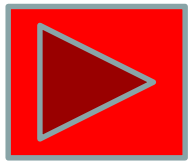
AP LCT:
Low emission energy technologies
(“Tecnologie energetiche a basse emissioni”)

Contributo slides INM_Roma

NOTA:
dove compare  *va inserito un video corrispondente all’immagine che trovate.*
Vi manderemo I file video separatamente

Project Area: Low emission energy technologies

Renewable energy: wind energy

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective: *Offshore & Onshore wind turbines aerodynamic, aeroelastic and aeroacoustic modelling*

Prediction of rotor aeroloads under steady and unsteady (wind shear, yaw misalignement, floater motion) conditions.

Integration with floater hydroelastic solvers and control tools for preliminary design purposes.

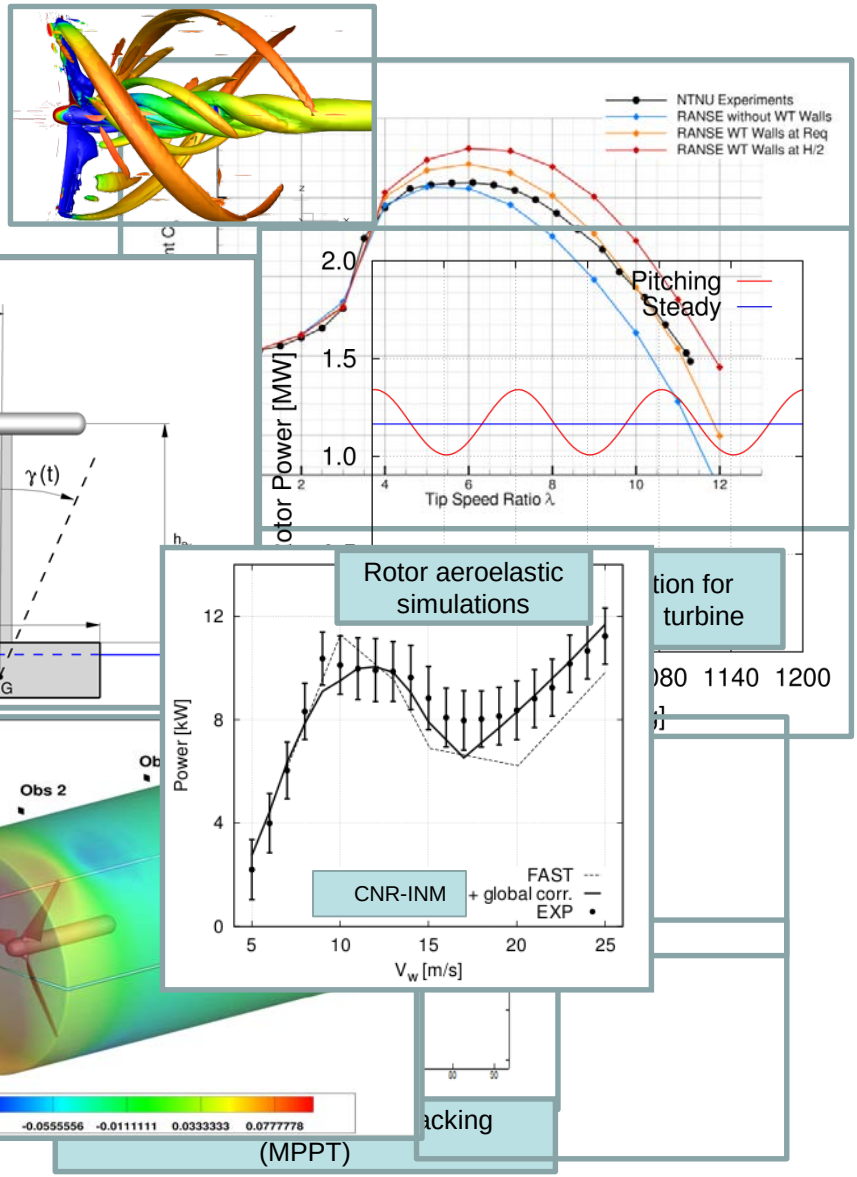
Noise prediction and analysis of blades elasticity effect on the radiated noise.

Approach:

Rotor aerodynamics: in-house 2D and 3D aerodynamic solvers

Rotor structural dynamics: Finite Element Method-based (FEM) solver

Rotor aeroacoustics: Acoustic Analogy formulation coupled with suitable CFD aerodynamic solvers.



Project Area: Low emission energy technologies

Renewable energy: Ocean energy / marine turbines

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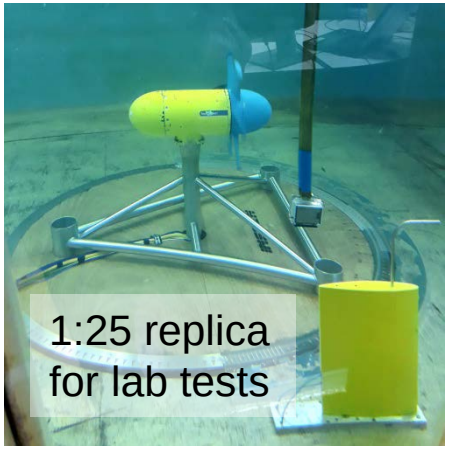
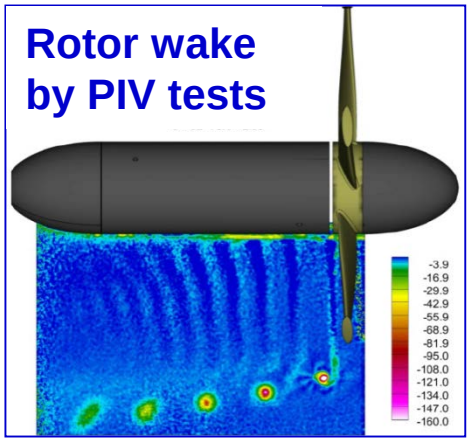
Objectives:

- Enhance comprehension of marine energy conversion physics in real operation at sea
- Underpin technology development through advanced testing and modelling
- Focus on tidal current turbines and OWC systems for onshore wave energy

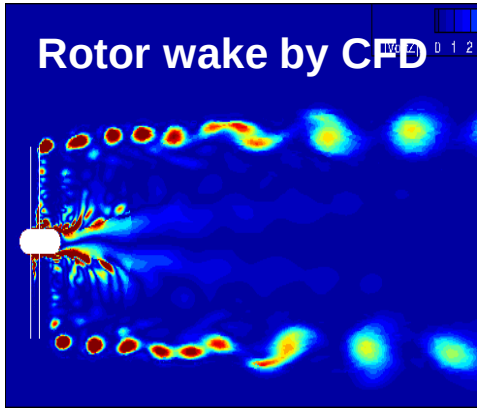


Rotor wake by PIV tests



Approach by INM:

- Enhance experimental technique to simulate sea-relevant conditions by lab tests and compare with full scale
- Develop variable-fidelity computational models for analysis & design of turbines to convert current and wave energy



Scientific impact/results:

- New knowledge by technology transfer from traditional R&D sectors
- Strong internationalization of researchers with EU and global partners
- Research infrastructures part of the EU leading network on ocean energy

MARINET

Project Area: Low emission energy technologies

Renewable energy: Ocean energy / tidal arrays CFD

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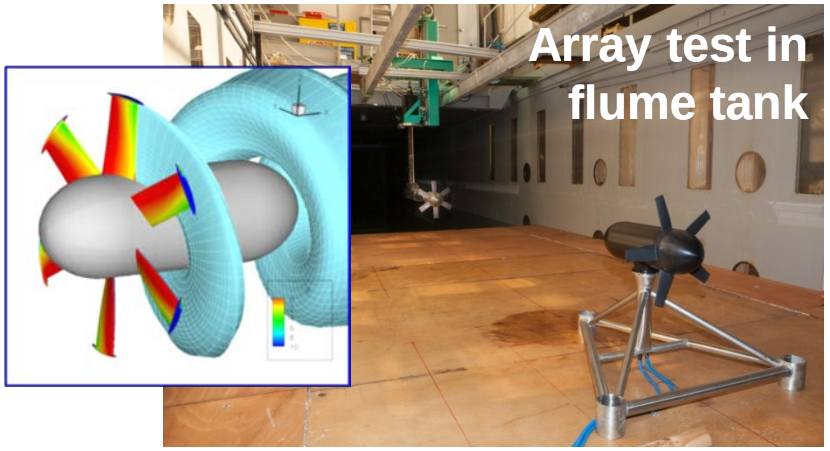
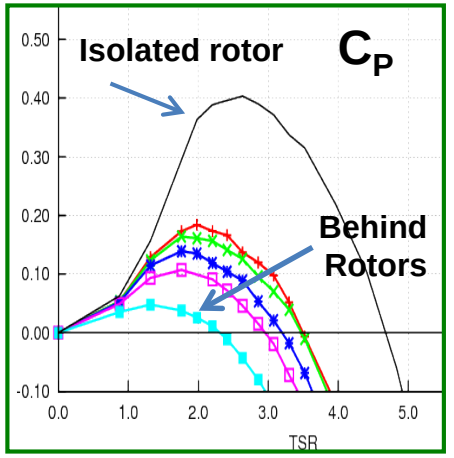
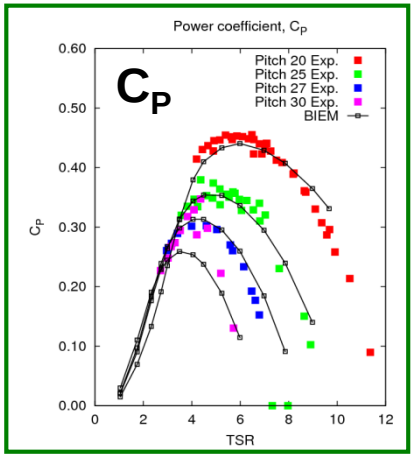
Objectives:

- Hydrodynamic models of tidal turbines
- Flow characterization of single devices and arrays of rotors in turbulent flow

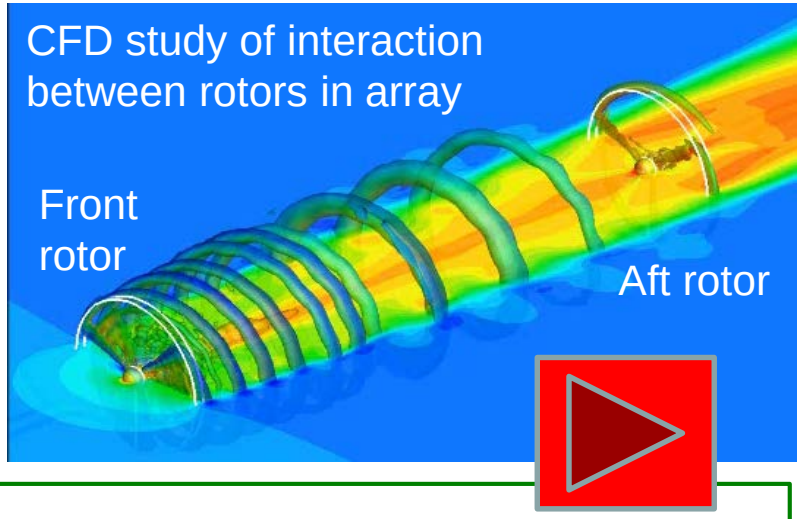






Approach by INM:

- Unsteady flow simulations
- Fast models (BEM) for single device power curves
- Hybrid RANS/BEM for turbine wake studies and device/device interactions in arrays



Scientific impact/results:

- Analysis of effects of geometrical and operational parameters on single device performance
- Prediction of device/device interaction effects on power produced in arrays

Project Area: Low emission energy technologies

Renewable energy: Ocean energy / wave energy

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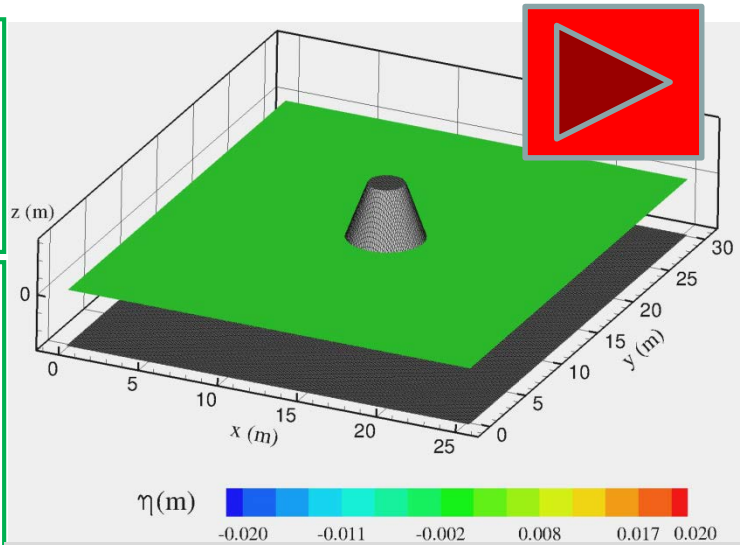
Objectives:

- Study of WECs arrays in design conditions and in extreme seas.
- Wave analysis and forecast in the deployment site.

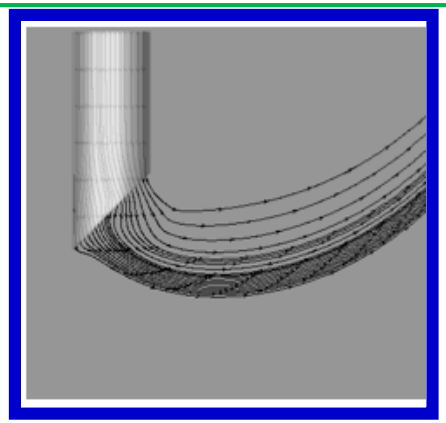
Approach by INM:

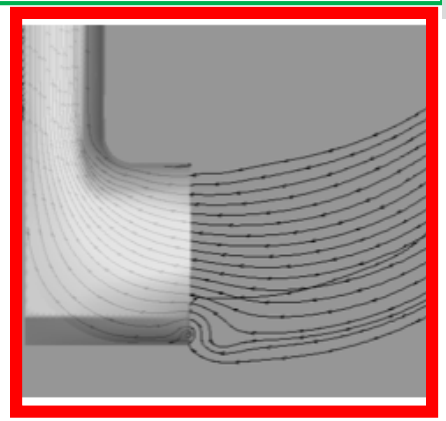
- Development of analytical and numerical tools for the analysis and optimization of WECs.
- Coupling of different numerical solvers to study local wave action on the WECs and in the region of the deployment site.

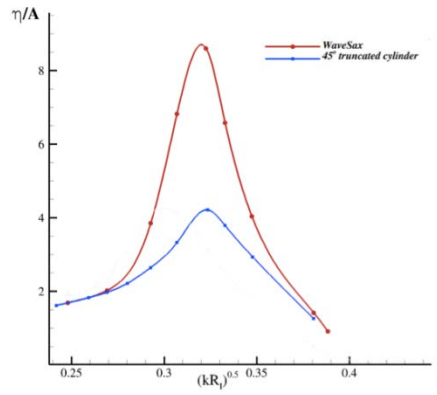


Tsunami wave towards an island

Water flow as a function of WEC intake







Scientific impact/results:

- Definition of a range of reliability of the commonly used numerical/analytical solvers
- Wave-to-wire control of WECs

Project Area: Low emission energy technologies

Renewable energy: Ocean energy / Turbine flow physics

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Objective:

Theme 1: Hydrodynamic characterization of elliptic profile models for tidal turbines by means of Temperature Sensitive Paints (Fig. 1).

Theme 2: Characterization of the interaction of tidal turbines wake at ground on tidal farm layout optimization by means of Temperature Sensitive Paints (Fig. 2).

Approach:

The capability of the Temperature Sensitive Paint to capture the laminar-turbulent transition in a boundary layer is connected to the Reynolds analogy that relates the thermal and the mechanical boundary layer growth.

Its application in the study of the elliptic profile blades for tidal turbines allows to shed light on the profile efficiency in a wide range of flow regimes. It can quickly provide information about separation, transition, reattachment and stall conditions.

Its application in the study of the wake-floor interaction inside and around a tidal turbine array can provide a large scale time resolved map of the wake extension and oscillation, providing a clear and immediate picture about the efficiency of the investigated farm layout and about the quality of the incoming flow for each element of the array.

Figures:

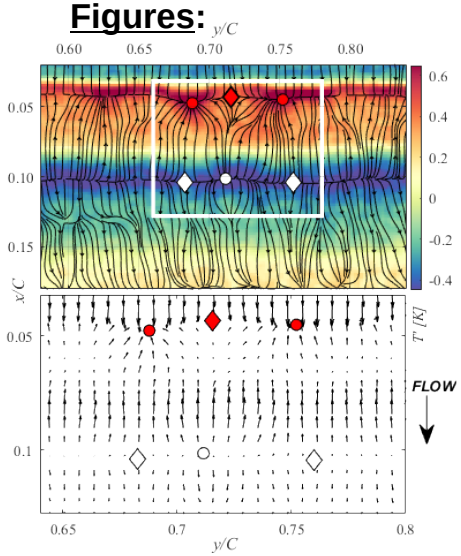

Fig. 1: Laminar Separation Bubble temperature, skin-friction topology (top) and vector field for a NACA0015 profile model at Re 1.8x105

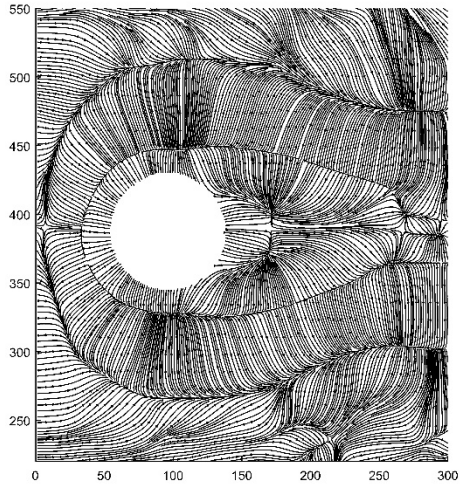

Fig. 2: Skin friction topology on the floor after a wall-mounted cylinder. Laminar condition.

Scientific Impact/Results:

Theme 1: The investigation about elliptical profile models is suggested in order to explore how their shape, noteworthy in tidal applications because of its intrinsic bi-directionality, influences the flow separation, transition, reattachment and stall occurrence. This is of particular interest because of the position of the profile's maximum thickness, which make difficult to study their behavior with classical approaches.

Theme 2: The interaction of a turbine wake with the floor and with other turbines in a farm is of extreme importance in the turbine farms layout optimization.

Project Area: Low emission energy technologies

Renewable energy: Wind, Marine Current, PV energy

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Objective:

- Development of distributed generation (*DG*) systems from renewable sources (*RES*), wind, marine current, photovoltaic, characterized by:
  - **High dynamic performance;**
  - **High power density;**
  - **Optimal exploitation of the energy source;**
  - **Reduced cost;**
  - **High reliability**;

Approach:.

High dynamic performance: new control strategies will be developed, based on both linear and non-control theory, aiming at the achievement of high performance control of the electrical/electromechanical variables of the DG unit

High power density: wide band gap (WBG) power devices technologies will be adopted, (SiC and GaN), permitting much higher voltages, frequencies and temperatures than conventional semiconductor materials.

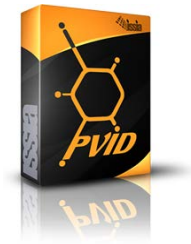
Optimal exploitation of the energy source: new maximum power point tracking techniques (*MPPTs*), of both the P&O (Perturb and Observe) and neural type for PV/wind/marine current generators will be devised and experimentally validated.

Reduced cost: specific power converter topologies will be addressed, permitting the adoption of the minimum number of power devices.

High reliability: Estimators and observers, based on both linear and non-control theory, will be developed in order to avoid the adoption of expensive sensors (sensorless techniques). The EMI reduction in power converters will be addressed by means of suitable PWM techniques and active/passive filters.

Figures:

ODEF software for PV panels characterization



Experimental tests In wind tunnel

Scientific Impact/Results:

- Development of up-to-date technologies with high TRL, related to distributed generation from renewable sources characterized by innovative features
- Technology transfer to SMEs and Industries
- Training of technicians and scientist in the field of distributed generation from renewable sources

Project Area: Low emission energy technologies

Renewable energy: Solar energy

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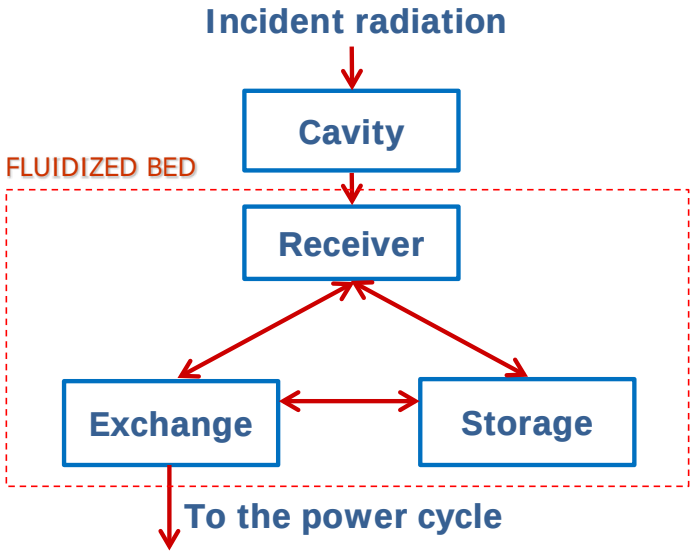
Objective:

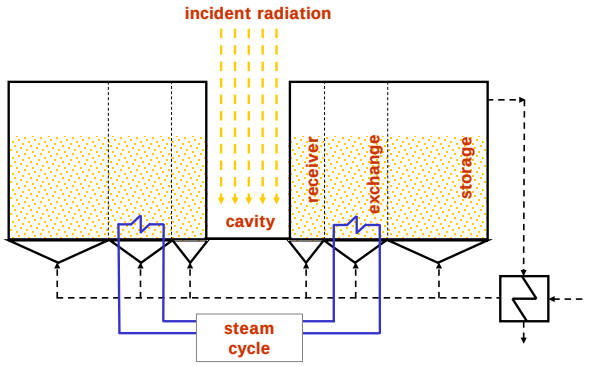
The study of indirectly or directly irradiated solar receivers based on compartmented dense gas fluidized beds coupled with thermal and thermochemical storage for CHP generation and/or materials production

Approach:.

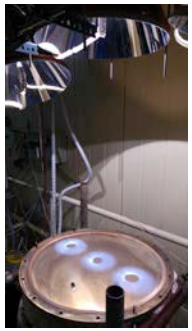


Figures:

Indirectly irradiated fluidized bed with thermal storage



directly irradiated fluidized bed for thermochemical storage and/or material production



Scientific Impact/Results:

the 125kWth peak load CSP plant at Buccino

MAGALDI Dependable Technologies

the 2MWth peak load CSP plant at San Filippo del Mela

Project Area: Low emission energy technologies

Flexibility and sustainability: Energy storage and carriers

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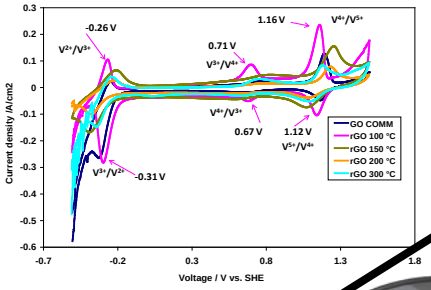
Objective:

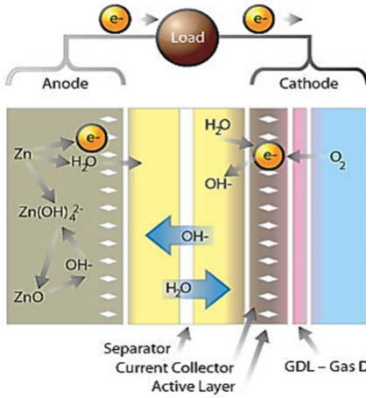
- Development of innovative and highly performing materials and components for electrochemical storage devices (vanadium redox flow, sodium-ions, iron-air, sodium-nickel chloride batteries and supercapacitors) from battery cell level up to kW battery.

- Improving electrochemical performance in terms of current and power density, round-trip efficiency and cycling.

The goal is a total costs reduction of the specific technology to allow the up-scaling favouring the market introduction

Vanadium Redox Flow Battery





Iron-air Battery process

$$O_2 + 2Fe + 2H_2O \underset{charge}{\overset{discharge}{\rightleftharpoons}} 2Fe(OH)_2$$

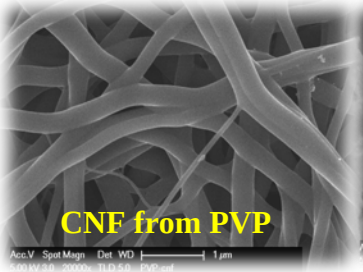
$$3Fe(OH)_2 + \tfrac{1}{2}O_2 \underset{charge}{\overset{discharge}{\rightleftharpoons}} Fe_3O_4 + 3H_2O$$

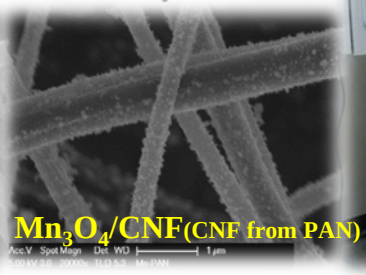
Approach:

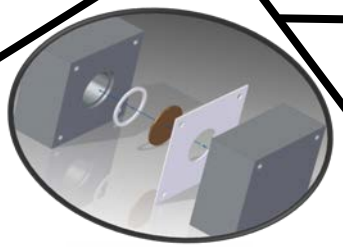
- Low cost synthesis methods suitable for scale-up materials:

- Electrospinning technique
- Sol-gel
- Hydrothermal

- Low cost materials and components







Na-NiCl$_2$ innovative planar battery

Supercap proof-of-concept

Scientific Impact/Results:

- Optimization of materials, components and design with respect to the state of art for current storage technologies
- Proof-of-concept of new electrochemical storage technology

Project Area: Low emission energy technologies

Flexibility and sustainability: Energy storage and carriers

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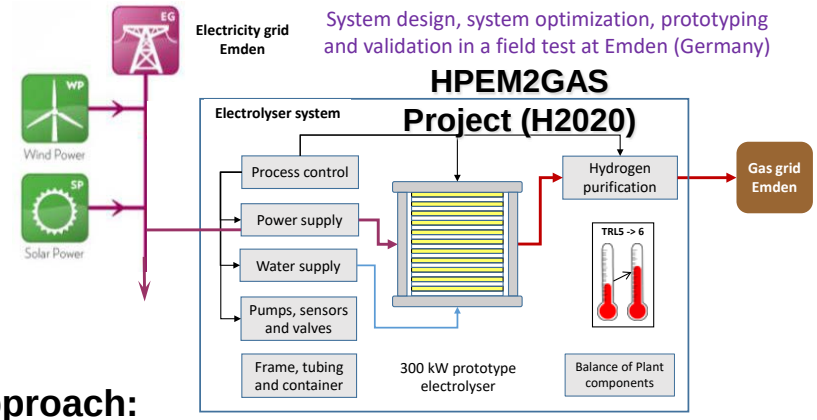
Energy storage of renewable energy is achieved producing H_2 for fuel cells by water electrolysis, photo-electrolysis, CO_2-H_2O co-electrolysis (to store electrical energy in chemicals such as methanol)

Objective:

- **Development of innovative and highly performing materials and components**
- **Improving the efficiency of the devices.**



Approach:

- Synthesis methods for catalysts suitable for scaling-up
- Cost-effective materials and components

1 kW PEM electrolyser system

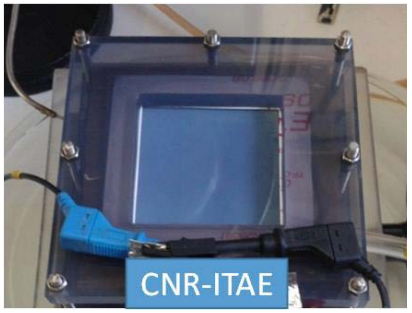
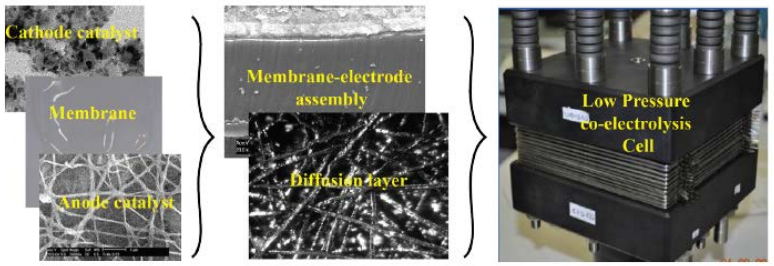


Photo-electrolysis cell

CO_2-H_2O co-electrolysis materials and components



Scientific Impact/Results:

- **Optimization of materials and components**
- **Development of prototypes to validate the technology and the developed materials.**
- **Technology transfer and training**

- High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications (HPEM2GAS): G.A. n° 700008
- Next Generation PEM Electrolyser under New Extremes (Neptune): G.A. n° 779540
- CRM-free Low Temperature Electrochemical Reduction of CO2 to Methanol (LOTER.CO2M): G.A. n° 761093
- Innovative Photoelectrochemical Cells for Solar Hydrogen Production (FotoH2): G.A. n° 760930

Project Area: Low emission energy technologies

Flexibility and sustainability: Fuel cells

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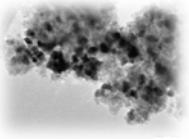
Objective: The EU targets are the reduction of greenhouse gas (GHG) emissions by 40% by 2030 and by 80-95% by 2050 compared with 1990. Polymeric Electrolyte Membrane Fuel Cells (PEMFC) are environmental friendly. Although substantial progress has been achieved in the development of membrane-electrode assemblies (MEAs) for fuel cells, their high cost hinders the commercial breakthrough of PEMFC. Therefore it is urgently to improve MEA performance and durability to reduce cost and enable marketability of FC.

Approach: The development of new materials and improved membrane electrode assemblies is required to enable cost, performance and lifetime targets to be attained. It is necessary to develop and modify materials, such as polymeric membranes, ionomer dispersions, catalysts (e.g. Pt alloys and new supports with higher stability), and integrate them into high performing MEAs with superior durability. At the same time, it is necessary to improve the design of the stack. The problem related to the sealing concepts and stack design, such as the edge protection of the membrane and the sealing concept for the cooling media, have to be depth investigated to enhance the lifetime of the system.

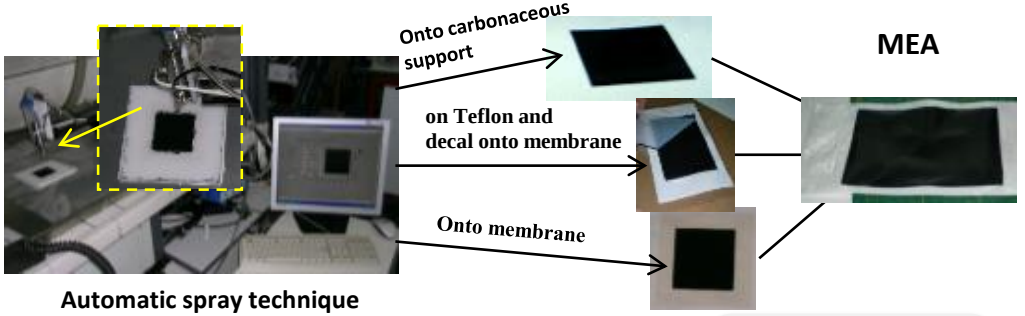
Figures:



Catalysts based on Pt

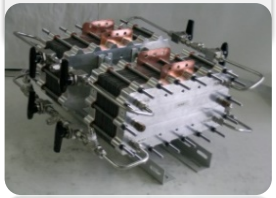
Polymer functionalisation

Membranes



3.5kW - M T PEM
2 x 1.5 kW modules

1 kW H_2/O_2
for Space application



5 kW H_2/air
for Marine application

Scientific Impact/Results: The development of components such as catalysts, polymeric membranes, electrodes and MEAs, and their scale up from the lab scale to bigger size, has permitted the realisation of prototypes in a wide range of electric power. In particular a 3.5kW stack operating at 120°C for automotive, a 1kW stack operating in H_2/O_2 for space application and a 5kW stack operating in H_2/air for marine APU applications were developed.

Project Area: Low emission energy technologies

Flexibility and sustainability: Fuel cells

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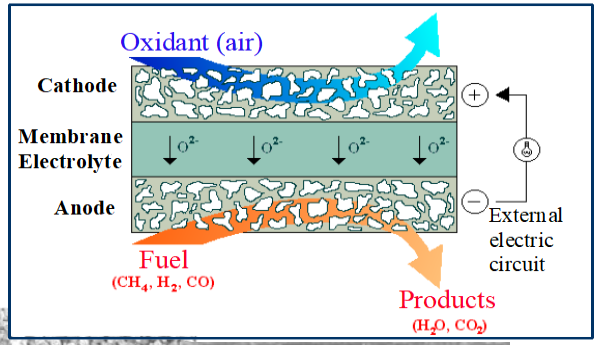
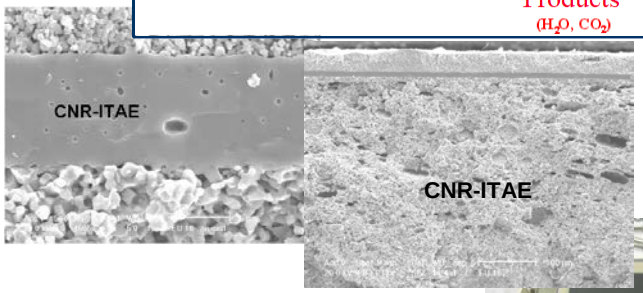
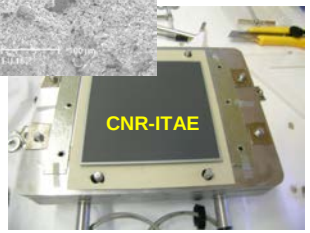
Objective:

- **Solid Oxide Fuel Cells (SOFCs)** are based on *ceramic materials* and operate at high temperatures between 800-1000°C.
- The challenges in this sector are regarding the *reduction of the operation temperature* and the direct utilization of hydrocarbons.
- This will allow to decrease degradation and make the device cost-effective by system simplification (reduced fuel processing) and use of cheap ferritic steel interconnectors.

Figures:







Approach:

- The approach is to develop ceramic electrolytes for intermediate temperature operation based on ceria and gallates, use a multifunctional electrocatalytic layer at the anode to favour internal fuel processing and tailor the composition of the perovskite cathodes to speed-up the oxygen reduction process

Scientific Impact/Results:

- The new materials and cell architectures have been validated for the direct oxidation of hydrocarbons such as methane, ethanol, bio-gas, propane, reformed diesel etc. in systems up to 2 kW power

Project Area: Low emission energy technologies

Flexibility and sustainability: Power grids

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Objective:

Design and experimental prototyping of several typologies and topologies of electronic power converters with high dynamic performance and high efficiency for interfacing the smart micro-grid with the main power network, renewables sources based generators and storage systems (batteries, supercapacitors).

Approach:.

Wide band gap (WBG) power devices technologies will be adopted, (SiC and GaN), permitting much higher voltages, frequencies and temperatures than conventional semiconductor materials.

The following typologies of power converters will be focused:

•DC-AC voltage source inverter (VSI), both in traditional 2-level and in multilevel configurations (particularly NPC = Neutral Point Clamped), including the related pulsewidth modulation techniques (PWM);

•AC-AC based on the combination of DC-AC converters in back-to-back configuration.

•DC-DC converters: buck, boost, bi-directional type. In particular boost converters with innovative structures characterized by high efficiency and low cost (low number of power devices) for the connection of fuel cell (FCS), micro-wind, marine and photovoltaic systems will be devised.

Innovative PWM and control techniques will be implemented experimentally on embedded platforms (DSP, FPGA, micro-controllers).

Figures:

3-level NPC
Voltage Source Inverter
(20 kW)

DC-DC bidirectional
Converter (2.6 kW)

Scientific Impact/Results:

- Development of innovative power converters and related PWM and control techniques
- Technology transfer to SMEs and Industries
- Training of technicians and scientist in the field power converter design and control.

Project Area: Low emission energy technologies

Flexibility and sustainability of energy and power:

Smart Micro-grids

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

- Definition of new architectures for the electric energy distribution in smart micro-grids: DC distribution systems and hybrid AC/DC, with one or more voltage levels and their adoption in residential/commercial buildings as well as in smart vehicles, including ships.
- Definition of methodologies for the optimal and coordinated management, in smart micro-grids, of the following actors:
  - Distributed generators from renewable sources;
  - Stationary generation units (Fuel-cells);
  - Storage systems.
  - Loads**.**

Approach:.

Development of data reconstruction and forecasting techniques of electric/meteo-climatic data as a part of the intelligent management of electric power grids:

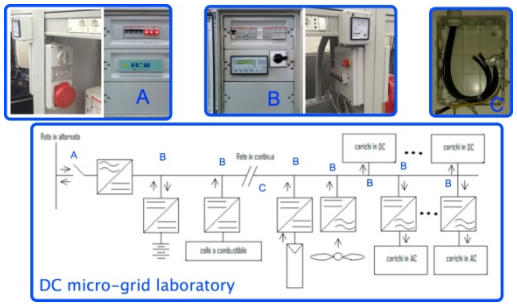
1) electric energy production from renewable sources;
2) load demand.

Definition of EMS algorithms pursuing one or several specific goals:

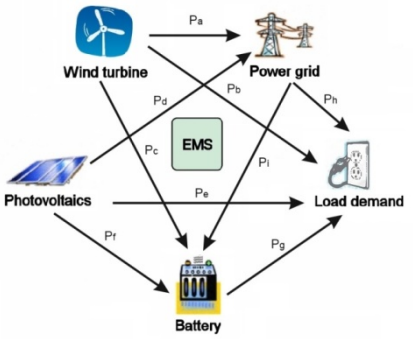
1) maximum efficiency;
2) minimum losses;
3) minimum operating cost;
4) maximum self-sufficiency in islanded operation;
5) minimum uncertainty of the grid exchanged power profile.

Implementation of the forecasting and management algorithms on embedded platforms (FPGA, micro-controllers).

Figures:



Flussi di potenza governati da EMS



Scientific Impact/Results:

- Development of innovative distribution architectures of smart micro-grids and related energy management systems, of potential interest from the power network manager and companies.
- Technology transfer to SMEs and Industries
- Training of technicians and scientist in the field smart micro-grids and their management

Project Area: Low emission energy technologies

Flexibility and sustainability of energy and power:

Integrated systems/mCHP

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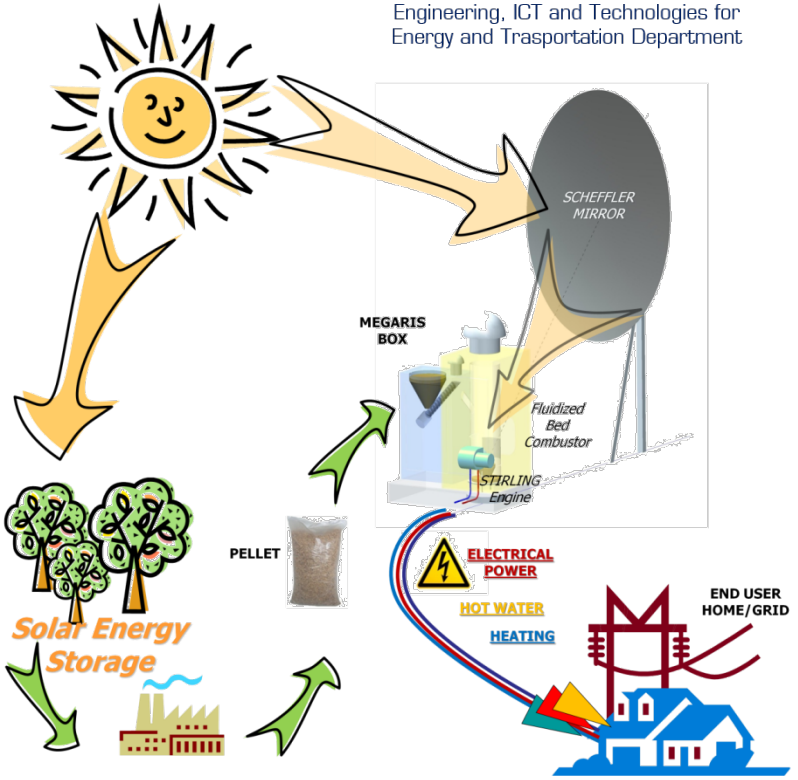
Objective:

Fluidized bed CSP is integrated with thermochemical conversion of biomass to obtain a micro-CHP generator very flexible on the renewable source.

Figures:



Approach:.

Fluidized bed combustion for clean conversion of different biomass
Heater of the Stirling engine immersed in the fluidized bed to exploit extremely high heat transfer coefficients and avoid fouling issues.
Scheffler fixed focus concentrator to reduce weight and cost.

Scientific Impact/Results:

This new system introduces several innovative solutions for micro-CHP enabling the possibility to produce heat and power 24h/day in off-grid sites practically at the sole cost of the system installation adopting locally harvested energy sources and without additional storage systems.

Project Area: Low emission energy technologies

Flexibility and sustainability of energy and power:

Energy storage and carriers

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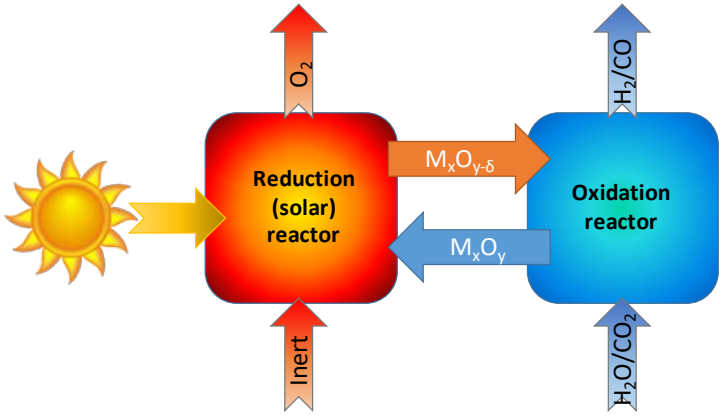
Objective:

Chemical storage of solar energy as fuels through two-step thermochemical H_2O/CO_2 splitting cycles. H_2/CO mixture can be used as fuel itself or as feed for gaseous and liquid fuels production.

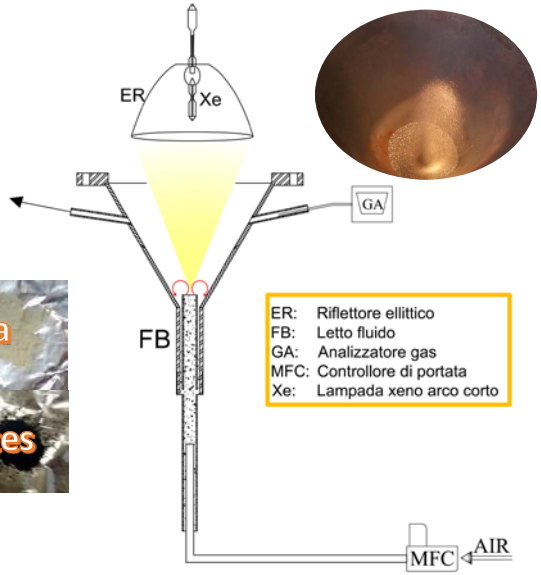


Approach:

- Developing novel bi-functional ceria- and perovskite-based materials showing improved splitting features.
- Developing novel reactor configurations based on fluidized bed solar receivers considering both internally circulating and interconnected fluidized bed options

Scientific Impact/Results:

- Doped ceria and bi-functional perovskites successfully prepared and tested in H_2O/CO_2-STS
- Tunable redox properties of materials by tuning their chemical composition
- materials and solar receivers optimization to increase the solar-to-chemical efficiency up to levels feasible for industrial applications improving reactor solar capture efficiency and enhancing the self-reduction and splitting properties of the materials



Project Area: Low emission energy technologies

Flexibility and sustainability: Emission control

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Objective:

•Change in fuel composition or energy mix influence the design of the conversion system but also pollutants. It is urgent to improve knowledge on Formation mechanisms of new pollutants, and develop new diagnostics and abatement metodology.

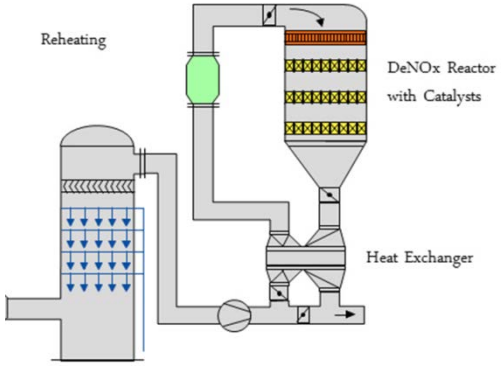
Approach:

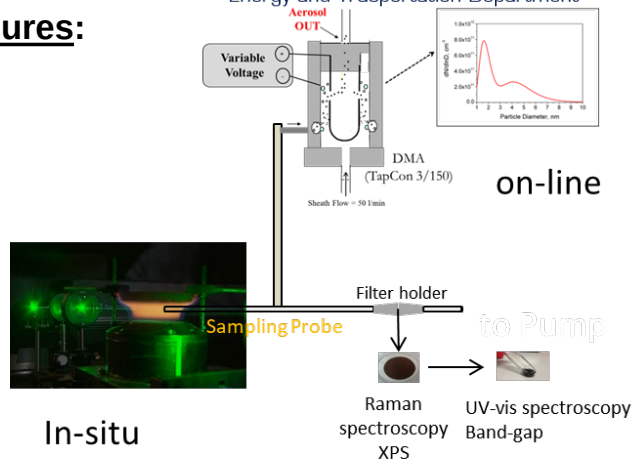
Research activities are focused on:

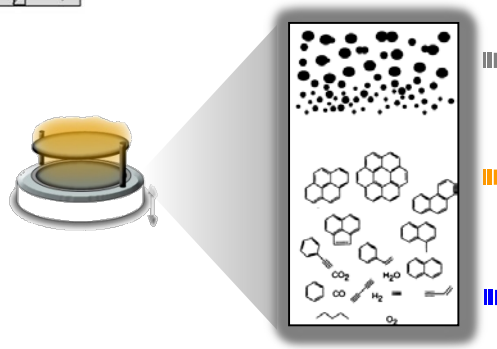
1. Formation mechanisms of pollutants;
2. Advanced diagnostics for regulated / unregulated pollutants;
3. Reduction of pollutants from fossil and alternative fuels.

Specific activities include in-situ, on-line and off line advanced diagnostics of pollutants and ultrafine particles; diagnostic of flame instabilities; NO_x , SO_x and particulate reduction; SCR; Combined particulate and NO_x reduction; NO_x storage-decomposition for automotive application; PM reduction through water vapor condensation; Hg capture from flue gases; purification of CO_2 streams; tar and VOC abatement.

Figures:







Scientific Impact/Results:

- Physicochemical characterization of combustion generated carbon nanoparticles
- Characterization of main combustion products and intermediates
- Intensification of catalytic processes and development of novel materials

Project Area: Low emission energy technologies

Flexibility and sustainability: Efficiency of fossil fuels plants

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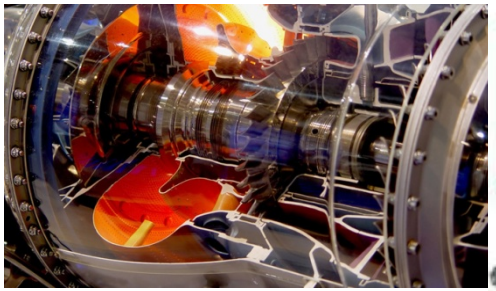
Objective

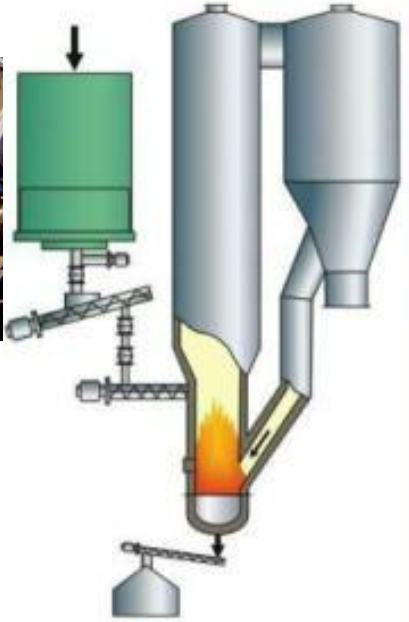
To sustain technological development of thermal power plants in the scenario of intermittent operation and diversification of fuels

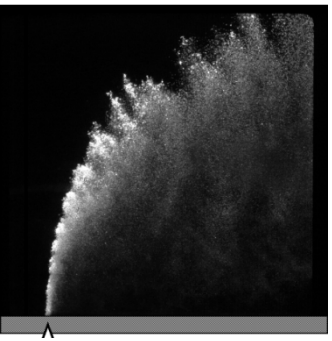
Approach:

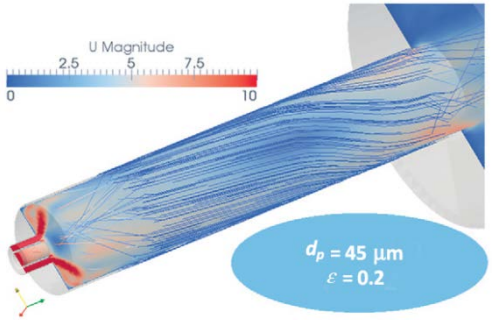
Flames diagnostics
Atomization and sprays
Turbulent flow mixing
Fluid-dynamics of multiphase reactors
Single particles reaction modeling
Reaction kinetics under steady and dynamic operation
Dynamics of granular systems
Dynamics of fluidized bed reactors
Dinamics of non linear processess

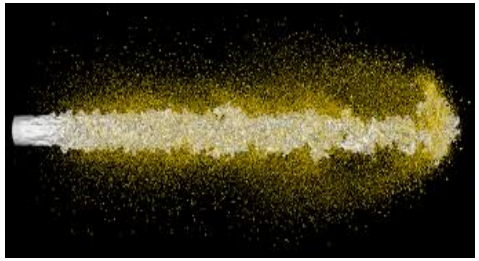
Figures:











Scientific Impact/Results:

Fundamentals of combustion
Fundamentals of reactor design
Deateiled kinetics
Fragmentation/annealing/Particels-wall interaction
Optimization of reactor design
Increse of efficiency, minimization of environmental impact

Project Area: Low emission energy technologies

Flexibility and sustainability: Operational and fuel flexibility

Consiglio Nazionale delle Ricerche
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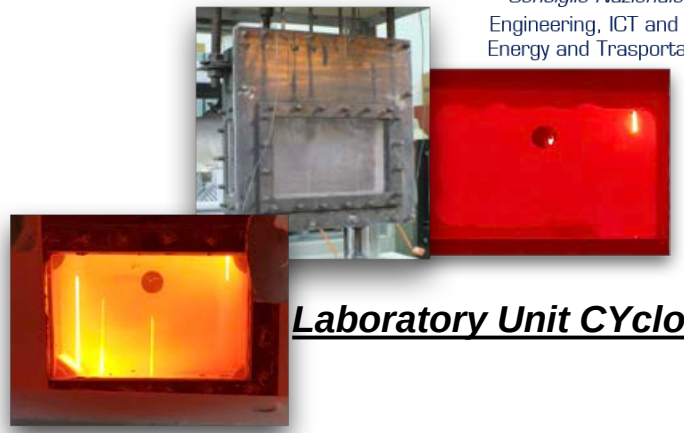
Objective:

Development of innovative combustion technologies to meet the need of:

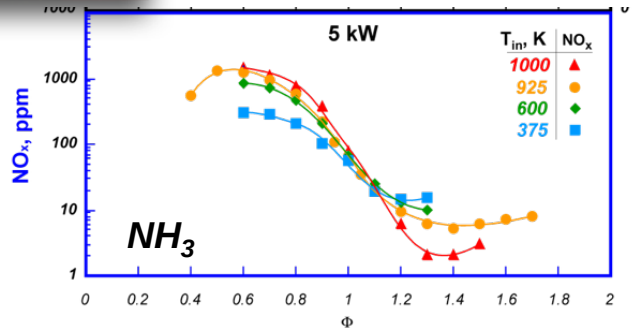
-Operational ***flexibility and efficiency*** in a wide minimum/maximum and variable load range (minimum load, hot/cold start, ramp rate)

-***Fuel flexibility*** for the ***exploitation of*** energy carriers derived from locally available resource and from ***chemical energy storage***

For supporting the low carbon economy and the exploitation of variable renewable energy resource



Laboratory Unit CYclonic burner



Approach:

Identification of
-new paradigms: ***MILD Combustion*** (flameless, noiseless, no or extremely low pollutant emission)
-Innovative "scale bridging" configurations

Exploration of :
-wide ranges of operational parameters (power, temperature, pressure, dilution, oxygen concentration)
-standard and ***new energy carriers*** (carbon based and no carbon fuels, like ***Hydrogen*** and ***Ammonia***)

Scientific Impact/Results:

- **MILD Cyclonic burner technology validated in lab (TRL4-5)**
- **Optimization of tools for modeling and design of innovative combustion processes (kinetic models, advanced reactive turbulent system modeling, turbulence-chemistry interaction models)**
- **Characterization of Elementary reactive structures in MILD/flameless conditions**

Project Area: Low emission energy technologies

Bio and alternative fuels

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Objective:

Development of Processes and Technologies for material recovery and for the energetic valorization of wastes and biomasses

Technologies:

Fluidized beds
Entraiened flow reactor
Fixed beds
Rotary kilns
Plug flow reactors

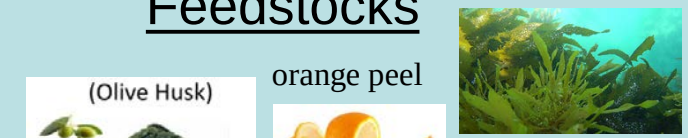
Approach:.

Detailed fuel and products characterization
Reactor design
Catalyst design
chemical kinetics definition
transport phenomena effects
Fluid-dynamics and chemical kinetics optimization
Feedstock and process evolution interactions

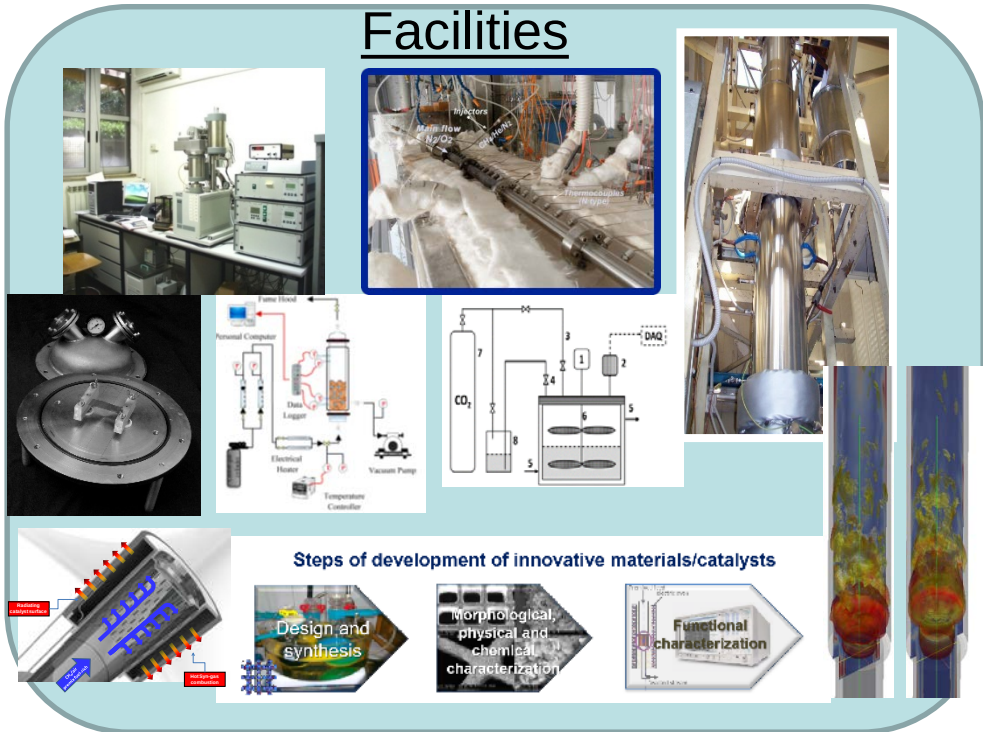
Scientific Impact/Results:

Valorizzaition of biomass, agro-wastes, wastes from industry, end-of-life consumer goods for the production of gaseous and liquid fuels by thermochemical (torrefaction, pyrolysis, gasification combustion) and biotechnological and biorefinery processes

Feedstocks



Facilities



Project Area: Low emission energy technologies

Bio and alternative fuels

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Upgrading of thermo-chemical processes applied to waste and residual biomass to produce energy carriers (H2 rich syngas / bio-oil)

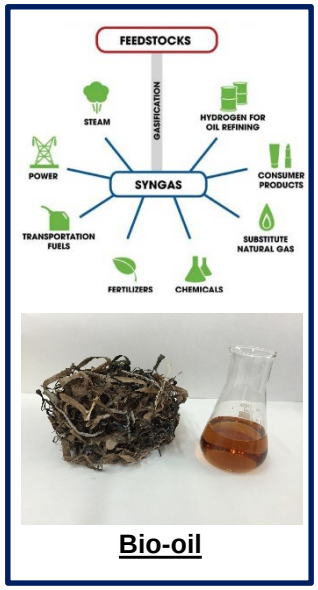
Approach:

- ✓ **Improvement of H2 content in gasification syngas stream working with:**
  - **fluidized bed reactor (BFB)**
  - **solid catalysts**
  - **air-steam as oxidant agent**
  - **Computational fluid dynamics modelling (CFD)**
- ✓ **Production of "high quality pyrolysis bio-oil" through *in situ* catalytic upgrading - Preparation, characterization and testing of solid supported catalysts**

Citrus peel residues

Beached seaweed

Thermo-catalytic conversion
- **Gasification**
- **Pyrolysis**



Bio-oil

Scientific Impact/Results:

Citrus peel residues resulted a promising biomass for syngas production due to the lower lignin content than woody material

Citrus peels air-steam gasification (750°C, E/R=0.3; S/B=1 wt/wt) recorded an H_2 yield= 2.55 Nm^3/kgbiomass; syngas yield=0.69 Nm^3/Kgbiomass

Bio-oil from Posidonia Oceanica sea-plant was obtained with a yield=52 wt% (T=500°C)

The bio-oil oxygen content was reduced from 30 wt.% to 6.8 wt.% through *in situ* upgrading with CeO_2 catalyst than no-catalysts pyrolysis run

Project Area: Low emission energy technologies

Bio and alternative fuels: H_2/syngas from biogas

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Objective:

Design, realization and tests of compact reactors and small-scale demonstrative units for the conversion of the biogas into a hydrogen-rich mixture by different reforming processes, finalized to hydrogen or syngas production and/or integration with Fuel Cell systems for mobile and stationary applications in the range of 2kW.

Reformer features

- Hydrogen Production (in syngas) : Nominal = 2 Nm^3h^{-1}, Maximum = 3 Nm^3h^{-1}
- Size: Length = 80cm, Height = 100cm, Width = 100cm
- Process : SR reforming /oxy-steam reforming

View of the Reformer connected with SOFC (SOFCOM EU Project)

Approach:

Design finalised to:

- develop a compact unit, integrable with different downstream processes;
- process different biogas feedstocks with high efficiency;
- use of low-cost Ni-based catalysts.

Scientific Impact/Results:

- Conversion of biogas into a bio-syngas rich in H2 and CO with high efficiency 75-80%(LHV);
- Optimal thermal integration with SOFC for CHP application;
- Stable performance toward real biogas (CH_4=60%, CO_2=40%, flow = 10 Nl/min) feed from industrial Waste Water Treatment Plant (around 6 months of operation, SOFCOM EU project);
- Possibility of adjusting the H_2/CO molar ratio for other application such as Fischer–Tropsch or Oxo-synthesis processes;

Project Area: Low emission energy technologies

Bio and alternative fuels

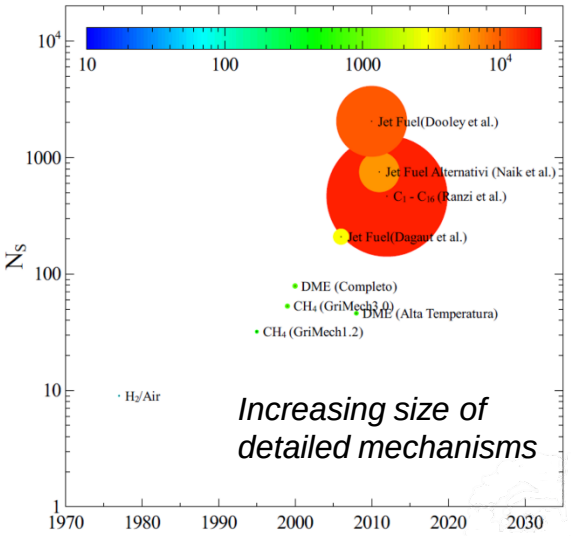
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

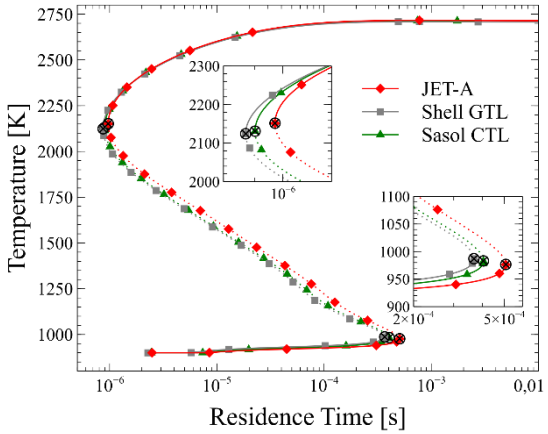
Objective:

Combustion properties and kinetics of gen II and III biofuels

Approach:

The chemical composition of Bio and Alternative fuels is extremely complex, leading to huge chemical detailed mechanism.
To study their property, propose surrogate fuel compositions, assess their reliability in practical combustion device, numerical tools needs to be developed:
•Integration of stiff ODE
•Parametric continuation of large system of equations and detection of bifurcation points
•Automatic reduction of detailed kinetic schemes





Parametric continuation of three different Jet fuels with detailed mechanisms

Scientific Impact/Results:

A numerical library developed and continuously updated
A new approach for automatic reduction of detailed mechanisms based on entropy functions developed and assessed
New algorithms to perform parametric continuation using detailed mechanisms to accurately reproduce the behavior of bio and alternative fuels
New test functions for detection of bifurcation points proposed

Project Area: Low emission energy technologies

Bio and alternative fuels

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Thermochemical conversion of solid fuels:
- in different atmospheres
- up to 2200°C
- up to 20 bar
- Heating rate up to 10000 K/s
- Bulk or single particles condtions

Approach:.

Fuel's physical and chemical transformation are studied under a wide range of conditions:

Pyrolysis/combustion/gasification kinetics

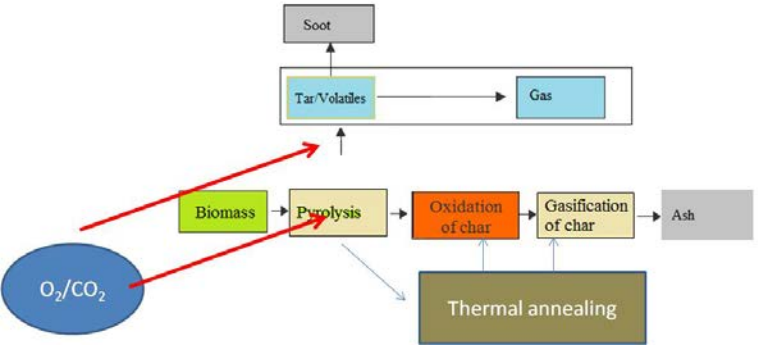
Swelling, fragmentation

Annealing and microstructure

Volatiles and soot r

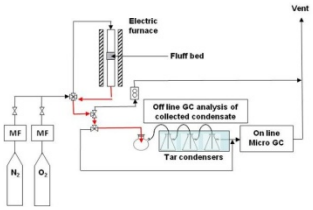
Scientific Impact/Results

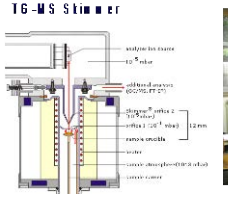
Fundamentals of biomass transformation
Kinetics and process design
Optimization of thermochemical processes of biomass and wastes

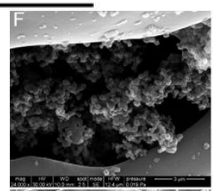


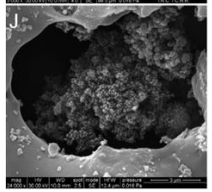
Facilities

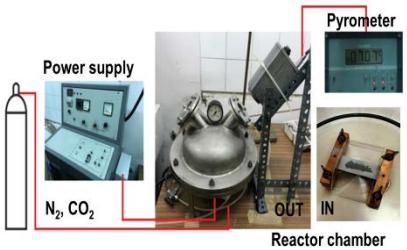
Reactor type	TGA	FixBR	FBR	DTR	WMR/HSR	ALPR
Process type	Batch	Batch	Batch	Continuous	Batch	Batch
Temperature	<900°C	<900°C	850°C	1300°C	1500-2000°C	700-1000°C
Particle size	0.1 mm	0.1-1 mm	1-10mm	0.1 mm	0.1-1 mm	0.1-1 mm
Sample mass	10 mg	1 g	1-10 g	-	0.1-1 g	0.1-1 g
Heating rate	1-50 °C/min	5 °C/min	10^3 °C/s *	10^4 C/s	10^5 °C/s	10^3 -104 °C/s
Residence time (s)	Min-hours	Min-hours	min	<1s	0.1-10 s	min
Gas analysis	yes	yes	yes	yes	ni	yes
Tar analysis		yes		yes	ni	
Solid analysis		yes	yes	yes	yes	

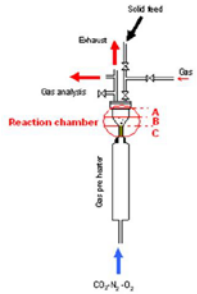


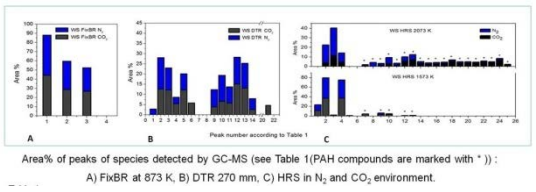












Area% of peaks of species detected by GC-MS (see Table 1(PAH compounds are marked with *)) :
A) FixBR at 873 K, B) DTR 270 mm, C) HRS in N_2 and CO_2 environment.

Project Area: Low emission energy technologies

Bio and alternative fuels

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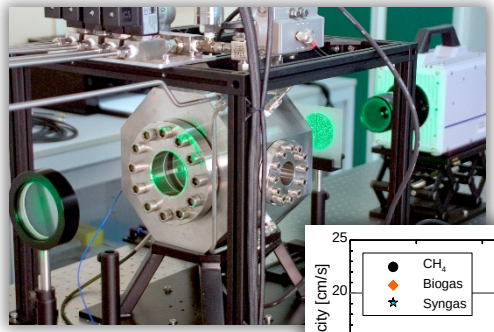
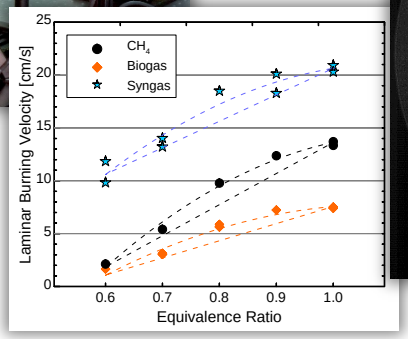
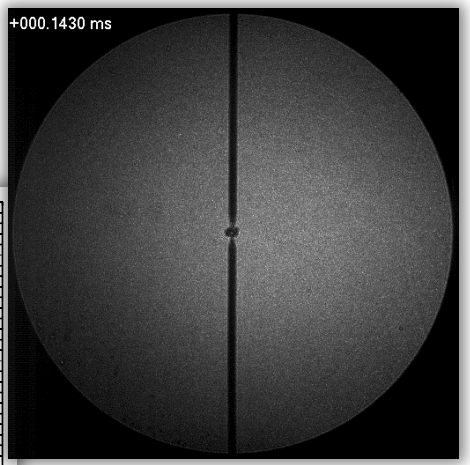
Objective:

Characterization of the burning properties of biogas and syngas, in conditions typical of heat engines & burners







syngas flame at P_0=10bar

Approach:

Study of the core process in precision-controlled conditions:

- Constant-volume reactor (P_{max} >200 bar)
- Working range:
  - base pressure (≤ 30 bar)
  - air/fuel ratio (spanning the flammability range)
  - mixture composition (CH_4 H_2 CO CO_2 N_2)
- High time & space resolution diagnostics

Scientific Impact/Results:

To suggest guidelines (design specifications and operating strategies) for the development of high-efficiency, ultra low-emission energy conversion systems, based on:

- biomass & waste derived fuels (biogas, syngas)
- H_2 enhanced fuels

Twofold development path:

- direct, through the compared analysis of combustion tests and real systems operation
- indirect, using the test results to implement/validate kinetic models and to improve multidimensional codes.

Project Area: Low emission energy technologies

Bio and alternative fuels

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

- Efficient use and low emissions of bio fuels for applications in practical systems.

- Development of high efficiency and low emission combustors.

Approach:.

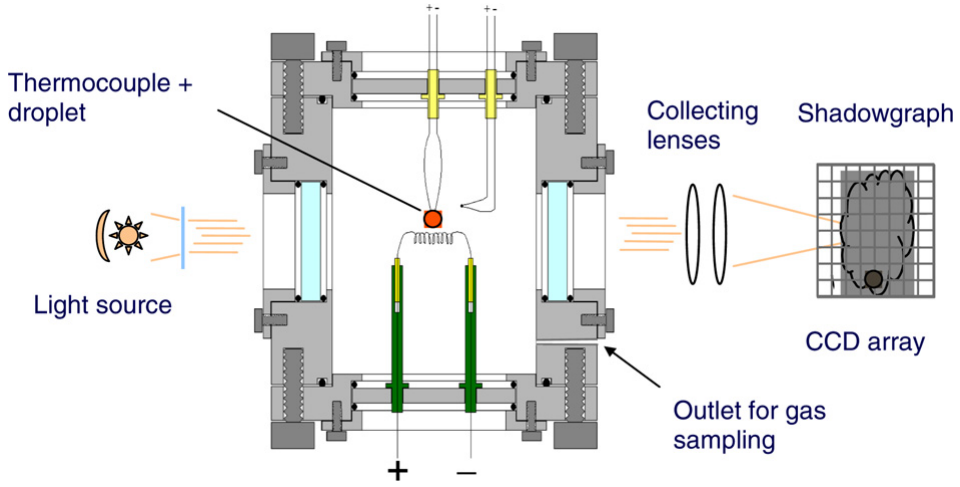
The optimization of a fuel passes through the knowledge and the analysis of the combustion characteristics exhibited by the fuel in the conditions in which it must be used (in particular ambient temperature and pressure).

The main characteristics of a fuel droplet to be determined are the ignition delay, evaporation/combustion rate, temperature evolution, swelling, micro-explosion, flame thickness and distance from the surface of the droplet, formation of submicronic (soot) and macroscopic (cenosphere) carbonaceous particulate.

Scientific Impact/Results:

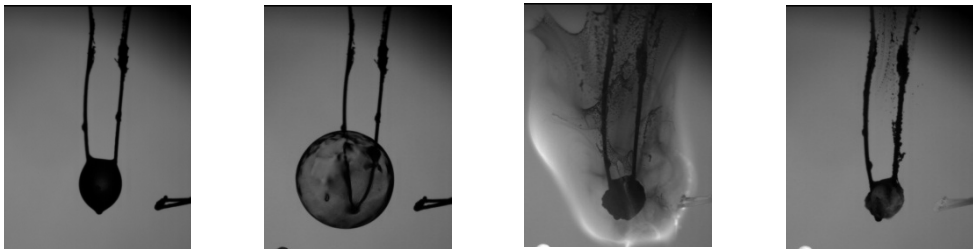
- Optimization of bio-fuels production processes
- Characterization of II and III gen bio fuels (pyrolysis oil, algal biomass, etc.)
- Bio fuels from waste and biomass of low commercial value
- High quality bio fuels (e.g., aeronautical applications)

Layout of the single droplet combustion chamber to investigate the combustion properties of biofuels



Main characteristics: synchronized acquisition chain (thermocouple data and images), test in controlled conditions (pressure and temperature). pressure up to 10MPa.

Some images from test of crude pyrolysis oil droplet (European project: R2H - Renewable residential heating with fast pyrolysis bio - oil)



Start of test | Droplet swelling | Soot formation | Cenosphere

Project Area: Low emission energy technologies

Bio and alternative fuels

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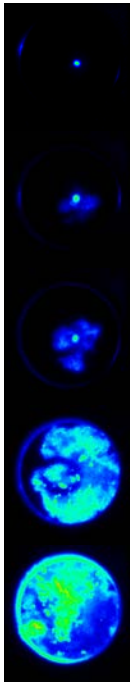
High energy ignition system – optical characterization DI SI engine fueled with bio-butanol

Objective:

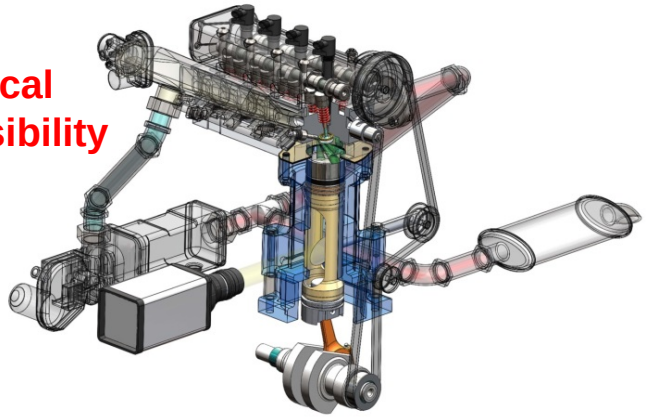
Characterization of a plasma-assisted ignition system for bio-butanol fueling

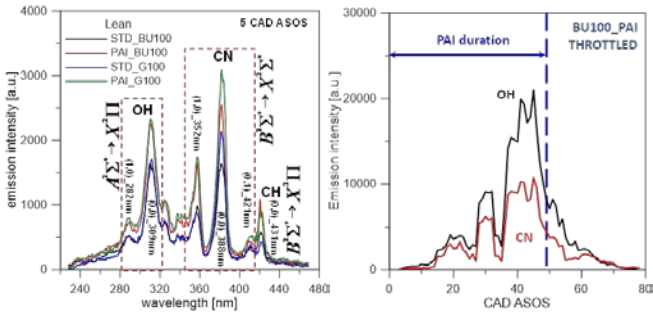
Approach:

Combined thermodynamic and optical techniques were applied on a light duty spark ignition engine for characterizing the performance of a high energy ignition system during butanol fueling. Plasma properties were analyzed based on visualization data for arc dimension and location, as well as chemical species through spectroscopy. Post-processing of the optical data allowed the comparison of flame front characteristics with cyclic variability determined based on recorded in-cylinder pressure. Optimization of ignition settings with respect to fuel properties was based on correlating measured engine output parameters with flame propagation. Integration with variables monitored by the control unit provided by the industry partner was continuously achieved throughout the project.



optical accessibility





Scientific Impact/Results:

Improved stability was obtained by applying plasma-assisted ignition, especially during lean operation, which proved problematic for bio-butanol and other bio-alcohol fuels with respect to gasoline..

Project Area: Low emission energy technologies

Bio and alternative fuels

Syngas fueling – optically accessible spark ignition engine

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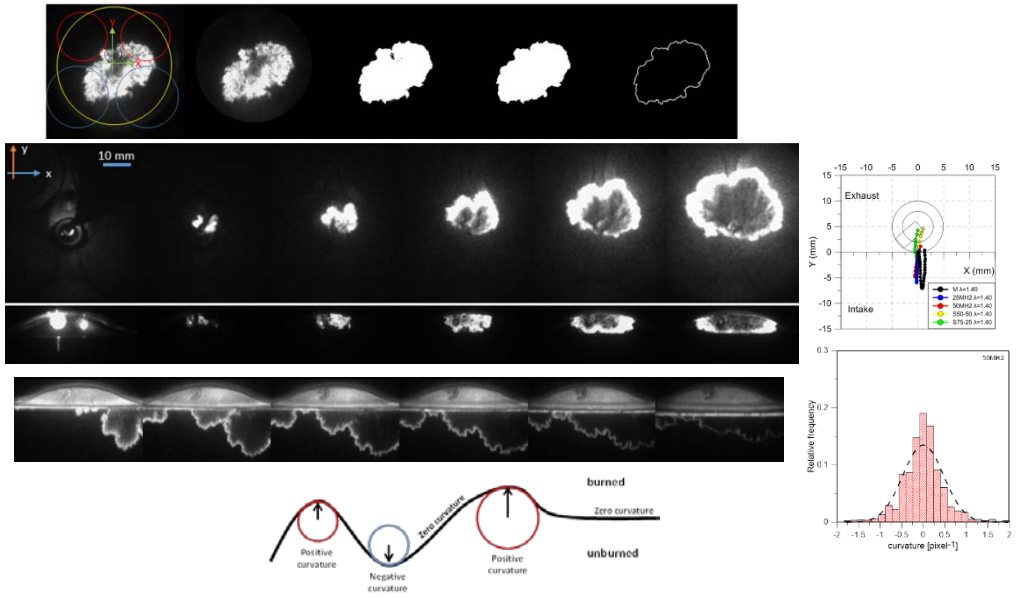
experimental data ITA, Brazil → **in-depth analysis and post-processing IM-CNR, Italy**

Objective:

Identification of hydrogen concentration effects on syngas combustion in spark ignition engines



Approach:

In-cylinder pressure measurements, exhaust gas emissions data and flame visualization were combined for a comprehensive characterization of combustion in an optically accessible SI engine fueled with syngas. Different compositions were investigated, with an emphasis on the combustible components (CO, H_2, CH_4), as well as the effects of inert gases, such as N_2 and CO_2. Detailed post-processing of imaging data was aimed at identifying the concentration of hydrogen as a significant factor of influence on flame front characteristics. Numerical investigations were used as a complementary technique and offered the potential of opening a new line of research to further enhance the international collaboration with several partners.

Scientific Impact/Results:

Custom image-processing was developed in the framework of international cooperation with Brazilian University. Results related to the macroscopic and microscopic analysis of the combustion process constituted a shared-database for the optimization of syngas fuelled engines.

Project Area: Low emission energy technologies

Bio and alternative fuels

Heavy duty engine powered with renewable fuels

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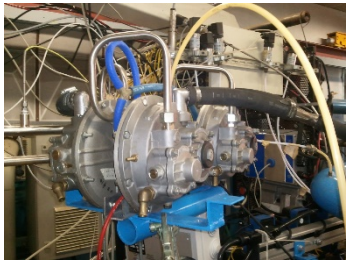
Objective:

Optimization of ignition parameters for heavy duty engine fueled with syngas of different compositions.



Approach:

The approach was mainly experimental on a multi-cylinder spark ignition turbocharged engine, operating at stoichiometric conditions. The fuel composition has a great influence on engine performance. The study analysed the combustion development and propagation varying the blends composition and the most important ignition parameters, such as current intensity and spark duration, as well as the spark advance. To control the fuel composition a dedicated device was realized for introducing into the engine inert species (N2, CO2) proportional to combustible species (NG and H2). The ratio of each species was set to simulate the right properties of syngas.

Scientific Impact/Results:

Definition of the optimal ignition parameters, such us electrode gap and spark energy for use of alternative gaseous fuels, of different composition, with the aim to improve not only in cylinder combustion propagation, but also the use of the resources to reduce the global CO2 emissions.

Project Area: Low emission energy technologies

Bio and alternative fuels

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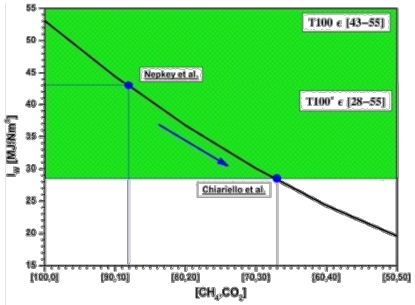
Objective:

Identification and overcoming of the technological issues and economic constraints regarding the adoption of bio and alternative LHV fuels in a commercial 100 kW micro gas turbine, aimed to a more rational exploitation of the available resources, while respecting the constraints imposed by a rational and sustainable exploitation of low-energy resources.
The interest in using a MGT is related to the possibility of feeding this system with a wide range of bio and alternative fuel mixtures and to realize efficient cogenerative cycles by recovering heat from exhaust gases at higher temperatures.

View of the micro gas turbine installed at Istituto Motori - CNR in Naples (Turbec T100P). It is a single-shaft MGT which generates, by a regenerative cycle, 100 kW of electrical power with a global efficiency of 30%.



Extension of the domain of operation of a MGT for different alternative fuel mixtures (reduction of I_W lower limit).

Approach:

The activities are based on a synergistic approach between the numerical modelling and experimental analysis of a commercial machine installed in a test rig at the IM-CNR facility. The MGT is a 100 kWe Ansaldo-Turbec T100P, instrumented for run under different operating conditions and with different fuels. A plant for decompression and distribution of fuel gas mixtures allows to feed the combustor by gas mixtures with different composition. The fuel supply system can currently run gas mixture with variable percentage of CH_4, H_2, CO_2 and CO in addition to the normal NG supply line.

Scientific Impact/Results:

The research will help transform the current energy system into a more sustainable one, making it less dependent on imported traditional fuels. The end result will be a diverse mix of energy sources, in particular renewable ones, energy carriers and non-polluting sources. Energy efficiency, which includes rationalizing use and storage of energy, will be enhanced, thus addressing the pressing challenges of security of supply and climate change.
Citizens will benefit from energy research through more affordable energy costs and through more efficient use of energies provided by different sources. Consequently, this will help reduce the causes of climate change, which will benefit everyone directly

Project Area: Low emission energy technologies

CO_2 capture and use: capture ready combustion systems

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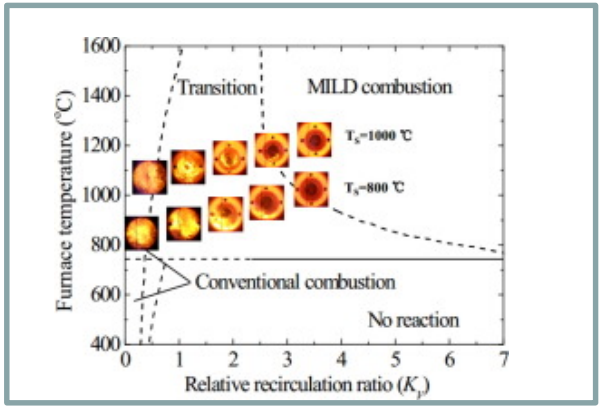
Objective:

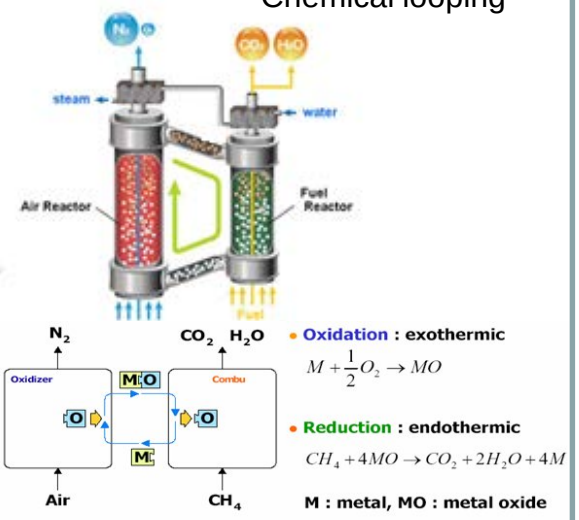
Innovative combustion processes suitable for CO2 sequestration:
Oxyfiring of coal and biomass
CLC of coal and solid fuels
Carboloop of coal and residues with high metal content
MILD combustion of fossil and bio-fuels
Catalitytic combustion
Co-combustion of fossil and bio fuels

Scientific Impact/Results:

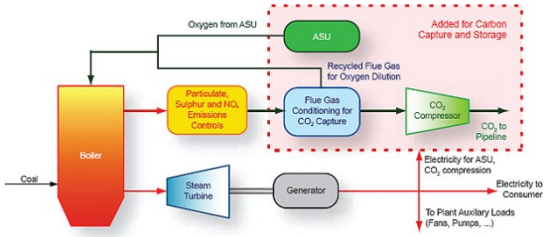
Fundamentals of combustion under unconvetional conditions:
mild combustion conditions; cyclyc/looping conditions;
oxycombustion atmospheres ; high pressure
Catalysts of Chemical Looping
Patents for CCS processes of solid fuels combustion (CarboLoop)



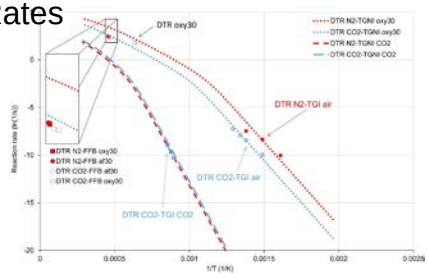
Chemical looping



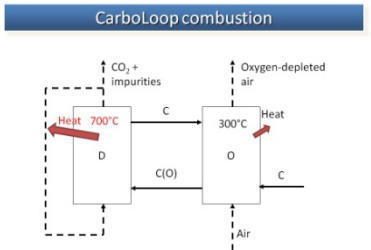
Oxycombustion

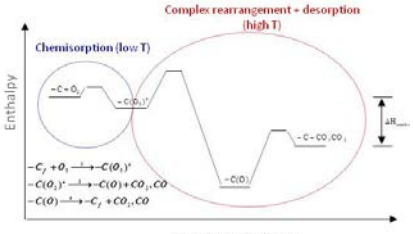


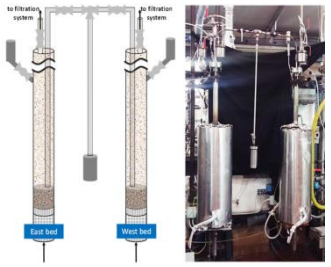
Rates

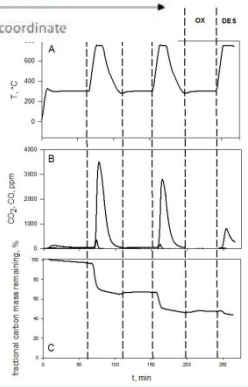


Chemical looping of solids (CarboLoop)









Project Area: Low emission energy technologies

CO_2 capture and use

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Engineering, ICT and Technologies for Energy and Trasportation Department

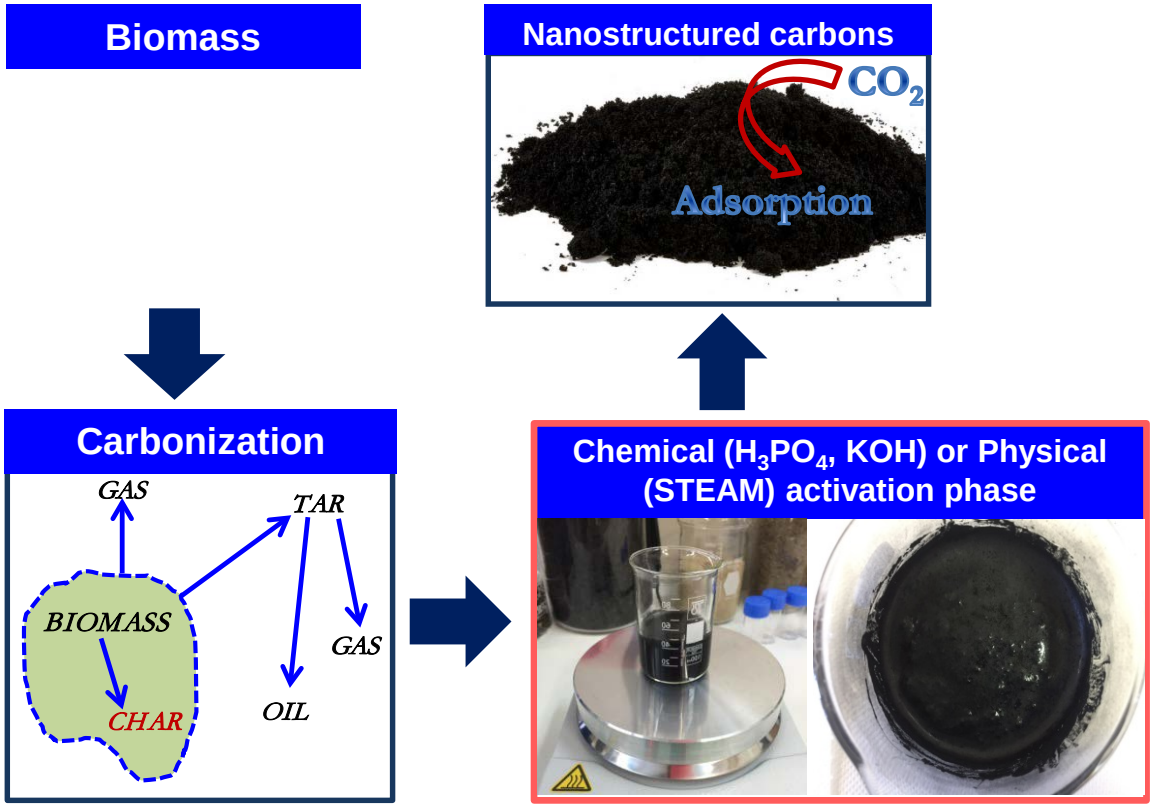
Objective:

Production of activated bio-carbons with a high surface area and remarkable CO_2 adsorption properties from pyrolysis of local residual biomasses and algae

Approach:

- ✓ **Pyrolysis experiments on raw material suitable to produce bio-char (reduced sulphur and ash contents);**
- ✓ **Chemical and physical activation steps depending of bio-char characteristics**
- ✓ **CO2 adsorption isotherms measurements (Micromertics ASAP 2020)**

Figures:



Scientific Impact/Results:

A CO_2 capture capacity value of 4.8 mmol/g was obtained by beached seaweed activated bio-char; it is among the highest reported, so far, for biomass-derived carbons.

Project Area: Low emission energy technologies

CO_2 capture and use: CO_2 to methane (PtG concept)

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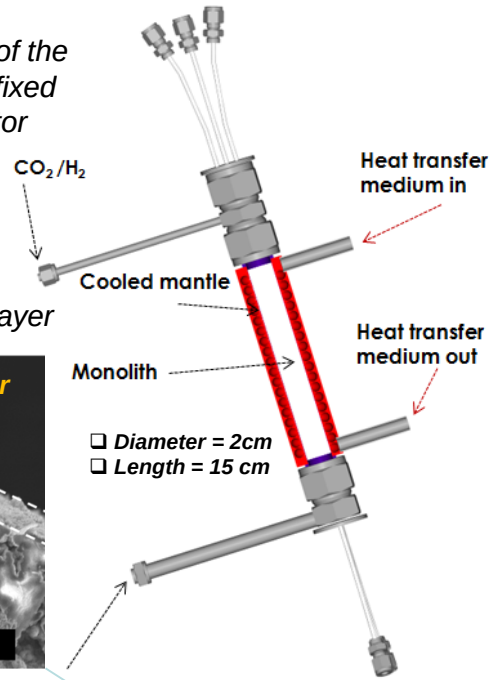
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Development of advanced compact reactors for catalytic conversion of CO_2 into synthetic natural gas needed to scaling down the conventional processes (used at large scale for CO_2 conversion) for small-scale application and integration with hydrogen produced by the energy excess coming from renewable solar source (Power to Gas concept).

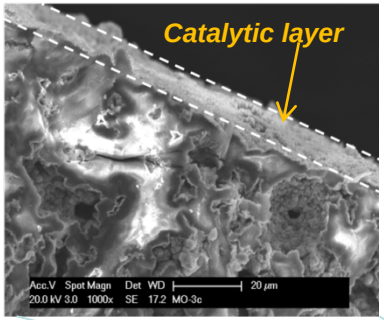
3D drawing of the Isothermal fixed bed reactor



Approach:

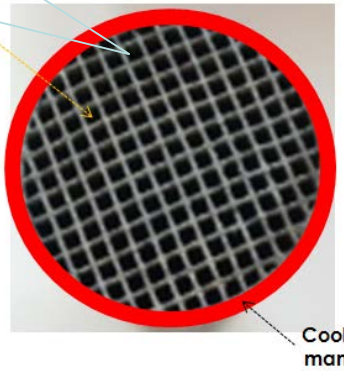
- The reactor design is based on the Process Intensification concept.
- The reactor integrates a structured catalyst and a cooling system with the aim to enhance crucial aspects such as surface-to-volume ratio, mass and heat transfer, control of pressure drop, catalyst lifetime and methane productivity to

SEM image of the coated layer



Scientific Impact/Results:

- Optimal control of the heat released by the exothermic methanation reaction (flat temperature profile along the catalytic bed)
- Improved life time of the catalyst (no deactivation by sintering and carbon deposition)
- Increased methane productivity (high performance at high space velocity, $6LCH_4/h•cm^3react$)
- Combining separate unit operations such as reaction and cooling into a single piece of equipment resulting in a more efficient, cleaner, and economical manufacturing process.



Front view : Monolith and cooled Mantle surrounding the catalytic bed.

Project Area: Low emission energy technologies

CO_2 capture and use: CO_2 Enzymatic Reactive Absorption

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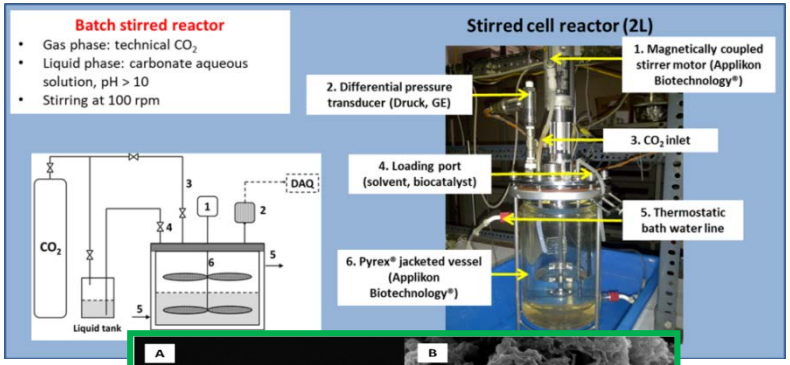
Objective:

The research activity is aimed at the development of the process for **CO_2 capture through Enzymatic Reactive Absorption (ERA)** using K_2CO_3 solutions as aq solvents and recombinant thermostable carbonic anhydrase as biocatalyst to enable CO_2 capture from flue gases



Approach:

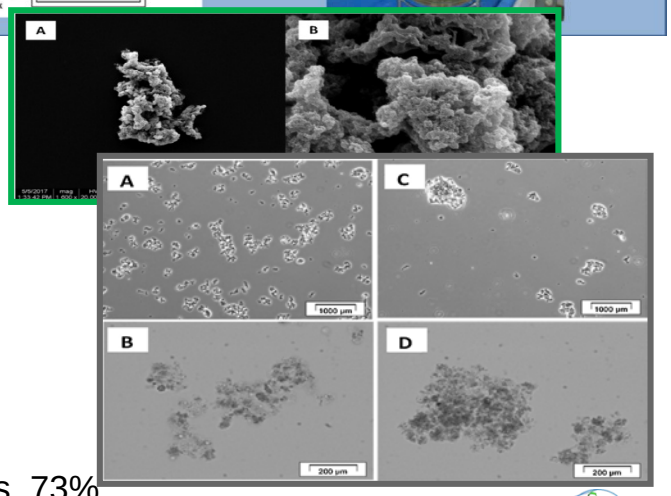
Development CO_2 Enzymatic Reactive Absorption (ERA) through:

Process simulation

Reactor design (absorption contact units)

Biocatalyst development (immobilized carbonic anhydrase - CA)

- **CA immobilization** by different covalent technique to obtain slurry (fine dispersed particles) biocatalyst allowing effective absorption rate enhancement at gas-liquid interface
- **Kinetic characterization** of both free and immobilized CA
- The reactor design through **theoretical modelling of ERA units** including experimentally assessed kinetic parameters for both free and immobilized CA

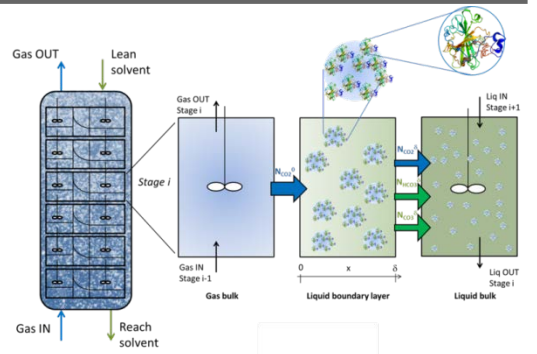


Scientific Impact/Results:

- 90% immobilization yield of CA in magnetic Cross-Linked Enzyme Aggregates, 73% immobilization yield of CA through direct binding on magnetic NPs.

-Kinetic characterization of both free CA and CA immobilized on magnetic NPs at industrially relevant conditions (solvent composition, temperature).

-Performances of slurry staged ERA units by theoretical modelling based on experimentally assessed kinetics of CA immobilized on magnetic NPs → pilot bubble column with capture efficiency between 67-99% depending on solid biocatalyst hold-up (2-0.1%vol)



Project Area: Low emission energy technologies

CO_2 capture and use: development of sound assisted fluidized bed technology for CO_2 capture

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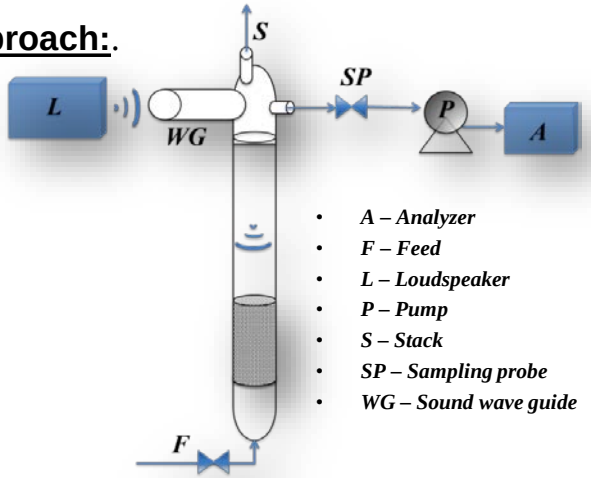
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Fluidized bed technologies allow efficient gas-solid contact and intense solid mixing, easier temperature control during both adsorption and regeneration, indirect heating by internal heat exchanger and lower pressure drop needed for reactor design. **Sound assisted fluidized bed technology** is able to dynamically brake up large agglomerate of particles into small fluidizable aggregates avoiding plugging, channeling and agglomeration typical of fine powders.

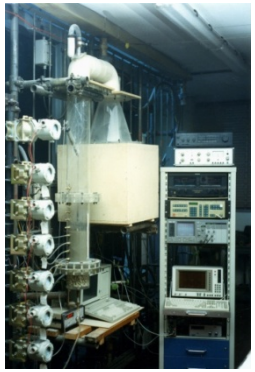
Approach:.



- *A – Analyzer*
- *F – Feed*
- *L – Loudspeaker*
- *P – Pump*
- *S – Stack*
- *SP – Sampling probe*
- *WG – Sound wave guide*

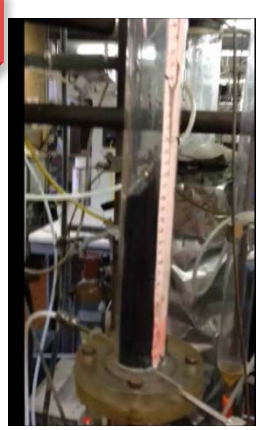
Figures:

Experimental Apparatus

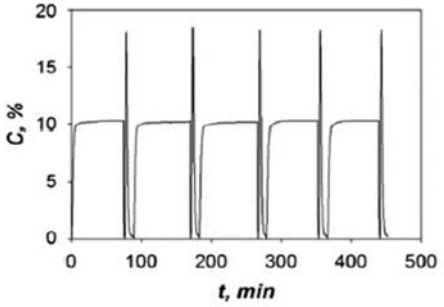


No sound

sound assisted fluidization



In-situ sorbent regeneration



Scientific Impact/Results:

Effect of sound

- ✓ More regular pressure drop (DP/DP0=>1)
- ✓ Higher bed expansion ratios
- ✓ Not intrusive
- ✓ Fine powders do not need to have any peculiar property
- ✓ Economic and user - friendly

Project Area: Low emission energy technologies

CO2 capture and use: CaL-CSP process

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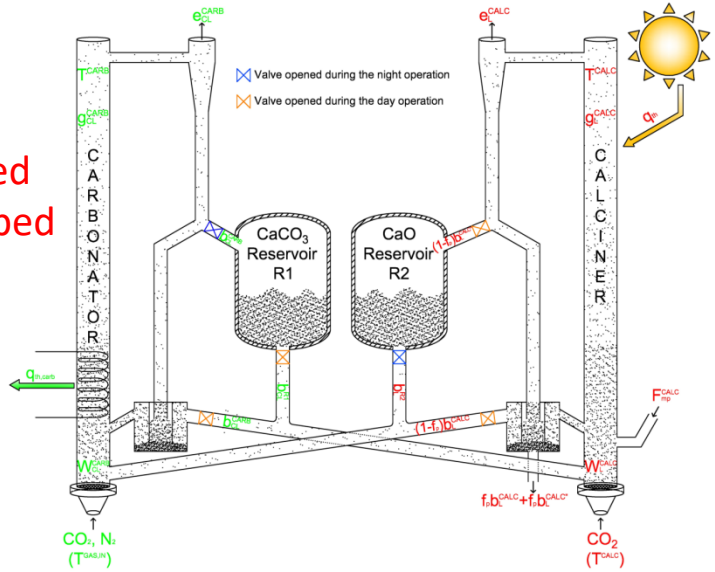
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

The study of the integration of Calcium looping process with concentrated solar power for CO2 capture and thermochemical storage to increase power flexibility

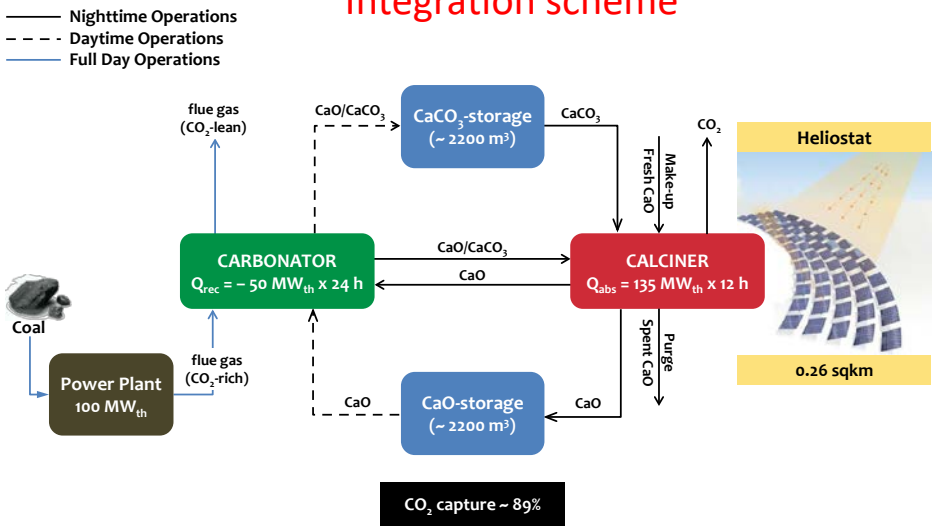
Figures:

Interconnected fluidized bed configuration proposed



Approach:.

Integration scheme



Scientific Impact/Results:

CO2 capture and carbonation conversion degree over iterated cylces

Project Area: Low emission energy technologies

CO_2 capture and use: production of advanced solid sorbent materials with enhanced CO_2 capture efficiency

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Engineering, ICT and Technologies for Energy and Trasportation Department

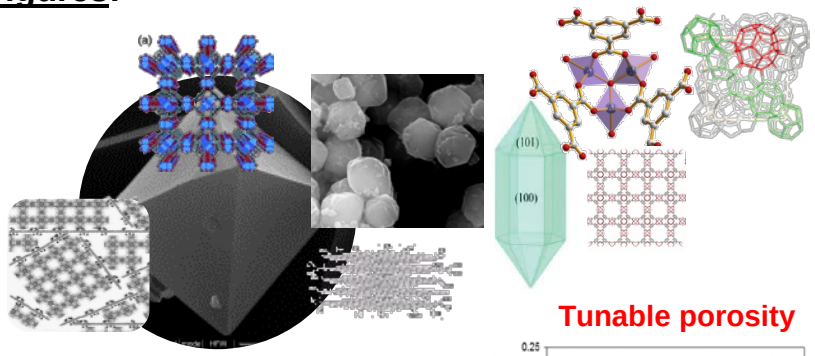
Objective:

Development and tailoring of advanced nanostructured solid sorbents (also composites, hybrids and magnetic particles) with physical and chemical properties finely tunable at the molecular level by eco-friendly wet-chemistry approaches.

Approach:.

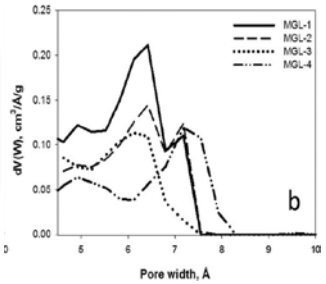
Carbonaceous materials typically present structural features prone to be easily modified at molecular level. We mostly use **green solvents** (water) and develop **cost-effective** protocols (the precursors are easily available and not expensive) and simple synthesis procedure (i.e. anhydrous conditions not required) starting from carbonaceous materials (carbon black, carbon-based pollutants) also from **agricultural wastes** (carbonized and pyrolyzed biomasses).
Wet-chemistry approaches are specifically developed to preserve the **conductive** properties of the carbonaceous core.

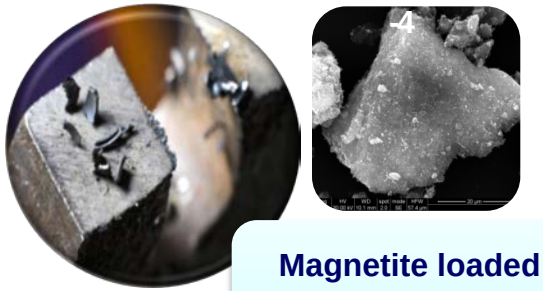
Figures:



Metal organic framework (MOF)/graphene-like composites (Fe, Cu, Zn, Al Ti- based)

Tunable porosity





Magnetite loaded carbon fine particles and carbonized biomasses

Scientific Impact/Results:

- A wide array of advanced low-cost water stable solid sorbents for CO_2 capture has been produced and tested in **real condition** (breakthrough experiments);
- Sorbent are produced by tuning surface area (up to 2700m^2/g in the case of MOF) and micro-meso pore size distribution.
- **Recyclable (thermal desorption allows production of CO_2 ultra pure streams)**;
- Suitable for technological advanced application (sound assisted fluidized bed reactors);
- A m_{ads} = 25 mg_{CO2}/g in real post conditions CO_2/N_2 gas mixture (15 Nl/h) at a fixed CO_2 concentration (3% vol) was measured (best case).

- Chemi and physisorption phenomena
- Fe_2O_3 dispersion on a carbonaceous support limits the Fe_2O_3 tendency to aggregate
- magnetic

Project Area: Low emission energy technologies

Cooling and Heating: HVAC&R systems and components

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

•Improve energy efficiency and environmental sustainability of components and systems for the HVAC&R sector and household appliances.

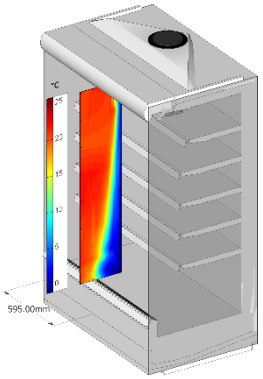
Approach:.

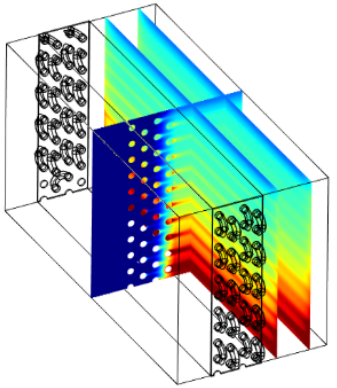
- Components: numerical and experimental thermo-fluid-dynamic analysis of heat exchangers, fans, refrigerated display cabinets, fan-coils, etc.
- Systems: numerical performance evaluation, principle design, test and field data processing of refrigerating units for supermarkets and heat pumps and chillers for residential, commercial, industrial applications.
- Refrigerants: use of natural refrigerants (carbon dioxide) in refrigeration systems and heat pumps.

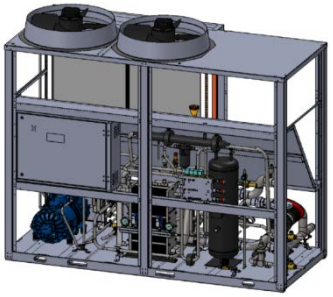
Scientific Impact/Results:

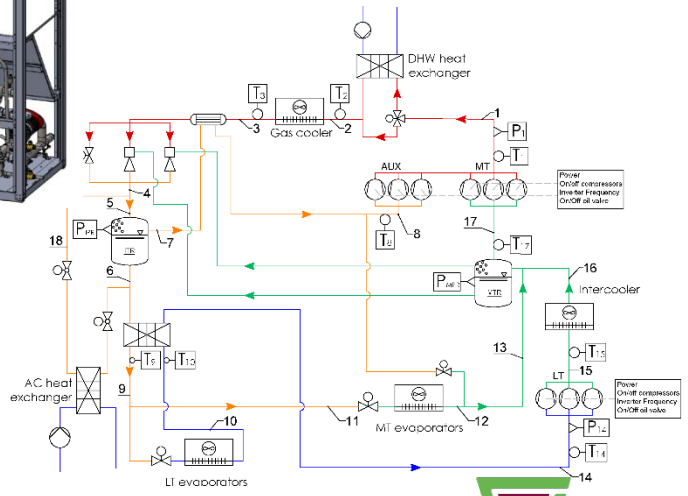
- Introduce innovation and promote fast implementation of energy efficient heating and cooling solutions for the HVAC&R sector.
- Demonstrate of the next generation standardised integrated cooling and heating packages for commercial and public buildings based on environment-friendly carbon dioxide vapour compression cycles.

Figures:









The SuperSmart project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 696076.

SUPERSMART

The MultiPACK project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 723137.

multi PACK

Project Area: Low emission energy technologies

Cooling and Heating: Low GWP Refrigerants and PCMs

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Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Low GWP Refrigerants

The reduction of the negative environmental impacts of working fluids in refrigeration is a strict demand of the market, due to the several regulations against ODP and GWP fluids.

PCMs and nano-PCMs

PCMs for energy storage have become of crucial importance in the strategy for energy and environmental sustainability.Their characterization is necessary to understand their capability to manage thermal energy.

Approach:.

Low GWP Refrigerants

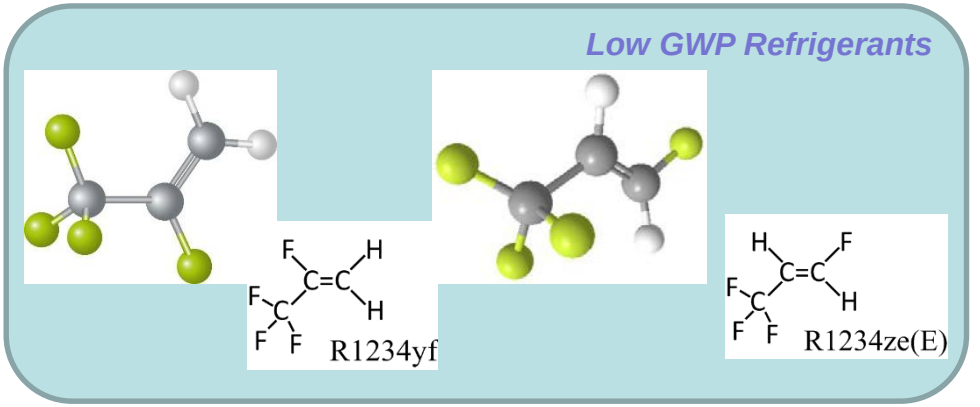
Beyond natural fluids, a few HFCs and a dozen of HFOs, are potentially appropriate for a number of HVACR applications. The study of HFOs, fluorinated olefins characterized by the presence of a C=C double bond in the molecule, is really important to define their performance in the final applications.

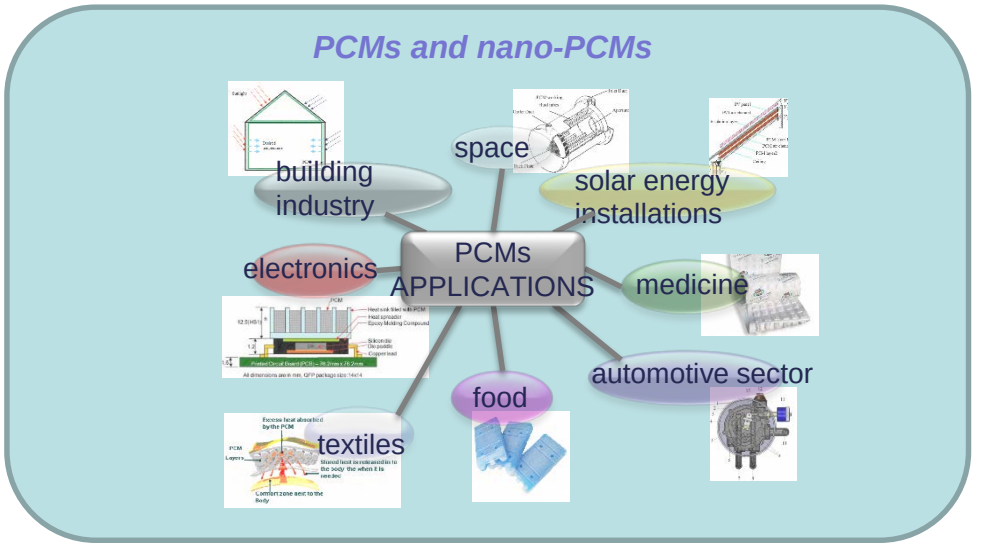
PCMs and nano-PCMs

PCMs characterization is necessary to understand their capability to manage thermal energy.

Scientific Impact/Results:

Figures:





GEO4CIVHIC: “Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings”

Project Area: Low emission energy technologies

Cooling and Heating: Diagnostics, energy saving and eco-sustainability in buildings

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Photocatalysis

Activity measurement of heterogeneous photocatalysts in gas/solid and liquid/solid phase applied to the development of special photocatalysts for sustainable construction materials.

Diagnostics

Embedding the waste from building demolition in a geopolymer matrix to produce prefabricated radiant heating panels for cooling and heating

Approach

Photocatalysis

Development of specialized analytical systems for photocatalytic activity measurements in gas/solid and liquid/solid phase.

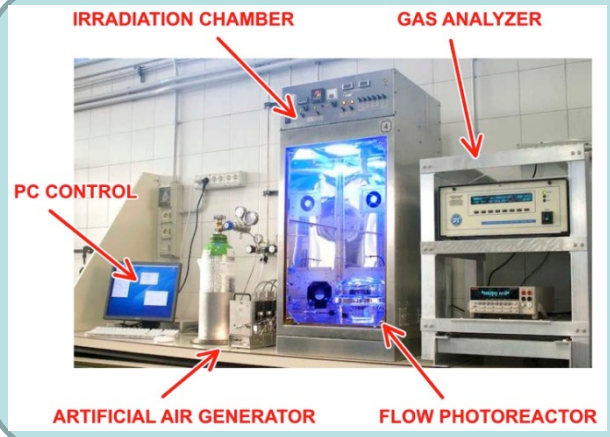
Diagnostics

IR thermography applied to enhance the performance evaluation of radiant heating/cooling panels beyond the standardized enthalpy test

Scientific Impact/Results

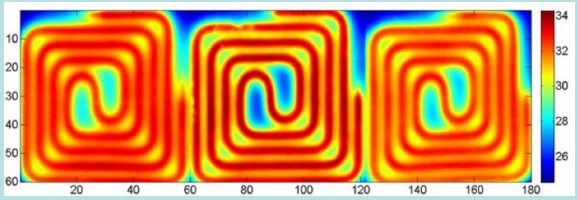
Various collaborations with Universities and research Institutes with several published papers. Partecipation to the INTEGRATE and I-ZEB projects financed by Regione Lombardia.

Figures:



Photocatalysis

Diagnostics



IR images of the monitored radiant panels

Test facility for testing radiant heating panels

InnoWEE Innovative pre-fabricated components including different waste construction materials reducing building energy and minimising environmental impacts Grant Agreement number 723916

Project Area: Low emission energy technologies

Cooling and Heating: Solar cooling and heating

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

- Increasing the share of renewables at building scale;
- Development of innovative hybrid solutions for solar heating, cooling and storage.

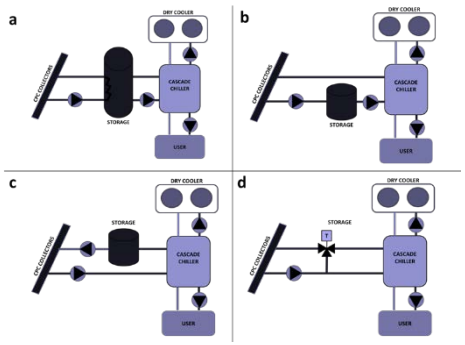
Approach:.

-Simulation of different system layouts, design and testing of an integrated hybrid sorption/compression machine for cooling applications
-Optimization of components and systems for hybrid electric/thermal storage solutions for domestic applications;
-Realization of prototypes and validation in relevant environments (TRL 5).

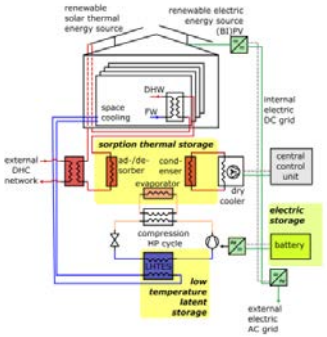
Scientific Impact/Results:

-Design and testing of a hybrid chiller, characterized by an electrical COP up to 6.0, under typical operating space cooling operating conditions;
-Modelling of fully integrated hybrid electric/thermal energy storage systems for Mediterranean and Continental climates.

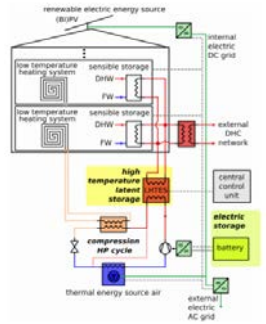
Figures:



ZEOSOL



Mediterranean system



Continental system

HYBUILD Hybrid Energy Storage for Buildings

The Zeosol project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 760210.

ZEOSOL

The Hybuild project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 768824.

HYBUILD Hybrid Energy Storage for Buildings

Fossil fuels and new concepts for clean combustion

- Efficiency of thermal power/combustion
- Emission control
- Fuel and operational flexibility
- New concepts and capture ready combustion
- CO2 capture and use

Project Area: Low emission energy technologies

Clean combustion: Efficiency of thermal power/combustion

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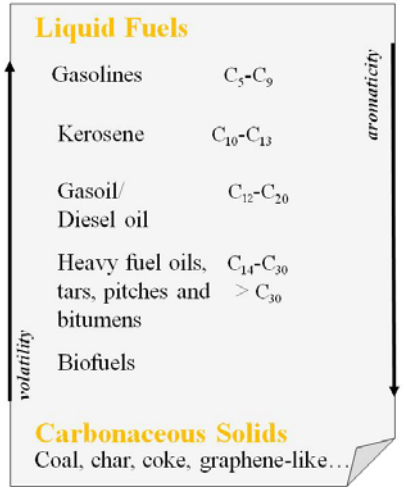
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Detailed chemico-physical Analysis of liquid and solid fuels;

Understand the thermochemical behavior of solid and liquid fuels;

Assess reaction kinetics and networks



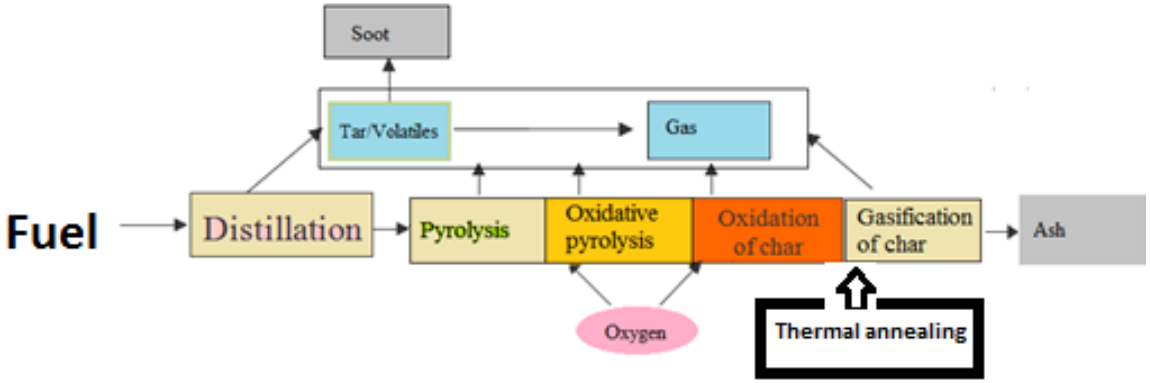
- Volatility, Distillation, oxidation reactivity, Coking yield, Conradson residue by **Thermogravimetry** (TGA,Perkin Elmer)
- Metal and inorganic content by **ICP-MS** (Agilent Technology)
- Molecular weight distribution and functional groups determination by **mass spectrometry** (GC-MS, Ion Trap-MS, Agilent Technology)
- Aliphatic and Aromatic Hydrocarbons distribution by **Liquid and Gas-chromatography** (GC, GC-MS,HPLC, Agilent Technology)
- Polycyclic aromatic hydrocarbons content and BaP equivalent (carcinogenic index) by **Gas-chromatography/Mass spectrometry** (GC-MS, Agilent Technology)
- **Elemental Analysis** (C,H,N,S content) (LECO)
- Aromaticity and oxygen content by **Infrared, UV-Vis and fluorescence spectroscopy** (FT-IR, ThermoFisher, UV-Vis Absorption, Agilent Technology, UV-Vis Fluorescence , Perkin Elmer)
- Solubility by **solvent extraction**
- Amorphous/graphenic degree by **Raman spectroscopy** (Horiba XploRA)

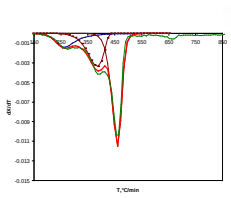
Microsturctural and chemico-physical analysis of solids

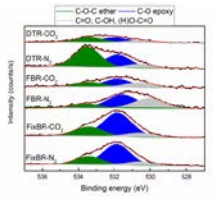
(Porosimetric analysis, SEM, TEM, XPS, XRD, Raman)

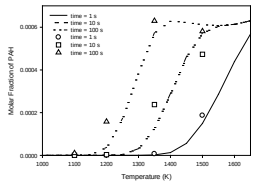
Kinetics of solid fuels reactions under a wide range of conditions

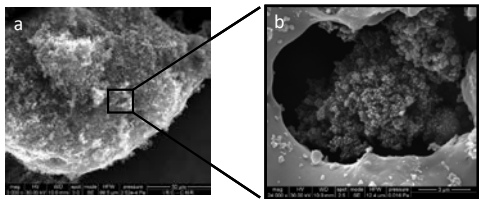
(TGA/DSC coupled with MS or FTIR, fixed beds, suspension firing, pressurized heated strip reactor, fluidized beds)











Project Area: Low emission energy technologies

Clean combustion:

Efficiency of thermal power/combustion

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Engineering, ICT and Technologies for Energy and Trasportation Department

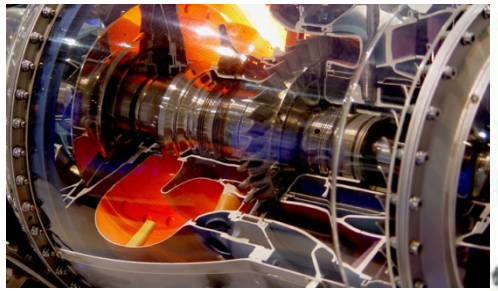
Objective

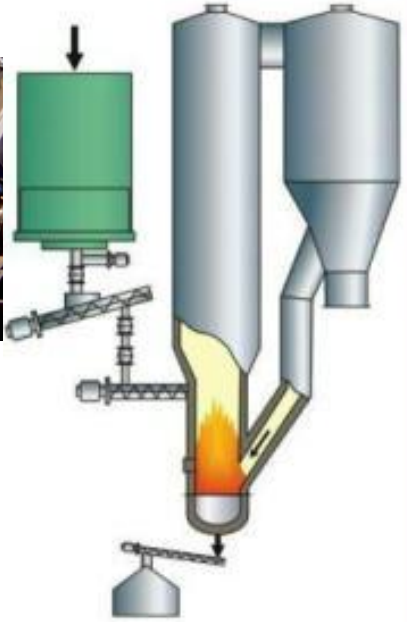
To sustain technological development of thermal power plants in the scenario of intermittent operation and diversification of fuels

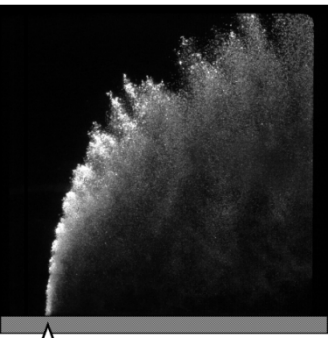
Approach:

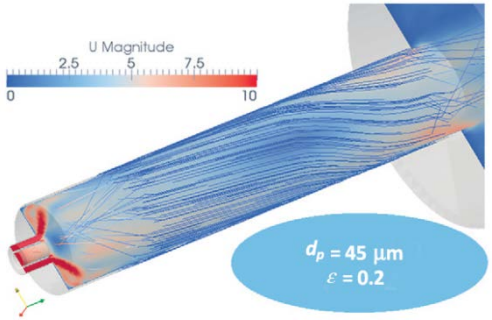
Flames diagnostics
Atomization and sprays
Turbulent flow mixing
Fluid-dynamics of multiphase reactors
Single particles reaction modeling
Reaction kinetics under steady and dynamic operation
Dynamics of granular systems
Dynamics of fluidized bed reactors
Dinamics of non linear processess

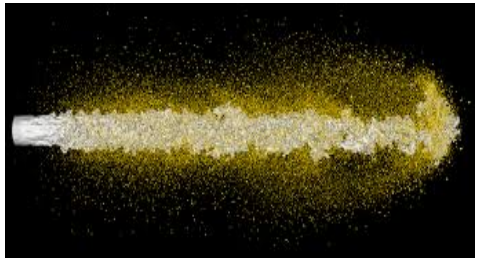
Figures:











Scientific Impact/Results:

Fundamentals of combustion
Fundamentals of reactor design
Deateiled kinetics
Fragmentation/annealing/Particels-wall interaction
Optimization of reactor design
Increse of efficiency, minimization of environmental impact

Project Area: Low emission energy technologies

Clean combustion:

Emission control

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Objective:

•Change in fuel composition or energy mix influence the design of the conversion system but also pollutants. It is urgent to improve knowledge on Formation mechanisms of new pollutants, and develop new diagnostics and abatement metodology.

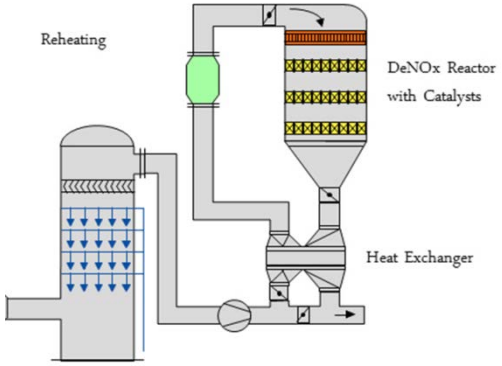
Approach:

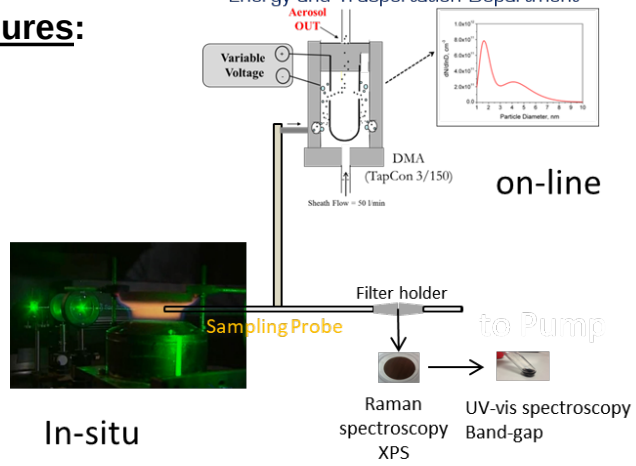
Research activities are focused on:

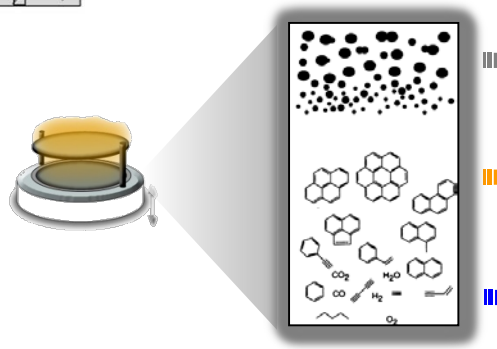
1. Formation mechanisms of pollutants;
2. Advanced diagnostics for regulated / unregulated pollutants;
3. Reduction of pollutants from fossil and alternative fuels.

Specific activities include in-situ, on-line and off line advanced diagnostics of pollutants and ultrafine particles; diagnostic of flame instabilities; NO_x , SO_x and particulate reduction; SCR; Combined particulate and NO_x reduction; NO_x storage-decomposition for automotive application; PM reduction through water vapor condensation; Hg capture from flue gases; purification of CO_2 streams; tar and VOC abatement.

Figures:







Scientific Impact/Results:

•Physicochemical characterization of combustion generated carbon nanoparticles

•Characterization of main combustion products and intermediates

•Intensification of catalytic processes and development of novel materials

Project Area: Low emission energy technologies

Clean combustion:

Operational and fuel flexibility

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Engineering, ICT and Technologies for Energy and Trasportation Department

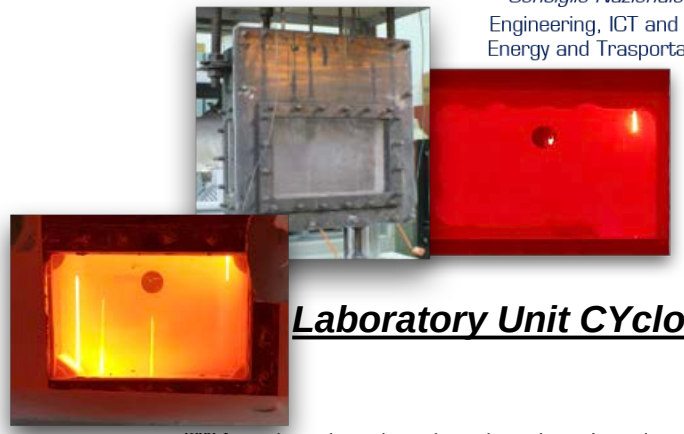
Objective:

Development of innovative combustion technologies to meet the need of:

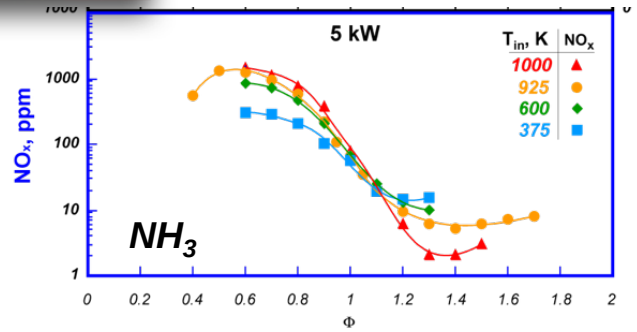
-Operational ***flexibility and efficiency*** in a wide minimum/maximum and variable load range (minimum load, hot/cold start, ramp rate)

-***Fuel flexibility*** for the ***exploitation of*** energy carriers derived from locally available resource and from ***chemical energy storage***

For supporting the low carbon economy and the exploitation of variable renewable energy resource



Laboratory Unit CYclonic burner



Approach:

Identification of
-new paradigms: ***MILD Combustion*** (flameless, noiseless, no or extremely low pollutant emission)
-Innovative "scale bridging" configurations

Exploration of :
-wide ranges of operational parameters (power, temperature, pressure, dilution, oxygen concentration)
-standard and ***new energy carriers*** (carbon based and no carbon fuels, like ***Hydrogen*** and ***Ammonia***)

Scientific Impact/Results:

- **MILD Cyclonic burner technology validated in lab (TRL4-5)**
- **Optimization of tools for modeling and design of innovative combustion processes (kinetic models, advanced reactive turbulent system modeling, turbulence-chemistry interaction models)**
- **Characterization of Elementary reactive structures in MILD/flameless conditions**

Project Area: Low emission energy technologies

Clean combustion:

New concepts and capture ready combustion

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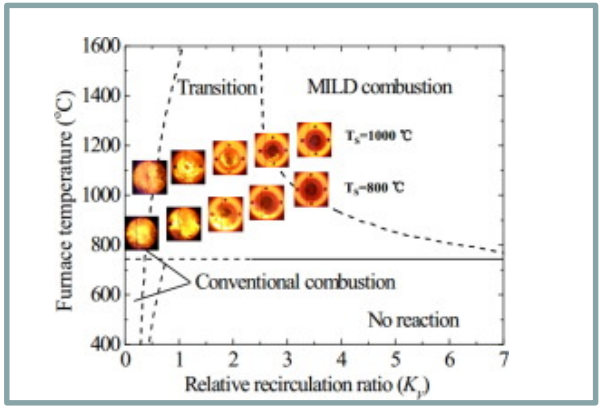
Objective:

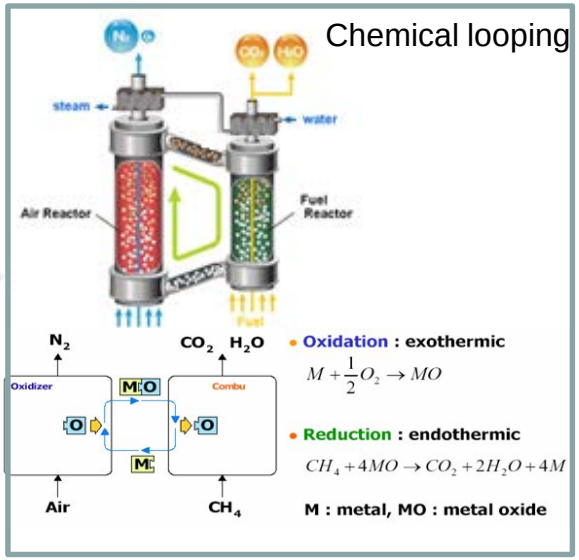
- Innovative combustion processes:
- MILD combustion of fossil and bio-fuels
- Catalitytic combustion
- Co-combustion of fossil and bio fuels
- Oxyfiring of coal and biomass
- CLC of coal and solid fuels
- Carboloop of coal and residues with high metal content

Scientific Impact/Results:

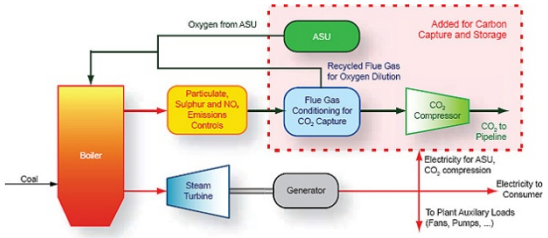
Fundamentals of combustion under unconvetional conditions:
mild combustion conditions; cyclyc/looping conditions;
oxycombustion atmospheres ; high pressure
Catalysts of Chemical Looping
Patents for CCS processes of solid fuels combustion (CarboLoop)



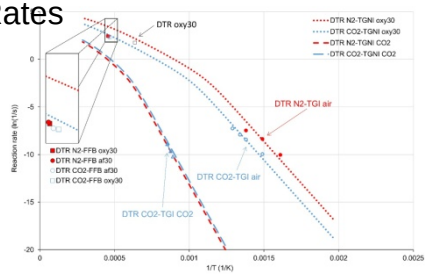
Chemical looping



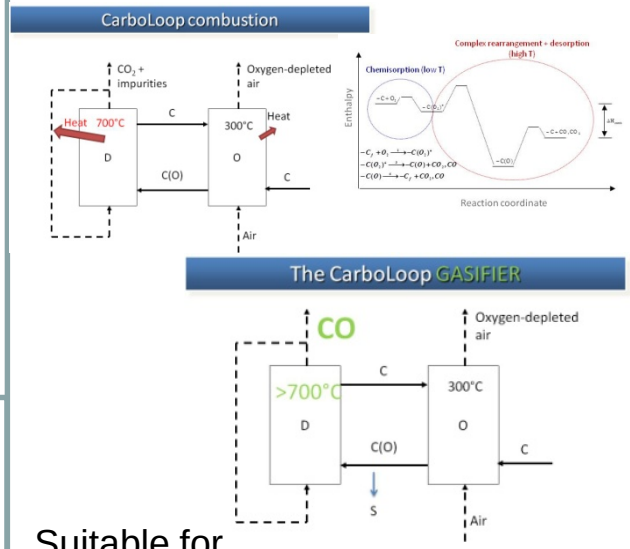
Oxycombustion



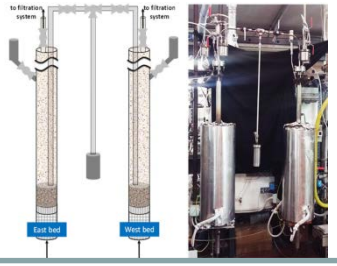
Rates

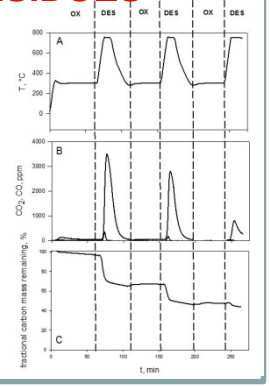


Carboloop: chemical looping of solids without use of metal oxygen carriers



Suitable for
METAL RECOVERY
from REFINERY RESIDUES





Project Area: Low emission energy technologies

Clean combustion:

CO_2 capture

CNR DIITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

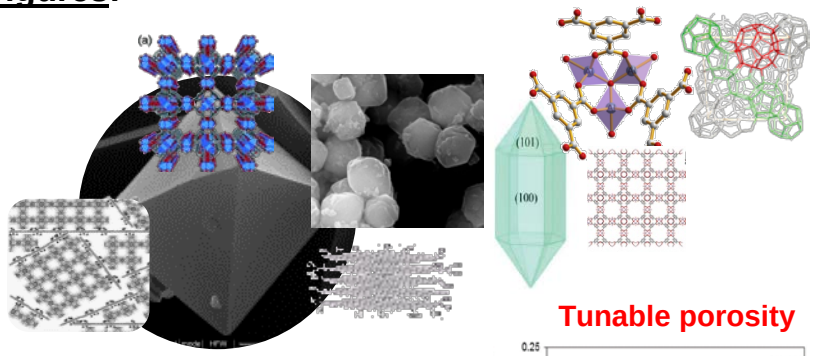
Objective:

Development and tailoring of advanced nanostructured solid sorbents (also composites, hybrids and magnetic particles) with physical and chemical properties finely tunable at the molecular level by eco-friendly wet-chemistry approaches.

Approach:.

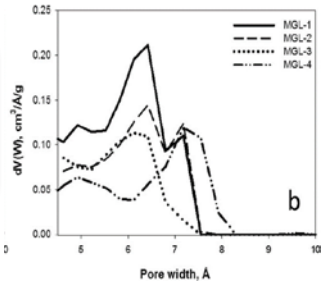
Carbonaceous materials typically present structural features prone to be easily modified at molecular level. We mostly use **green solvents** (water) and develop **cost-effective** protocols (the precursors are easily available and not expensive) and simple synthesis procedure (i.e. anhydrous conditions not required) starting from carbonaceous materials (carbon black, carbon-based pollutants) also from **agricultural wastes** (carbonized and pyrolyzed biomasses).
Wet-chemistry approaches are specifically developed to preserve the **conductive** properties of the carbonaceous core.

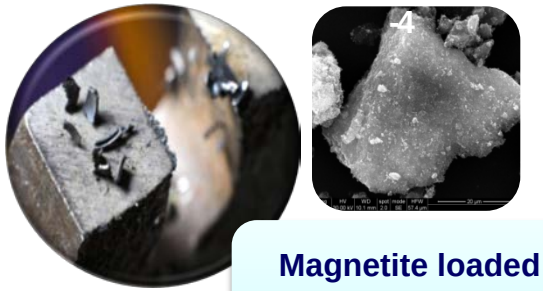
Figures:



Metal organic framework (MOF)/graphene-like composites (Fe, Cu, Zn, Al Ti- based)

Tunable porosity





Magnetite loaded carbon fine particles and carbonized biomasses

Scientific Impact/Results:

- A wide array of advanced low-cost water stable solid sorbents for CO_2 capture has been produced and tested in **real condition** (breakthrough experiments);
- Sorbent are produced by tuning surface area (up to 2700m^2/g in the case of MOF) and micro-meso pore size distribution.
- **Recyclable (thermal desorption allows production of CO_2 ultra pure streams)**;
- Suitable for technological advanced application (sound assisted fluidized bed reactors);
- A m_{ads} = 25 mg_{CO2}/g in real post conditions CO_2/N_2 gas mixture (15 Nl/h) at a fixed CO_2 concentration (3% vol) was measured (best case).

- Chemi and physisorption phenomena
- Fe_2O_3 dispersion on a carbonaceous support limits the Fe_2O_3 tendency to aggregate
- magnetic

Project Area: Low emission energy technologies

Clean combustion:

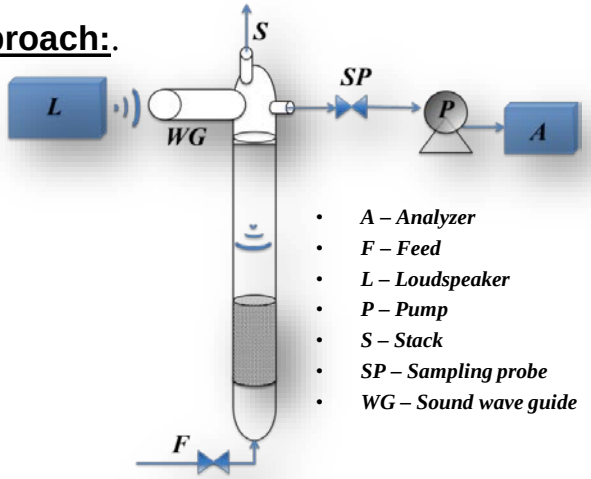
CO_2 capture

cnr DIITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Fluidized bed technologies allow efficient gas-solid contact and intense solid mixing, easier temperature control during both adsorption and regeneration, indirect heating by internal heat exchanger and lower pressure drop needed for reactor design. **Sound assisted fluidized bed technology** is able to dynamically brake up large agglomerate of particles into small fluidizable aggregates avoiding plugging, channeling and agglomeration typical of fine powders.

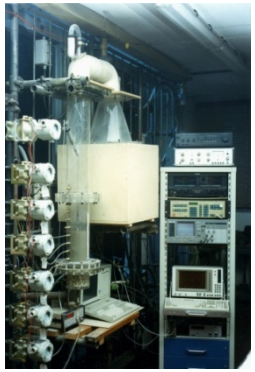
Approach:.



- *A – Analyzer*
- *F – Feed*
- *L – Loudspeaker*
- *P – Pump*
- *S – Stack*
- *SP – Sampling probe*
- *WG – Sound wave guide*

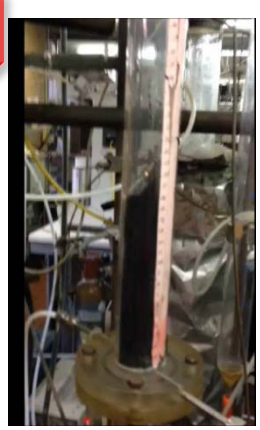
Figures:

Experimental Apparatus

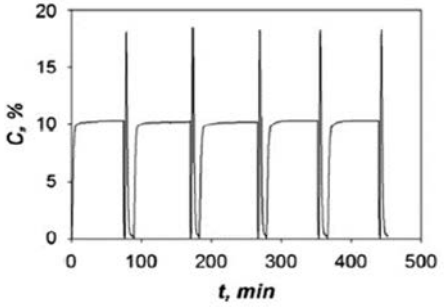


No sound

sound assisted fluidization



In-situ sorbent regeneration



Scientific Impact/Results:

Effect of sound

- ✓ More regular pressure drop (DP/DP0=>1)
- ✓ Higher bed expansion ratios
- ✓ Not intrusive
- ✓ Fine powders do not need to have any peculiar property
- ✓ Economic and user - friendly

Project Area: Low emission energy technologies

Clean combustion:

CO_2 capture

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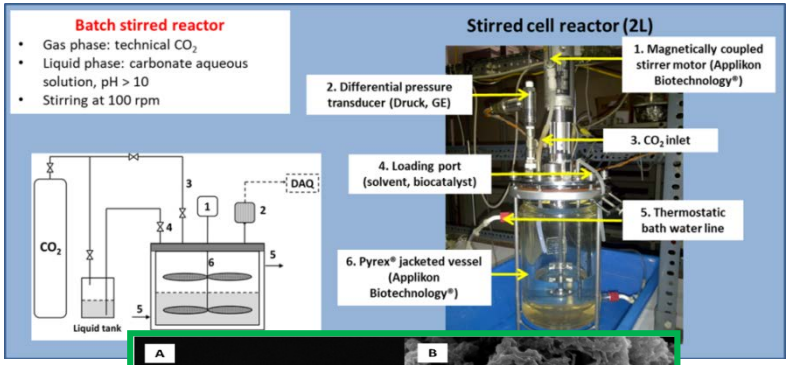
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

The research activity is aimed at the development of the process for **CO_2 capture through Enzymatic Reactive Absorption (ERA)** using K_2CO_3 solutions as aq solvents and recombinant thermostable carbonic anhydrase as biocatalyst to enable CO_2 capture from flue gases



Approach:

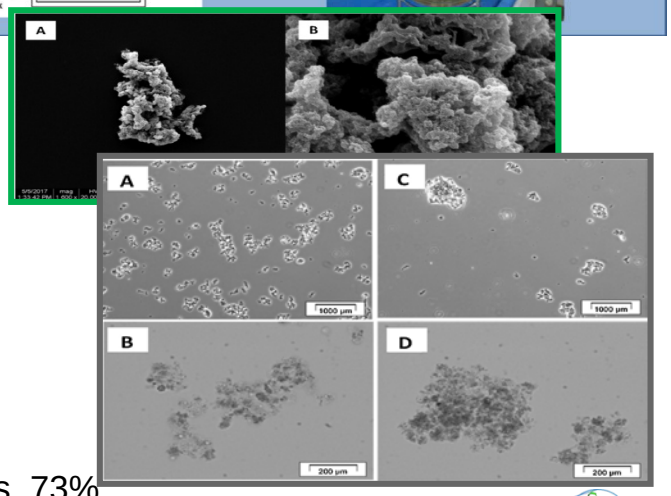
Development CO_2 Enzymatic Reactive Absorption (ERA) through:

Process simulation

Reactor design (absorption contact units)

Biocatalyst development (immobilized carbonic anhydrase - CA)

- **CA immobilization** by different covalent technique to obtain slurry (fine dispersed particles) biocatalyst allowing effective absorption rate enhancement at gas-liquid interface
- **Kinetic characterization** of both free and immobilized CA
- The reactor design through **theoretical modelling of ERA units** including experimentally assessed kinetic parameters for both free and immobilized CA

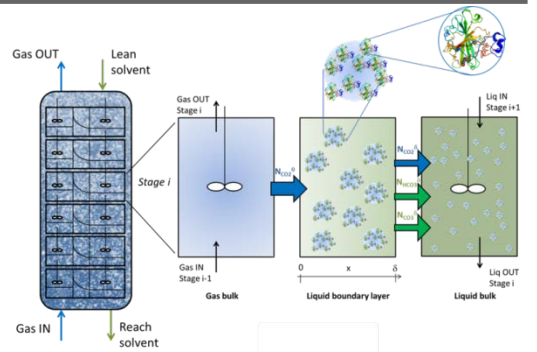


Scientific Impact/Results:

- 90% immobilization yield of CA in magnetic Cross-Linked Enzyme Aggregates, 73% immobilization yield of CA through direct binding on magnetic NPs.

-Kinetic characterization of both free CA and CA immobilized on magnetic NPs at industrially relevant conditions (solvent composition, temperature).

-Performances of slurry staged ERA units by theoretical modelling based on experimentally assessed kinetics of CA immobilized on magnetic NPs → pilot bubble column with capture efficiency between 67-99% depending on solid biocatalyst hold-up (2-0.1%vol)



Project Area: Low emission energy technologies

Clean combustion:

CO2 capture and storage

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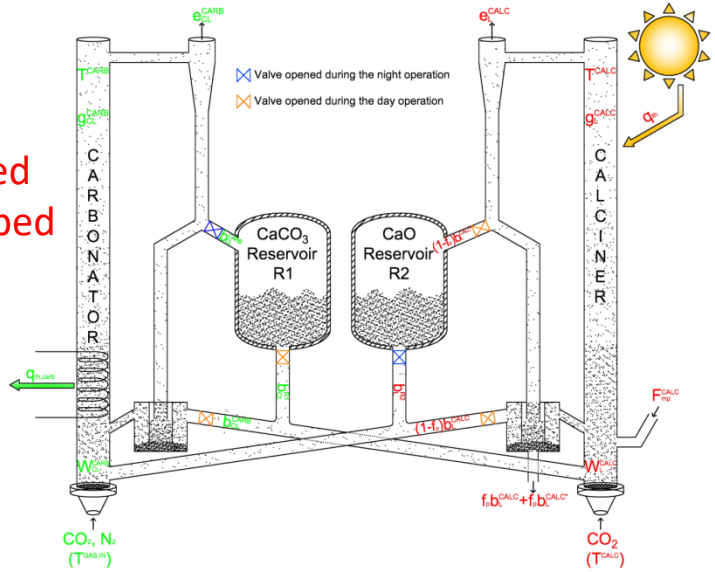
Objective:

The study of the integration of Calcium looping process with concentrated solar power for CO2 capture and thermochemical storage to increase power flexibility

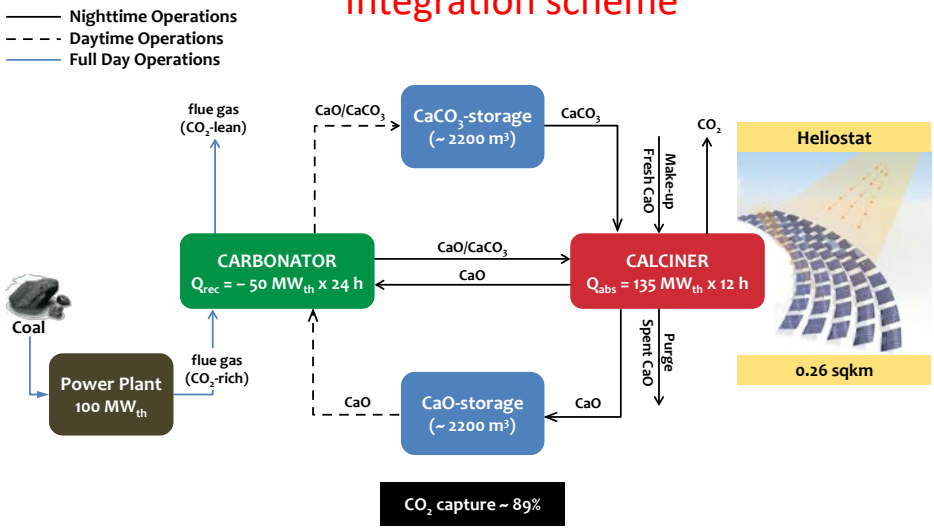
Figures:

Interconnected fluidized bed configuration proposed



Approach:.

Integration scheme



Scientific Impact/Results:

CO2 capture and carbonation conversion degree over iterated cylces

Project Area: Low emission energy technologies

Clean combustion: catalysis

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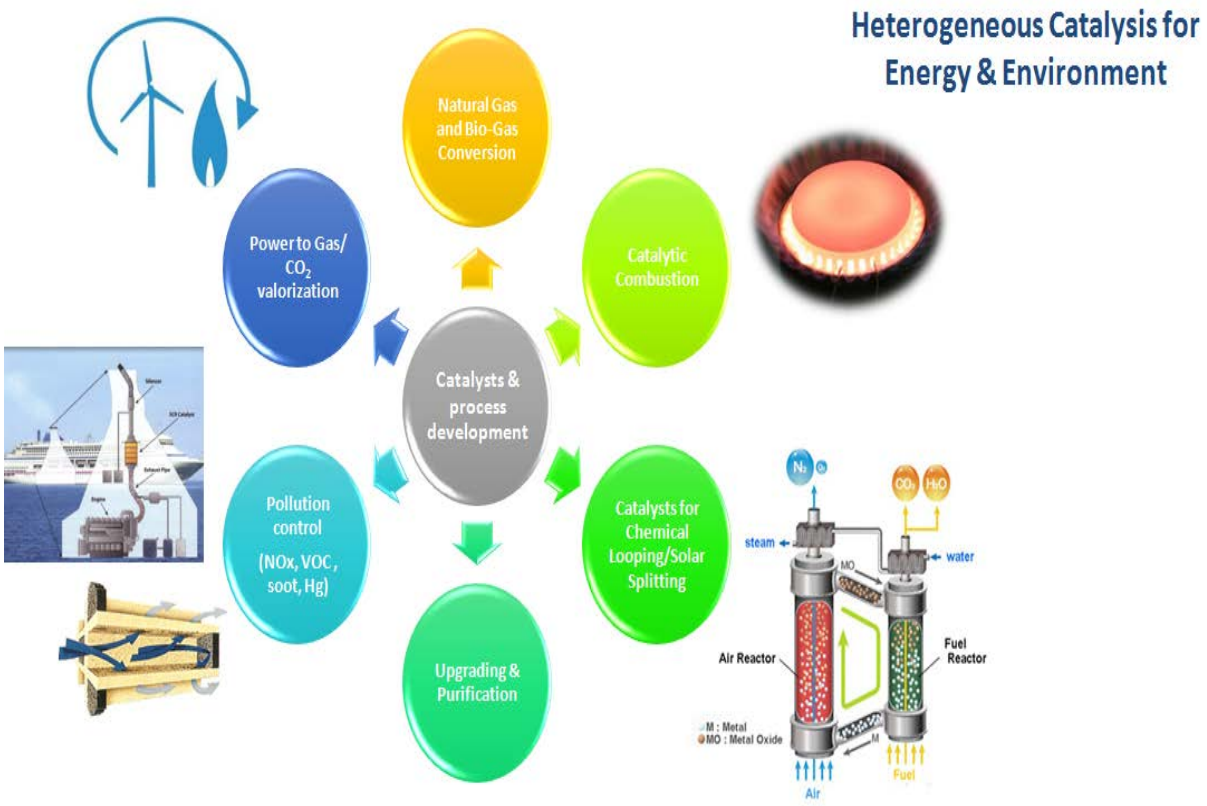
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective

To develop catalysts and catalytic procesesses for a large range of applications:

- Partial oxidation (production of syngas from methane or biogas) on sulfur-tolerant catalysts;
- Total oxidation (hybrid or high pressure catalytic combustion for gas turbine);
- Chemical looping combustion or reforming and solar water splitting with highly perfoming carriers;
- Gas upgrade (reforming of tar from biomass pyrolysis, purification of hydrogen stream for fuel-cell; purification of biogas from H_2S);
- Catalytic conversion of ethanol to butanol as fuel additive;
- Abatement of NO_x (low temperature SCR) and soot from diesel engines;
- CO_2 valorisation through methanation and methanol synthesis.



Biofuels

- **Production:**
  - II and III gen liquid biofuels
  - Biogas
  - Syngas
- **Utilization:**
  - Efficient and low emission utilization of biofuels
  - Furnaces, engines and micro gas turbine
  - LHV biogas in commercial engines
  - Energy storage

Project Area: Low emission energy technologies

Bio and alternative fuels production: thermochemical

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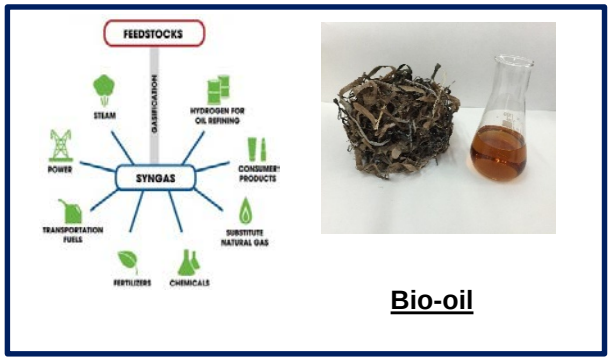
Objective: **Upgrading of thermo-chemical processes applied to waste and residual biomass to produce energy, H2 rich syngas, bio-oil**

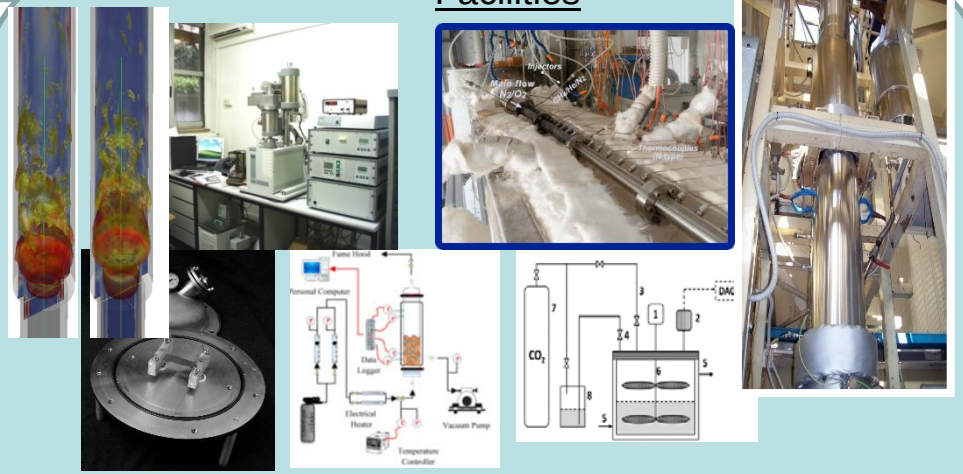
Feedstocks: biomass, wastes

Thermo-catalytic conversion
- **Gasification**
- **Pyrolysis**



Technologies:
Fluidized beds
Entraiened flow reactor
Fixed beds
Rotary kilns
Plug flow reactors

Facilities



Approach:

✓Analysis and characteriz. of feedsock and products
✓Chemistry and knetics
✓Experiments from lab scale to pilot scale
✓CFD modelling
✓Preparation, characteriz. and testing of solid supported catalysts

Project Area: Low emission energy technologies

Bio and alternative fuels: upgrading and characterization

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Objective:

High quality gen II and III biofuels upgrading and characterization by means experimental characterization and numerical modeling

Approach:

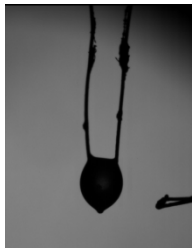
Numerical and experimental dedicated tools:

- Chemical analysis
- Reactions kinetics
- High pressure combustion cell
- Drop tube furnace
- Spray lab

Scientific Impact/Results:

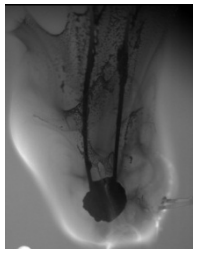
- Automatic reduction of detailed mechanisms
- New algorithms to accurately reproduce the behavior of bio and alternative fuels
- Bio fuels from waste and biomass of low commercial value
- Fundamental combustion properties of II and III gen bio fuels
- High quality bio fuels (e.g., aeronautical applications)
- Optimization of bio-fuels production processes

Some images from test of crude pyrolysis oil droplet (European project: R2H - Renewable residential heating with fast pyrolysis bio - oil)



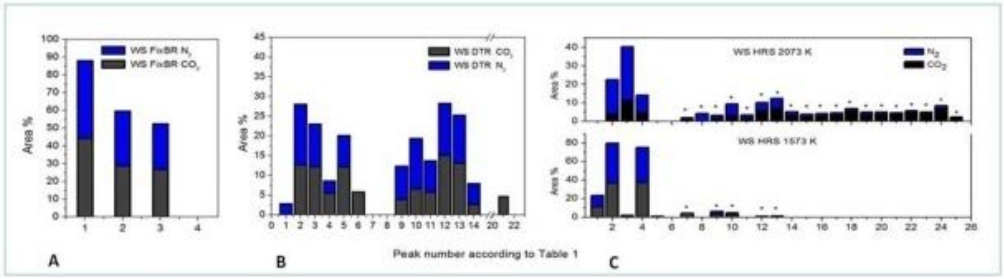
Start of test

Droplet swelling

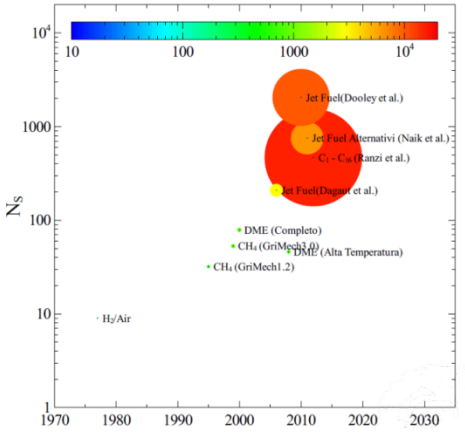


Soot formation

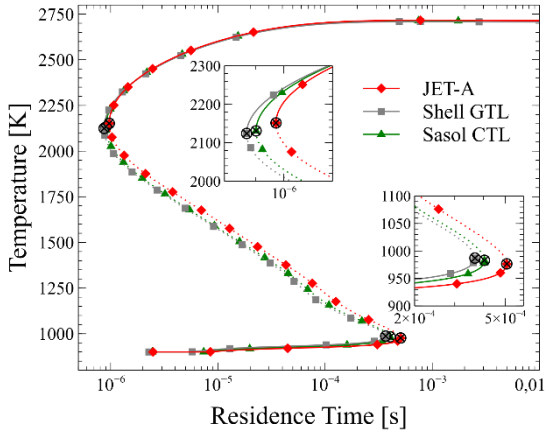
Cenosphere



Tar Analysis



Increasing size of detailed mechanisms



Parametric continuation of three different Jet fuels with detailed mechanisms

Project Area: Low emission energy technologies

Bio and alternative fuels: biogas/syngas upgrading and characterization

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Engineering, ICT and Technologies for Energy and Trasportation Department

View of the Reformer connected with SOFC (SOFCOM EU Project)

Design, realization and tests of compact reformers for the conversion of the biogas into a H_2 and CO rich syngas

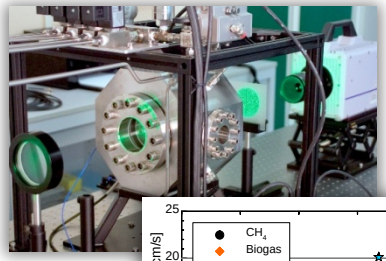
Approach: SR reforming /oxy-steam reforming, finalized to hydrogen or syngas production and/or integration with Fuel Cell systems for mobile and stationary applications in the range of 2kW.

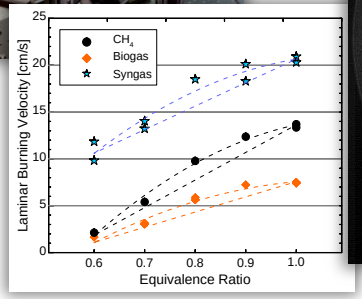
Target: developing a compact unit, integrable with different downstream processes; high efficiency processing of different biogas feedstocks; use of low-cost Ni-based catalysts.

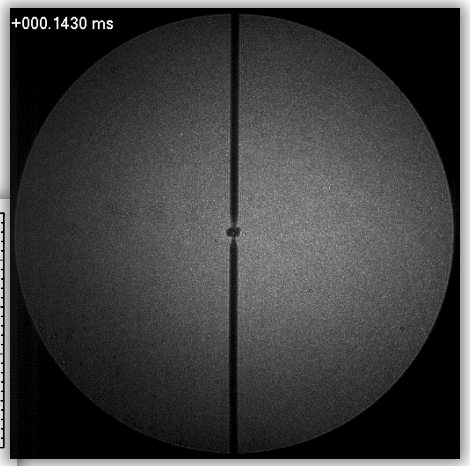
Characterization of the burning properties of biogas and syngas, in precision-controlled conditions, typical of heat engines & burners.

Approach: high-pressure, optically accessible cell, high time and space resolution diagnostics, precision-metered gas mixture composition.

Target: suggesting guidelines (design specifications and operating strategies) for the development of high-efficiency, ultra low-emission energy conversion systems







syngas flame at P_0=10bar

Project Area: Low emission energy technologies

Bio and alternative fuels: end-user applications

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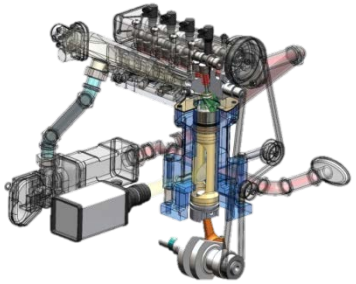
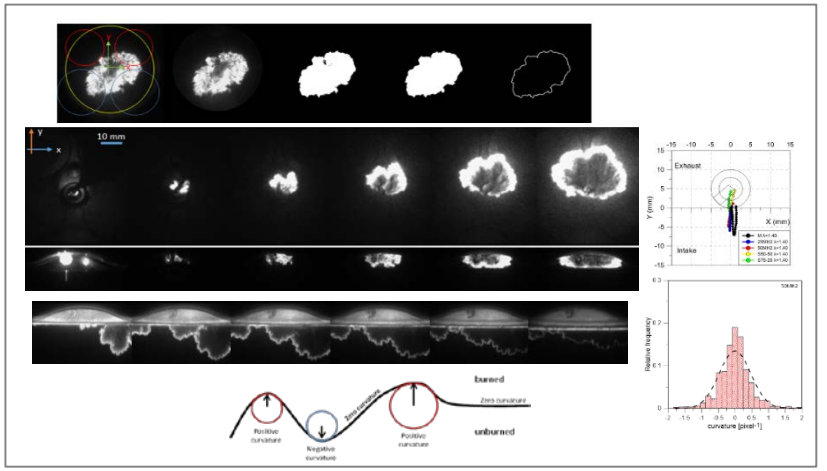
Identification of hydrogen concentration effects on syngas combustion in s.i. engines

Approach: combination of in-cylinder pressure measurements, exhaust gas emissions data and flame visualization in optically-accessible syngas-fueled SI engine.

Target: identifying the effect of syngas composition (specifically H_2) on engine performance.





Heavy duty s.i. engine powered with renewable gas fuels

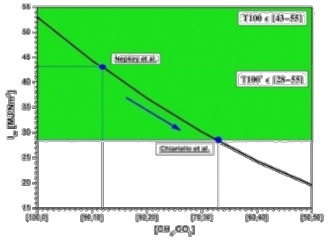
Approach: bench testing of multi-cylinder s.i. turbocharged engine; performance analysis as a function of the blend composition and the ignition parameters.

Target: Optimization of engine control parameters to maximize performance as a function of fuel composition

Utilization of bio and alternative LHV fuels in micro gas turbines

Approach: combination of numerical modelling and experimental analysis of a commercial 100kW MGT, customized to run under different operating conditions and with different fuels; purposely-built fuel supply system, providing gas mixture with variable amount of CH4, H2, CO2 and CO.

Target: Extending the domain of operation and maximizing the efficiency of MGT running on alternative fuels.



Flexibility and sustainability

- Energy storage and carriers
- Fuel cells

- Power grids
- Smart Micro-grids

Project Area: Low emission energy technologies

Flexibility and sustainability: Energy storage and carriers

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

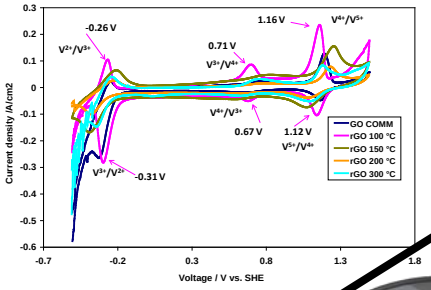
Objective:

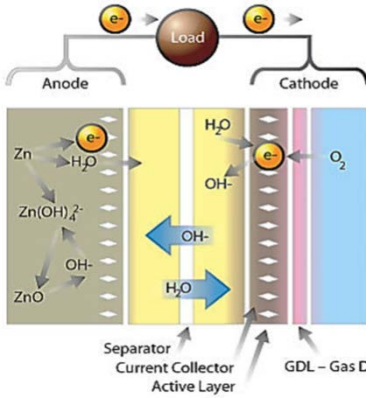
- Development of innovative and highly performing materials and components for electrochemical storage devices (vanadium redox flow, sodium-ions, iron-air, sodium-nickel chloride batteries and supercapacitors) from battery cell level up to kW battery.

- Improving electrochemical performance in terms of current and power density, round-trip efficiency and cycling.

The goal is a total costs reduction of the specific technology to allow the up-scaling favouring the market introduction

Vanadium Redox Flow Battery





Iron-air Battery process

$$O_2 + 2Fe + 2H_2O \underset{charge}{\overset{discharge}{\rightleftharpoons}} 2Fe(OH)_2$$

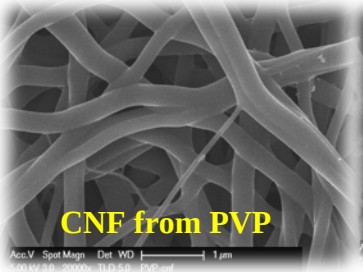
$$3Fe(OH)_2 + \tfrac{1}{2}O_2 \underset{charge}{\overset{discharge}{\rightleftharpoons}} Fe_3O_4 + 3H_2O$$

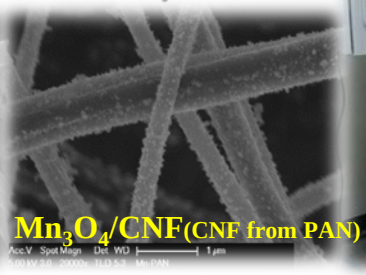
Approach:

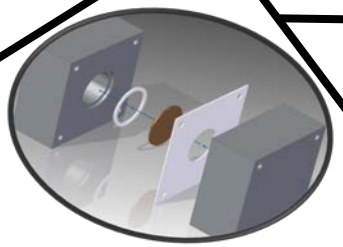
- Low cost synthesis methods suitable for scale-up materials:

- Electrospinning technique
- Sol-gel
- Hydrothermal

- Low cost materials and components







Na-NiCl$_2$ innovative planar battery

Supercap proof-of-concept

Scientific Impact/Results:

- Optimization of materials, components and design with respect to the state of art for current storage technologies
- Proof-of-concept of new electrochemical storage technology

Project Area: Low emission energy technologies

Flexibility and sustainability: Emission control

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Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

•Change in fuel composition or energy mix influence the design of the conversion system but also pollutants. It is urgent to improve knowledge on Formation mechanisms of new pollutants, and develop new diagnostics and abatement metodology.

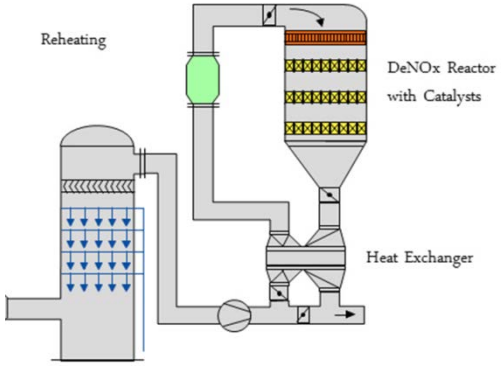
Approach:

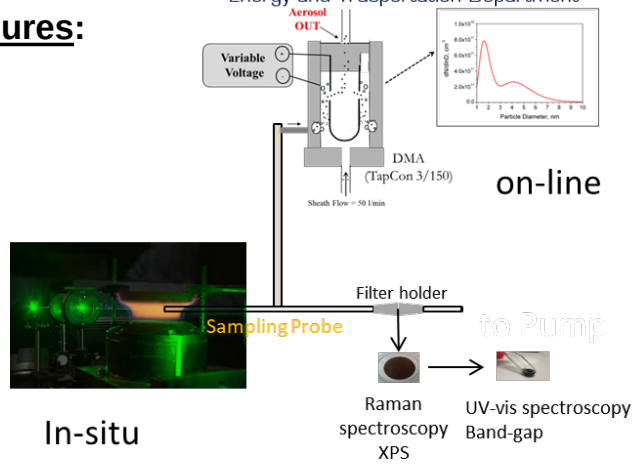
Research activities are focused on:

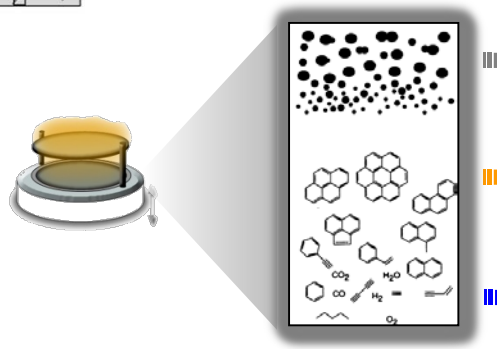
1. Formation mechanisms of pollutants;
2. Advanced diagnostics for regulated / unregulated pollutants;
3. Reduction of pollutants from fossil and alternative fuels.

Specific activities include in-situ, on-line and off line advanced diagnostics of pollutants and ultrafine particles; diagnostic of flame instabilities; NO_x , SO_x and particulate reduction; SCR; Combined particulate and NO_x reduction; NO_x storage-decomposition for automotive application; PM reduction through water vapor condensation; Hg capture from flue gases; purification of CO_2 streams; tar and VOC abatement.

Figures:







Scientific Impact/Results:

- Physicochemical characterization of combustion generated carbon nanoparticles
- Characterization of main combustion products and intermediates
- Intensification of catalytic processes and development of novel materials

Project Area: Low emission energy technologies

Flexibility and sustainability: Energy storage and carriers

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

- Development of innovative and highly performing materials and components for electrochemical storage devices (vanadium redox flow, sodium-ions, iron-air, sodium-nickel chloride batteries and supercapacitors) from battery cell level up to kW battery.

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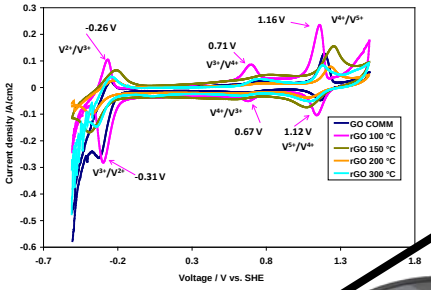

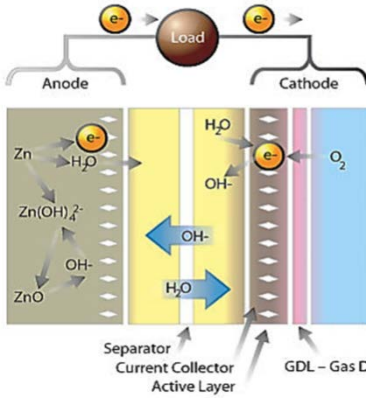

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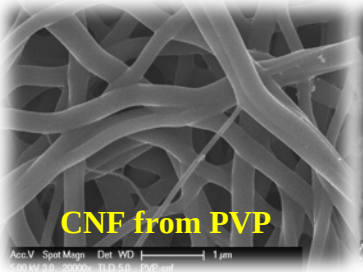

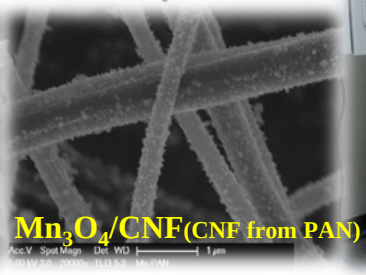

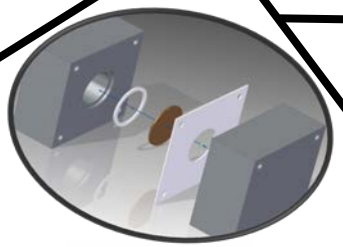

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Project Area: Low emission energy technologies

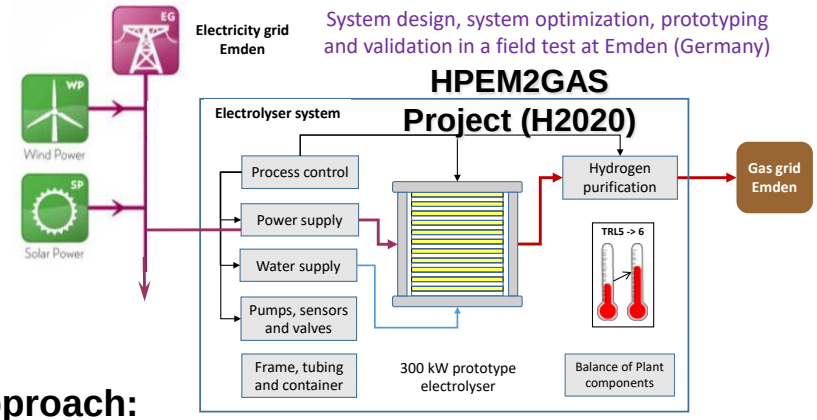
Flexibility and sustainability: Energy storage and carriers

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Energy storage of renewable energy is achieved producing H_2 for fuel cells by water electrolysis, photo-electrolysis, CO_2-H_2O co-electrolysis (to store electrical energy in chemicals such as methanol)

Objective:

- **Development of innovative and highly performing materials and components**
- **Improving the efficiency of the devices.**



Approach:

- Synthesis methods for catalysts suitable for scaling-up
- Cost-effective materials and components

1 kW PEM electrolyser system

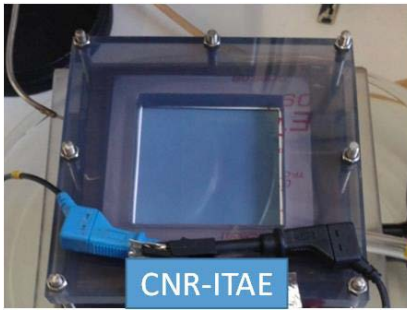
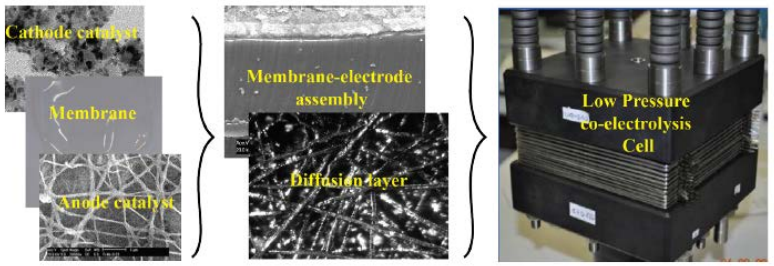


Photo-electrolysis cell

CO_2-H_2O co-electrolysis materials and components



Scientific Impact/Results:

- **Optimization of materials and components**
- **Development of prototypes to validate the technology and the developed materials.**
- **Technology transfer and training**

- High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications (HPEM2GAS): G.A. n° 700008
- Next Generation PEM Electrolyser under New Extremes (Neptune): G.A. n° 779540
- CRM-free Low Temperature Electrochemical Reduction of CO2 to Methanol (LOTER.CO2M): G.A. n° 761093
- Innovative Photoelectrochemical Cells for Solar Hydrogen Production (FotoH2): G.A. n° 760930

Project Area: Low emission energy technologies

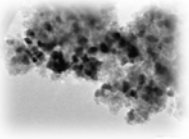
Flexibility and sustainability: Fuel cells

cnr DIITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective: The EU targets are the reduction of greenhouse gas (GHG) emissions by 40% by 2030 and by 80-95% by 2050 compared with 1990. Polymeric Electrolyte Membrane Fuel Cells (PEMFC) are environmental friendly. Although substantial progress has been achieved in the development of membrane-electrode assemblies (MEAs) for fuel cells, their high cost hinders the commercial breakthrough of PEMFC. Therefore it is urgently to improve MEA performance and durability to reduce cost and enable marketability of FC.

Approach: The development of new materials and improved membrane electrode assemblies is required to enable cost, performance and lifetime targets to be attained. It is necessary to develop and modify materials, such as polymeric membranes, ionomer dispersions, catalysts (e.g. Pt alloys and new supports with higher stability), and integrate them into high performing MEAs with superior durability. At the same time, it is necessary to improve the design of the stack. The problem related to the sealing concepts and stack design, such as the edge protection of the membrane and the sealing concept for the cooling media, have to be depth investigated to enhance the lifetime of the system.

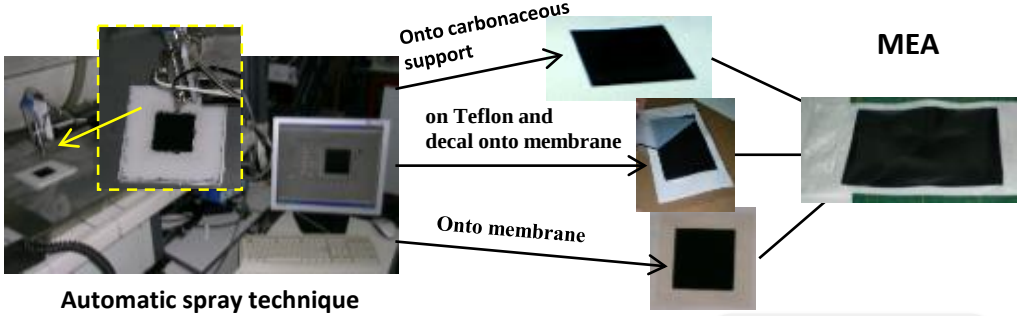
Figures:



Catalysts based on Pt

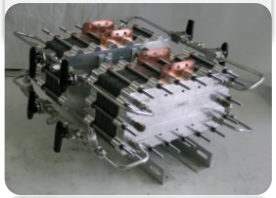
Polymer functionalisation

Membranes



3.5kW - M T PEM
2 x 1.5 kW modules

1 kW H_2/O_2
for Space application



5 kW H_2/air
for Marine application

Scientific Impact/Results: The development of components such as catalysts, polymeric membranes, electrodes and MEAs, and their scale up from the lab scale to bigger size, has permitted the realisation of prototypes in a wide range of electric power. In particular a 3.5kW stack operating at 120°C for automotive, a 1kW stack operating in H_2/O_2 for space application and a 5kW stack operating in H_2/air for marine APU applications were developed.

Project Area: Low emission energy technologies

Flexibility and sustainability: Fuel cells

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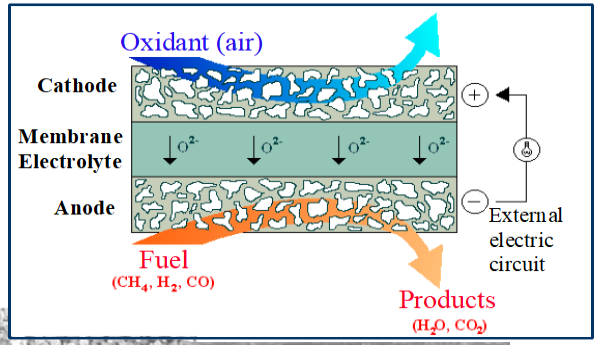
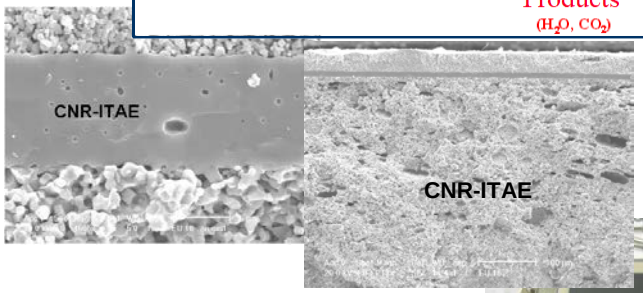
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

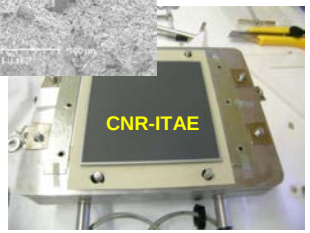
Objective:

- **Solid Oxide Fuel Cells (SOFCs)** are based on *ceramic materials* and operate at high temperatures between 800-1000°C.
- The challenges in this sector are regarding the *reduction of the operation temperature* and the direct utilization of hydrocarbons.
- This will allow to decrease degradation and make the device cost-effective by system simplification (reduced fuel processing) and use of cheap ferritic steel interconnectors.

Figures:







Approach:

- The approach is to develop ceramic electrolytes for intermediate temperature operation based on ceria and gallates, use a multifunctional electrocatalytic layer at the anode to favour internal fuel processing and tailor the composition of the perovskite cathodes to speed-up the oxygen reduction process

Scientific Impact/Results:

- The new materials and cell architectures have been validated for the direct oxidation of hydrocarbons such as methane, ethanol, bio-gas, propane, reformed diesel etc. in systems up to 2 kW power

Project Area: Low emission energy technologies

Flexibility and sustainability: Power grids

cnr DIITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

Design and experimental prototyping of several typologies and topologies of electronic power converters with high dynamic performance and high efficiency for interfacing the smart micro-grid with the main power network, renewables sources based generators and storage systems (batteries, supercapacitors).

Approach:.

Wide band gap (WBG) power devices technologies will be adopted, (SiC and GaN), permitting much higher voltages, frequencies and temperatures than conventional semiconductor materials.

The following typologies of power converters will be focused:

•DC-AC voltage source inverter (VSI), both in traditional 2-level and in multilevel configurations (particularly NPC = Neutral Point Clamped), including the related pulsewidth modulation techniques (PWM);

•AC-AC based on the combination of DC-AC converters in back-to-back configuration.

•DC-DC converters: buck, boost, bi-directional type. In particular boost converters with innovative structures characterized by high efficiency and low cost (low number of power devices) for the connection of fuel cell (FCS), micro-wind, marine and photovoltaic systems will be devised.

Innovative PWM and control techniques will be implemented experimentally on embedded platforms (DSP, FPGA, micro-controllers).

Figures:

3-level NPC
Voltage Source Inverter
(20 kW)

DC-DC bidirectional
Converter (2.6 kW)

Scientific Impact/Results:

- Development of innovative power converters and related PWM and control techniques
- Technology transfer to SMEs and Industries
- Training of technicians and scientist in the field power converter design and control.

Project Area: Low emission energy technologies

Flexibility and sustainability of energy and power:

Smart Micro-grids

cnr DITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

Objective:

- Definition of new architectures for the electric energy distribution in smart micro-grids: DC distribution systems and hybrid AC/DC, with one or more voltage levels and their adoption in residential/commercial buildings as well as in smart vehicles, including ships.
- Definition of methodologies for the optimal and coordinated management, in smart micro-grids, of the following actors:
  - Distributed generators from renewable sources;
  - Stationary generation units (Fuel-cells);
  - Storage systems.
  - Loads**.**

Approach:.

Development of data reconstruction and forecasting techniques of electric/meteo-climatic data as a part of the intelligent management of electric power grids:

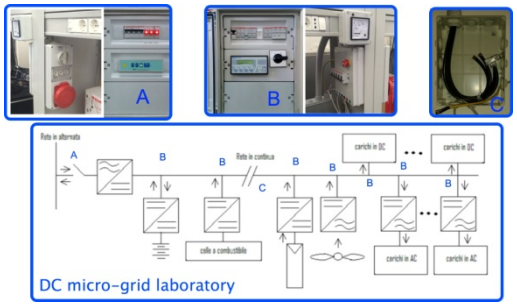
1) electric energy production from renewable sources;
2) load demand.

Definition of EMS algorithms pursuing one or several specific goals:

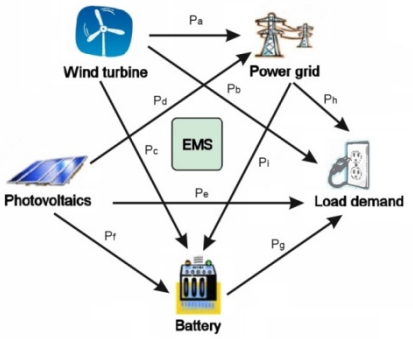
1) maximum efficiency;
2) minimum losses;
3) minimum operating cost;
4) maximum self-sufficiency in islanded operation;
5) minimum uncertainty of the grid exchanged power profile.

Implementation of the forecasting and management algorithms on embedded platforms (FPGA, micro-controllers).

Figures:



Flussi di potenza governati da EMS



Scientific Impact/Results:

- Development of innovative distribution architectures of smart micro-grids and related energy management systems, of potential interest from the power network manager and companies.
- Technology transfer to SMEs and Industries
- Training of technicians and scientist in the field smart micro-grids and their management