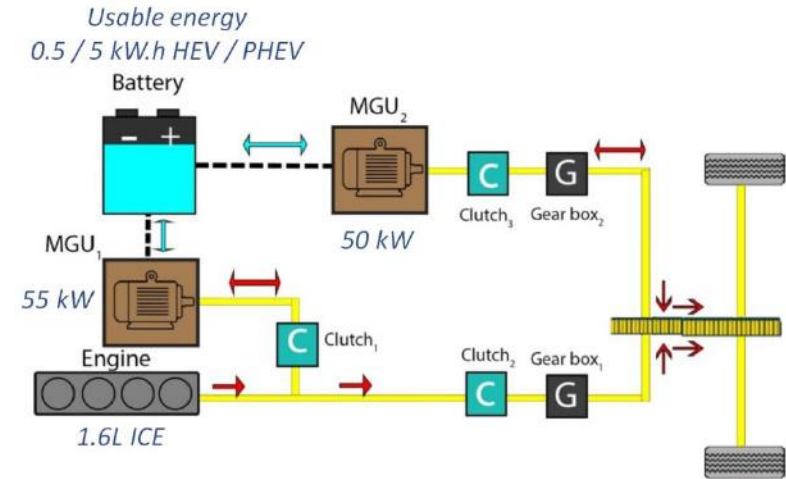
- ▶ Overall concept
 - ▶▶ Breakthrough combustion system
 - ▶▶ Ultra-lean mixtures
 - ▶▶ H₂ boosting
 - ▶▶ Pre-chamber ignition system
 - ▶▶ Optimized intake ports
 - ▶▶ Smart coatings
 - ▶▶ Optimized NO_x after-treatment systems
- ▶ Final demonstrator: multi-cylinder engine
 - ▶▶ Including turbocharging and EAT systems



Activities expected to focus on TRL 3-5

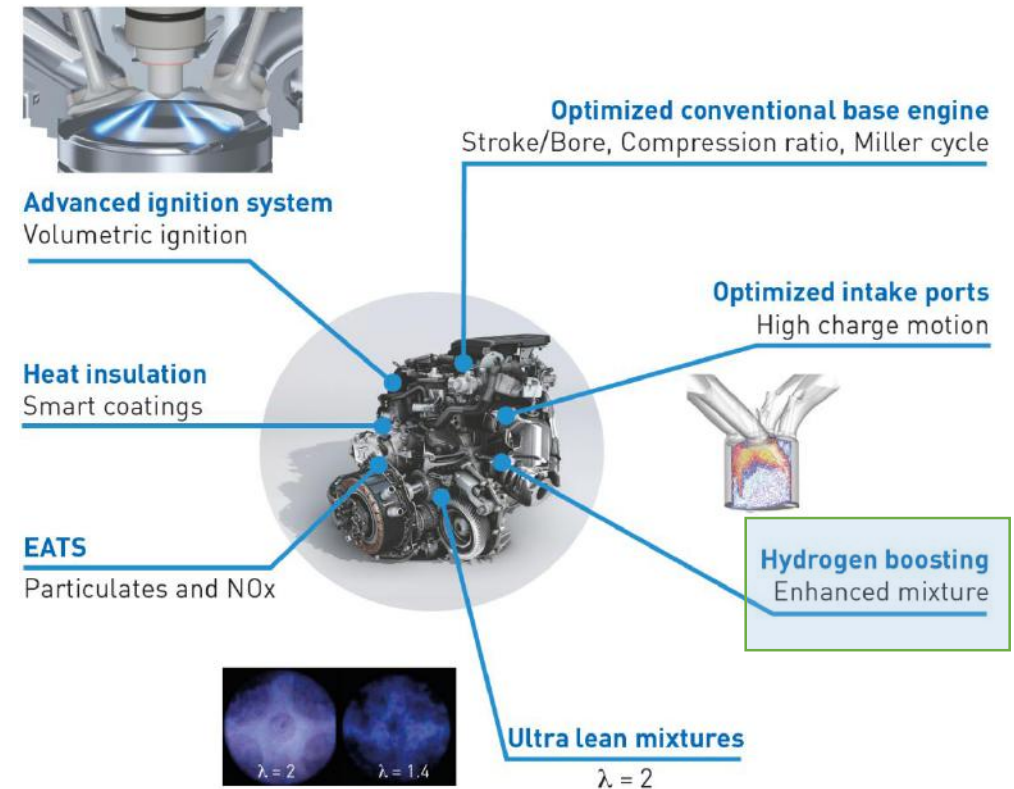
Vehicle simulations

- ▶ EAGLE core application: C-class vehicle with a multi-mode series/parallel architecture
- ▶ 50 gCO₂/km can be achieved without 50 % BTE (battery dependent)
- ▶ Why increasing the ICE brake thermal efficiency ?
 - ▶ To further minimize fuel consumption in RDC, especially in highway conditions
 - ▶ To lower the battery requirements and costs
 - ▶ To further lower the HEV CO₂ emissions



Ultra-lean combustion with hydrogen

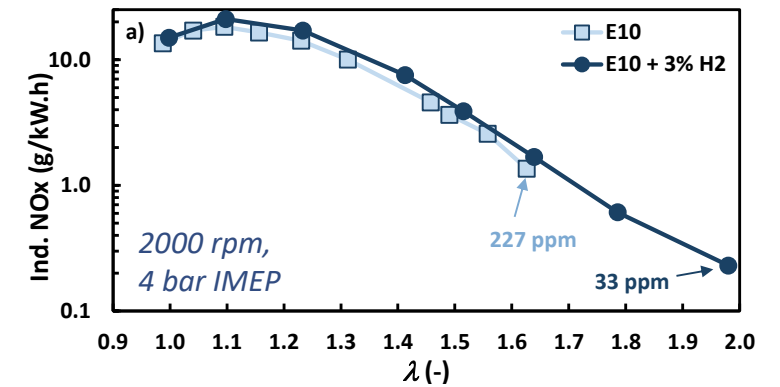
- ▶ H₂ supplementation for lean burn SI engines already studied back in the 1970s
 - ▶ EAGLE is extending the current knowledge with an up-to-date combustion system
- ▶ New context for H₂
 - ▶ Now seen as viable energy carrier
 - ▶ Why not for clean ICE?
- ▶ Minimal H₂ amount of 2-4 % vol. to achieve $\lambda = 2$
- ▶ Major and delicate challenge: efficient on-board production
 - ▶ Water electrolysis and fuel reforming difficult with regards to overall efficiency and package, resp.



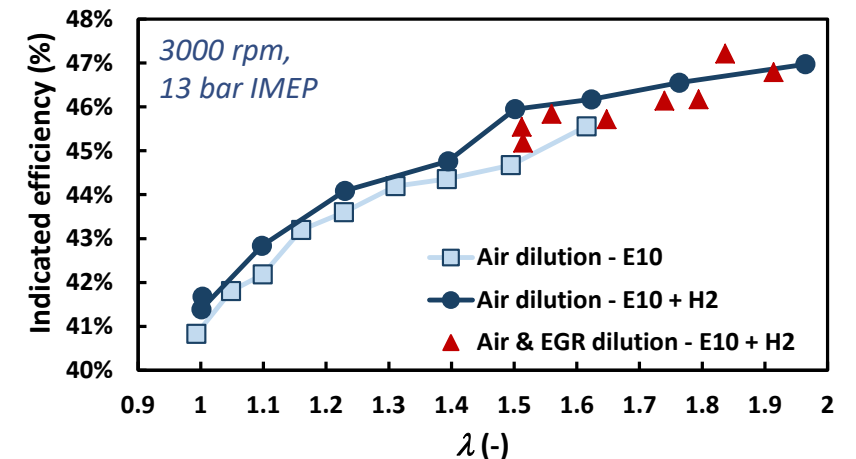
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- ▶ Major and delicate challenge: efficient on-board production
 - ▶ Water electrolysis and fuel reforming seem compromised

NO_x reduction thanks to dilution, not to H₂

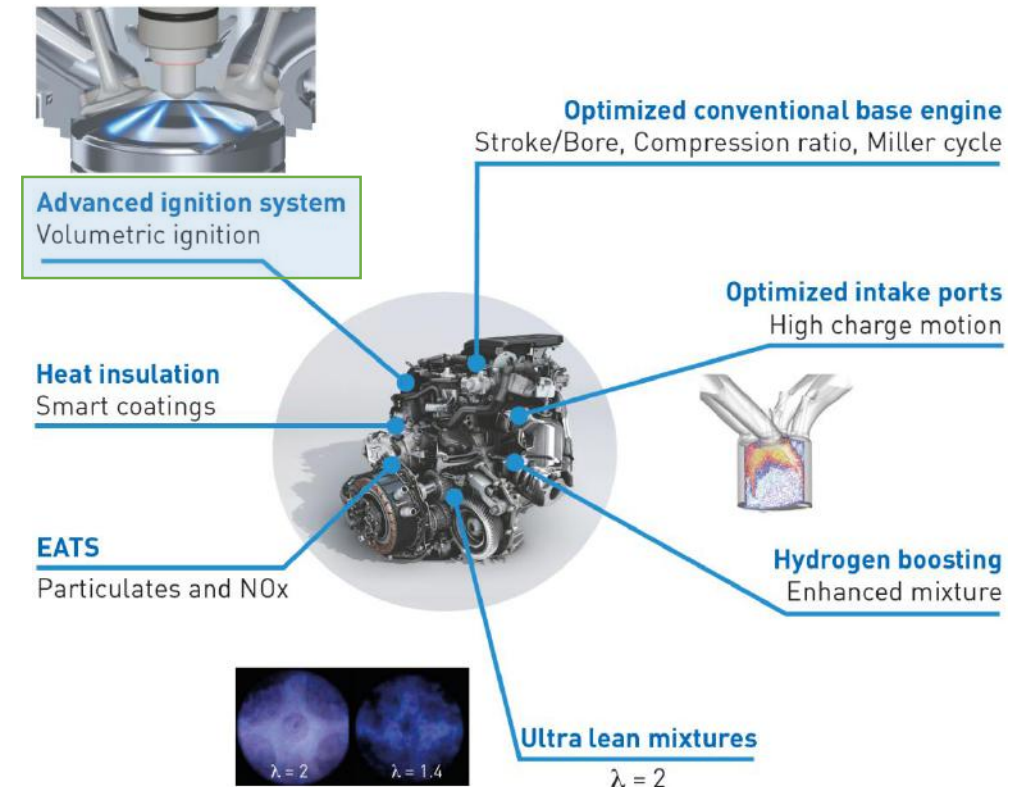
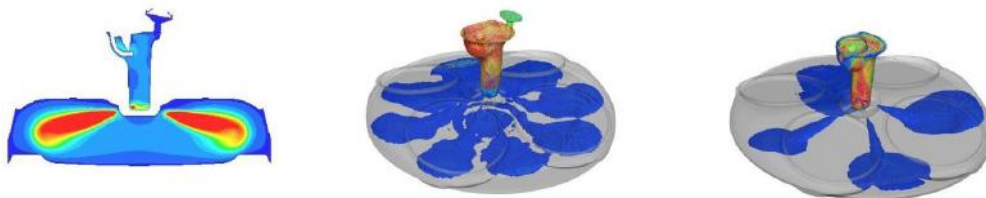


Towards high efficiency with high dilution rates, short burn durations and optimal combustion timings



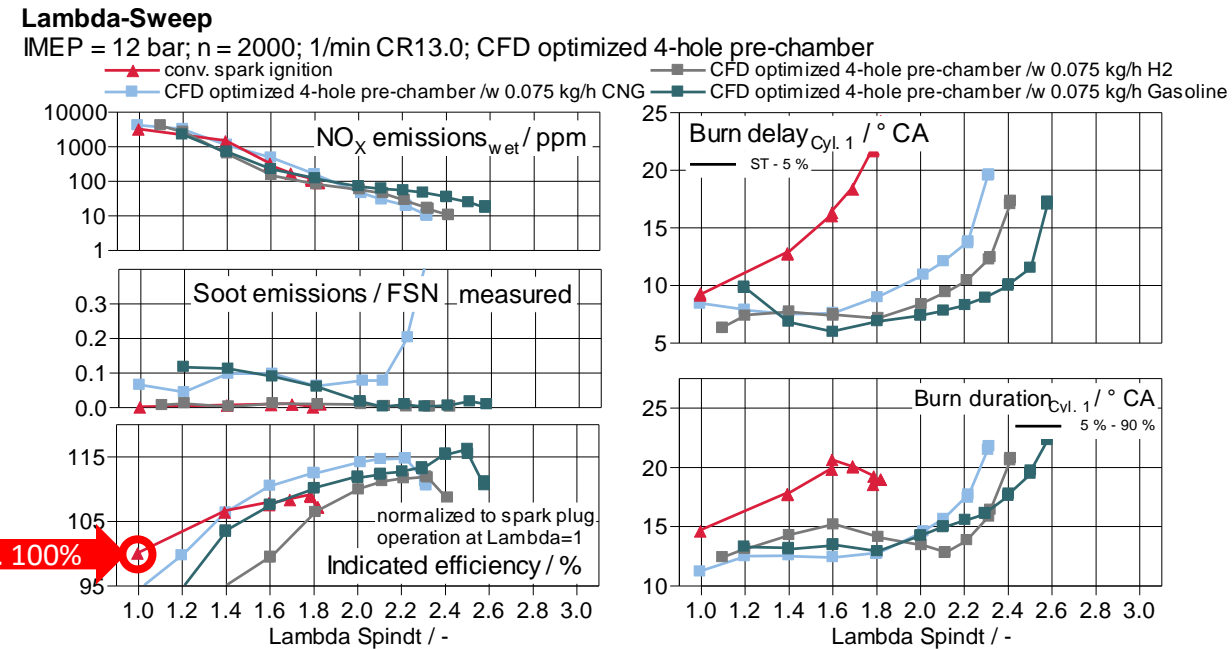
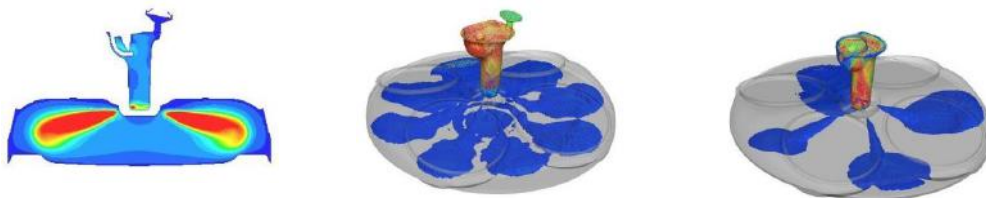
Ultra-lean combustion with pre-chamber

- ▶ Space ignition technology
 - ▶ To ignite a larger share of the combustible volume
 - ▶ To increase the energy transfer to fresh gases
 - ▶ To reduce the flame travel
- ▶ Active pre-chamber ignition system required for ultra-lean mixtures
 - ▶ Stoichiometric mixture in the pre-chamber
 - ▶ Homogeneous lean mixture in the main combustion chamber



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Short burn durations up to $\lambda = 2$ and above

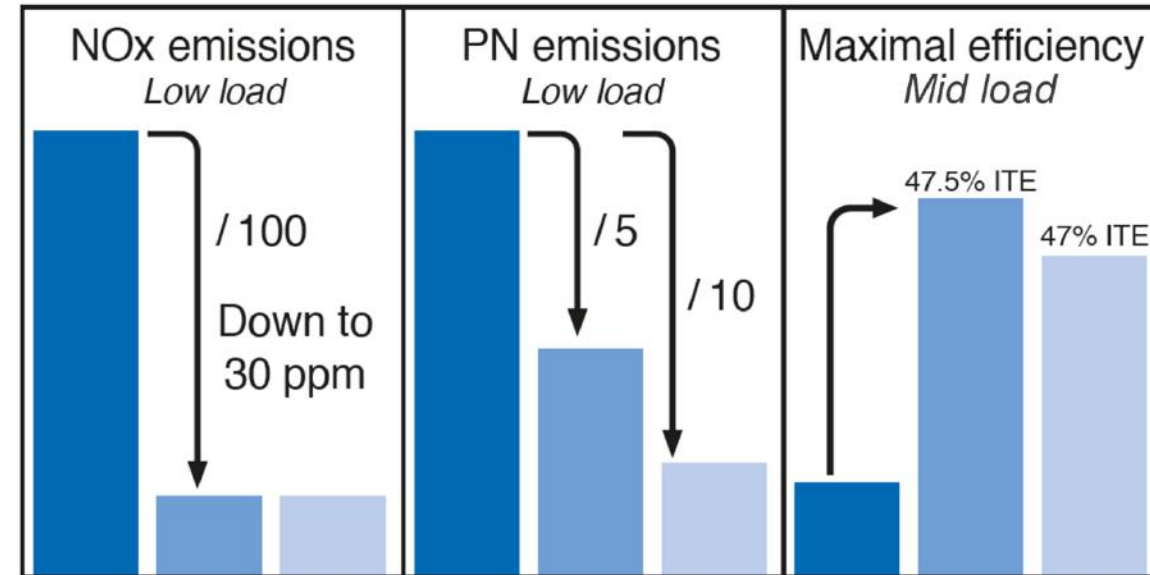
Limited smoke emissions with near-stoichiometric mixtures in pre-chamber

Stable combustion process possible up to $\lambda = 3$ (excellent pre-conditions for calibration)

*Compatible with **different fuels** (liquid or gaseous fuels)*

Ultra-lean combustion

- ▶ Distinct positive impact of dilution on NOx emissions
 - ▶ High NO₂/NOx ratio at $\lambda = 2$
- ▶ Higher potential for PN emissions reduction with hydrogen supplementation
 - ▶ H₂ fueled pre-chamber could be a PN-beater
- ▶ Better overall performance with a gasoline fueled pre-chamber ignition system
 - ▶ Maximal indicated efficiencies higher than 48%
 - ▶ Stable operation over a large λ -window
 - ▶ $\lambda = 2$ (and above) possible over a large operating range



Reference: spark-plug, w/o H₂, $\lambda = 1$

Pre-chamber, w/o H₂, $\lambda = 1$

Pre-chamber, w/ H₂ boosting, $\lambda = 1$
Energy cost of H₂ on-board production is not considered, here

Engine configuration: CR 14:1-15:1,
EIVC, neutral low-pressure loop

EAGLE combustion system

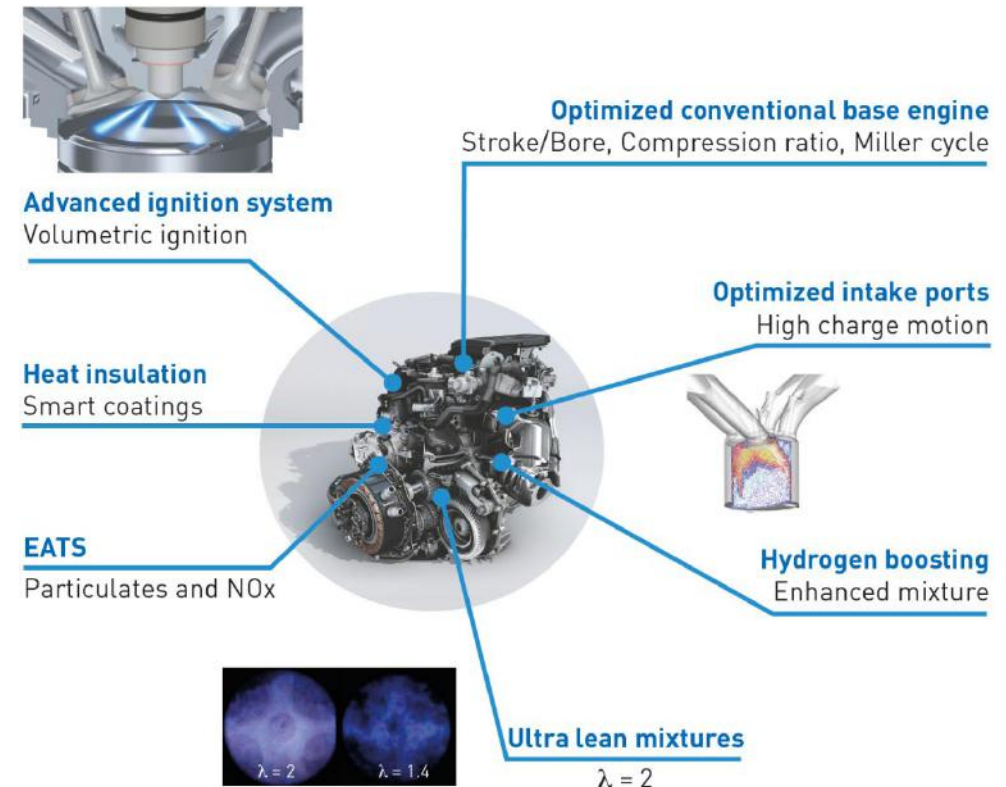
- ▶ Designed for ultra-lean conditions through 1D simulations & 3D CFD

High thermodynamic efficiency
Low cooling losses
Turbulent jet ignition



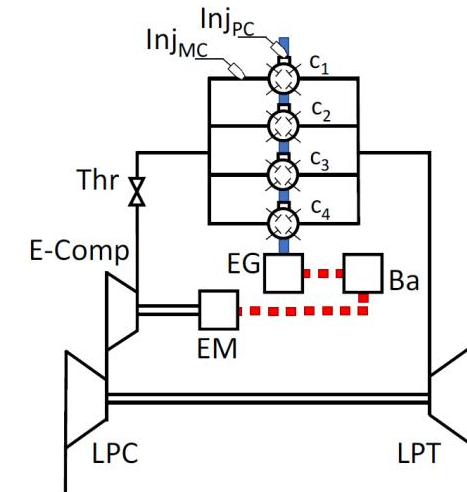
High compression ratio
S/B ratio, combustion chamber shape
Charge motion

- ▶ Experimentally assessed with single cylinder engine tests and more than 15 configurations
 - ▶ Two injection modes for the main chamber
 - ▶ Two cylinder head concepts
 - ▶ Three pre-chamber variants
 - ▶ Hydrogen supplementation
 - ▶ Closed loop combustion control
 - ▶ Insulation coating (on-going)



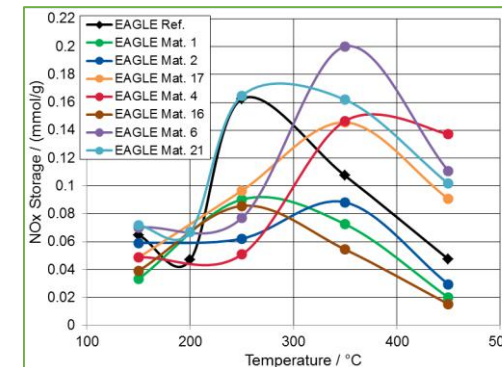
EAGLE multi-cylinder engine

- ▶▶ Dual stage turbocharging system
 - ▶▶ Low Pressure Variable Nozzle Turbine
 - ▶▶ High Pressure E-charger
 - ▶▶ Combined with flexible valve actuation (VVT & VVL) to achieve $\lambda = 2$ over the complete engine map



- ▶ Dual stage turbocharging system
 - ▶ Low Pressure Variable Nozzle Turbine
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 - ▶ Combined with flexible valve actuation (VVT & VVL) to achieve $\lambda = 2$ over the complete engine map
- ▶ Exhaust after-treatment
 - ▶ Oxidation catalyst
 - ▶ Gasoline Particulate Filter
 - ▶ Innovative NOx Storage Catalyst

Material selection and mini cat evaluation



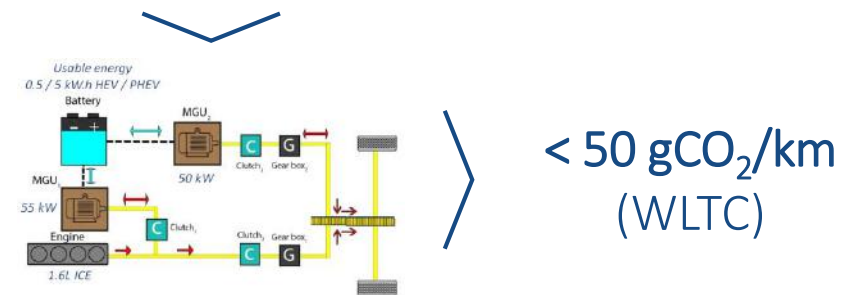
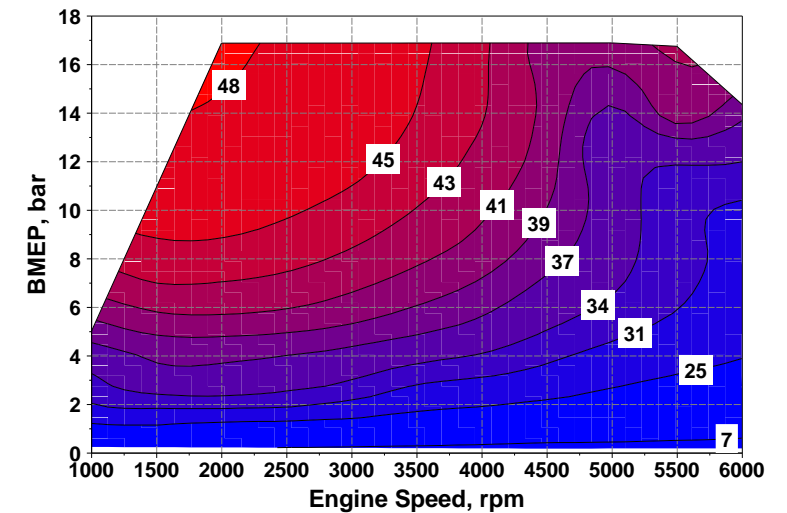
Coating of a full size NSC demonstrator



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- ▶ Exhaust after-treatment
 - ▶ Oxidation catalyst
 - ▶ Gasoline Particulate Filter
 - ▶ Innovative NOx Storage Catalyst
- ▶ Experimental assessment on-going
 - ▶ Expected maximal BTE higher than 48%
 - ▶ Final results to be published in 2020, including updated vehicle simulations for WLTC and RDC

Simulated brake thermal efficiency map
(E-charger power not included)



Communication and dissemination

➤ <https://www.h2020-eagle.eu/>

- Press releases
- Flyer
- Full lists of publications, conferences, EU related events and other communications made by the EAGLE consortium
- Presentations made during the EAGLE workshop
- Several publications already available for
 - Vehicle simulations
 - Insulation coatings
 - Pre-chamber ignition
 - Hydrogen supplementation
- More to come in 2020



The infographic is divided into several sections:

- Overall concept:** Focuses on reducing CO2 emissions through advanced combustion, hydrogen supplementation, and improved thermal efficiency.
- Scenario:** Discusses the impact of different scenarios on CO2 emissions and fuel consumption.
- Eagle achievements:** Lists key milestones such as:
 - Advanced Ignition System (AIS): Development of a pre-chamber ignition system.
 - Advanced Insulation Coatings (AIC): Development of high-temperature resistant coatings.
 - Advanced combustion coatings for the thermal barrier (ACC): Development of coatings for the combustion chamber.
 - After treatment devices for particulates and NOx (ATD): Development of catalytic converters.
- Key figures:** Provides a summary of project statistics, including a budget of 1,880,000,740 €, a start date of 1 October 2018, and a duration of 48 months.
- Other sections:** Includes information on hydrogen supplementation, ultra-low combustion, and combustion system optimization.

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Thank you

Any questions?



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