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PaREGEn + PEMs 4Nano

Efficient additivated gasoline lean engine

Project overview and preliminary results

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EAGLE

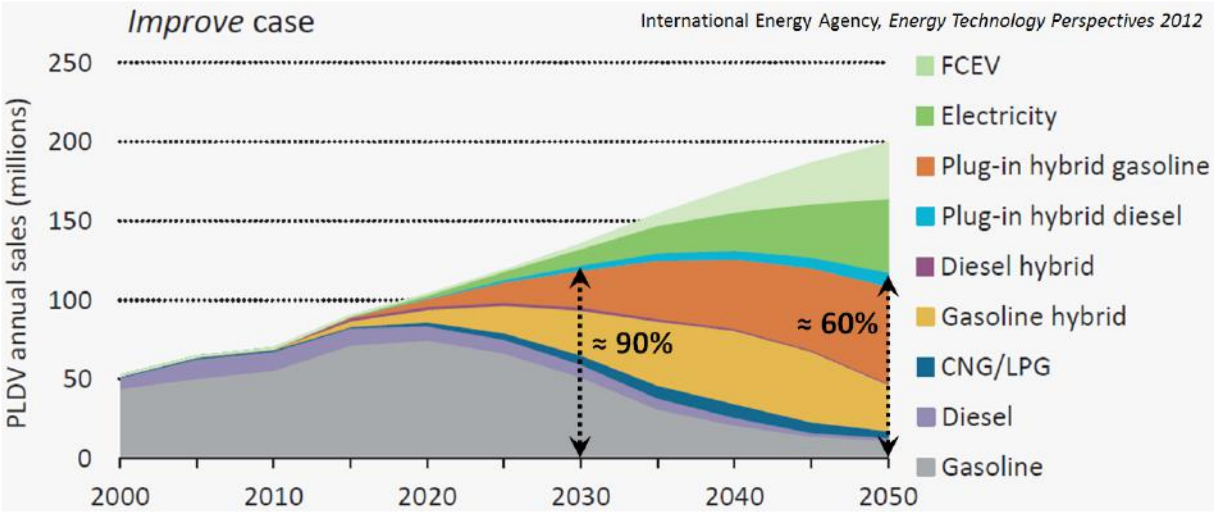
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 724084

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 CO_2** (WLTP)
  - Peak brake thermal efficiency of **50%**
  - Real driving €6 values with no conformity factor

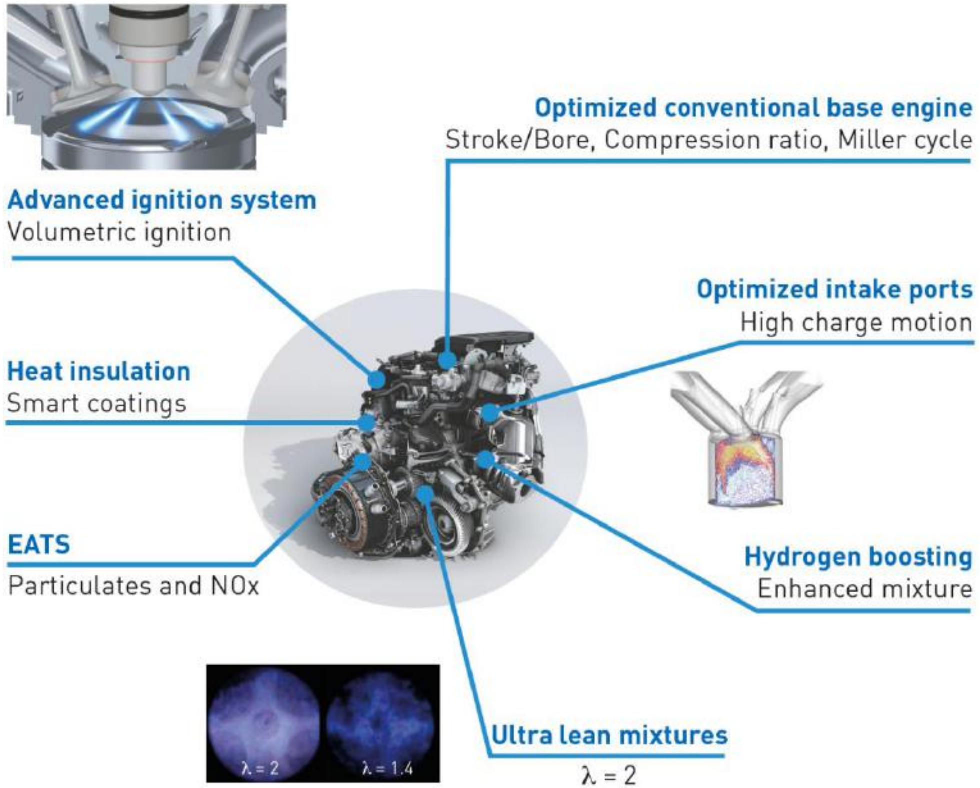


EAGLE Consortium

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

Engine concept

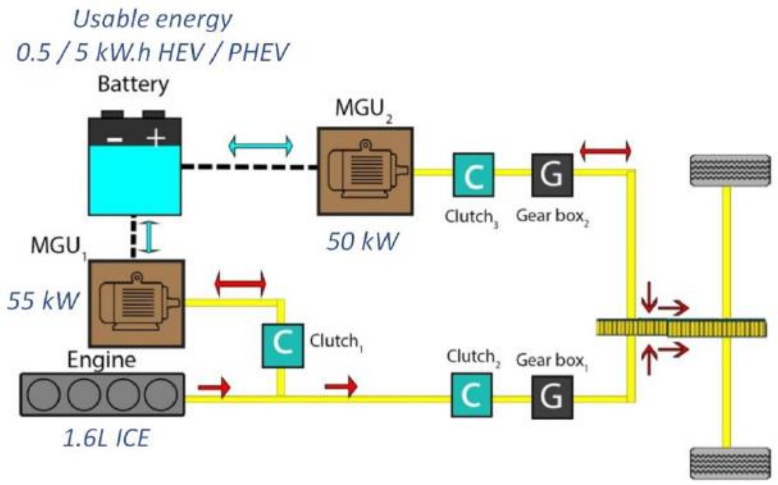
- Overall concept
  - Breakthrough combustion system
    - Ultra-lean mixtures
    - H_2 boosting
    - Pre-chamber ignition system
    - Optimized intake ports
    - Smart coatings
  - Optimized NOx after-treatment systems
- Final demonstrator: multi-cylinder engine
  - Including turbocharging and EAT systems

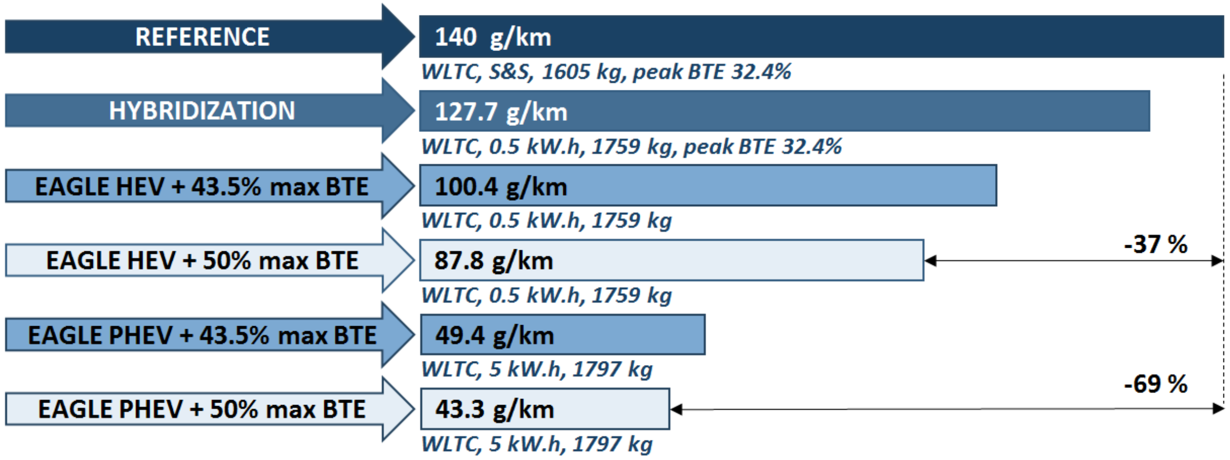


Activities expected to focus on TRL 3-5

Vehicle simulations

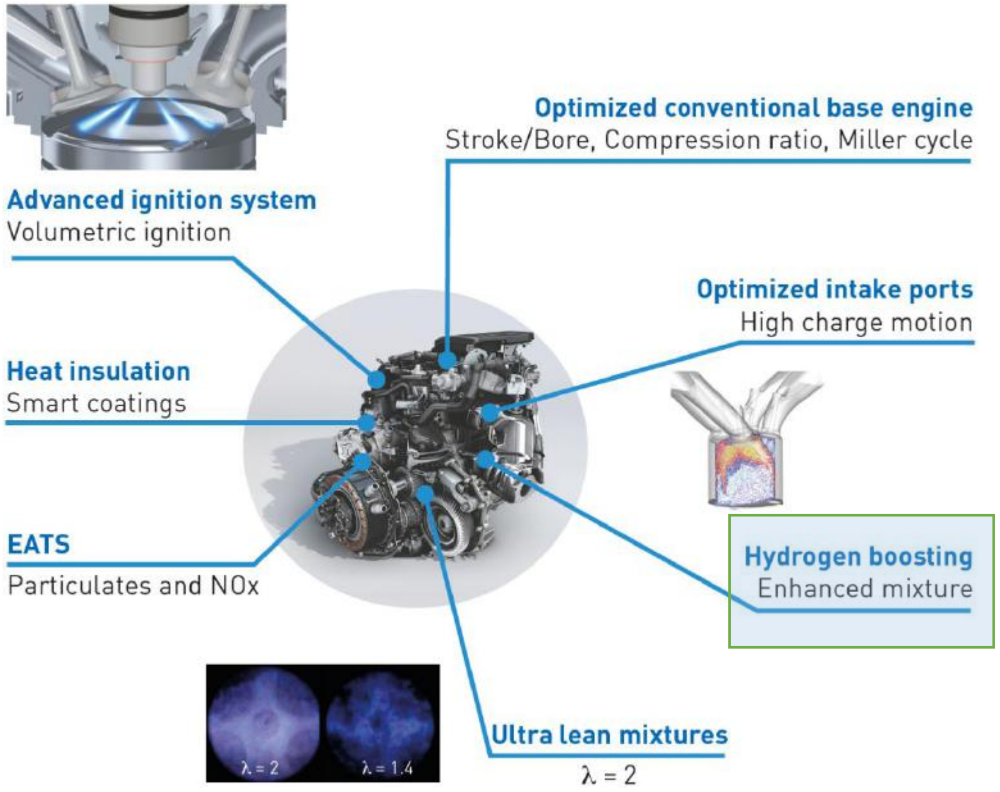
- EAGLE core application: C-class vehicle with a multi-mode series/parallel architecture
- 50 gCO_2/km can be achieved without 50 % BTE (battery dependent)
- Why increasing the ICE brake thermal efficiency ?
  - To further minimize fuel consumption in RDC, especially in highway conditions
  - To lower the battery requirements and costs
  - To further lower the HEV CO_2 emissions





Ultra-lean combustion with hydrogen

- H_2 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 H_2
  - Now seen as viable energy carrier
  - Why not for clean ICE?
- Minimal H_2 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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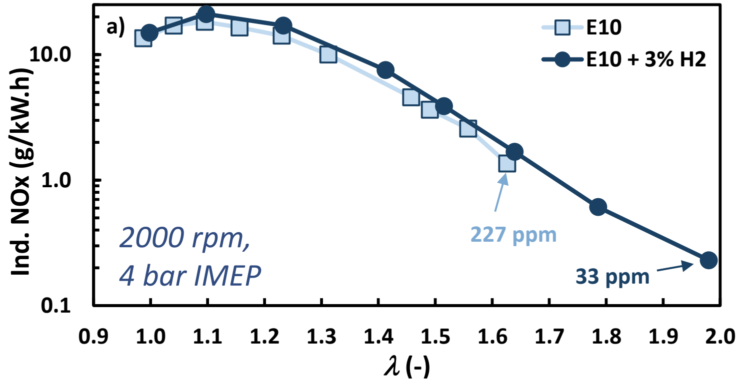
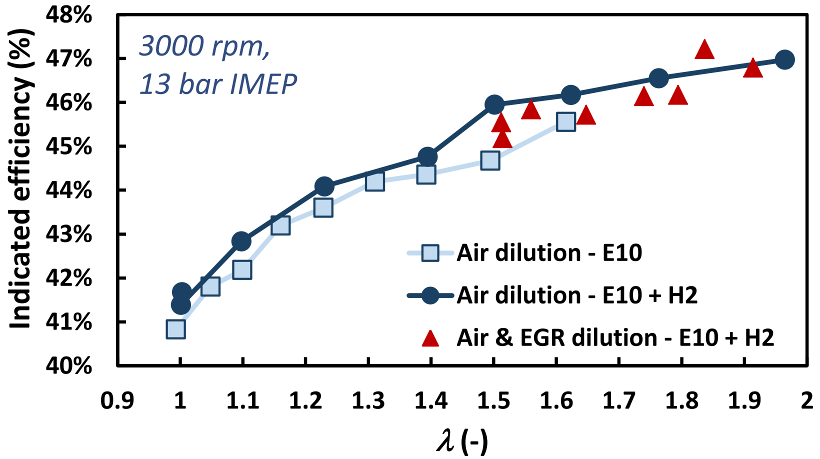
NOx reduction thanks to dilution, not to H_2

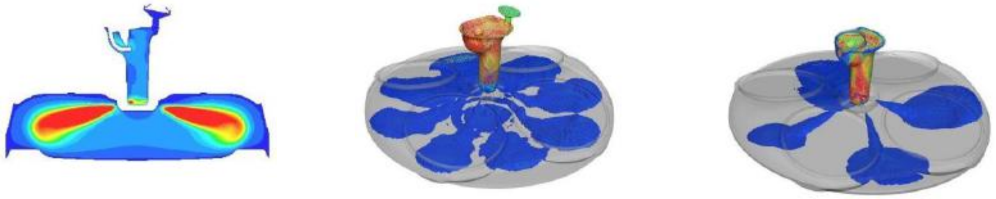


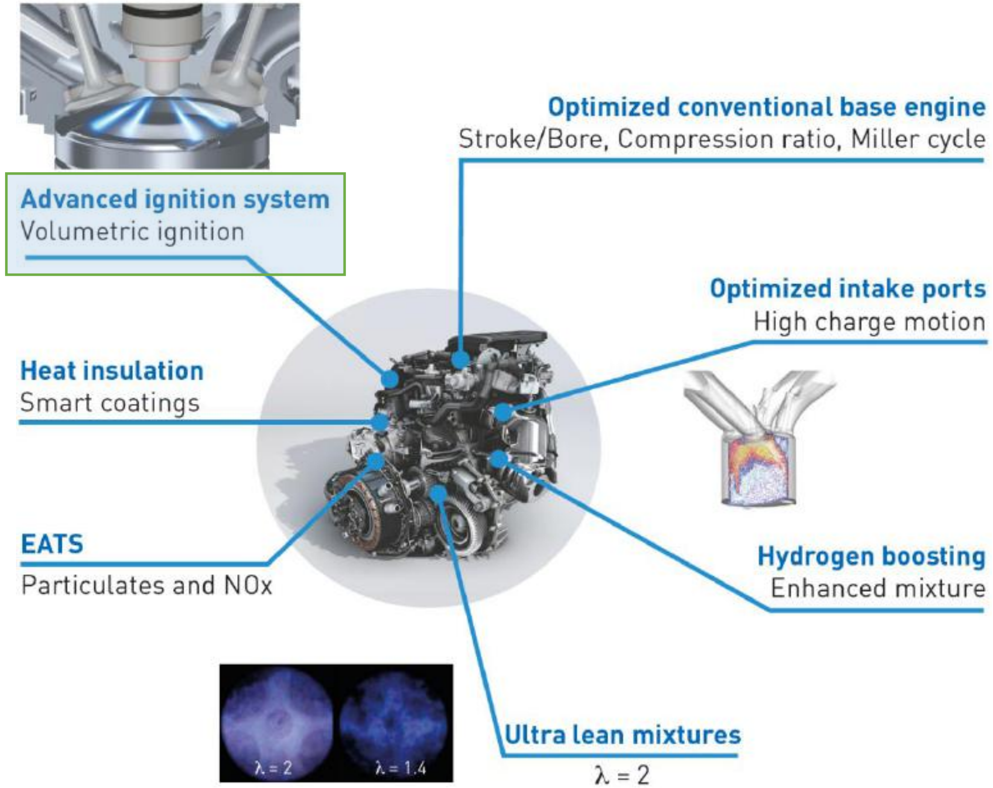
Towards high efficiency with high dilution rates, short burn durations and optimal combustion timings



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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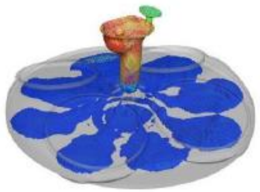
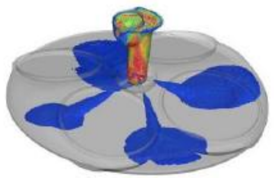
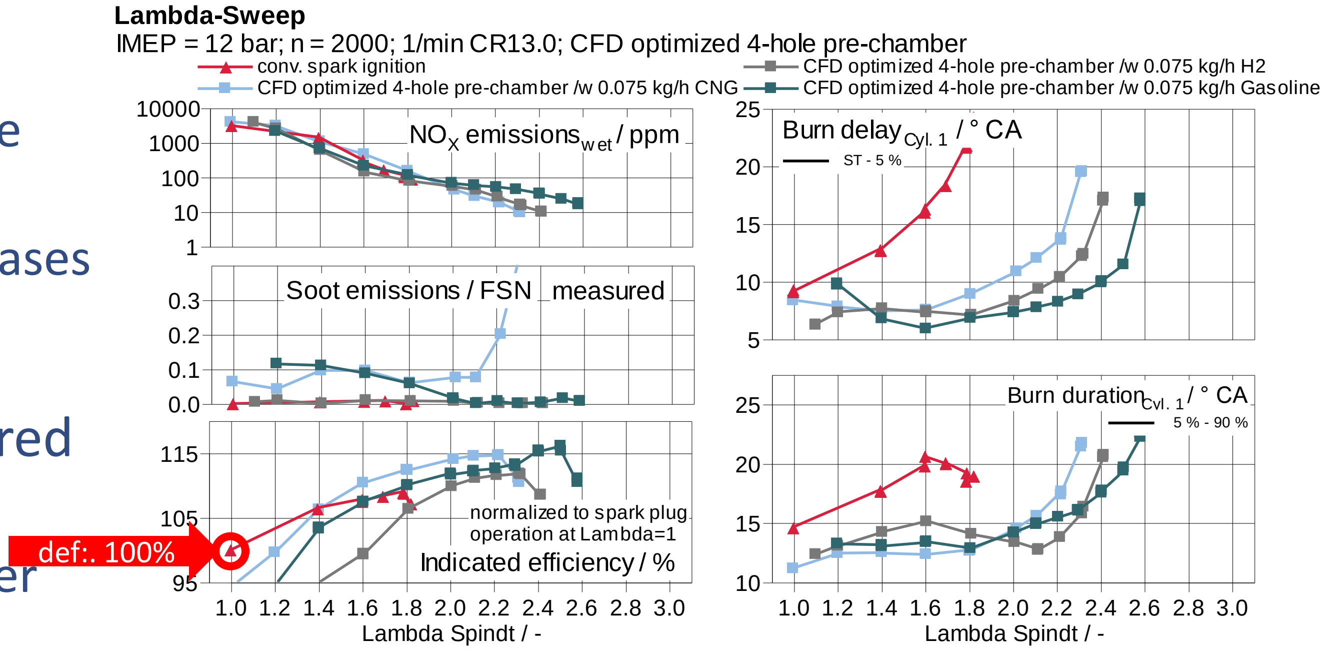






***Short burn durations** up to λ = 2 and above*

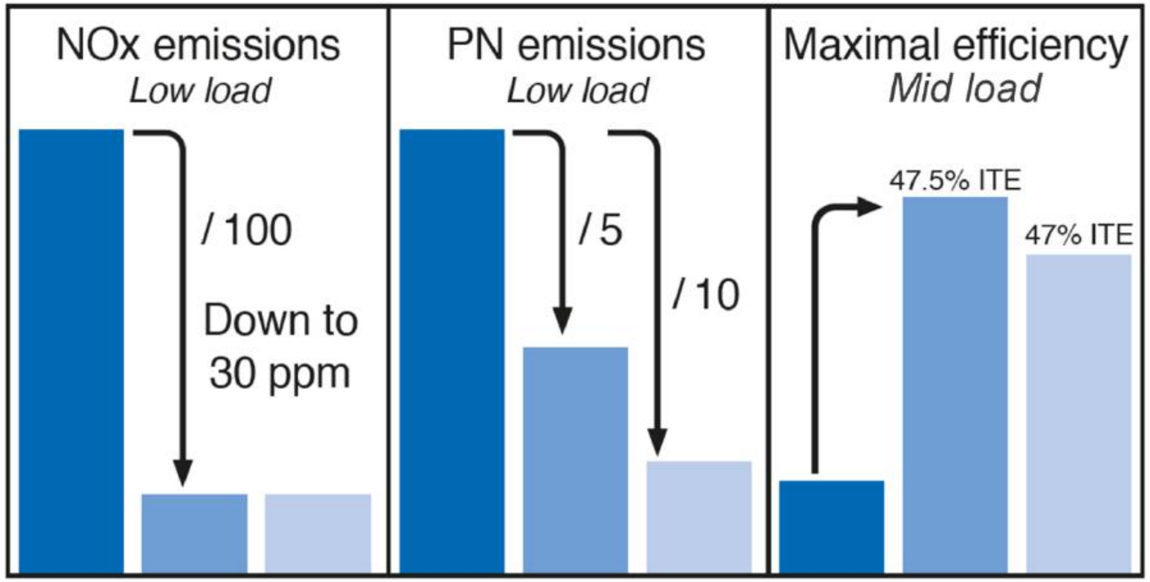
***Limited smoke emissions** with near-stoichiometric mixtures in pre-chamber*

*Stable combustion process possible **up to λ = 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 NO_2/NOx ratio at $\lambda = 2$
- Higher potential for PN emissions reduction with hydrogen supplementation
  - H_2 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 H_2, $\lambda = 1$

Pre-chamber, w/o H_2, $\lambda = 1$

Pre-chamber, w/ H_2 boosting, $\lambda = 1$
Energy cost of H_2 on-board production is not considered, here

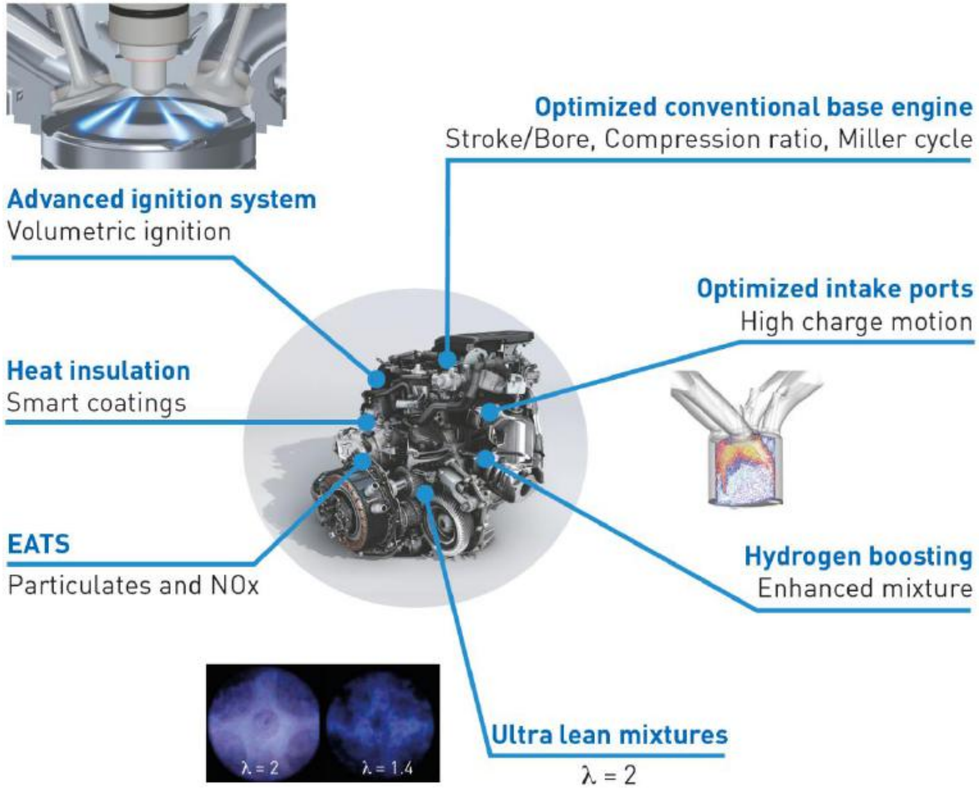
Engine configuration: CR 14:1-15:1, EIVC, neutral low-pressure loop

EAGLE combustion system

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

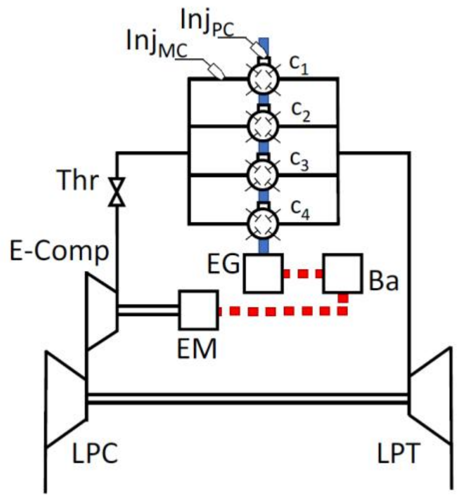
High thermodynamic efficiency		*High compression ratio*
Low cooling losses	⟷	*S/B ratio, combustion chamber shape*
Turbulent jet ignition		*Charge motion*

- 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



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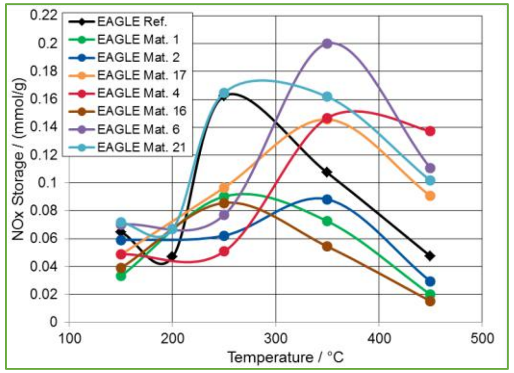
- Exhaust after-treatment
  - Oxidation catalyst
  - Gasoline Particulate Filter
  - Innovative NOx Storage Catalyst

Material selection and mini cat evaluation



Coating of a full size NSC demonstrator

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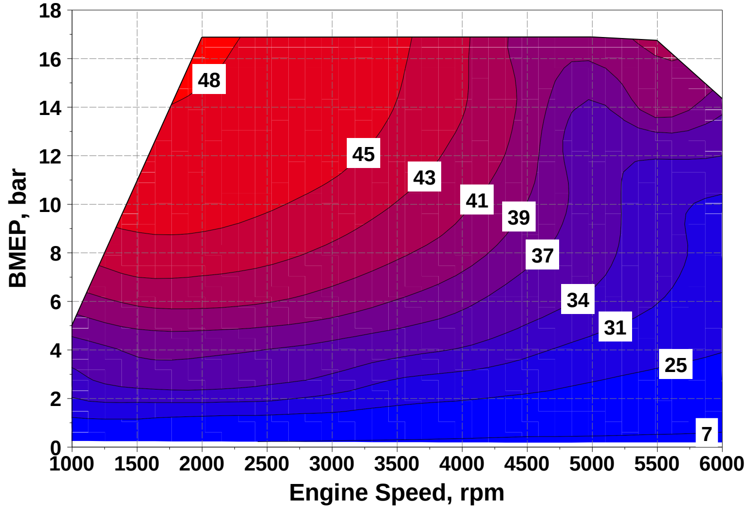
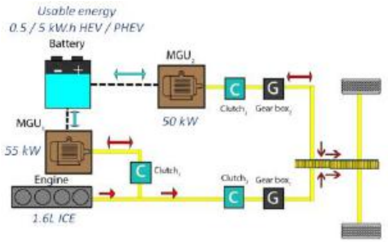
- Exhaust after-treatment
  - Oxidation catalyst
  - Gasoline Particulate Filter
  - Innovative NOx Storage Catalyst
- Experimental assessment on-going
  - Expected maximal BTE higher than 48%
  - Final results to be published in 2020, including updated vehicle simulations for WLTC and RDC

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





< 50 gCO_2/km
(WLTC)

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

Thank you

Any questions?

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Disclaimer

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