The SFERO project

DESCRIPTION

The nature is a dynamic equilibrium between atmosphere, hydrosphere, biosphere and lithosphere. These "spheres" store and exchange each other energy and mass via interweaving and complex connections. In the course of time, among these spheres we have created a new one, the *technosphere* (*or anthroposphere*) which has permitted the fire domestication, agrarianization and industrialization of our society. However, the continuous and rapid expansion of this "synthetic" sphere is having an impact in the delicate equilibrium among the "natural spheres". Due to the actions of humans on the environment, a new redistribution of energy and mass is occurring in the nature.

We are digging carbon out of the lithosphere and accumulating it mainly into the atmosphere and hydrosphere. Global warming and acidification of oceans are the main dramatic outcomes of this new carbon balance. It is urgent to complement the techno-sphere with the other natural spheres and re-orientate the effects of the permeation of human activities in the global environment.

The vision of the SFERO (Systems for Flexible Energy Reusing carbOn) project is to harmonise energy production, transportation and industries composing techno-sphere with the other natural pools from which a more complex organization emerges: *the SFERO*.

THE SFERO CONCEPT

The core activity of the SFERO project is the implementation of the calcium looping as a process for both the decarbonisation of the industry and power sector and the flexible hybrid storage of energy. The calcium based solid sorbents that will be developed in the project will show improved chemical and mechanical properties via multi-cycling use. The materials developed in the SFERO project are solid sorbents that are much cheaper than state-of-the-art solutions proposed for carbon capture such as amines. The individual and unique feature of the integration of calcium looping process with power and energy intensive industry is the possibility to use the CaO-based spent solids as raw material of the cement production process or as flux in the iron making process.

The calcium looping process is gaining considerable interest as **hybrid chemical energy storage** where calcination is the process for energy gathering and carbonation is the step for energy release (see reaction below).

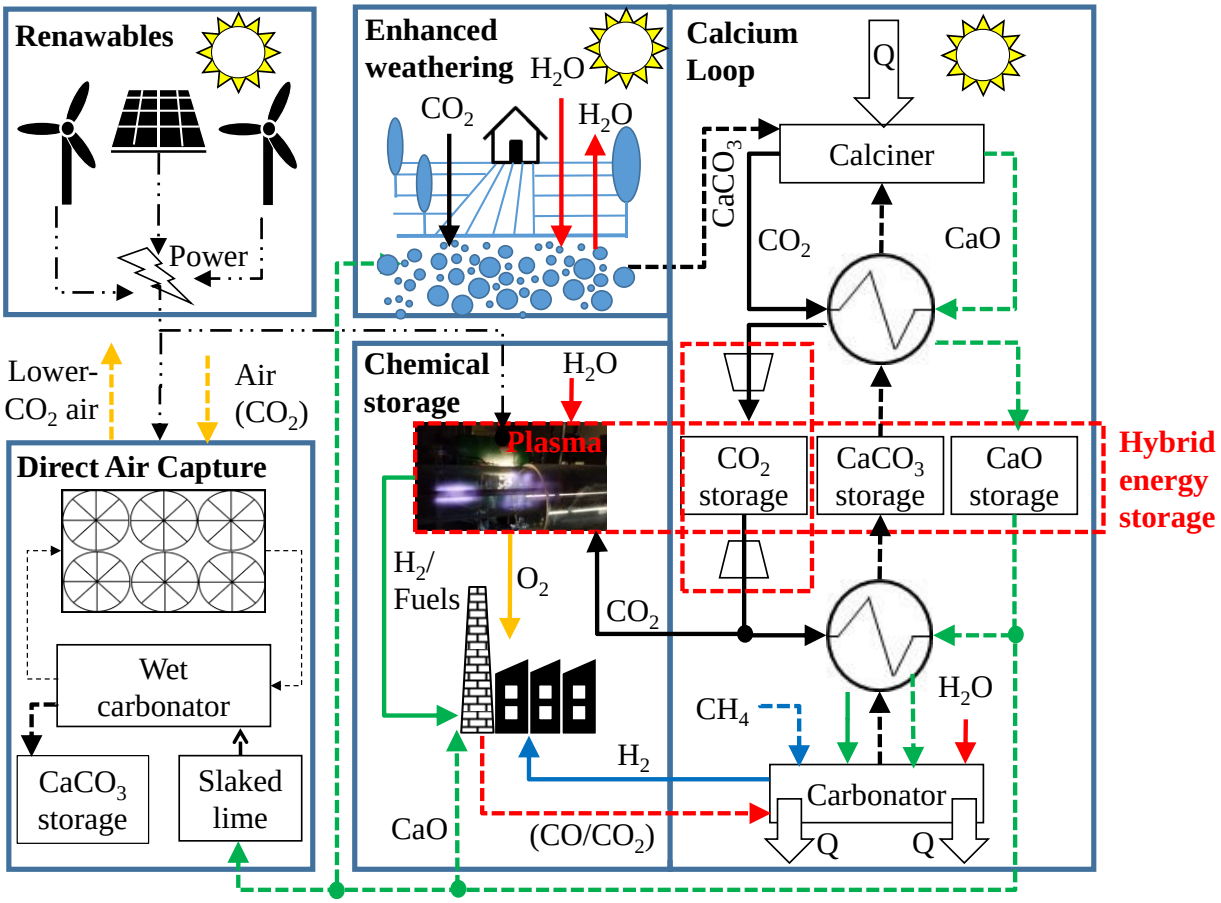
$$CaCO_3 \rightarrow CaO + CO_2 \ \ (calcination; energy\ storage; sorbent\ regenartion)$$

$$CaO + CO_2 \ \rightarrow CaCO_3\ (carbonation; energy\ release; CO2\ capture))$$

Since the carbonation reaction is an exothermic reaction, heat is released and steam can be produced to generate electricity by a submerged heat exchange in a fluidised bed carbonator. The produced $CaCO_3$ can be stored and successively transported to the calciner reactor to gather the excess of energy.

In the SFERO process a further new process based on plasma will be also investigated for the valorisation of the captured CO2 and the production of e-fuels via excess of renewable power. SFERO proposes a **paradigm shift by combining the synergetic process between plasma and catalysis with membrane, with the ability**

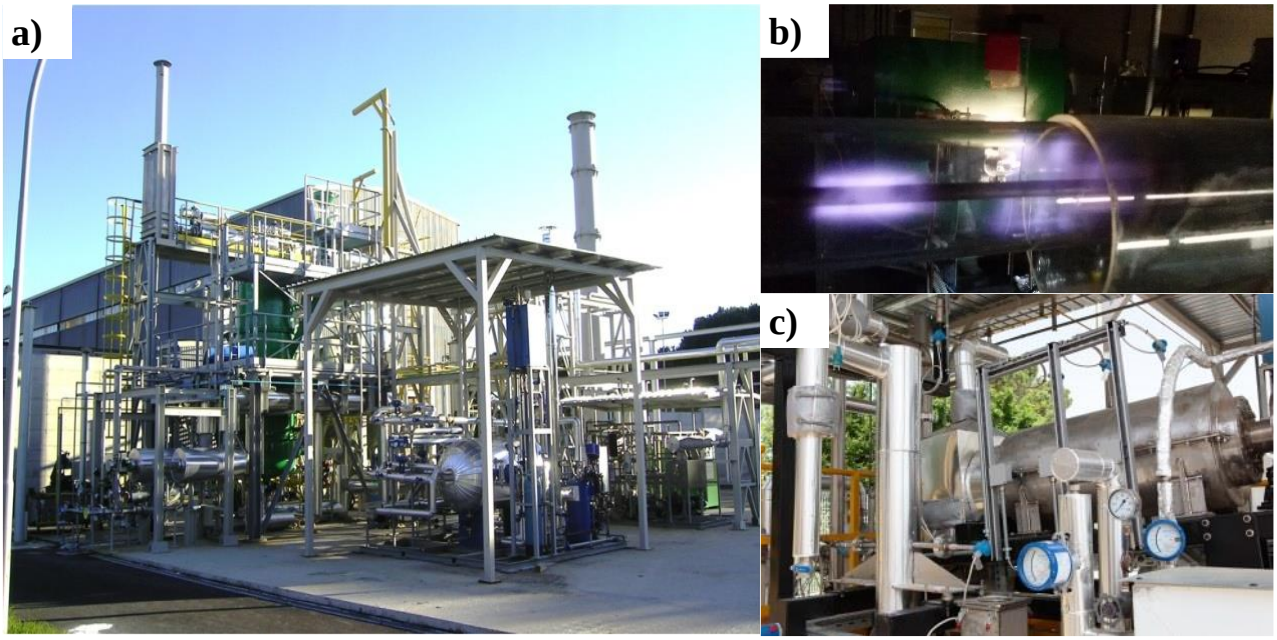
to modify the entire chemical landscape of renewable fuels, thanks to a strong intensification process. In this way, strong intensification offers the possibility of **shaping the kinetics of catalytic fuel production by interaction with O2 removal and H2 production**. More precisely, the formation of radicals can be used as a versatile means to overcome current limitations in many catalytic processes such as lack of selectivity or reduced efficiency. Beyond the fundamental importance to understand and create various light-matter hybrids, modelling chemical reactivity by light is an unprecedented, ecologically friendly and cheaper technology, with a decreased need for new chemicals and therefore less waste and cleaning cost.



The SFERO concept

SFERO is a project within the Research Line "*1.6 Efficienza energetica dei prodotti e dei processi industriali*" coordinated by the Department of Efficiency of ENEA within the Italian research programme 2019-2021: "Ricerca di Sistema" funded by the Italian Ministry of Sustainable Economic Development (Grant number I34I19005780001). Economic size: 1.4 M€

The main objective of SFERO is the development of efficient processes for closing the carbon cycle by means of the use of excesses of renewable electricity. The activities will be carried out in the ecosystem of technologies composing the ECCSEL research infrastructure ZECOMIX (Zero Emission of Carbon with MIXed technologies). Being a member of ECCSEL consortium is a label of quality: it has been evaluated through European process based on commonly agreed criteria and recognised as being of the highest standards and relevance to research in Europe.



ZECOMIX research infrastructure: (a) Calcium looping (CaL) pilot plant; (b) Glow discharge plasma reactor for carbon valorisation; (c) Enhanced Weathering reactor for hydrated CaO carbonation

WORK PACKAGES (WP)

WP 1. EVALUATION OF THE EFFICIENCY AND PERFORMANCE CRITERIA OF OPTIMAL DECARBONISED INDUSTRIES

Definition of basic industrial configurations and comparison with innovative technological solutions*.** Identification of performance criteria for the CaL process (e.g. SPECCA index, Specific Primary Energy Consumption for Carbon Avoided, cost of avoided CO2, system perimeter) implemented in real case studies. ***Evaluation of performance criteria - The performance indexes (e.g. SPECCA index, cost of avoided CO2, cost of leveled product) will be defined and calculated for the processes under examination and integrated on an industrial scale (cement plants, steel mills). These results will be used to adapt existing research infrastructures (e.g. ZECOMIX) to the new operating conditions.

WP 2. DESIGN OF NEW MATERIALS FOR CO2 CAPTURE AND CHEMICAL STORAGE IN THE INDUSTRY

Development of calcium-based materials for simultaneous CO2 capture and thermochemical accumulation of excess energy. These materials must be resistant to high temperatures with high chemical and mechanical stability even after several cycles of carbonation and calcination. In particular, the behaviour of the sorbent will be studied and compared with metals such as iron. Furthermore, CaO-based composite materials supported on Zirconates or Calcium ferrites The Ca-based sorbents developed in this WP will be extensively used in the reactor designed in WP3.

Catalysts for PAC (Plasma-Assisted Catalysis) processes. The optimal synthesis method will be identified to obtain catalysts with low cost and environmental impact resistant to deactivation. Catalyst supports will also be studied in order to optimize the chemical interaction with the catalyst itself for the plasma-assisted catalysis (PAC) process. The activity, selectivity and stability of the catalysts for valorisation of CO2 will be tested in the prototype developed in WP4.

Development of membrane for O2 separation – During the plasma-assisted catalysis, CO2 will be dissociated into CO and O2. As a consequence, in order to increase the conversion of CO2, O2 will be captured and removed from the reaction zone via a perovskite membrane. Graphene oxide based membrane will be taken into consideration as well.

WP 3. DESIGN AND CONSTRUCTION OF A DUAL FLUIDISED BED SYSTEM FOR H2 PRODUCTION VIA CALCIUM LOOPING PROCESS

Formulation of computational fluid-particle dynamics models – A multiphase model will be formulated to evaluate the main geometrical sizes and the optimal operating window of a dual fluidised bed prototype for H2 production via sorption enhanced reforming (SER) process.

Design and construction of a mock-up model of a sorbent regenerator- A mock-up model of the sorbent regenerator will be constructed in order to (i) corroborate the model developed in the previous task and (ii) explore the optimal operating condition for a sorbent regenerator.

Design and construction continuous dual fluidised bed (DFB) A continuous DFB prototype will be designed and constructed in order to test and demonstrate in a single loop in a continuous H_2 production process under representative operating conditions.

WP 4. DESIGN AND CONSTRUCTION OF PLASMA ASSISTED CATALYTIC PROTOTYPE FOR CARBON VALORISATION

Selection of the plasma configuration - Different types of plasma will be studied: Dielectric-Barrier Discharge (DBD) and Atmospheric Pressure Glow Discharge (APGD) will be taken into consideration for the specific CO2 conversion reaction.

Preliminary assessment of the performance criteria. The key performance indicators will be defined and evaluated for the specific PAC process: Specific energy input (SEI), Energy efficiency (η) and Energy cost (EC) will be evaluated based on the experimental results obtained in terms of CO2 conversion.

Design of a test rig for plasma-assisted catalysis testing. A new dielectric barrier discharge will be constructed for testing of CO2 dissociation into CO and O2. A perovskite-based membrane will be integrated for O2 uptake and CO2 dissociation enhancing.

WP 5. COMMUNICATION AND DISSEMINATION

Construction of a website - Through the launch of a website, communication and dissemination of the results obtained during the useful life of the project will be carried out. However, the website will remain active six months after the end of the project in order to guarantee the dissemination of the final results.

Dissemination plan - The formulation and implementation of a dissemination plan will lead to the maximization of the exploitation of the results obtained by the project. The main results obtained will be reported, evaluating the impact on the Italian industry of cement and steel.

CONSORTIUM

University of L'Aquila

Politecnico di Torino

University of Rome Sapienza

University of Rome Tre

DOWNLOAD

- Solar-Powered Rankine Cycle Assisted by an Innovative Calcium Looping Process as an Energy Storage System
- CaO–CaZrO3 Mixed Oxides Prepared by Auto–Combustion for High Temperature CO2 Capture: The Effect of CaO Content on Cycle Stability