

Recent trends in Internal Combustion Engines Research at PoliTo

PT – ERC Politecnico di Torino – Engine Research Center

(www.pt-erc.polito.it)

contact person: Prof. E. Spessa (ezio.spessa@polito.it)



e3 - Engines, Energy and Environment

(<http://www.polito.it/engines>)

contact person: Prof. F. Millo (federico.millo@polito.it)



ICE & Hybrid Pwt Adv. Lab.: Test Facilities



HIGH-DYNAMIC TEST RIG

- **AVL APA 100 AC dynamometer:** nominal torque and power: 525 Nm and 220 kW.
- **PUMA Open 1.3.1 automation system + ISAC 400 software** for the simulation of vehicle over driving cycles.
- **AVL AMAi60** raw exhaust-gas analyzer
- **AVL Bag Mini Diluter (BMD) 150, AVL SPC472 Smart Sampler, AVL Particle Counter**



Moehwald-Bosch MEP2000/CA4000 injection-system test rig:

Maximum shaft power: 35 kW; maximum speed: 6100 rpm
Bosch EMI, EVI and KMM indicators.

DYNO TEST RIGS

- Diesel, Gasoline, CNG engines

Thanks to the partnership agreement with FEV Italy, additional test facilities including a roller chassis dyno and a climatic test cell are also accessible at the FEV Italy Technical Center.



CARS@POLITO: Centre for Automotive Res. & Sust. Mobility

Under acquisition: Test bed dedicated to the experimental characterization of a complete HEV/FEV vehicle/pwt (the only test bed in Italy in a public lab)



MAIN DATA

- Power Unit up to 240+60 kW (2WD e 4WD)
- Test of Vehicles (ISO SUV) with mass up to 2500 kg
- Ability to perform homologation tests
- Max speed: 180 km/h

➤ Cell temperature: 20° C (Tmax 35° C)

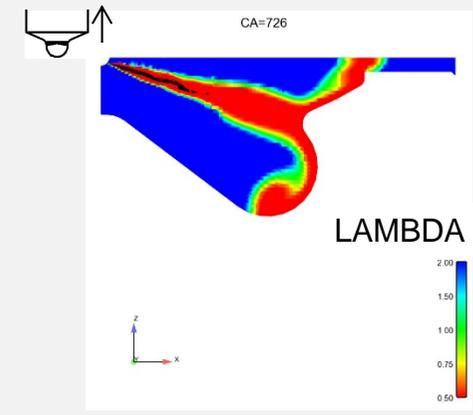
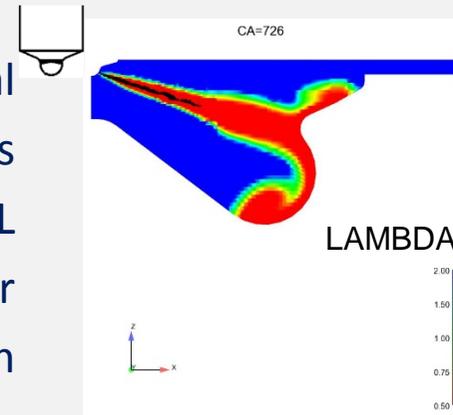
Prof. Mirko BARATTA

- Control Strategies for the energy management of HEVs/PHEVs/BEVs
- HEV/PHEV/BEV energy consumption referred to homologation cycles
- Components of HEV/PHEV/BEV powertrain and complete powertrains



ICE & Hybrid Pwt Adv. Lab.: Sim Capabilities

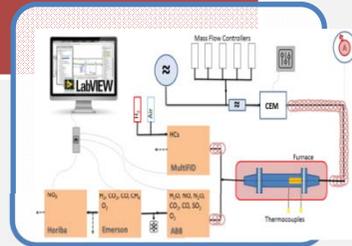
Along with the experimental facilities, several CAE tools such as 1-D fluid-dynamic codes (GT-SUITE) and CFD codes (STAR-CCM+, AVL Fire, Converge) are currently in use for research projects carried out in cooperation with several OEMs.



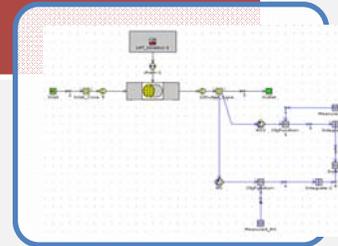
Sample Extraction



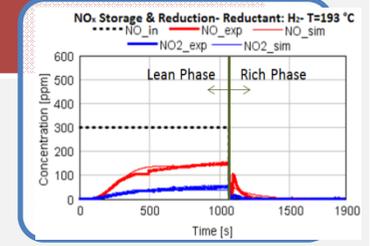
Reactor-scale Tests



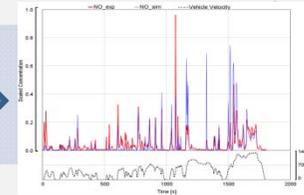
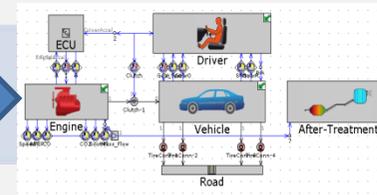
Simulation Model



Model Calibration



Validation of the model from roller bench data





**ACADEMIC PARTNERSHIP
RESEARCH AGREEMENT**



**ACADEMIC PARTNERSHIP
AGREEMENT ON EDUCATION
AND INTERSHIPS**



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Research and Education partnership agreements with major OEMs.

PT-ERC aims at developing new technologies and solutions for the efficient use of energy in conventional and hybrid powertrains, so as to minimize their GHG and pollutant emissions.

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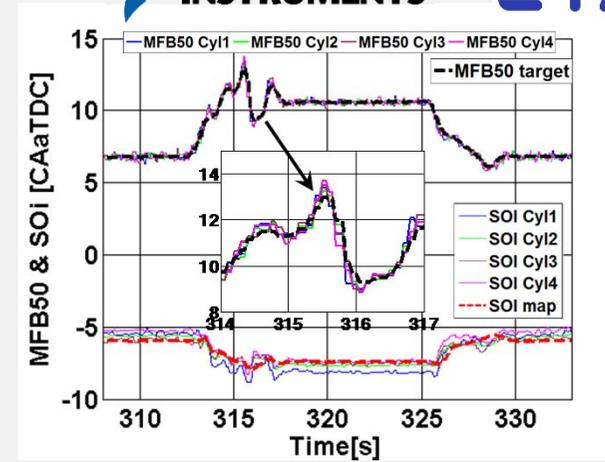
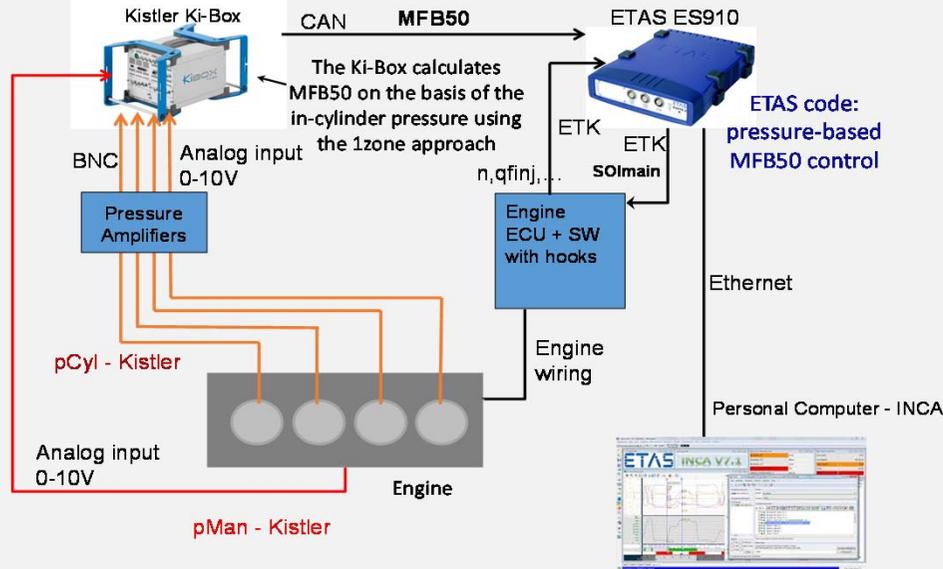
PT-ERC: Main research activities



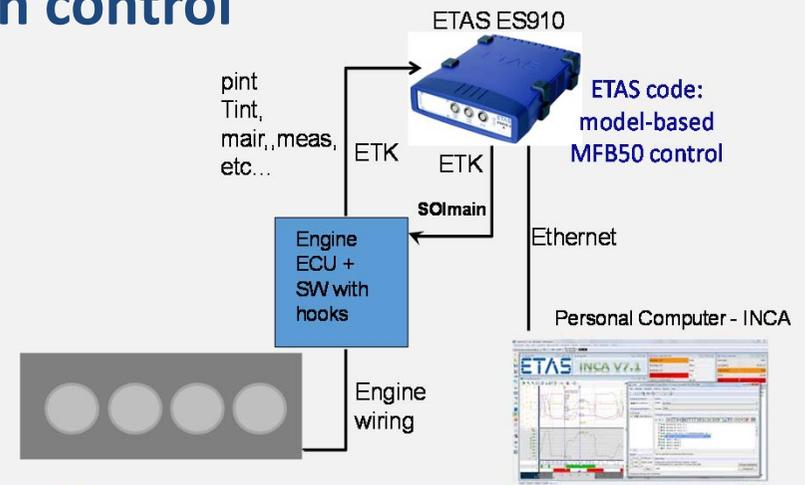
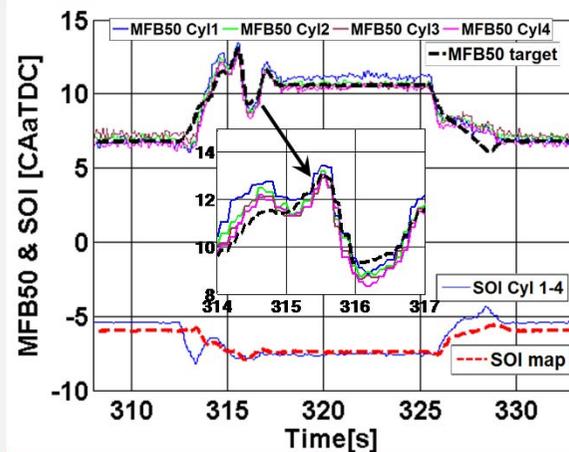
1. Combustion control in diesel engines
2. New Combustion Systems development
3. Alternative fuels
4. CI and SI engine combustion modeling
5. 3D-CFD injection and combustion modeling
6. (P)HEV optimal design

1. Combustion control in diesel engines

Pressure-based closed-loop combustion control



Model-based feed-forward combustion control



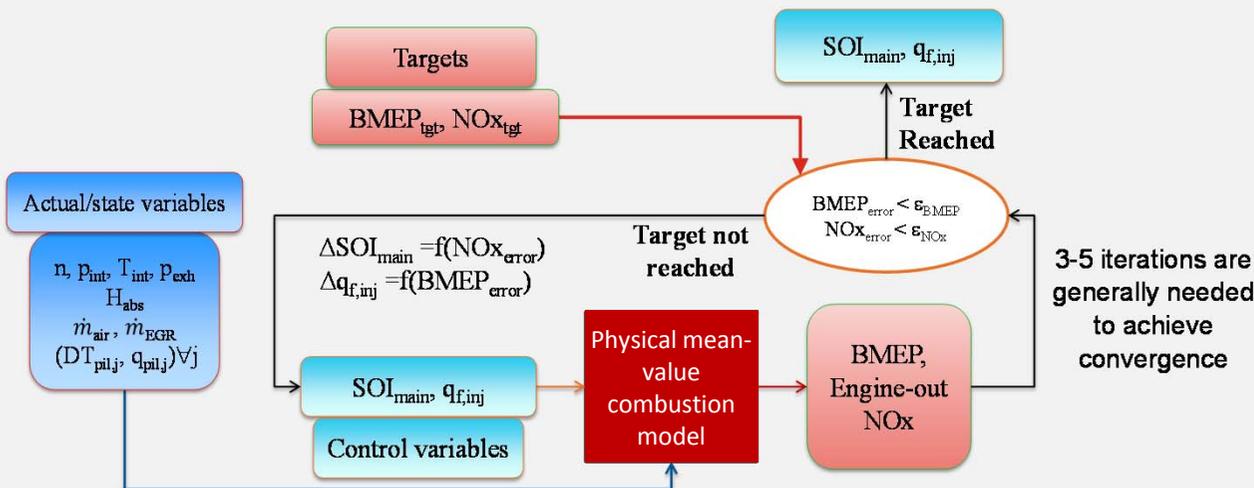
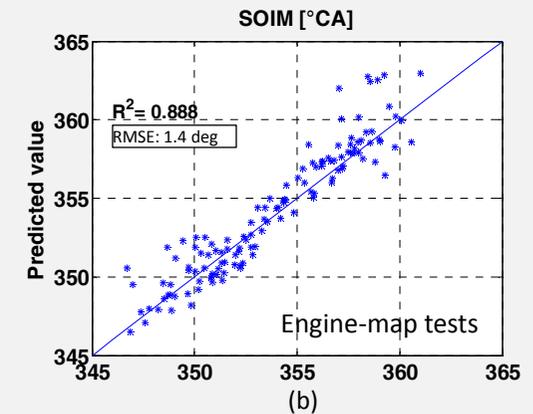
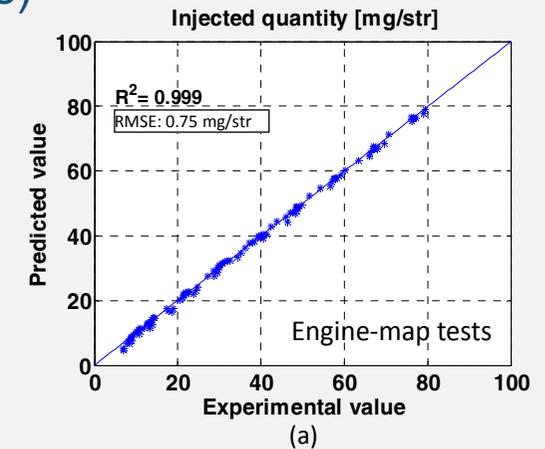
1. Combustion control in diesel engines

IMPERIUM: Implementation of Powertrain Control for Economic and Clean Real driving emission and fuel Consumption

IA H2020: 2016-2019 - <http://imperium-project.eu/>

DENERG (Spessa), DIMEAS (Tonoli, Amati), DAUIN (Violante)

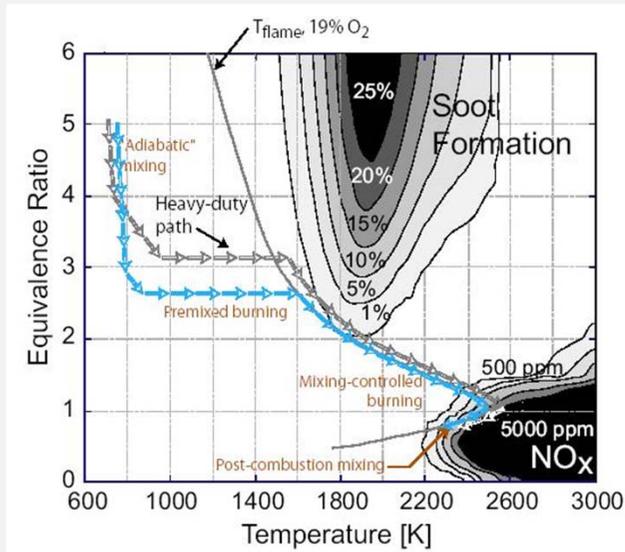
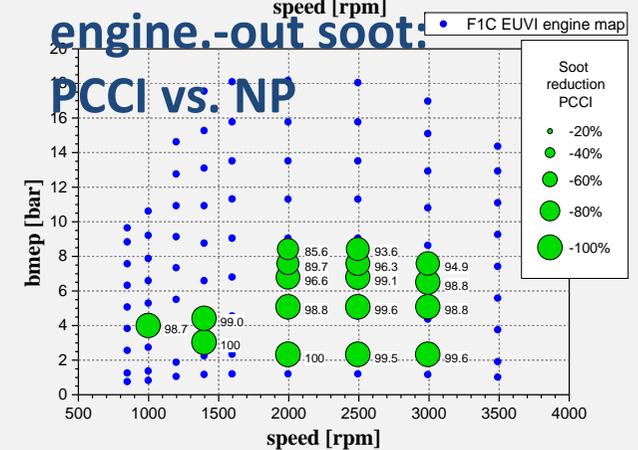
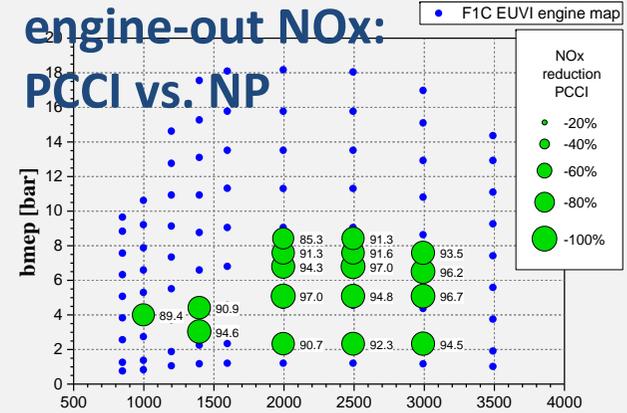
Reduce FC whilst keeping the vehicle within the legal limits for NOx emissions through direct optimization of the control of combustion, also considering a long-term optimization of the control strategy that takes a more comprehensive understanding of the mission into account (eHorizon, mission-based learning)



Development and assessment of PCCI combustion system



Rapid Prototyping device (ETAS ES910)



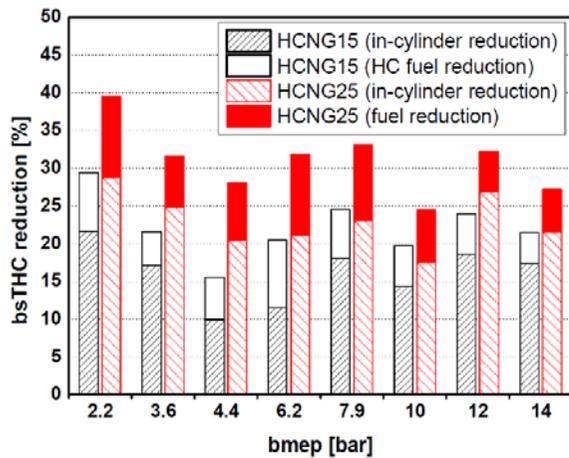
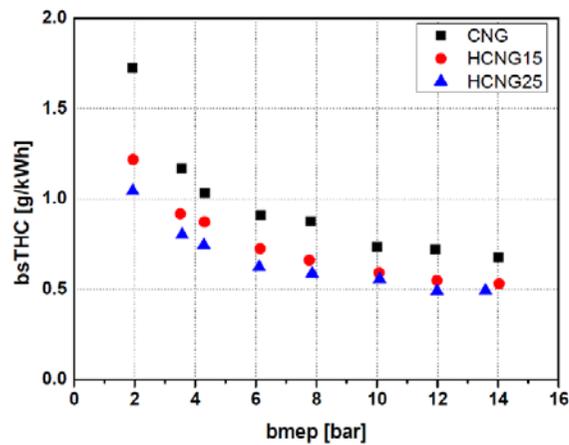
New ICE features:

- ✓ reduced compression ratio
- ✓ modified piston bowl
- ✓ new injectors with reduced cone angles and flow number)
- ✓ Advanced control of MFB50

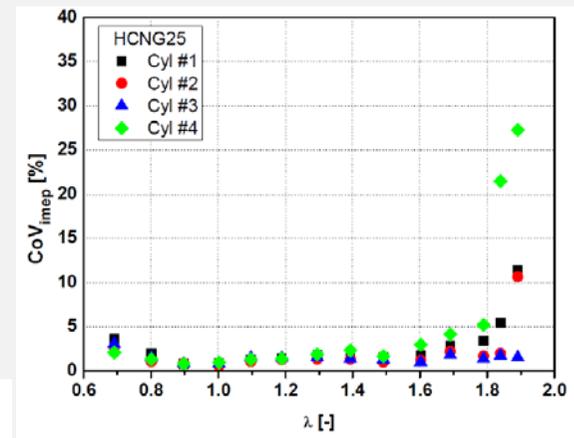
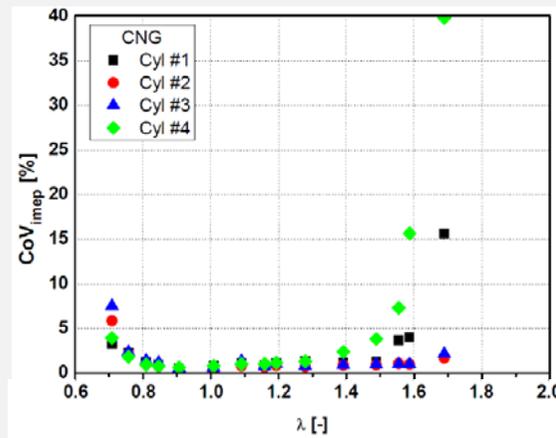
3. Alternative fuels

Performance and Emissions of a Turbocharged Spark Ignition Engine Fuelled with CNG and CNG/Hydrogen Blends (SAE Paper 2013-01-0866)

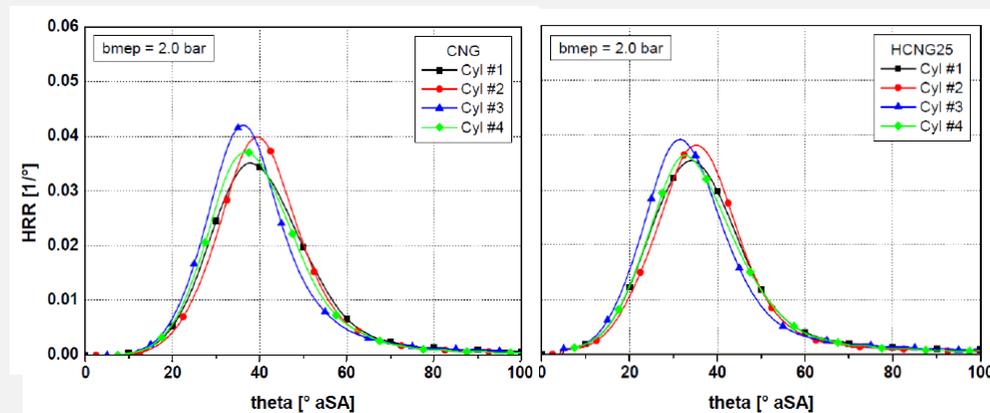
2000 rpm – $\lambda=1.0$ – MBT timing



CCV @ 2000 rpm, 6bar - λ -sweep



Cylinder-to-cylinder variation @2000 rpm, 2bar, $\lambda=1.0$



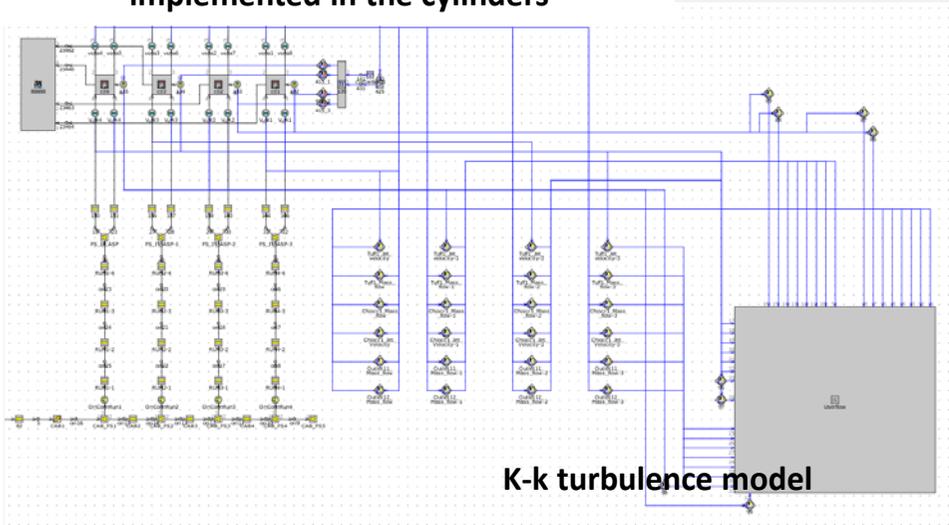
4. CI and SI engine combustion modeling

Knocking investigation on high-efficiency flex-fuel (liquid and gaseous biofuels) engines

(contract with FCA within the program “High efficient flex fuel engines (liquid and gaseous biofuels) for 2020+ targets”, 2014-2016)

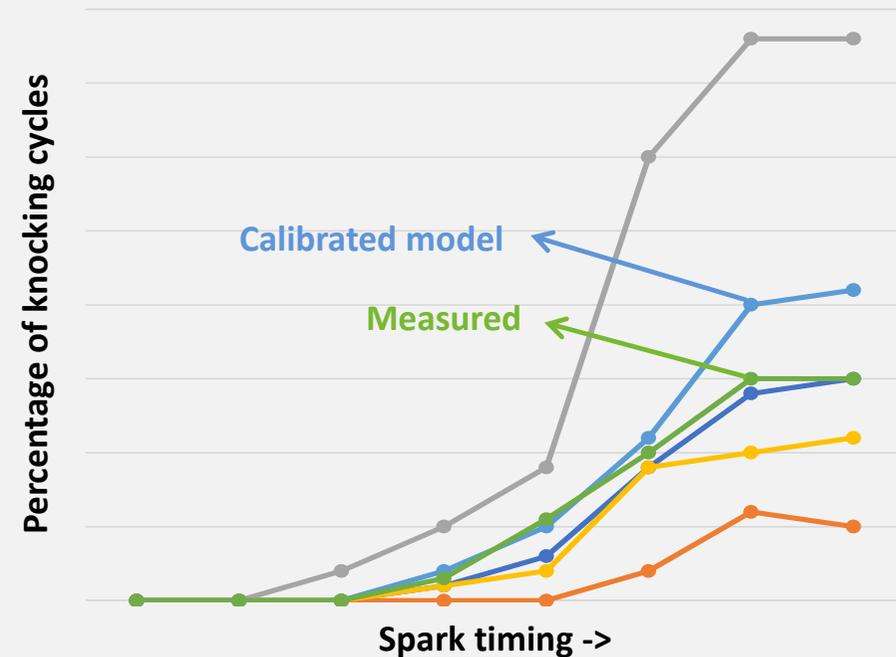


Fractal predictive combustion model implemented in the cylinders

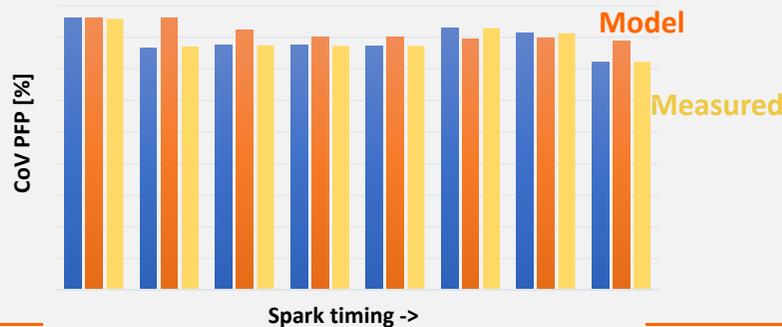


$$\int_{t_1}^{t_2} \frac{dt}{\tau} = 1; \tau = C_1 p^{-C_2} e^{C_3/T}$$

Percentage of knocking cycles – ST sweep @3500 rpm WOT



CCV simulation model – ST sweep @3500 rpm WOT

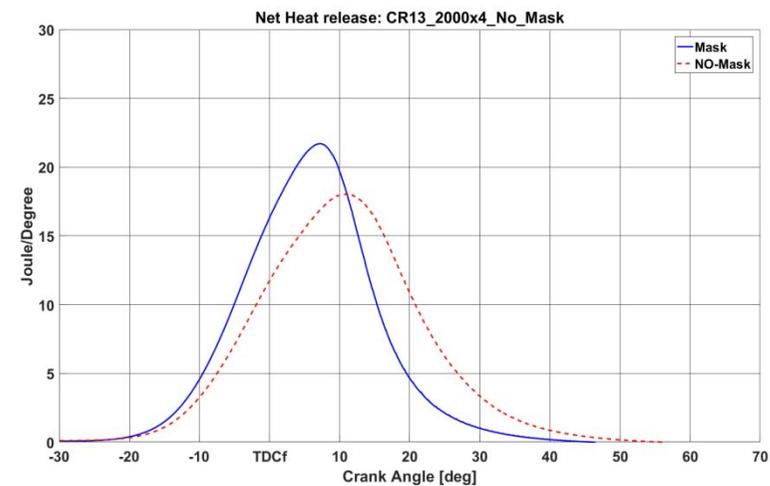
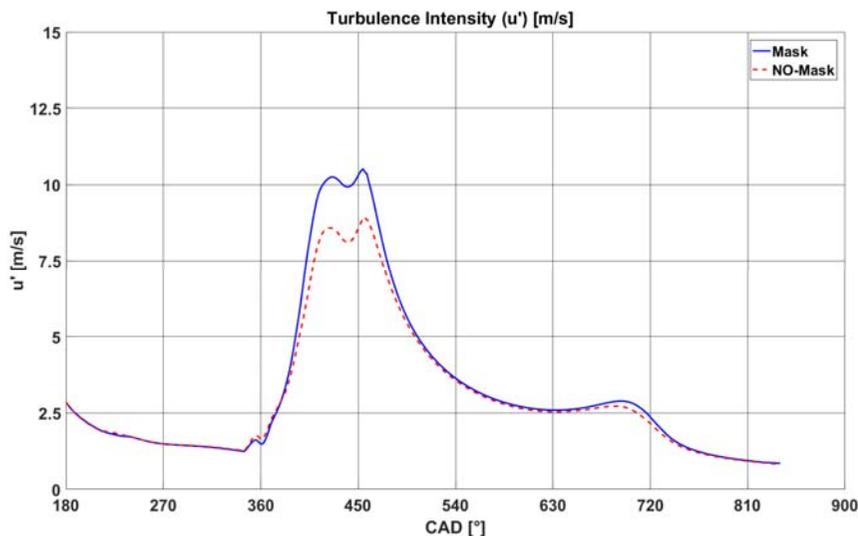
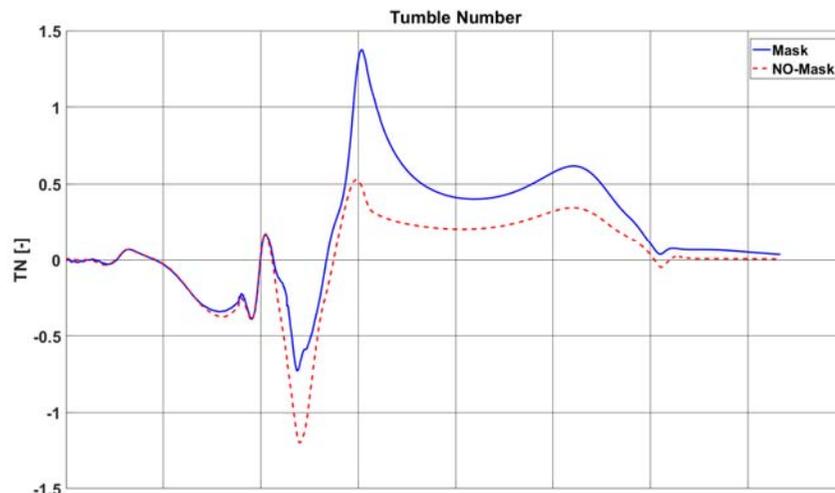


5. 3D-CFD injection and combustion modeling

Biomethair project

Optimization of a version of the TwinAir engine dedicated to CNG

- Increased CR for optimal efficiency at partial load
- Combustion chamber optimization: tumble/turbulence enhancement
- Focus on **Bio-methane** fuel (biomasses and waste thermal valorization)



Prof. Mirko BARATTA



CENTRO
RICERCHE
FIAT



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5. 3D-CFD injection and combustion modeling

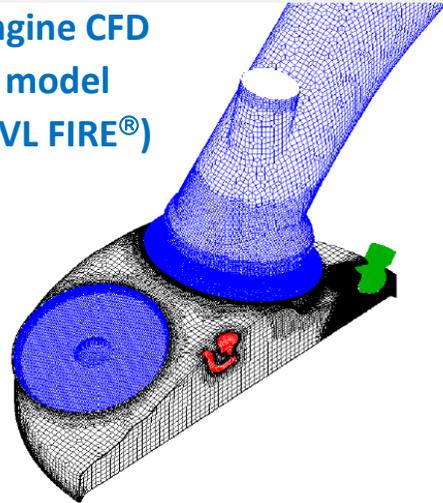
GASON project – WP2 (CRF, AVL, DELPHI, POLITO)



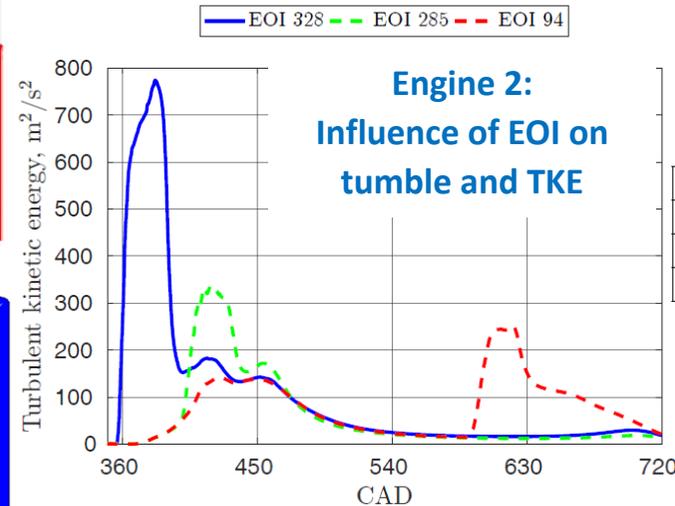
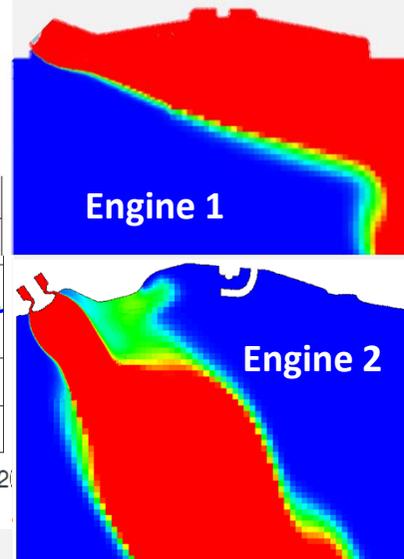
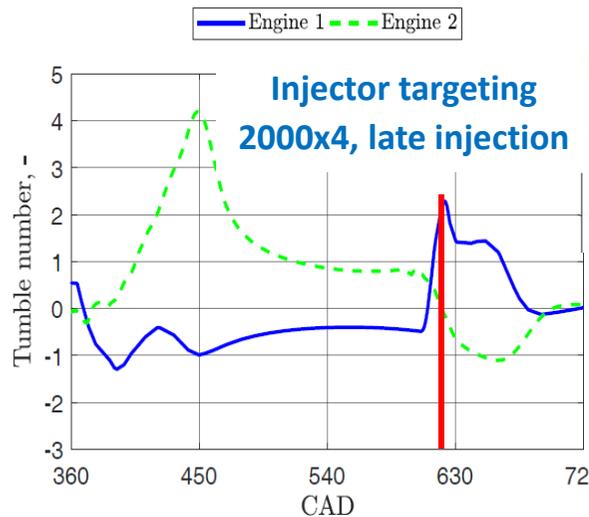
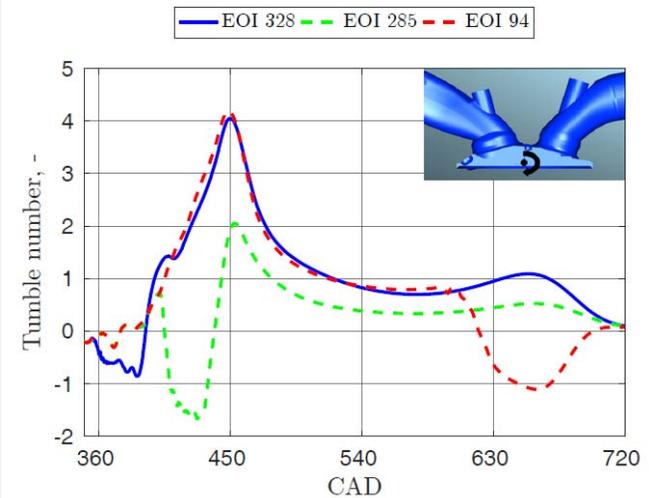
Stoichiometric & high structural integrity small TC VVA DI engine



Engine CFD model (AVL FIRE®)



- Direct injection is beneficial at low-end torque.
- Fuel injection can affect in-cylinder turbulence and tumble -> jet-guided mixing.
- Potential for stratified lean combustion demonstrated in previous project InGAS.



Values at TDC _f	
EOI 328	18.175
EOI 285	13.876
EOI 94	20.788



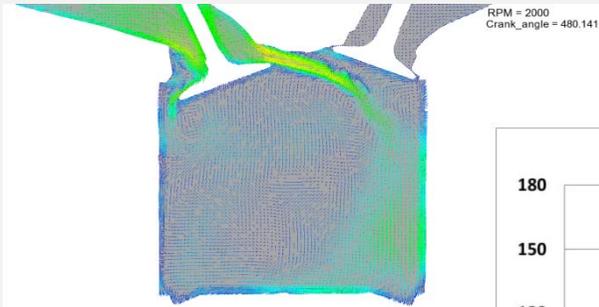
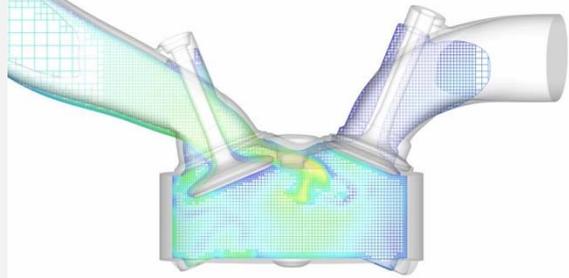
5. 3D-CFD injection and combustion modeling

GASON project – WP4 (RENAULT, Continental, CVUT, FEV GMBH, POLITO)

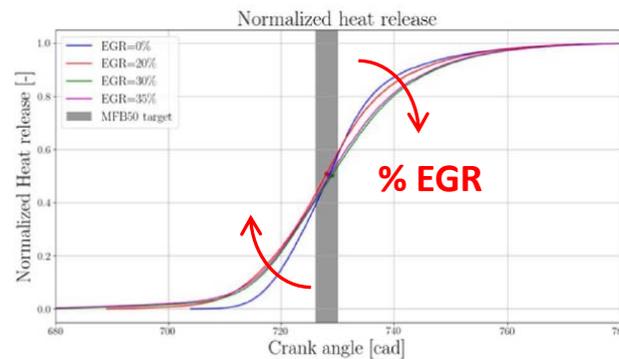
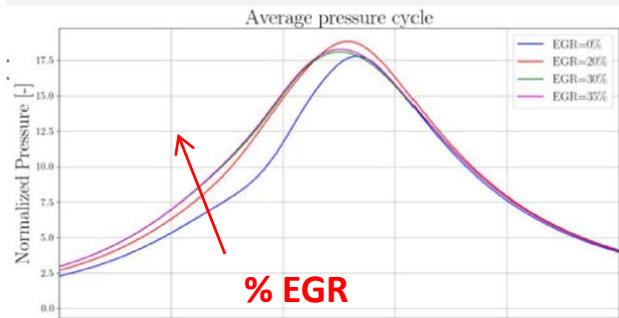
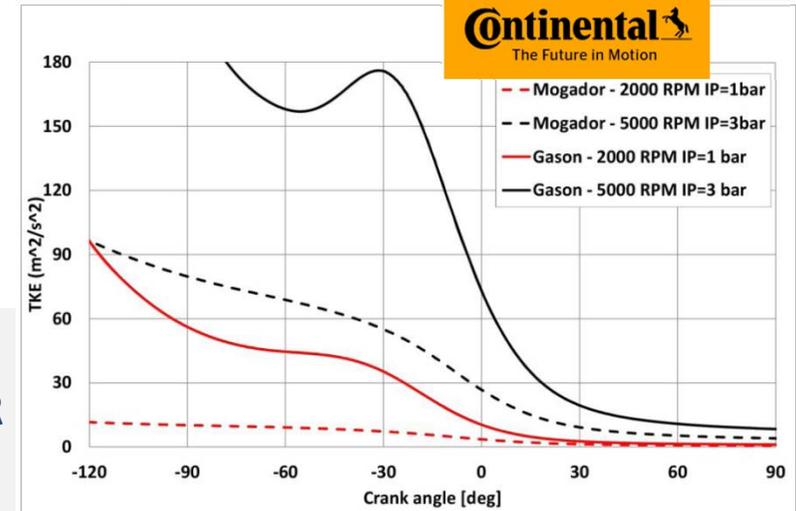
Charge dilution and exhaust-gas temperature management



CFD model (CONVERGE®)



Tumble flow (2000x8) (Intake)

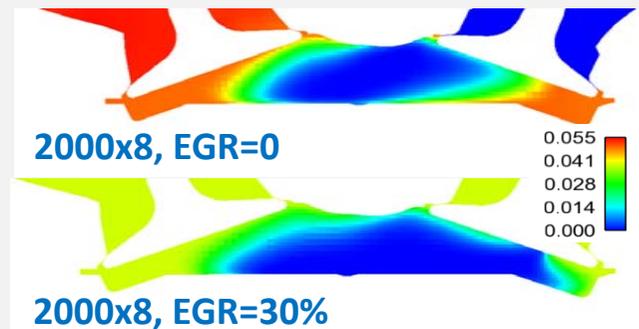


The activity has evidenced the potential of EGR to increase the boost level at full load and to reduce pumping losses at partial load.

The maximum EGR rate can be identified in correspondence to a threshold value of MFB0-50 interval around 50–60 deg CA.

(SAE Paper 2018-01-1142)

CH4 concentration contours @ TDC



High-efficient and Cost-effective Design of Hybrid Pwt for Commercial Vehicles & Buses



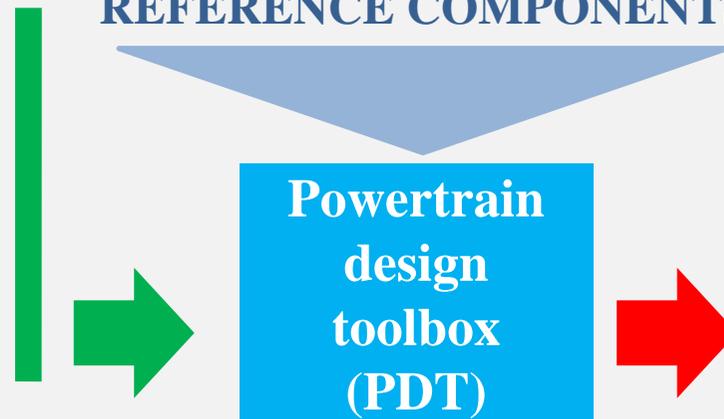
INPUTS

Vehicle typology
(type of LD/HD vehicle)

Powertrain
(HEV, plug-in HEV, REEV, FCEV and related architecture)

Driving mission

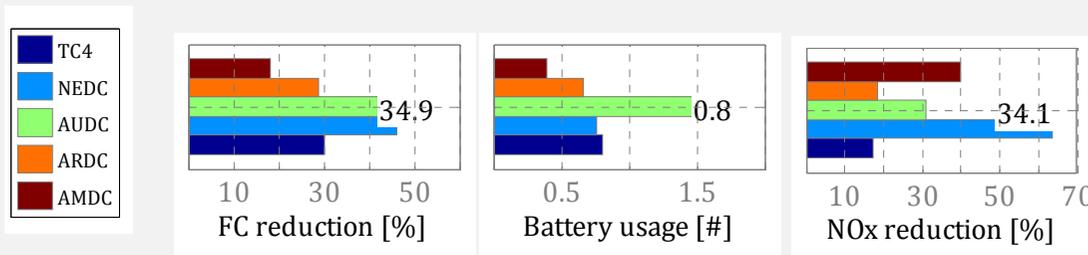
DATASET OF SPECS FOR REFERENCE COMPONENTS



OUTPUTS

- **Component sizing (ICE, EMs, battery, transmission and gear ratios, final drive ratios)**
- **Costs (OEM, TCO)**
- **FC & NOx emissions**
- **Battery usage**
- **Time histories of power/speed of ICE and e-machines, battery SOC over each driving mission**

Application to complex HEV for LD commercial vehicle



e³ - Engines, Energy and Environment

<http://www.polito.it/engines>

contact person: Prof. F. Millo (federico.millo@polito.it)



Mission:

the research activities of the e³ group are focused on the efficient use of **energy** from fossil and biofuels by means of internal combustion **engines** in order to minimize their carbon dioxide and pollutants emissions, preserving our **environment**.

Permanent staff:

- Federico MILLO (Associate Professor)



Temporary staff:

- Luciano ROLANDO (Post Doc)
- Alessandro ZANELLI (Research Engineer)



PhD students:

- Rocco FUSO



- Claudio CUBITO



- Mahsa RAFIGH



- Mohsen MIRZAEIAN



- Giulio BOCCARDO



- Andrea PIANO



- Sabino CAPUTO



- Daniele PORCU



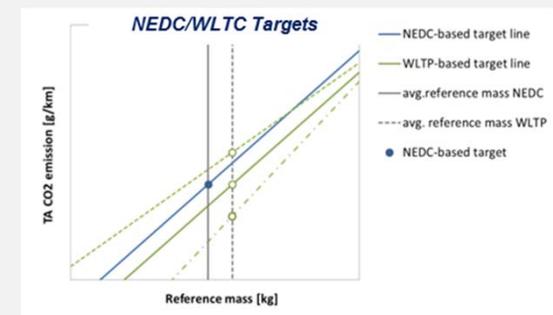
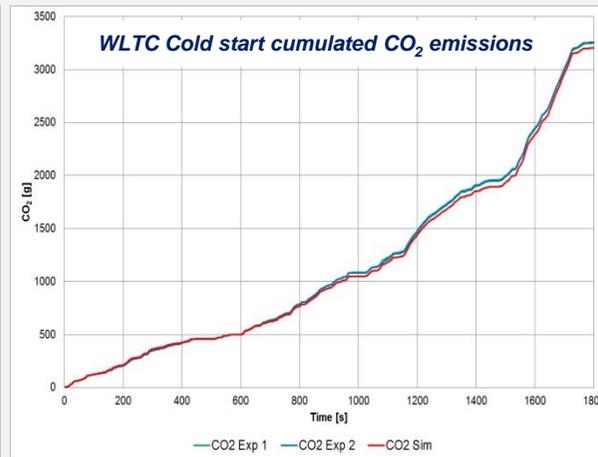
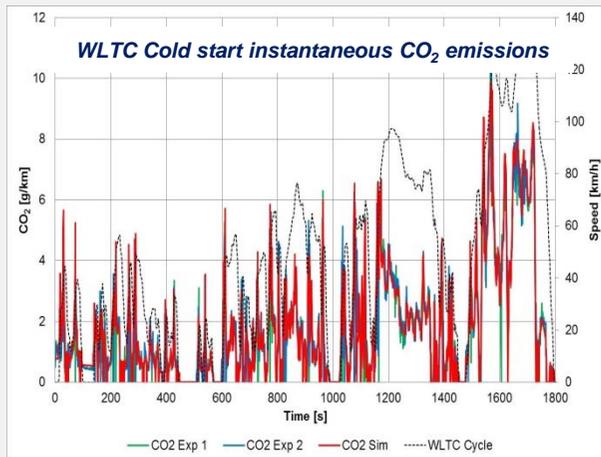
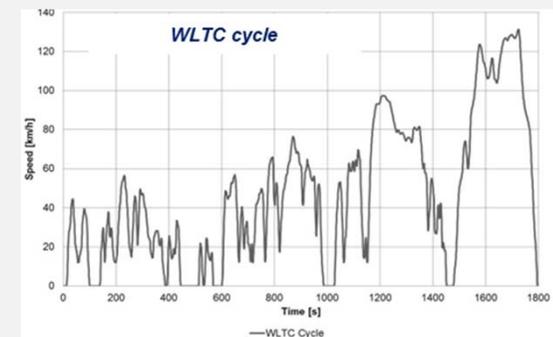
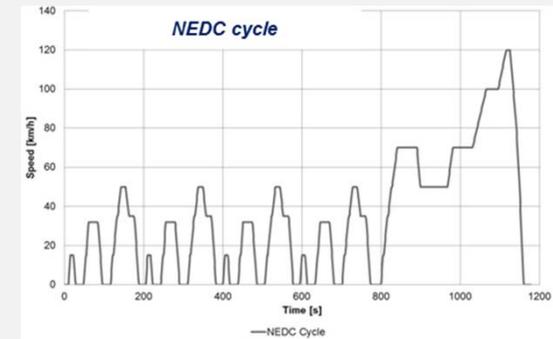
- Pranav ARYA





HEVs: Powertrain Modeling

Current cooperation with JRC (Joint Research Centre of the European Commission) in carrying out, by means of new simulation models, a correlation exercise, the goal of which is to **translate the current NEDC-based fleet average CO₂ targets for 2020 and 2025 into equivalent levels for CO₂ emissions measured on the WLTP (Worldwide harmonized Light duty Test Procedure) for HEVs.**

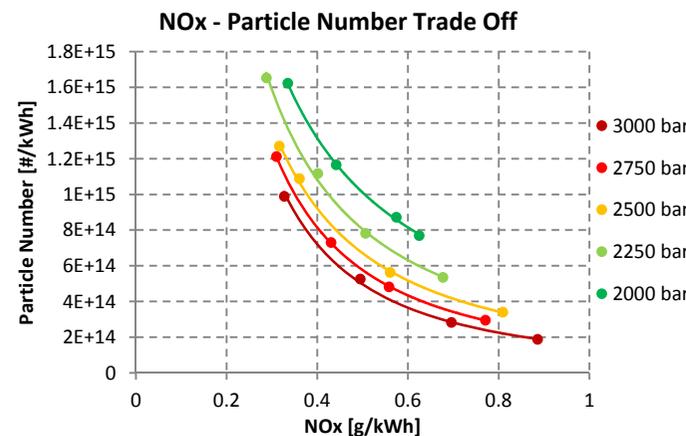
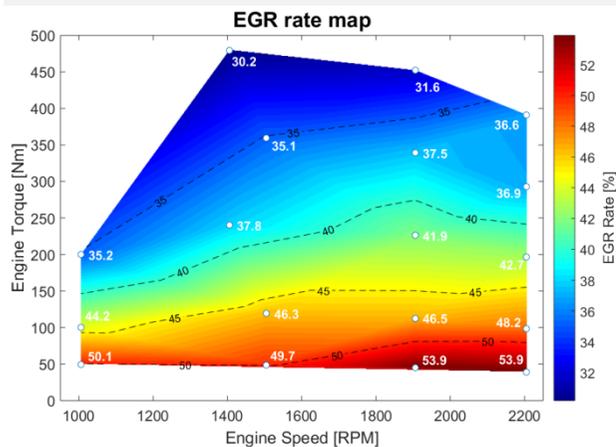
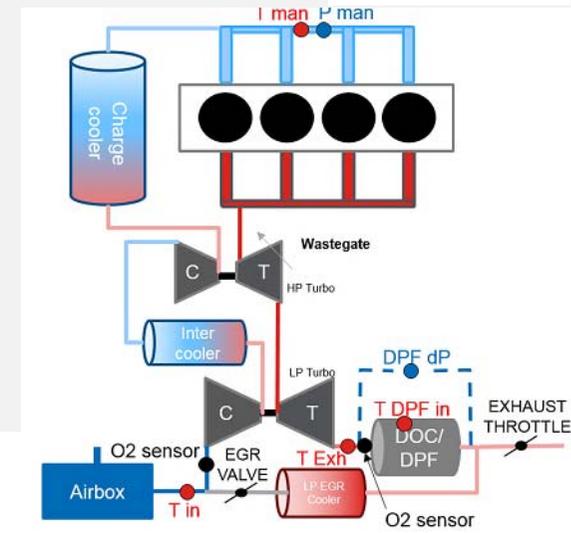




Pollutant emissions control in diesel engines: in cylinder control techniques

Achieving EU Stage V emissions limits ($\text{NO}_x < 0,4 \text{ g/kWh}$) for off-road diesel engines **without NO_x aftertreatment**, by means of in-cylinder pollutant emissions control techniques only.

Exploiting **Long Route EGR** – up to 30% EGR at full load – in combination with **extremely high pressure fuel injection (up to 3000 bar)** to achieve **NO_x conc. below 50 ppm** at full load.

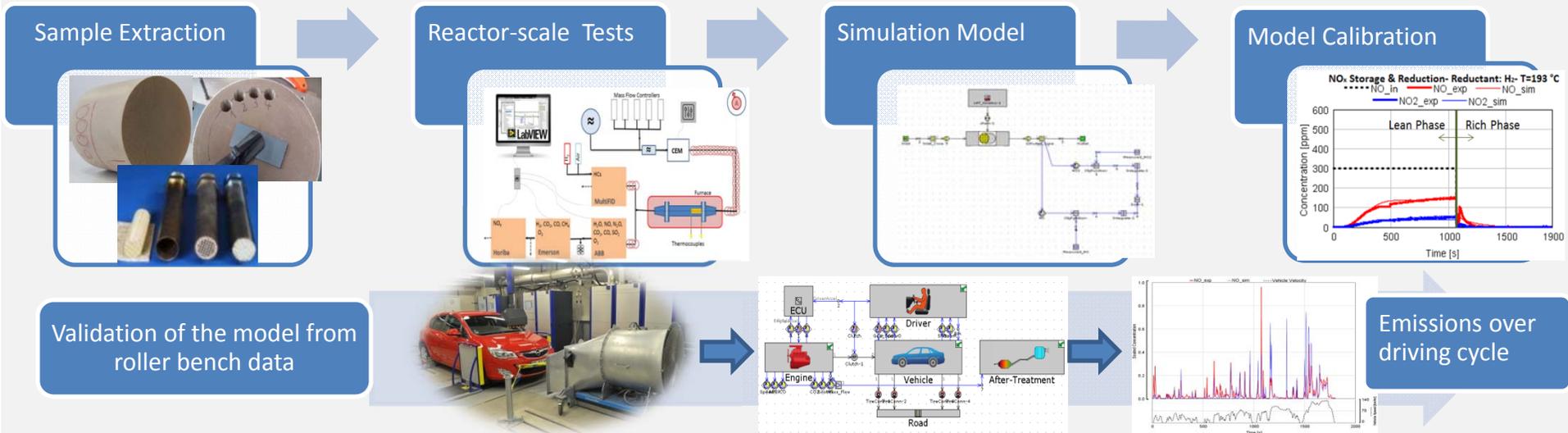




Pollutant emissions control in diesel engines: aftertreatment

Development of suitable combustion and **aftertreatment models** capable of reliable predicting performance and emissions of innovative diesel powertrain systems.

Assessment, through numerical simulation, of the more promising technology mix (e.g. LNT+DPF, SCRoF) to reach the future challenging emissions and fuel economy targets for diesel powertrains for passenger car applications.



Thank you for your attention



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