Project Area 18:
Low environmental impact vehicles

Version 28 July 2018

Project Area 18:
Low environmental impact vehicles
Challenges

Activities of this project area refer to three main pillars, in line with the Green Vehicle-H2020 work programme, the Italian PNR and the SNSI:

- Create more energy efficient vehicles using new/alternative powertrains, in all transport area (road, off-road, railways, waterborne and airspace), strengthening the future competitiveness of the industry;
- Help to reach the ambitious targets set by the EU transport, energy and climate protection policies;
- Match the transport needs within the EU with highly efficient and more flexible mobility products/services.

Project Area 18:
Low environmental impact vehicles
"Challenges and targets"

The involved institutes operates in four main research areas:

- Zero emission and high efficiency propulsion
- Autonomous vehicles
- Safety for zero-accident mobility
- Sustainable vehicles

For the objective of the development of environmental friendly vehicles, with focus on:

- zero or quasi-zero emission powertrains in terms of toxic pollutants, GHG and acoustic pollution, in all transport sectors (road, off-road, waterborne, railways and airspace);
- increase the safety of the vehicles contributing to the zero-accident target;
- support to the development of an integrated transport system and the ADAS technologies.

Research activities are carried out in co-operation with other complementary PAs, such as: "Low carbon technologies", "Smart cities", Marine technologies", "ICT" and "Applied mathematics".

Project Area 18:
Low environmental impact vehicles
«Institution involved»

- ICAR - Institute for high performance computing and networking;
- IM – Institute of the engines;
- IMAMOTER - Institute for Agricultural and Earthmoving Machines;
- IMEM - Istituto dei Materiali per l'Elettronica ed il Magnetismo;
- INM – Marine technology research institute;
- ISTI - Istituto di Scienza e Tecnologie dell'Informazione "A. Faedo";
- ITAE - Advanced Energy Technology Institute "Nicola Giordano"

Project Area 18:
Low environmental impact vehicles
«Locations»

Project Area 18:
Low environmental impact vehicles
Topics

Within the research areas, five main topics are covered (Institution involved):

Powertrains (ICE, HEV, BEV, FC)
(ICAR, IM, IMAMOTER, IMEM, INM, ISTI, ITAE)

Environmental impact qualification (LCA etc.)
(IM, IMAMOTER, IMEM, INM, ISTI, ITAE)

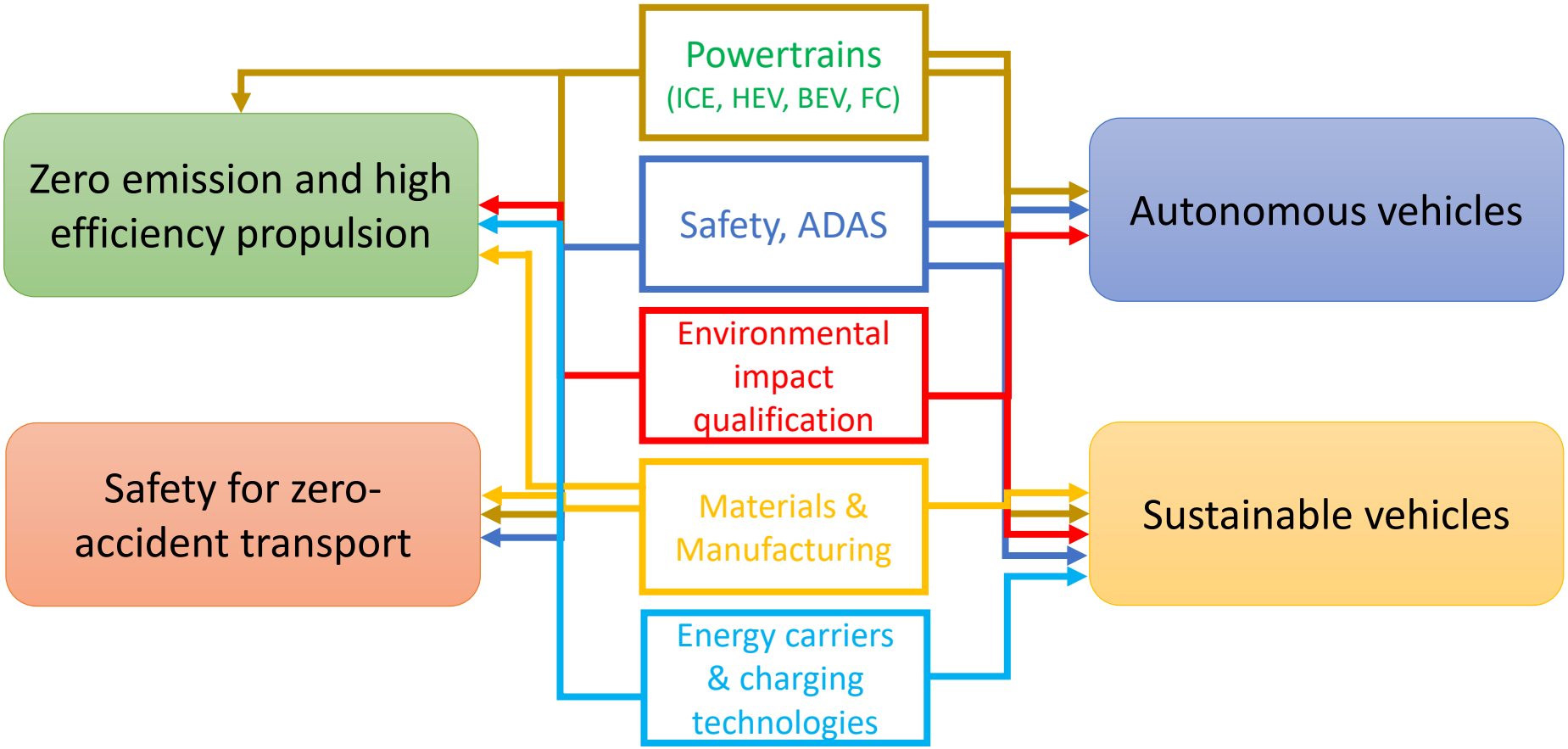
Safety, automation and ADAS
(ICAR, IMAMOTER, IMEM, INM, ISTI, ITAE)

Materials & Manufacturing
(IMAMOTER, IMEM, INM, ISTI, ITAE)

Energy carriers & charging technologies
(IM, IMAMOTER, IMEM, INM, ISTI, ITAE)

Verificare coinvolgimento Istituti vs topics

Connection between challenges and topics



The research themes under development are transversal to different challenges.
Taking into account the specific activities in each research group of the AP, topics are linked with challenges.

Zero emission vehicles (ZEV) and high efficiency propulsion

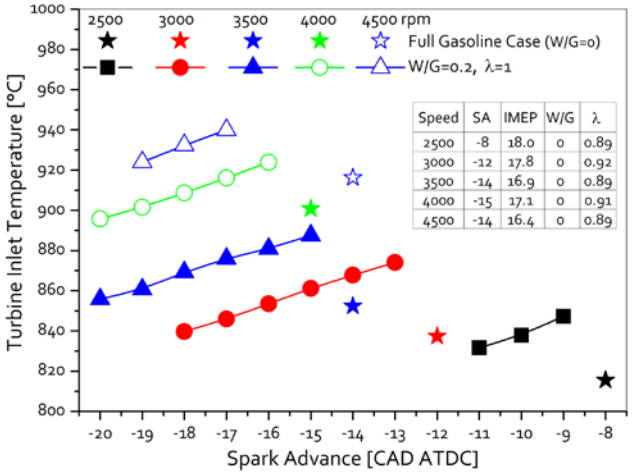
Zero emission vehicles (ZEV) and high efficiency propulsion

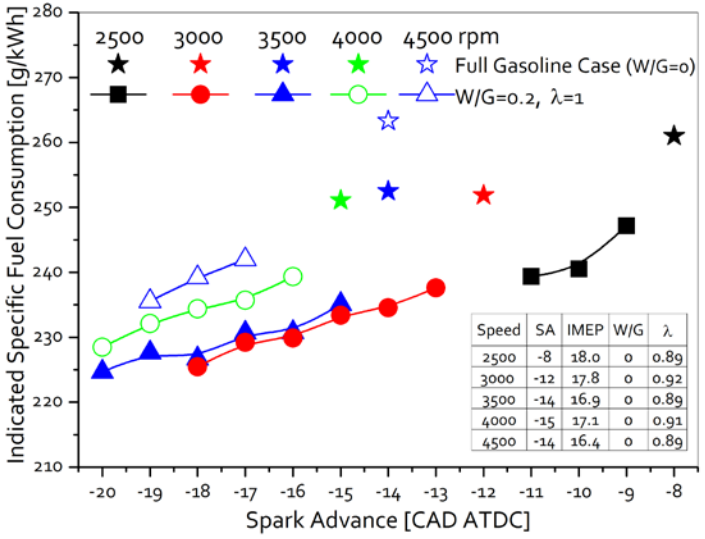
Research themes

- ALTERNATIVE, RENEWABLE, GASEOUS FUELS FOR
- COMBUSTION IMPROVEMENT
- ENGINE TECHNOLOGY & CONTROL
- EXHAUST AFTER-TREATMENT MANAGEMENT
- NOISE & VIBRATION REDUCTION
- ENVIRONMENTAL IMPACT OF VEHICLES ON REAL USE
- HYBRID & ALTERNATIVE PROPULSION

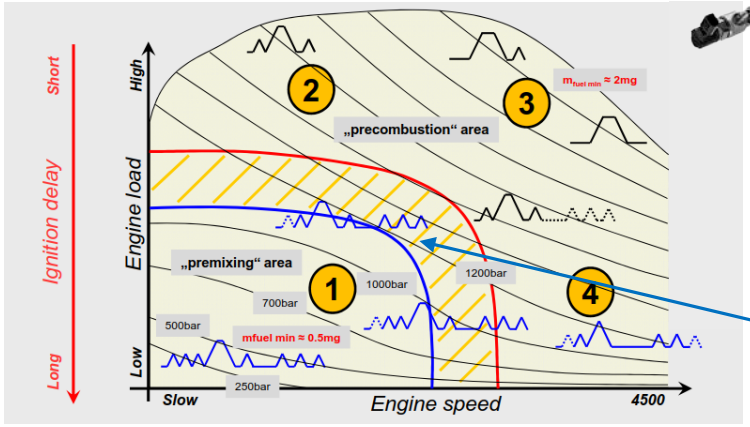
Toward to ZEV with combustion improvement

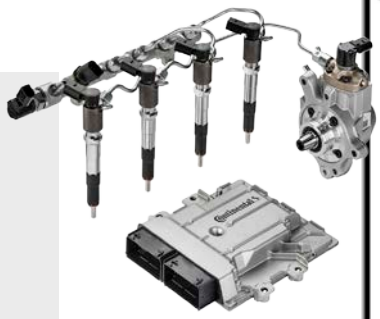
SI engine efficiency improvement with H_2O injection





Diesel efficiency improvement with advanced injection systems





Advanced injection patterns

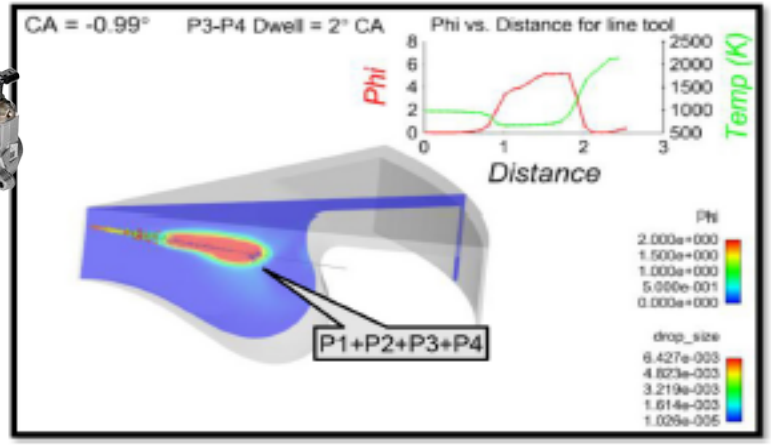


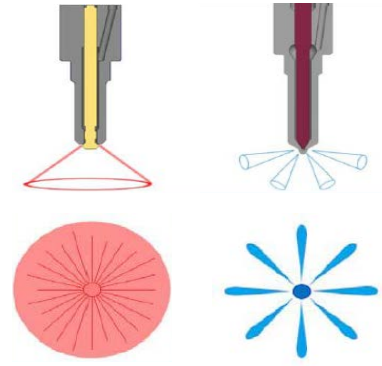
Figure 12b. In-cylinder fuel field at 1° BTDC - Dwell=2°CA, SOI=-21°CA

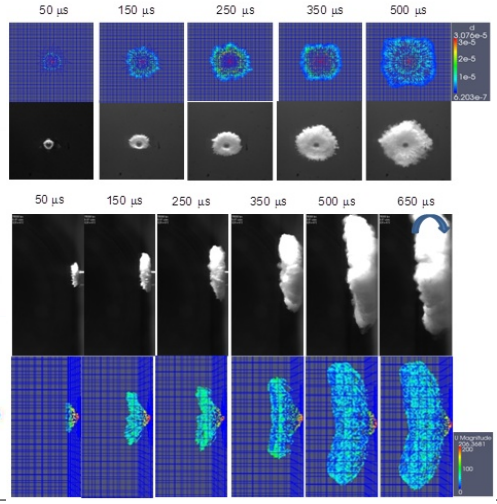
Toward to ZEV with engine technology development

Knocking/misfiring control development in SI engines

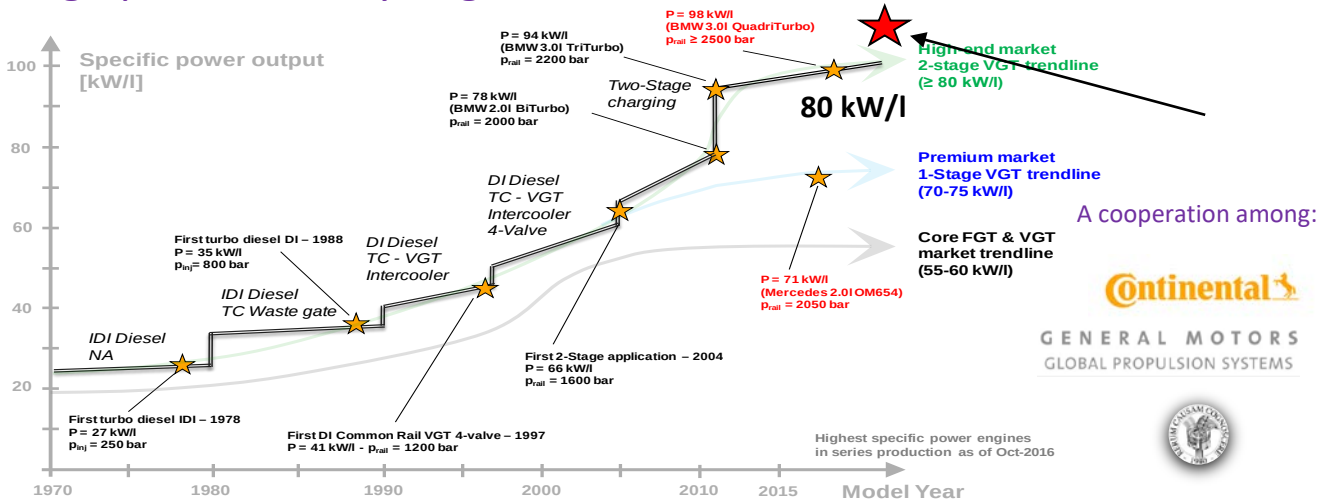
Development of innovative direct-injection systems

investiamo nel vostro futuro





High power density engine demonstrator



A cooperation among:

Continental

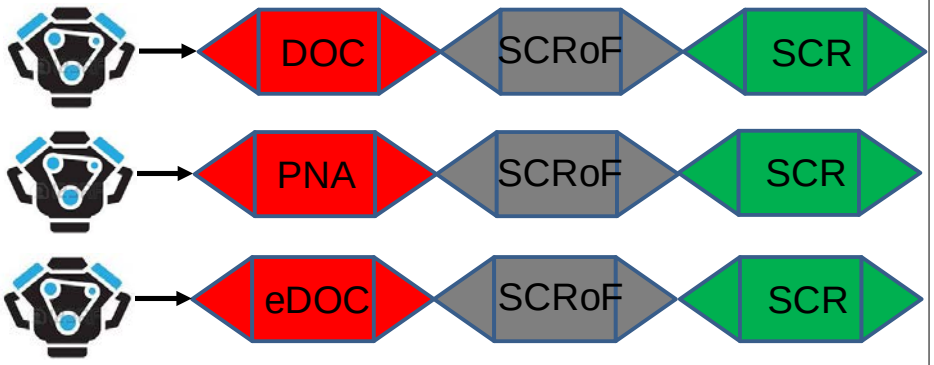
GENERAL MOTORS
GLOBAL PROPULSION SYSTEMS

IM Diesel engine 105 kW/l

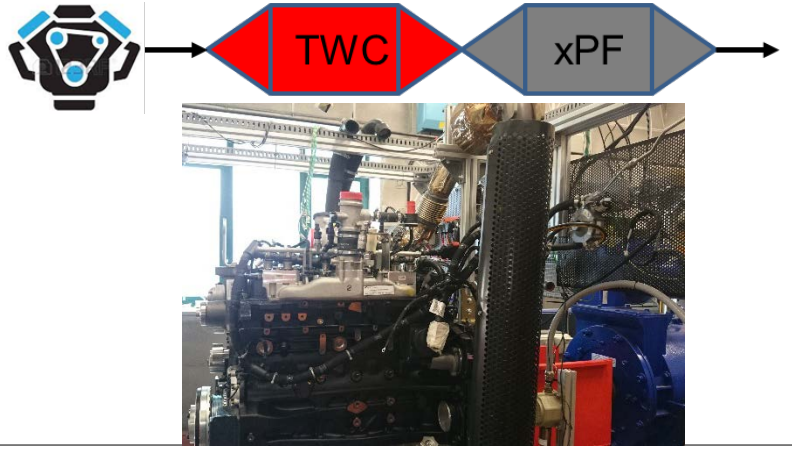
Toward to ZEV with gas after-treatment system (ATS) development

Soluzioni innovative per diesel post Eu6 con controllo delle emissioni particelle ≤23nm

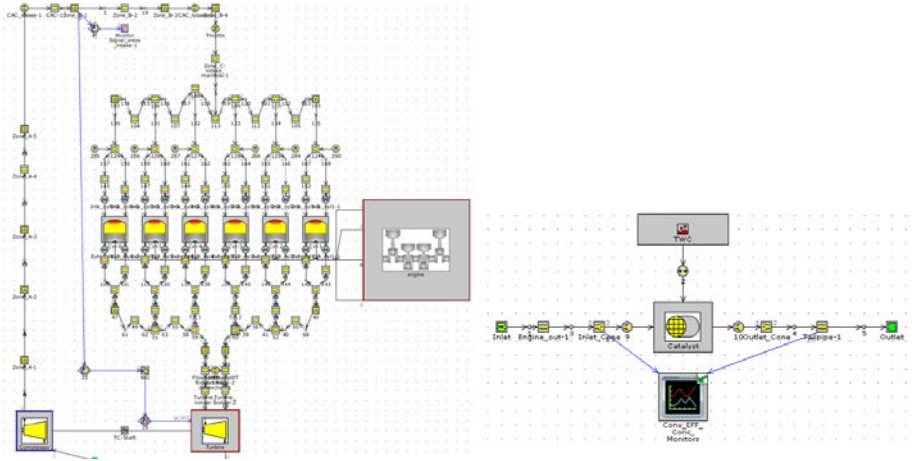
H2020 Dieper Project



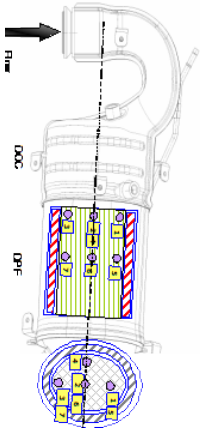
Soluzioni innovative per motori Natural Gas post Eu6

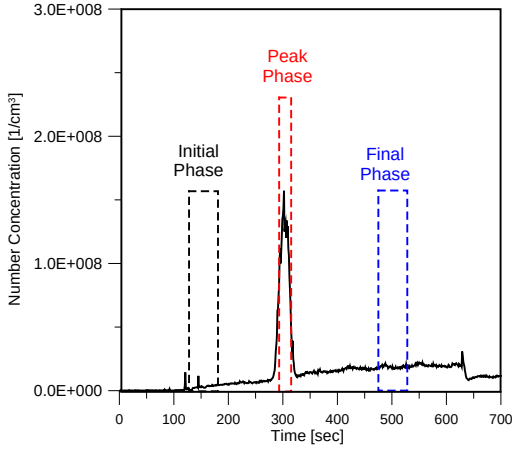


Modellistica ed ottimizzazione motore GAS + TWC



Gestione termica del DPF nelle fasi di rigenerazione





Energy storage systems for sustainable mobility

- Experimental analysis of electric storage systems in both stationary and dynamic operating conditions.
- Performance evaluation and comparison of various storage system technologies for on-board and stationary applications.
- Development of advanced Battery Management Systems (BMS).
- Controlled temperature and relative humidity tests.
- Storage systems Life Cycle Assessment (LCA).
- Advanced modelling of energy storage systems.

European Project Vision – xEV coordinated by AVL

Examples of storage systems technologies tested in IM Laboratories

Lead Acid

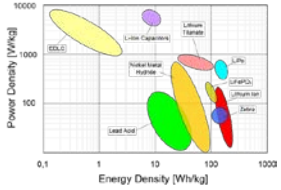
$LiFePO_4$

ZEBRA

$Li[NiCoMn]O_2$

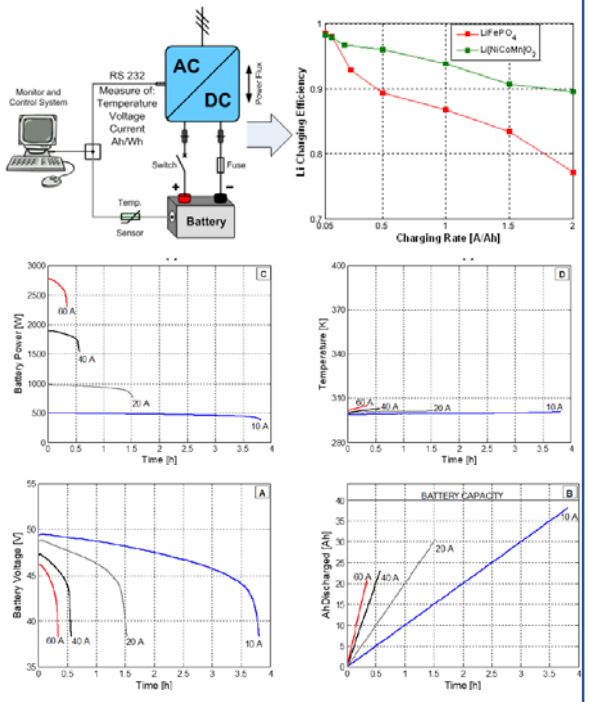
Super-Capacitor

Li-Ion Capacitors



Example of Battery Pack

Example of Experimental Results (*) on Lithium batteries



Actual Battery Capacity Evaluation

Main Laboratory Facilities

Energy Storage Life cicle Tester

AC Input	400 V AC
Max Output Voltage	18 V DC
Max Output Current	100 A
Output ripple	7 % Irms
Transition time From CH to DISCH	900 ms
Efficiency	0.91
Power Factor	0,78
Cooling	Forced Air
Protection degree	IP 21

Climate Chamber for energy storage units

- Temperature range: -40 °C + 180 °C
- Volume: 50 L
- Heat up rate: 3 °C/min
- Cool down rate: 1.7 °C/min
- Relative humidity range: 10 % - 98 %

(*) C. Capasso, O. Veneri "Experimental analysis on the performance of lithium based batteries for road full electric and hybrid vehicles" Applied Energy 2014

Hybrid electric propulsion systems

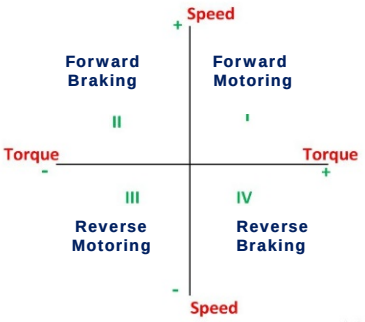
- Experimental analysis of hybrid/electric propulsion systems on stationary and dynamic test benches.
- Experimental performance evaluation and modelling of different hybrid powertrain architectures.
- Development and optimization of multi-objective on-board energy management strategies for hybrid powertrains.
- Laboratory research activities of electric powertrains supplied by hybrid energy storage systems (batteries + supercapacitors)

Main facilities: test benches of Istituto Motori for electric propulsion systems

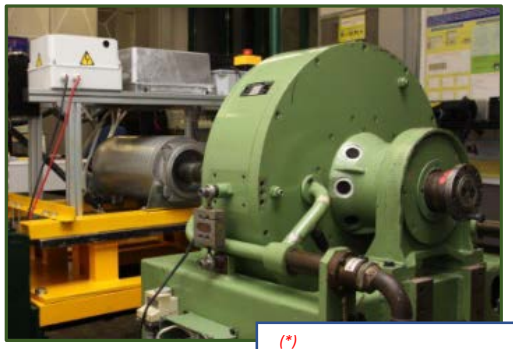
4-quadrant Dynamic Brakes for tests on driving cycles

Power Control System

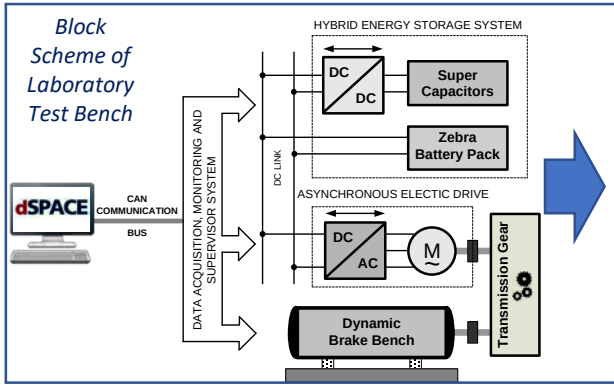
Operative modes



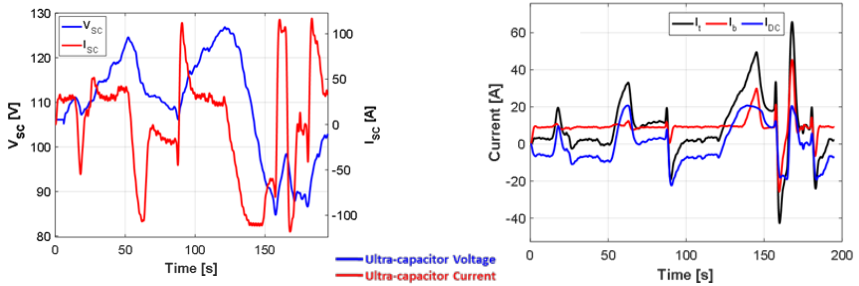
Eddy Current Brakes for stady state operations



Block Scheme of Laboratory Test Bench



Example of Experimental Results on Hybrid Energy Storage Systems (*)



(*)

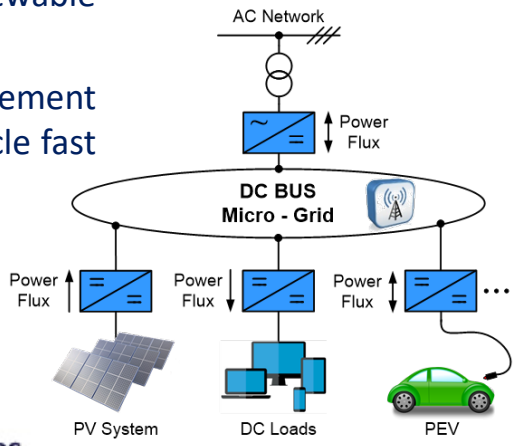
- C.Capasso, O. Veneri, et al. "Experimental investigation into the effectiveness of a super-capacitor based hybrid energy storage system for urban commercial vehicles", Applied Energy 2017

- C.Capasso, O. Veneri, et al. "Experimental evaluation of model based control strategies of supercapacitor - ZEBRA hybrid storage systems for urban electric vehicles", Applied Energy 2018

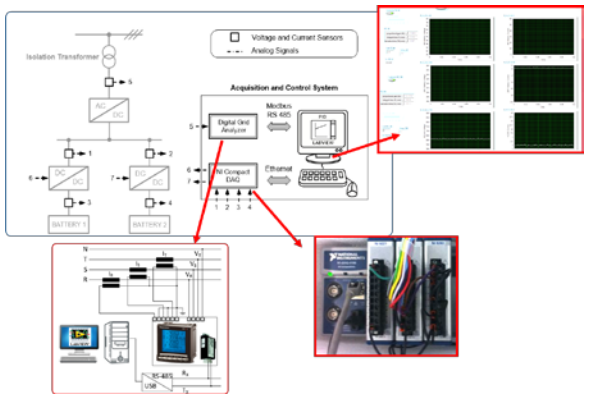
DC micro-grid power architectures for fast charging operations of PHEVs

- Development of DC micro-grid power architectures for the integration of the electric mobility with renewable energy and stationary storage systems.
- Experimental analysis of smart energy management strategies to support the electric grid during vehicle fast charging operations.

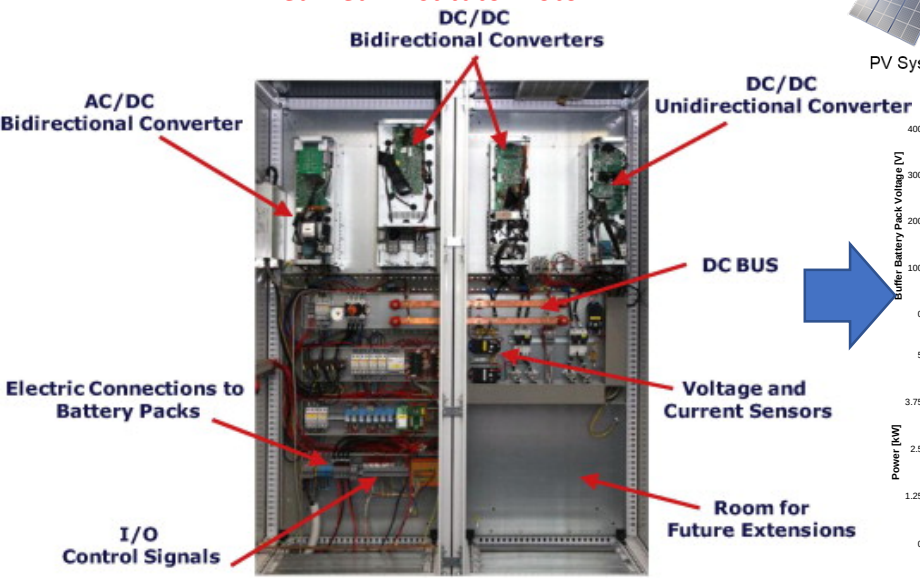
DC bus smart micro-grid

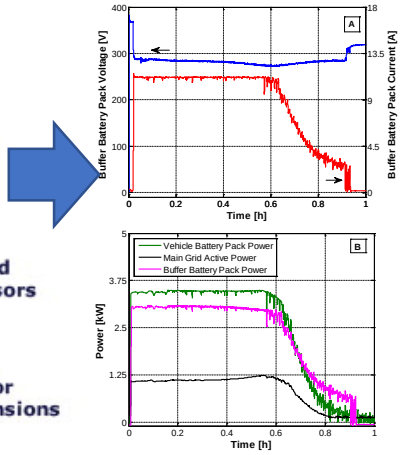


Charging Station Acquisition and Control Scheme



Prototipe of 800 V DC bus Micro-grid realized in Istituto Motori (*)

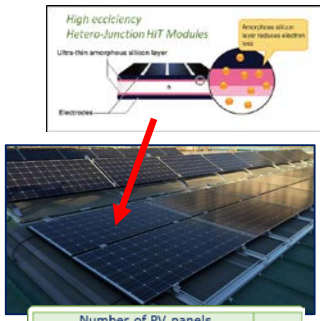




Example of Stationary Battery Pack under test

Number of Cells	90
Nominal Capacity C_{10}	90 Ah
Battery Pack Nominal Voltage	288 V
Max Charging Current	135 A (1.5 C)

PV panels under test



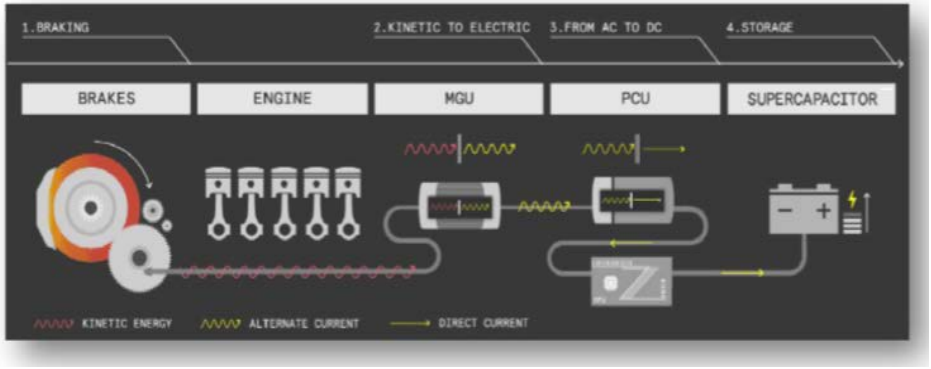
Number of PV panels for each string	8
Number of strings connected in parallel	4
PV Panels Maximum Power (W_p)	240.2
PV System Maximum Power (kW_p)	7.68
PV System Maximum Power Point Voltage (V)	350

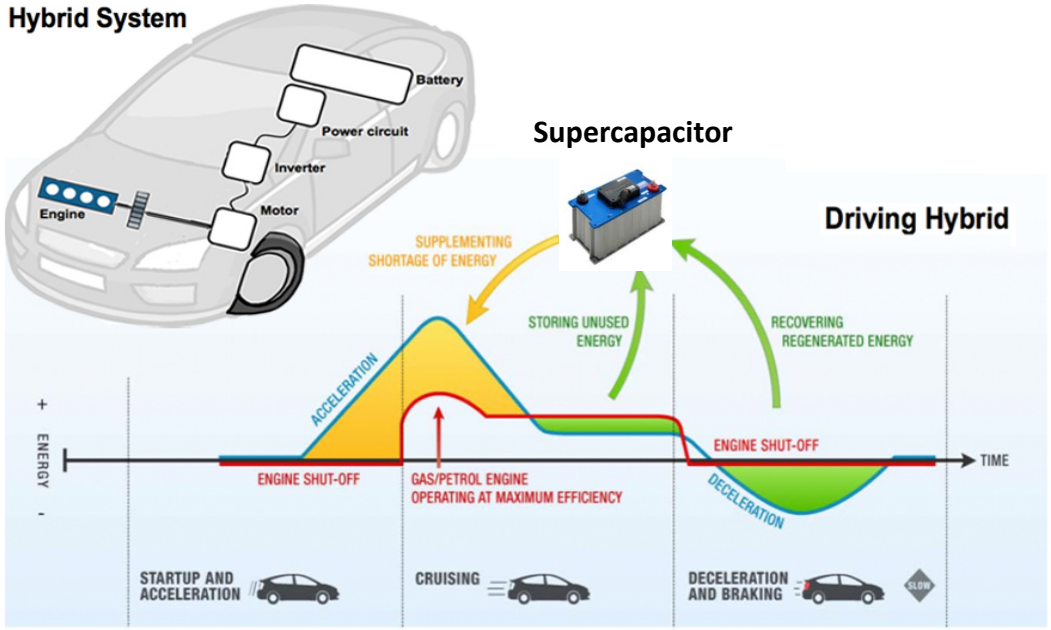
(*) C Capasso, O Veneri. Experimental study of a DC charging station for full electric and plug in hybrid vehicles. Applied Energy 2015

O Veneri. Technologies and applications for smart charging of electric and plug-in hybrid vehicles. Springer, 2017.

Challenges: Zero emission and high efficiency propulsion "Vehicles energy transients management by the use of supercapacitors"

The growing demand for sustainable mobility is driving researchers and vehicles manufacturers towards the exploration of low fuel consumption and environmental friendly solutions.

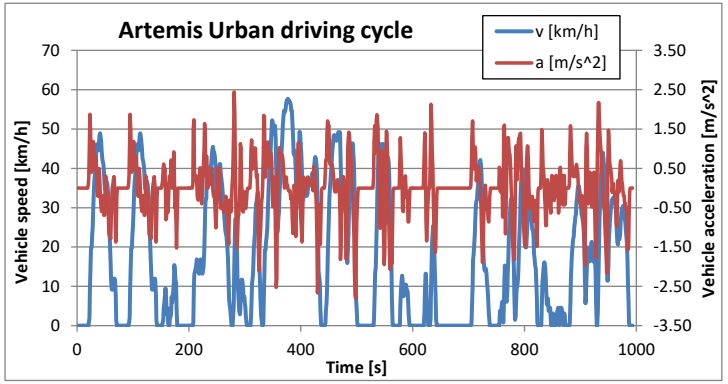




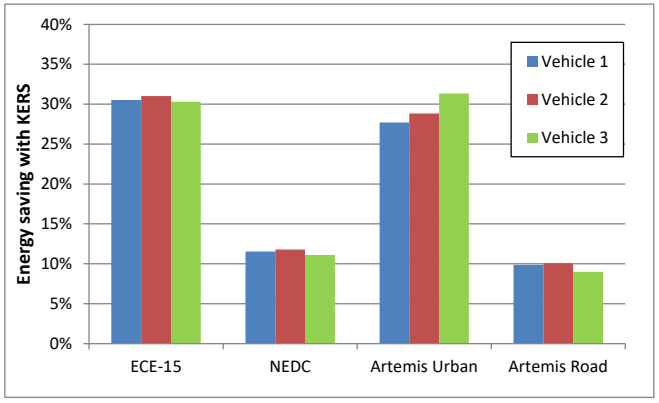
The use of supercapacitors (SCs) as fast and efficient energy storage solution in power application is widely recognized since they offer higher power densities with respect to traditional batteries, and energy densities from 10 to 20 times higher than electrolytic capacitors.

Challenges: Zero emission and high efficiency propulsion "Vehicles energy transients management by the use of supercapacitors"

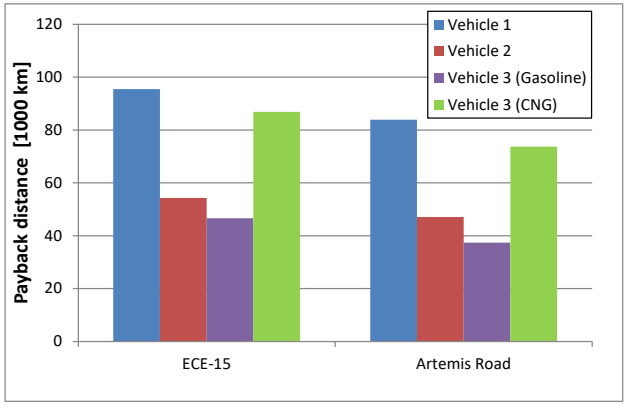
Urban driving cycle are characterized by a great amount of accelerations and braking phases



Modern supercapacitors and Motor Generators Units allow lost energy to be stored and re-used



An interesting amount of energy is saved and the payback time is lower than the lifecycle of the vehicle



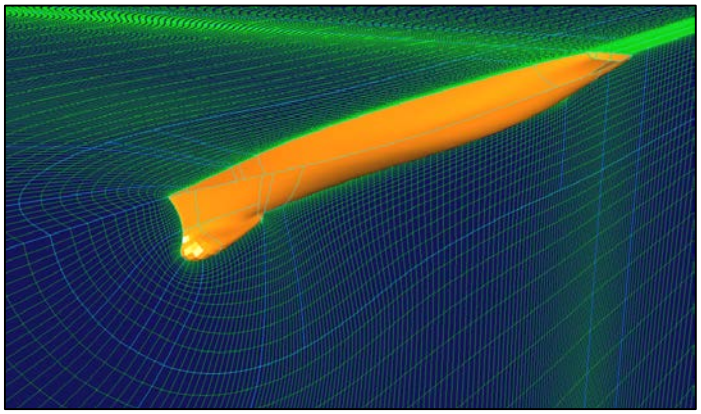
Simulation with **83F@48V** SC, Vehicle 1: Peugeot 308 e-Hdi FAP; Vehicle 2: Volkswagen Golf 1.4 TSI; Vehicle 3: Fiat Panda 1.2 Natural Power

Green *waterborne* vehicles
Topics

Experimental and numerical hydroacoustics
- Acoustic pollution and impact on marine fauna
- Regulations
- Ships identifiability and traceability

Materials (SHSs)
- Drag reduction and low fuel consumption
- Ship efficiency and on-board comfort (effects on wake-induced vibration and cavitation inception)

Design Optimization
- Coupling of meshing tools, CFD solvers, optimization algorithms
- Large design and operational spaces, with fully stochastic conditions (speed, heading, sea-states, etc.)



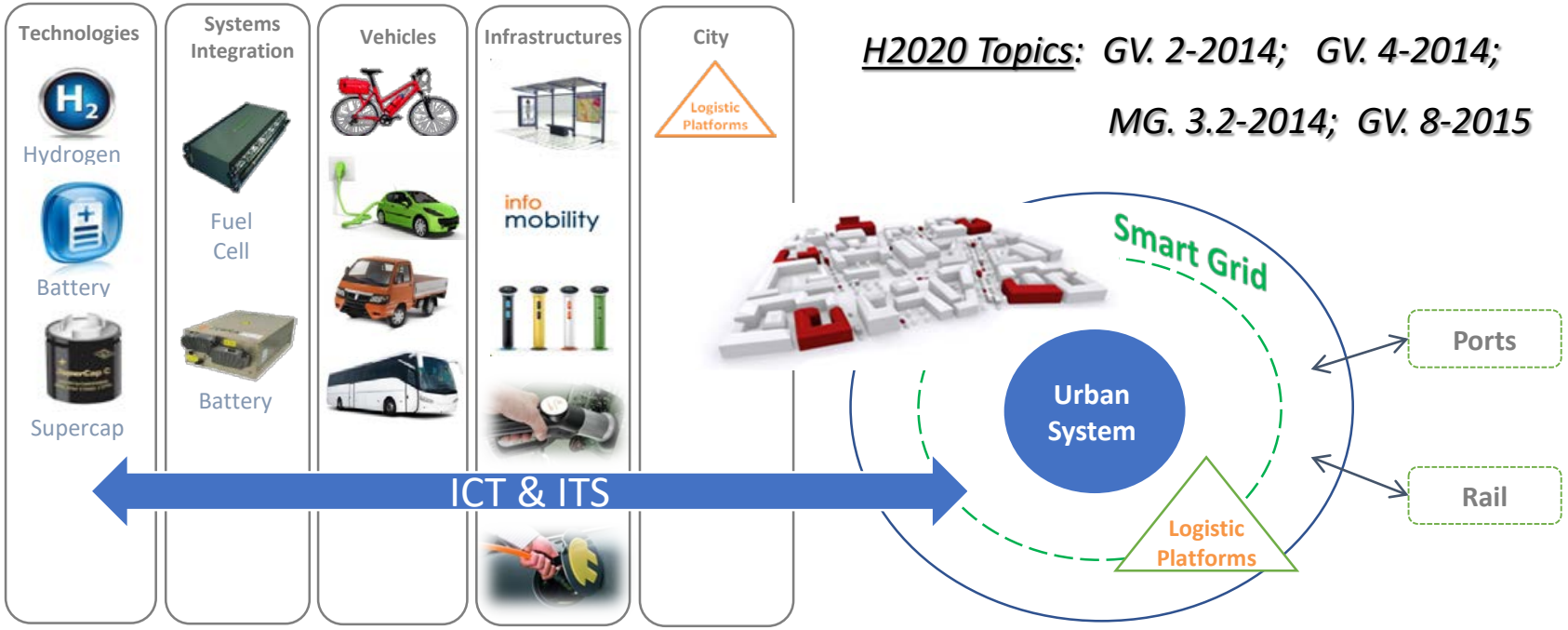
Zero emission and high efficiency propulsion

- **Zero emission and high efficiency propulsion**
  - Powertrains:
    - ICEs
    - HEV/BEVs
    - FC
    - ….
  - ADAS:
    - Automatic powertrain management
    - ….
  - Environmental impact qualification
    - LCA of vehicle and power system
    - New and unregulated pollutants
    - New methodologies for pollutant measurement/characterization
    - ….
  - Materials & Manufacturing
    - Lighter and more robust materials for vehicle and powertrain
    - Additive manufacturing
    - ….
  - Energy carriers
    - Alternative and renewable fuels (biofuels, e-fuels, bio-CH4, ecc.)
    - Fuel cell (H2, Methanol, ecc.)
    - Electricity (Battery, fast-charging systems, ecc.)

Challenges “details”

- **Zero emission and high efficiency propulsion (ITAE)**
  - Powertrains:
    - EV, HEV/BEVs, FCVs
  - Environmental impact qualification
    - Intelligent Transport System (ITS) in order to optimize city transfers and reduce emissions
  - Materials & Manufacturing
    - Development of H2 high pressure storage (up to 750 bar)
    - Waste heat recovery and valorization for cabin air conditioning (adsorption heat pumps)
  - Energy carriers
    - Alternative and renewable fuels (Green hydrogen produced from renewable energy by electrolysis, use of renewable energy sources instead of fossil fuels, Development of hydrogen and electric charging infrastructures)
    - Fuel cell (improvement of fuel cells performance, power density, useful life, thermal management and powertrain integration with batteries)
    - Electricity (Development of innovative batteries focused on electrochemical aspects, Development of battery monitoring systems (BMS), fast-charging systems)

Challenges: Intelligent Transport System (ITS) and Smart Cities



H2020 Topics: GV. 2-2014; GV. 4-2014; MG. 3.2-2014; GV. 8-2015

ACTIVITIES

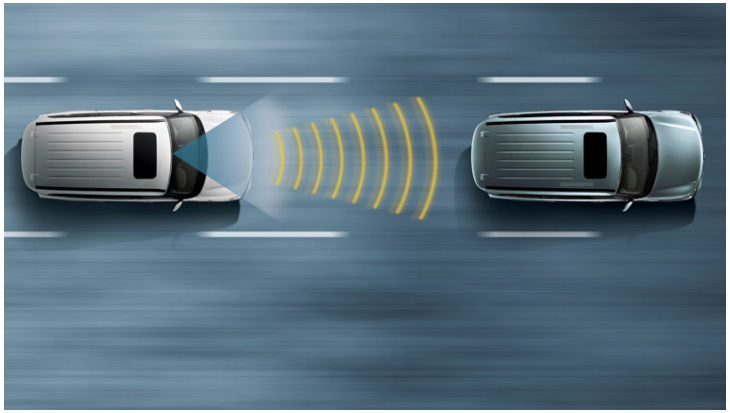
Fuel Cell Battery Supercap	Fuel Cell System Battery System Hybrid System	New concept of powertrain for: Bus Minibus Delivery Van Bicycle Tractor Airplane Ship	Electric recharge stations H2 Refill stations Info Mobility	Smart Mobility Logistic Transport

Smart Cities

Challenges “details”

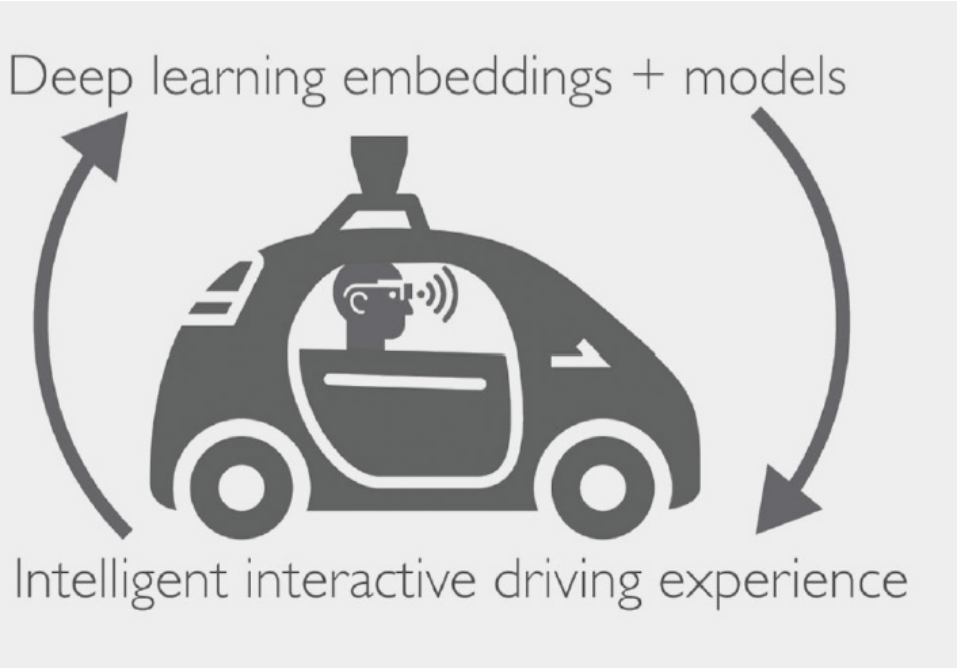
- **Zero emission and high efficiency propulsion**
  - Powertrains:
    - ICEs
    - HEV/BEVs
    - FC
    - ….
  - ADAS:
    - Automatic powertrain management
    - ….
  - Environmental impact qualification
    - LCA of vehicle and power system
    - New and unregulated pollutants
    - New methodologies for pollutant measurement/characterization
    - ….
  - Materials & Manufacturing
    - Lighter , more robust and more efficient materials for vehicle and powertrain
    - Additive manufacturing
    - Materials and technologies exploiting a reduced content of critical raw materials
    - Reuse, recyclability of materials and components
  - Energy carriers
    - Alternative and renewable fuels (biofuels, e-fuels, bio-CH4, ecc.)
    - Fuel cell (H2, Methanol, ecc.)
    - Electricity (Battery, fast-charging systems, ecc.)

Safety for zero-accident transport



Challenges: Safety for zero-accident mobility by intelligent monitoring of continuously the psycho-physiological status of the driver

Humans represent knowledge and learning experiences in the form of mental models. This concept from the field of cognitive psychology is one of the central theoretical paradigms for understanding and designing the interaction between humans and technical systems.



Challenges: Safety for zero-accident mobility by intelligent monitoring of continuously the psycho-physiological status of the driver

Guiding a vehicle demands a wide range of capabilities and skills of the driver, both on the perceptual-motor level (e.g. steering, shifting gears, etc.) and the cognitive level (e.g. making decisions, focusing attention selectively, etc.). Automated execution of these tasks can lead to the loss of the respective skills and at the same increase dependence on the technical system

Challenges: Safety for zero-accident mobility by intelligent monitoring of continuously the psycho-physiological status of the driver

Cognitive HMI

- Processing sensing data to detect and classify driver behaviors
- Identity recognition from sensing data to adopt different security levels
- Verbal interaction based Natural Language Processing based on explicable AI
- Sign based interaction by RGBD camera

The vehicle owns a mood and personality that influence its behaviour, the execution of security alerts, the implementation of safety actions. The software agent interact verbally with the driver to describe its «sensations», and to receive commands.

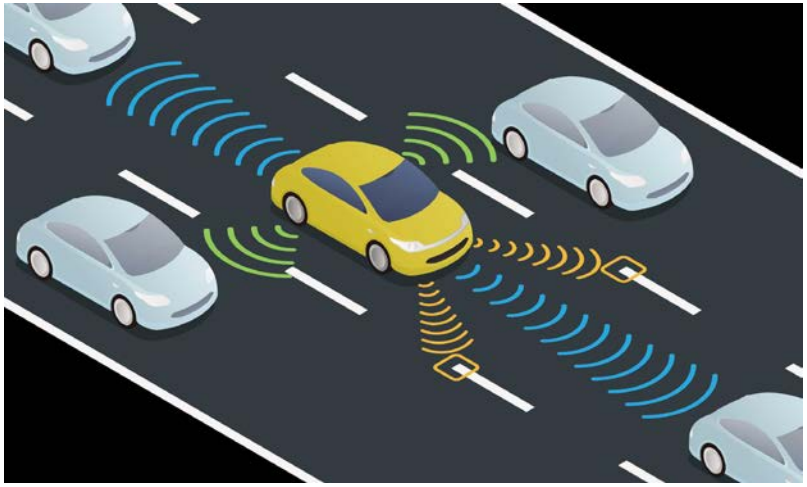
Challenges “details”

- **Safety for zero-accident transport**
  - Powertrains:
    - ….
  - ADAS:
    - ….
  - Materials & Manufacturing
    - Wearable and flexible electronics
    - New-concept sensors

Challenges “details”

- **Safety for zero-accident transport**
  - Powertrains:
    - ….
  - ADAS:
    - ….
  - Materials & Manufacturing
    - ….

Autonomous vehicles



Challenges “detailed”

- **Autonomous vehicles**
  - Powertrains:
    - ….
  - ADAS:
    - ….
  - Environmental impact qualification
    - ….
  - Materials & Manufacturing
    - Materials and technologies exploiting a reduced content of critical raw materials
    - Reuse, recyclability of materials and components
    - ….

Challenges “detailed”

- **Autonomous vehicles**
  - Powertrains:
    - ….
  - ADAS:
    - ….
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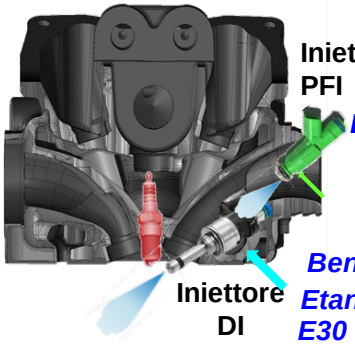
  - Materials & Manufacturing
    - ….

Sustainable vehicles

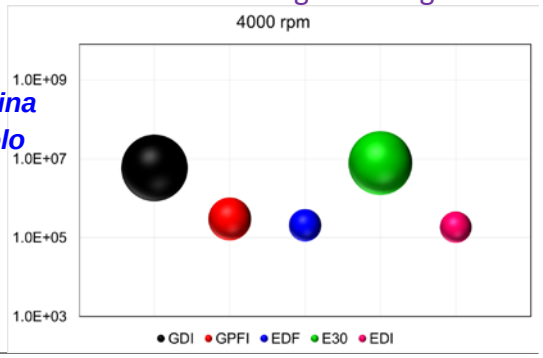
Alternative fuels for sustainable vehicles

Dual-Fuel Gas-Diesel engine

Spark-ignition Dual-Fuel Gasoline-Ethanol

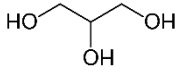


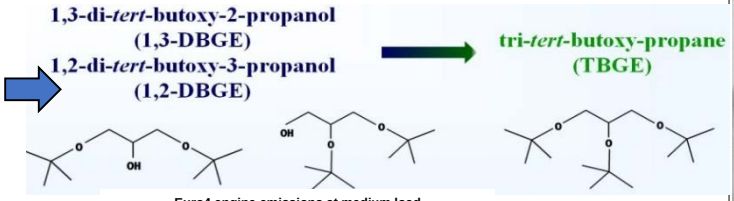
Particle number vs engine configuration

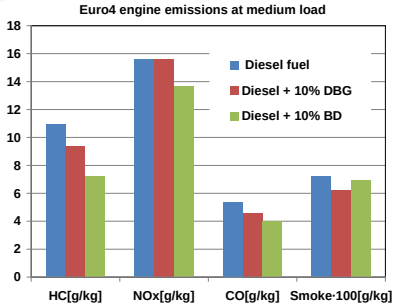


New renewable liquid fuels for CI and SI engines

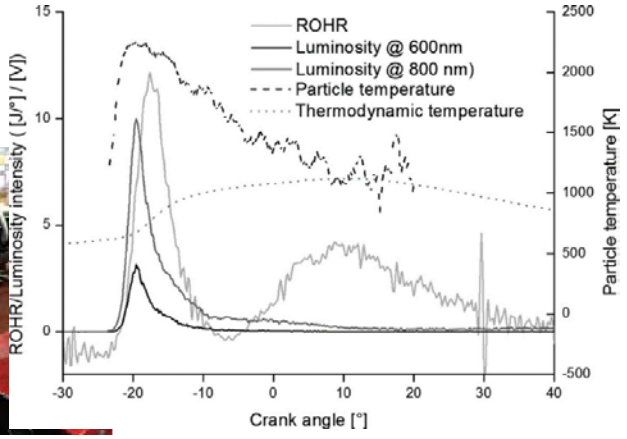
Glicerolo







Fully renewable solid metal fuels

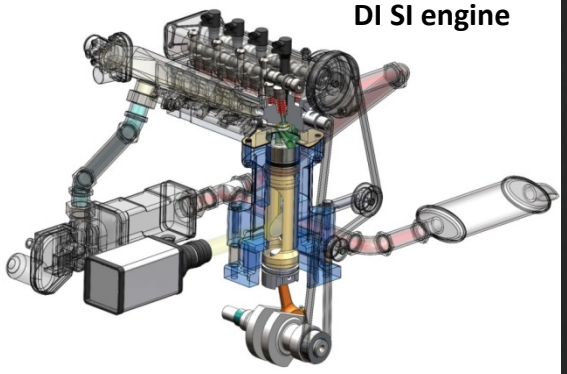


Liquid alternative fuels for sustainable vehicles

Collaboration IM (Napoli) – ISTM (Milano)

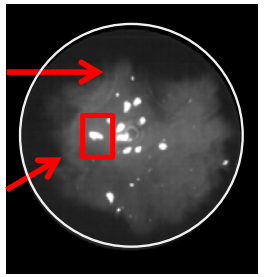
Alcohol produced by innovative one-step transformation of butanol into butyl butyrate

DI SI engine

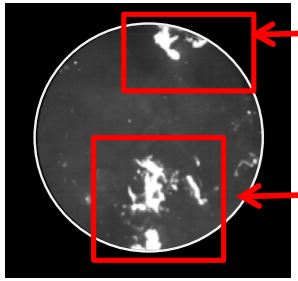


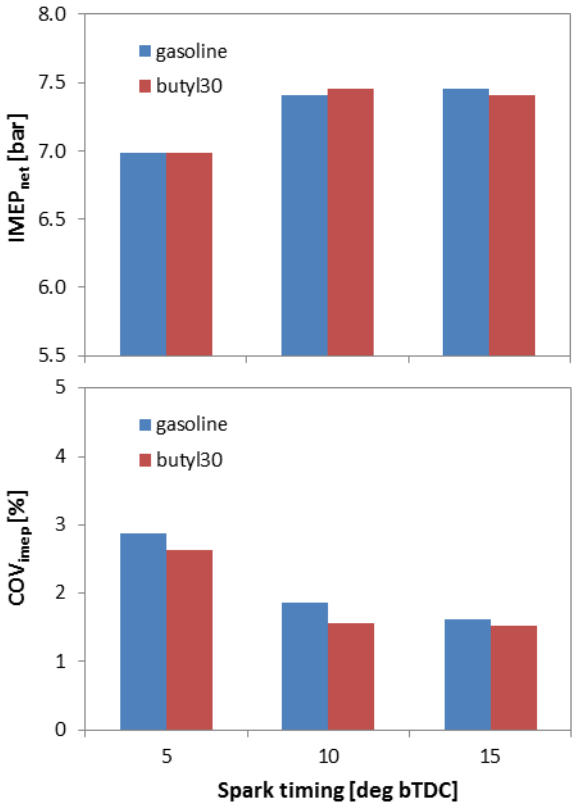
Butyl30
30%vol Alcohol/70%vol gasoline

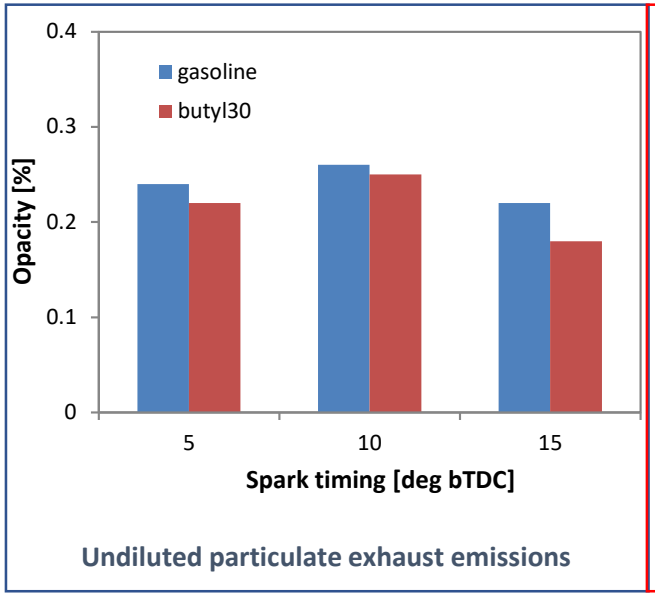
Early combustion stages (<0.1 MFB)



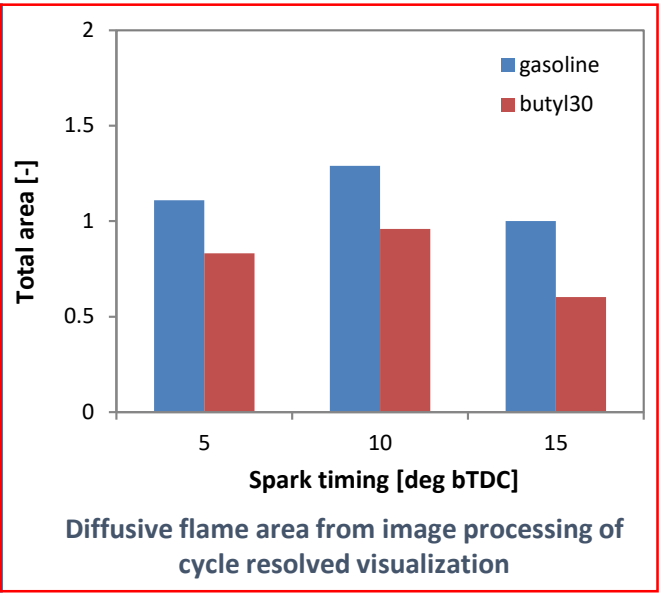
Late combustion (>0.9MFB)





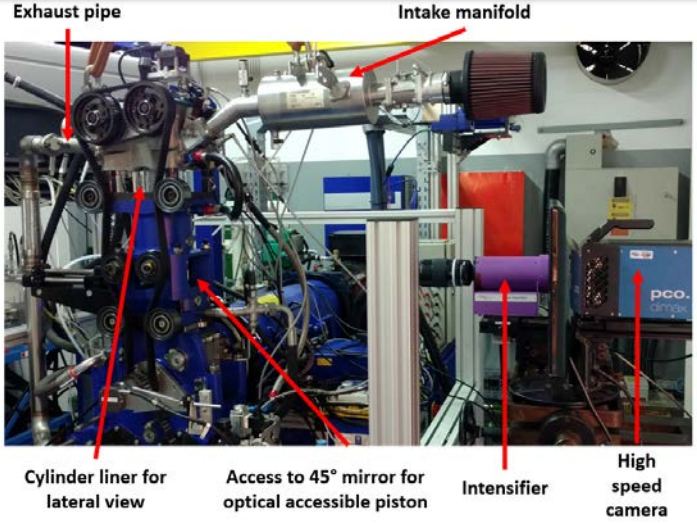


Undiluted particulate exhaust emissions



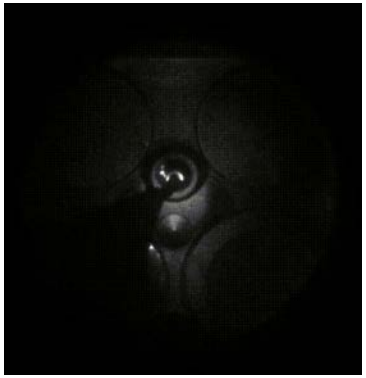
Diffusive flame area from image processing of cycle resolved visualization

Gaseous fuels for sustainable vehicles

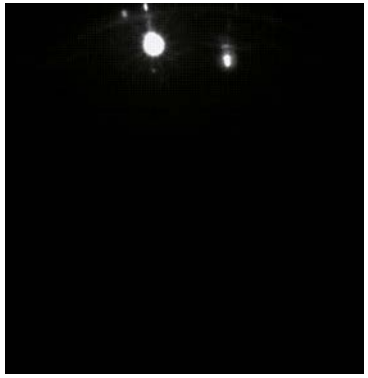


Collaboration
IM (Napoli)
ITA (Brazil)

Methane

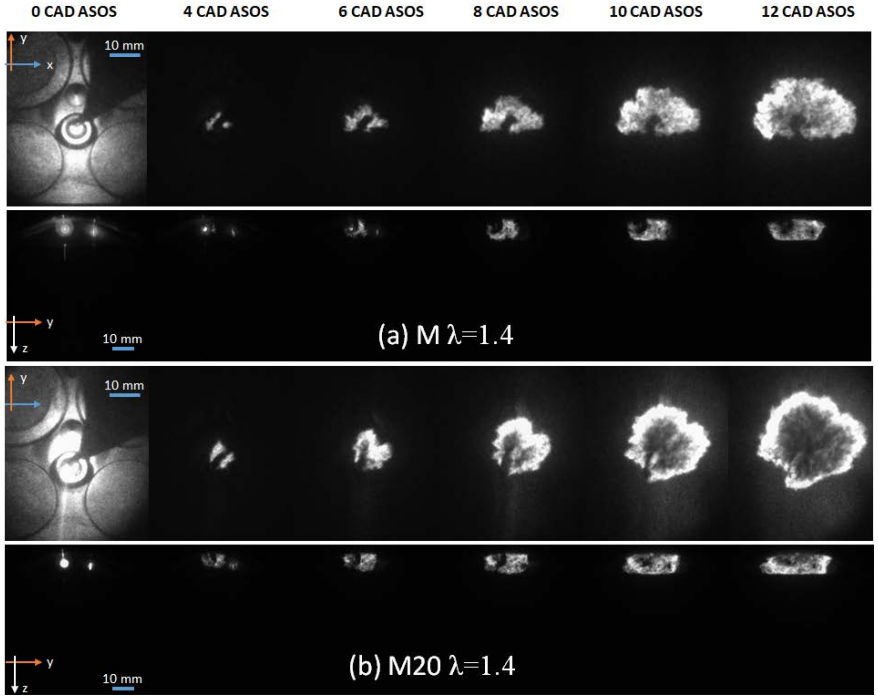


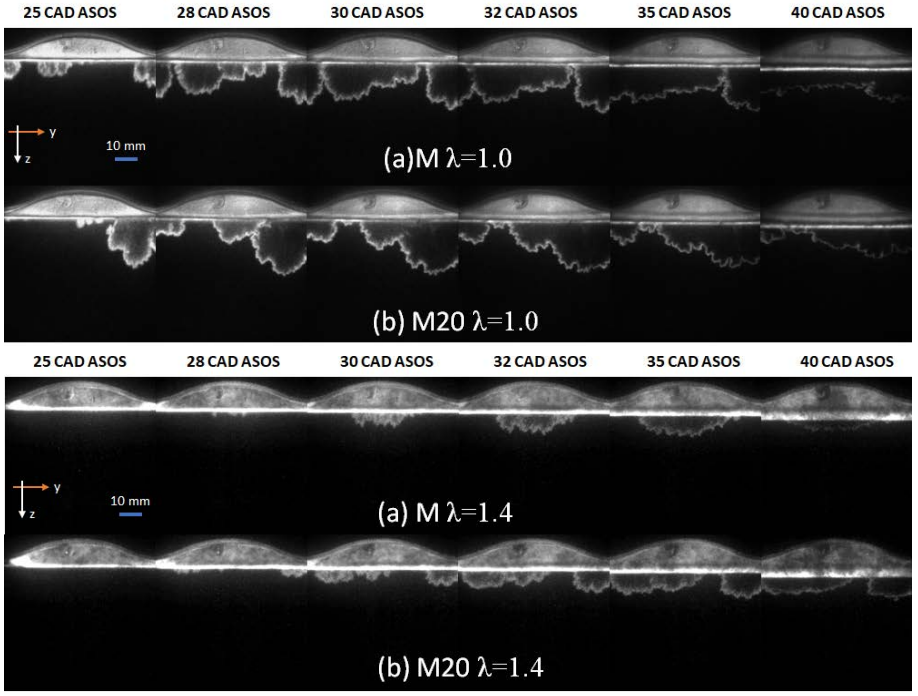
bottom view



side view

Top land region





(a) methane (b) methane with 20% H_2 addition (M20)

Challenges “detailed”

- **Sustainable vehicles**
  - Powertrains:
    - Reducing GHG emissions
    - ….
  - ADAS:
    - Vehicle management for CO2 reduction
    - ….
  - Environmental impact qualification
    - LCA
    - ….
  - Materials & Manufacturing
    - Materials and technologies exploiting a reduced content of critical raw materials
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  - Energy carriers
    - Low CO2 footprint fuels and energy carriers
    - ….

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    - ….
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SWOT analysis

AP18 - Low environmental impact vehicles

Strengths:

- **The quality of the team is world-leading in terms of originality, significance and rigour;**
- **The critical mass of the team assures a high research quality;**
- **The facilities and infrastructures allow to span from TRL1 to TRL6 of realization;**
- **The team has more than 5 M€ of funded projects including EU projects;**
- **Most of the activities are carried out in strict cooperation with the most important companies in the world.**
- **A huge impact at scientific, industrial, social and political level is expected.**

Weakness:

- The networking among the Institutes should be strengthened;
- Some PA show an overlapping with the topic covered by the AP18;
- Bureaucracy get slower the purchase of equipment.

Opportunities:

- **The team covers many research topics in the field of the green vehicles and sustainable transport system, in alignment with H2020 work program.**
- **Several open issues still remain;**
- **The activities can be coordinated with other proposals to attract funds.**

Threats:

- The evolution process of the transport system is characterized by a fast & ferocious competitiveness requiring a short time-to-market of the products;
- Extra-European countries are promoting research in the powertrain sector with a significant amount of funds;
- Presence of strong competitors.