GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN | CSIC | INCAR

Instituto de Ciencia y Tecnología del Carbono

Institute of Carbon Science & Technology

Consejo Superior de Investigaciones Científicas

CSIC

Oviedo - Spain

Spanish National Research Council (CSIC)

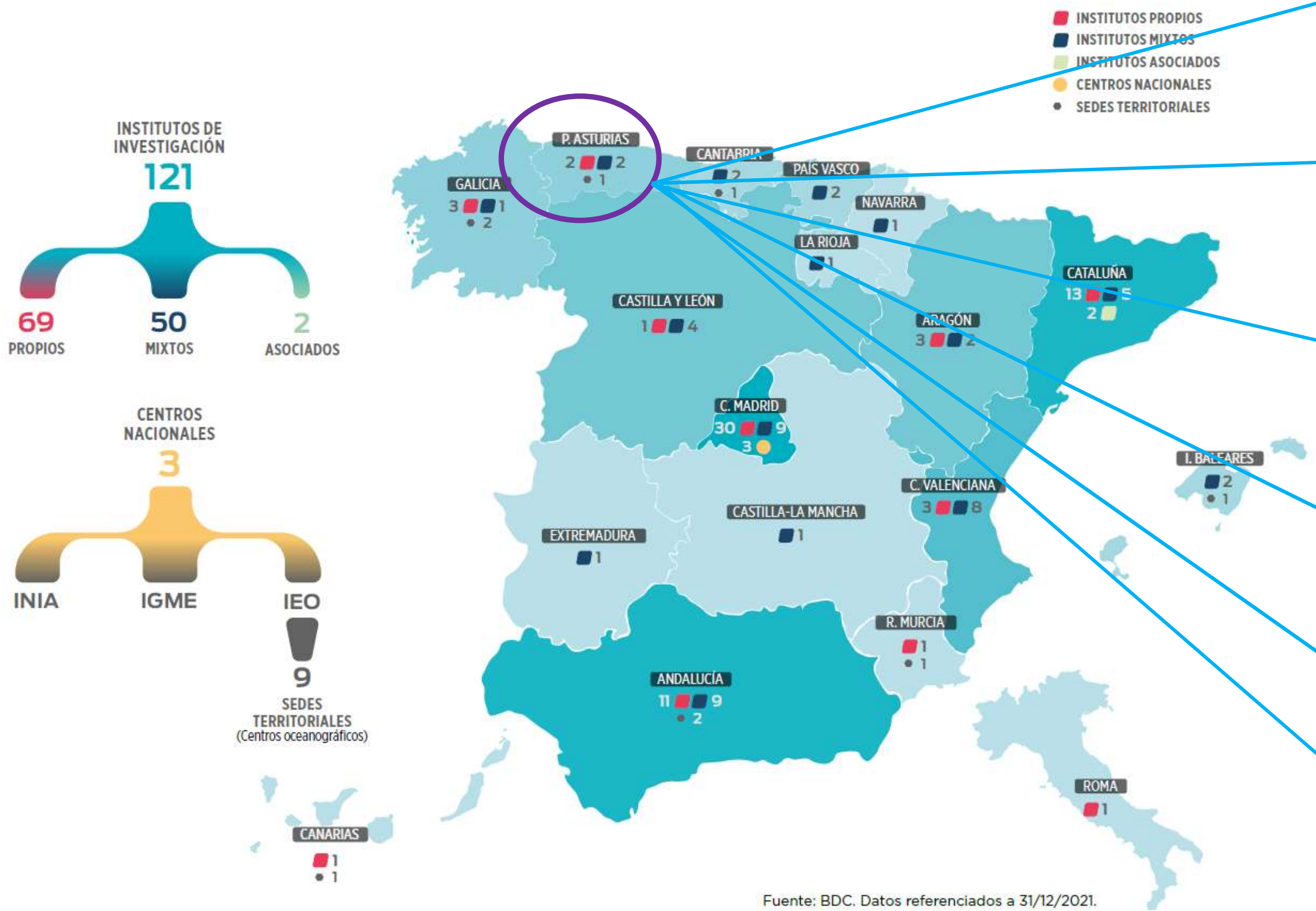
- Founded in 1939
- Belongs to the Ministry of Science and Innovation
- Research at CSIC is structured into three Global Areas, Society, Life and Matter, covering all disciplines of human knowledge, and is carried out in its 121 research centres distributed throughout Spain (& Italy).
- Multidisciplinar and multisectorial organisation. Its activity covers everything from basic research to technological development.

Research Areas

- Humanities and Social Sciences
- Biology and Biomedicine
- Natural Resources
- Agricultural Sciences
- Physical Science and Tecnologies
- Materials Science and Technology
- Food Science and Technology
- Chemical Science and Technology

The Spanish National Research Council (CSIC) is the largest public research organisation in Spain, the fourth largest in Europe and the seventh largest in the world. CSIC has 6% of all the staff dedicated to R&D in Spain, and they generate approximately 20% of all scientific production in the country.

CSIC



INCAR

IPLA

CINN

IMIB

IEO

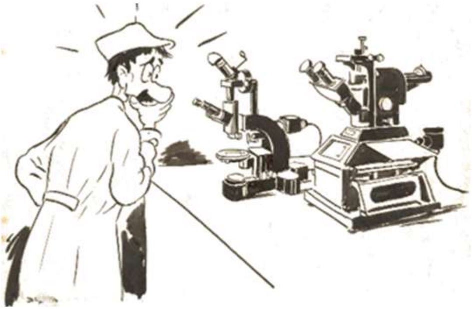
Instituto Geológico y Minero de España

IGME

- The <u>Institute of Science and Technology of Carbon</u> (INCAR) is located in Oviedo (Asturias). INCAR is a public research centre integrated into the global area of MATTER of the CSIC, and specifically in the CHEMICAL SCIENCE & TECHNOLOGY line.

- Founded in 1947, its activity was oriented towards the processes of preparation and utilisation of Asturian coals, giving support to the regional industry (coal mining, iron&steel, energetic).

INCAR 75 años
1947 · 2022



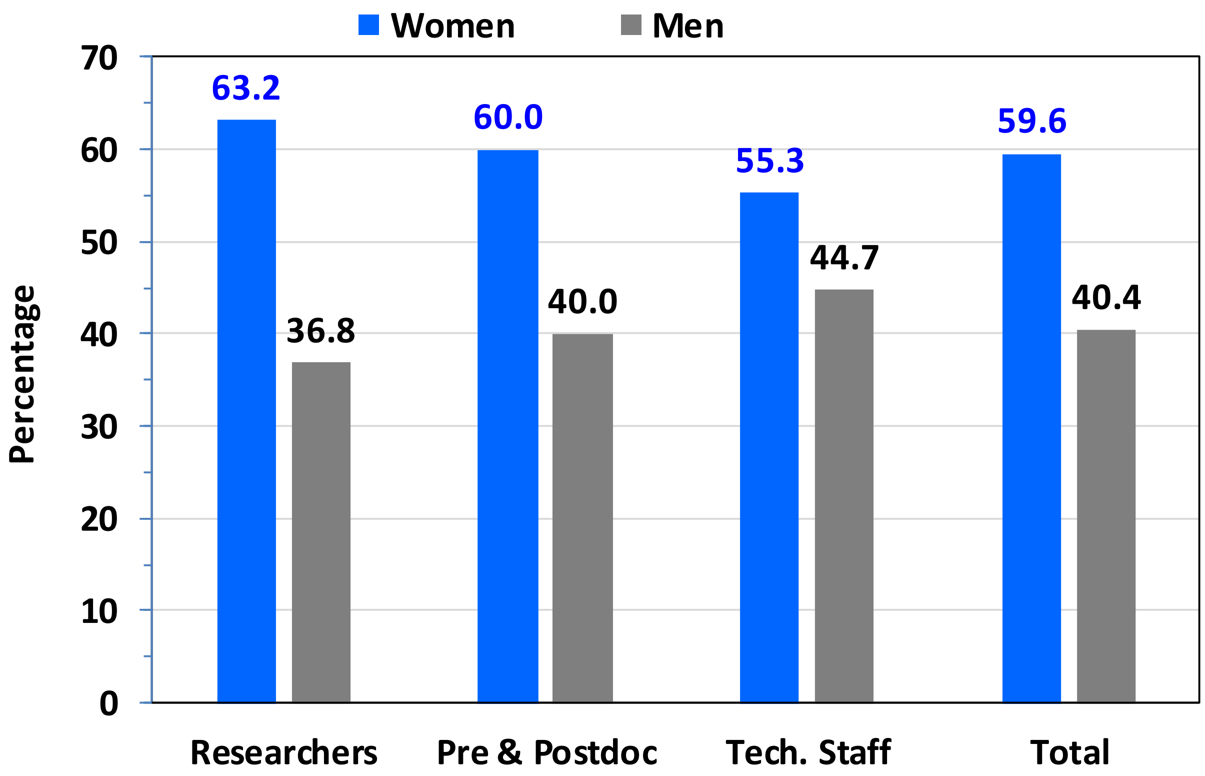
INCAR Personnel

INCAR Total staff: 136

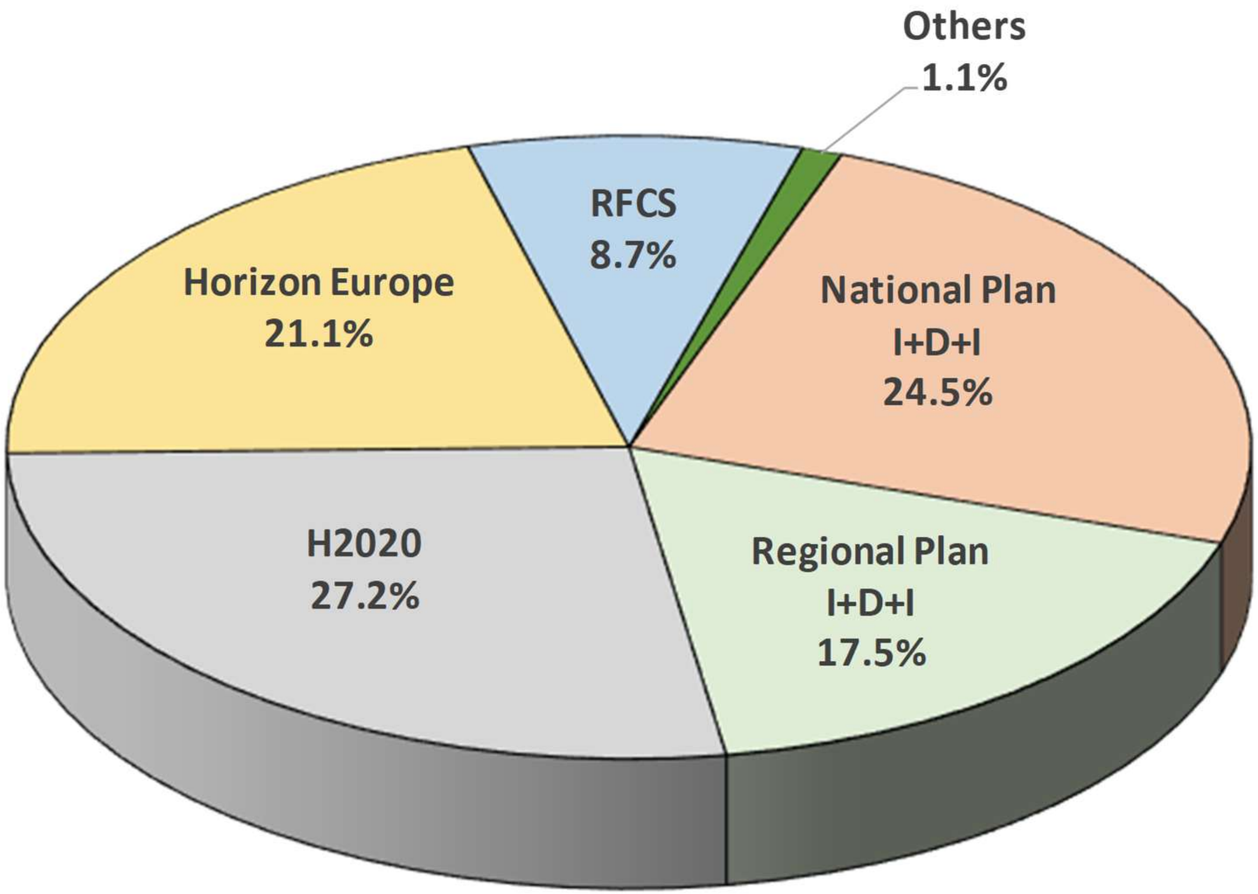
38 Researchers

60 Post- and Pre-docs

38 Technical Staff
(Services and Administration)



Current Projects



Total: 12.4 M€

Research lines

Development of high-performance carbon materials for energy

Decarbonisation of industrial sectors

Departments

- **PQEMA** – Sustainable Chemical Processes
- **QM** – Chemistry of Materials
- **CEMA** – Energy Transition Technologies

Line: **Development of high performance carbon materials for energy generation and storage applications**

Objectives:

- **Develop carbon materials (porous and graphene) by sustainable methods.**
- **Develop electrodes for batteries (ion-Li/Na, Li-S, redox flow, etc.) and supercapacitors based on sustainable carbon materials.**

Line: **Decarbonisation of industrial sectors**

Objectives:

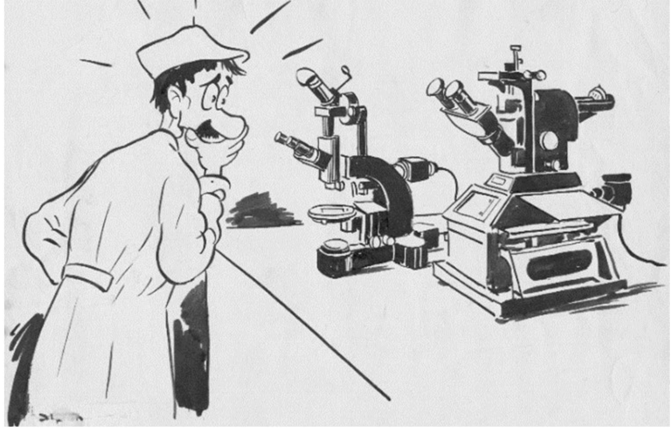
- **Develop CO_2 capture technologies for industrial processes and systems with negative emissions.**
- **Valorisation of biomass as an energy source.**
- **Develop processes and materials for the production and storage of H_2.**

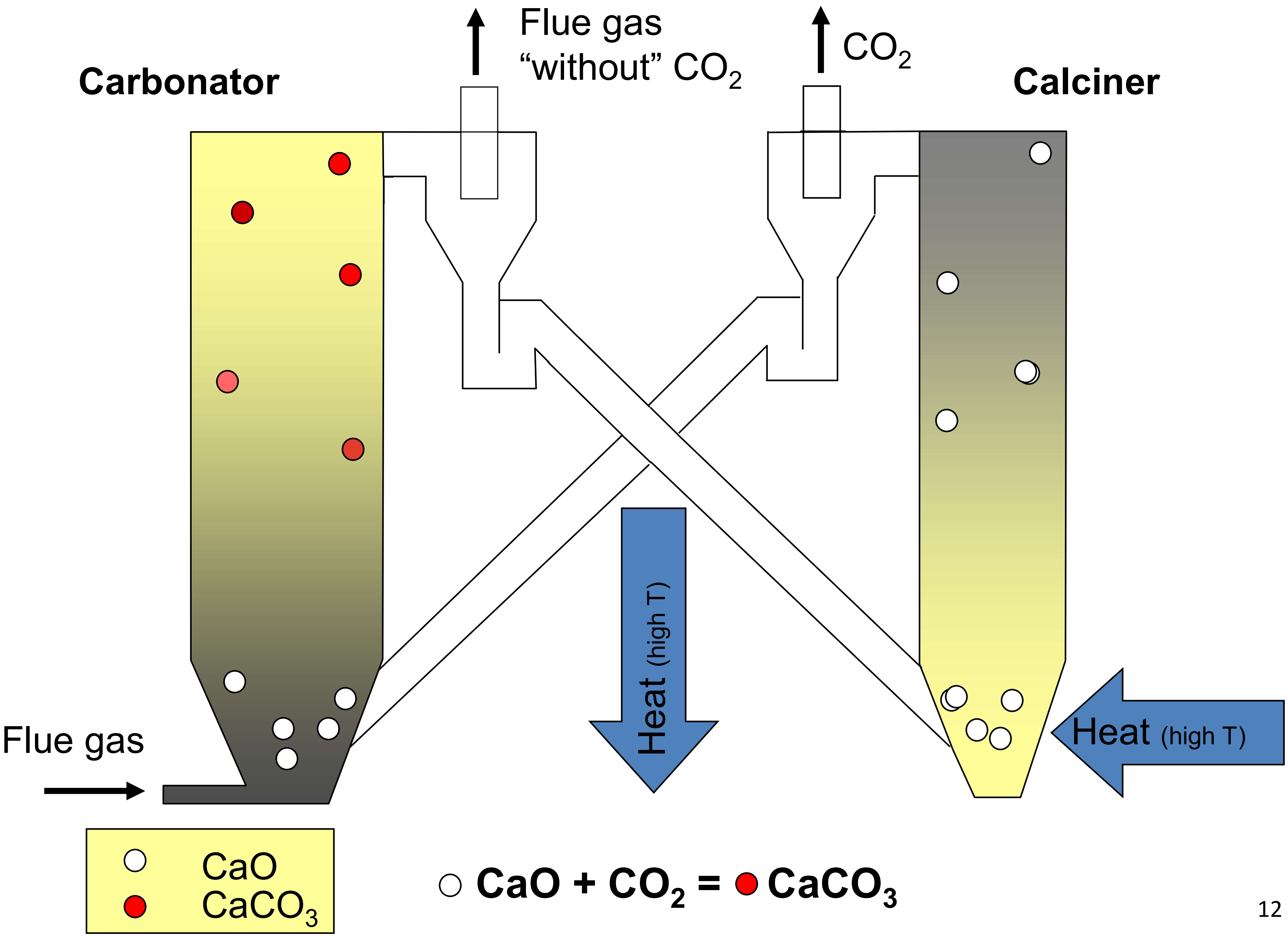
Research sublines

- Development of **carbon materials:** high surface area with tailored porosity.
- **Graphitic nanomaterials** as anodes of Li-ion and Na-ion batteries.
- Novel **carbon materials** as electrodes in electrochemical systems such as supercapacitors and vanadium flow redox batteries.
- Synthesis and applications of **graphene based materials**.
- Application of microwave heating to several industrial processes.
- **Valorisation of residues:** hydrogen production, electrodes of supercapacitors.
- Climate change proxies in organic deposits.
- **Biomass** densification: torrefaction, pelletisation, hydrothermal carbonisation.
- Petrographic caracterization of **coals**, disperse organic matter and solid residues.
- Optimisation of the **carbonisation** process to increase metallurgical **coke** quality.
- Reduction of toxic metals emissions, i.e., Hg.
- Conversion processes of **biomass**: combustión, gasification.
- **CO_2 capture**: Carbonation-calcination cycles (calcium looping/carbonate looping).

Common Equipment

- Physical adsorción: N_2, CO_2, H_2O, organic vapours
- Adsorption at high P: H_2, CO_2, CH_4, N_2
- He pycnometry
- Hg porosimetry
- Thermogravimetric analysis: TG, DTA, DSC
- Cromatography: GC-MS; GC-TCD
- SEM-EDX – Scanning electron microscopy
- DRX – X-ray diffraction
- XPS - X-ray photoelectron spectroscopy
- FTIR - Fourier-transform infrared spectroscopy
- XRF – X-ray fluorescence spectroscopy
- Raman spectroscopy
- ICP-MS - inductively coupled plasma mass spectrometry
- TOC – Total organic carbon
- Ash fusibility
- Diffusivity and termal conductivity





$$CaO + CO_2 = CaCO_3$$

CO_2 Capture – Calcium Looping

CSIC & the development of CaL technology

Multicycle testing TG at CSIC

Reactions kinetics, deactivation studies, reactivation methods

From 2000

Abanades and Alvarez, 2003. Conversion limits in the reaction of CO_2 with lime. *Energy and Fuels,* 17-2, 308-315

0.03 MW_{th} pilot at INCAR-CSIC

Twin CFB reactor concept validation in lab scale. Basic reactor and process modeling

From 2008

Rodriguez et al. 2010. Experimental investigation of a CFB reactor to capture CO_2 with CaO. *AIChe Journal*, 57, pp. 1356 - 1366

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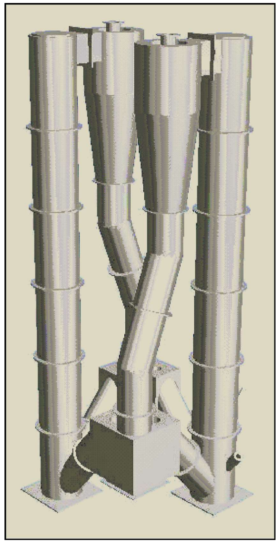
"La Pereda 1.7 MW_{th}" pilot

From 2012

Arias et al. *2013.* Demonstration of steady state CO_2 capture in a 1.7 MWth calcium looping pilot. *Int. J. of Greenhouse Gas Control 18, 237–245*

CO_2 Capture – Calcium Looping

1.7 MWt pilot plant in the CFB Boiler (50 MWe) "La Pereda", Asturias, Spain



Reactors:
15 m height, 0.7 m i.d.

endesa generación

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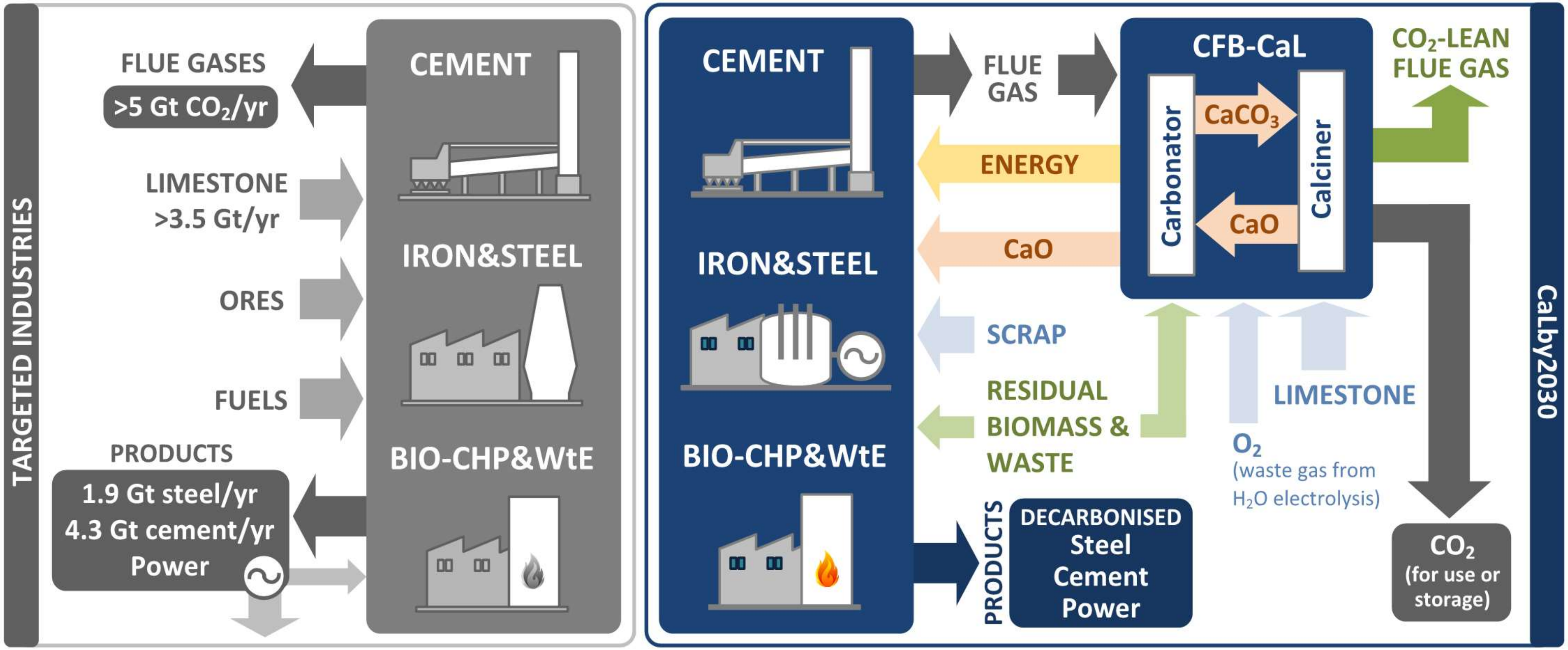
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

CSIC

INSTITUTO NACIONAL DEL CARBÓN

CO_2 Capture – Calcium Looping



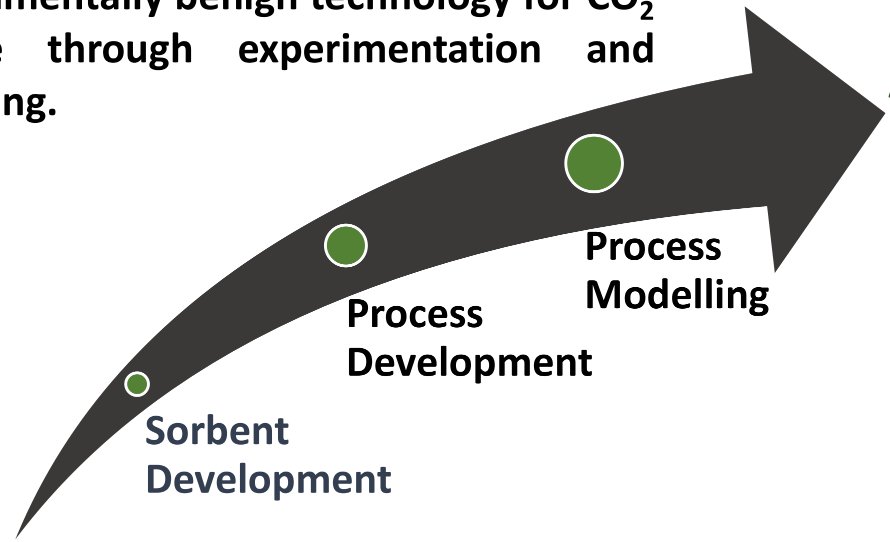
CaLby2030 is a European project granted under Horizon Europe framework programme. The main goal is to act as enabling tool **to achieve, by 2030, commercial deployment of Calcium Looping technology (CaL)** using Circulating Fluidised Bed reactors. Three pilot plants will be used in Germany, Sweden and Spain to demonstrate >99% CO_2 capture rates **in three hard to abate industrial sectors: cement, steel and waste to energy**.

This Project has received funding from the European Unión's Horizon Europe research and innovation programme under grant agreement No. 101075416

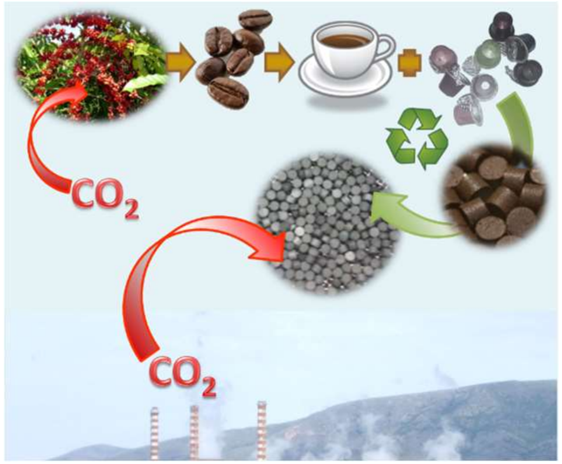
CO_2 Capture – Adsorption processes

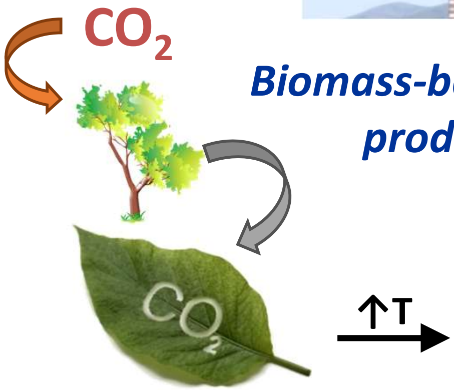
HiPerCap - High Performance Capture
FP7 Grant agreement n° 608555

Demonstrate low-temperature adsorption with solid sorbents as a highly efficient and environmentally benign technology for CO_2 capture through experimentation and modelling.



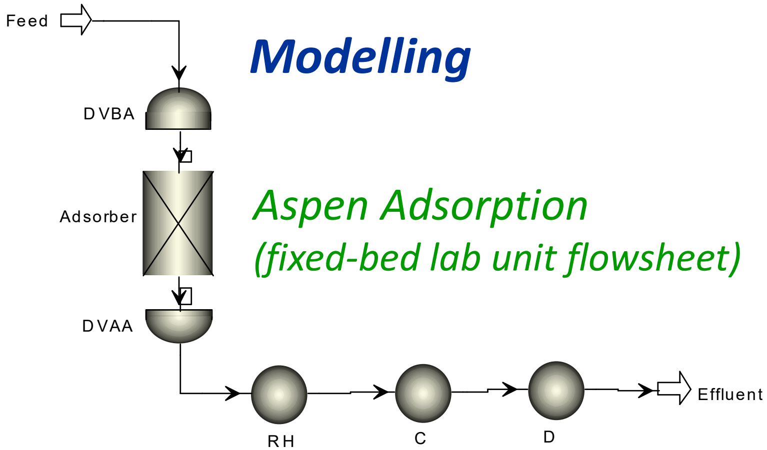
Technology Assessment





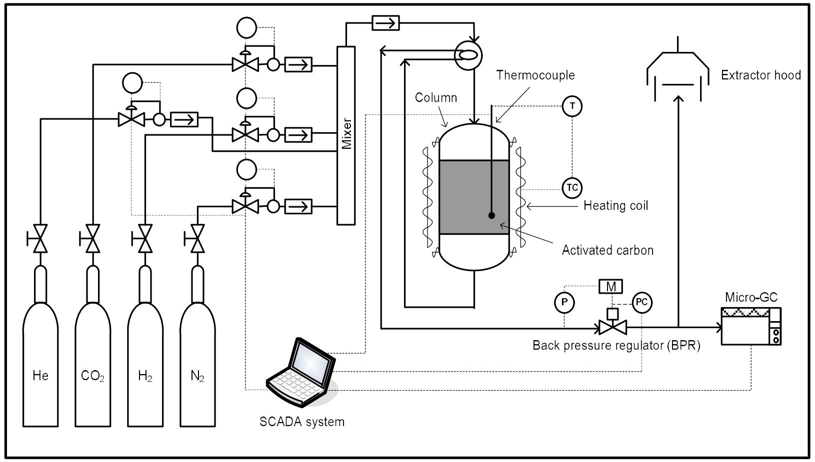
Biomass-based carbon production

Modelling



Aspen Adsorption
(fixed-bed lab unit flowsheet)

Fixed-bed process evaluation



HORIZON EUROPE Grant Agreement nº 101080377 – C-Sink
Funded by the European Union

Carbon dioxide removal (CDR) approaches

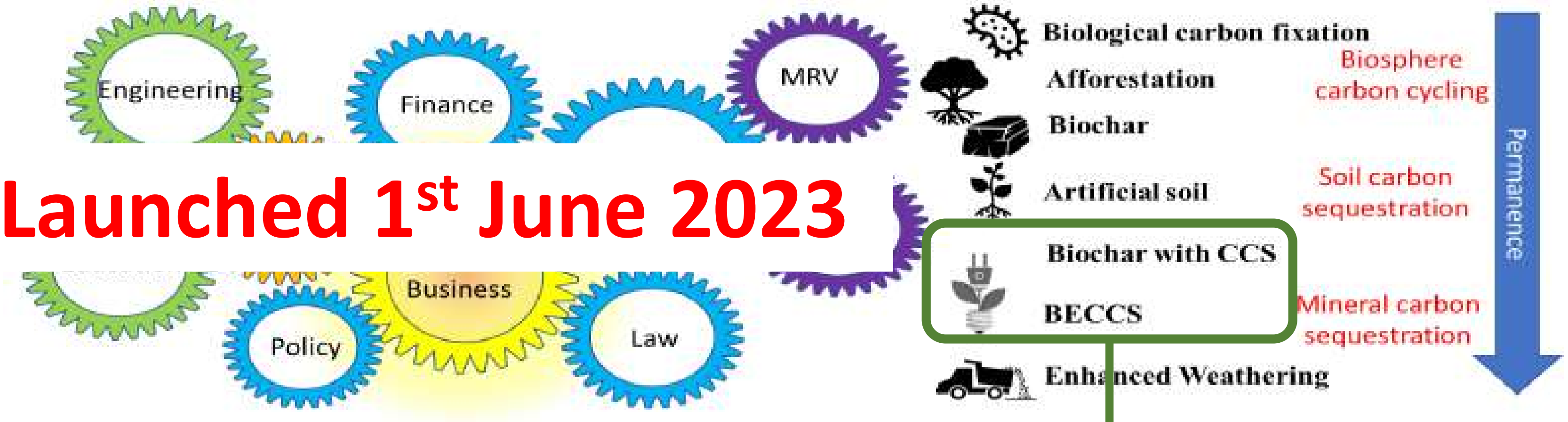
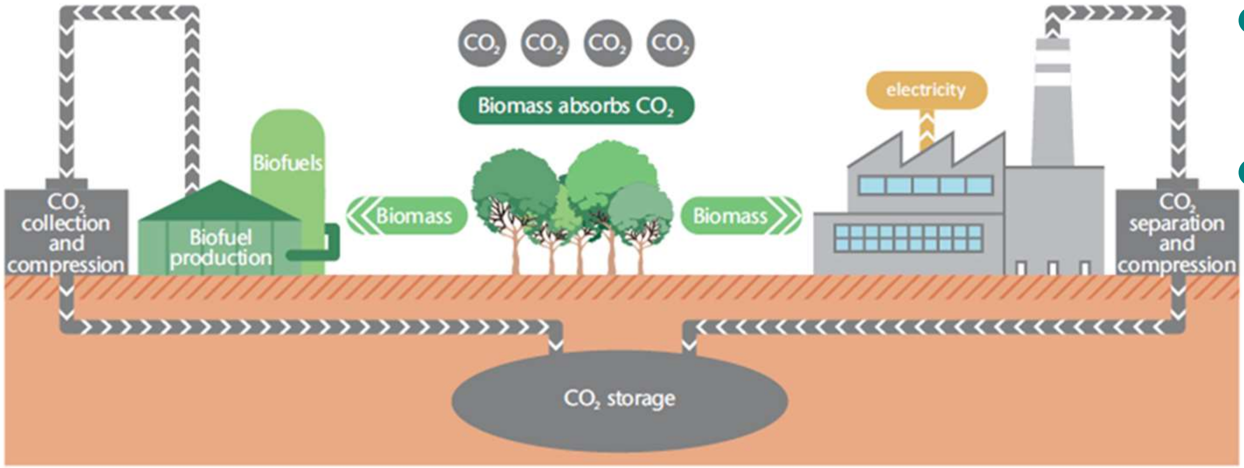


Figure 1. C-SINK view on the necessary key enabling components to ensure a trustable and sustainable CDR..

BECCS – Bioenergy with Carbon Capture and Storage



- **PrEM** will address **BECCS technologies** in **C-Sink**
- **BECCS** leads to **negative carbon emissions**

Energy Processes and Emission Reduction Group

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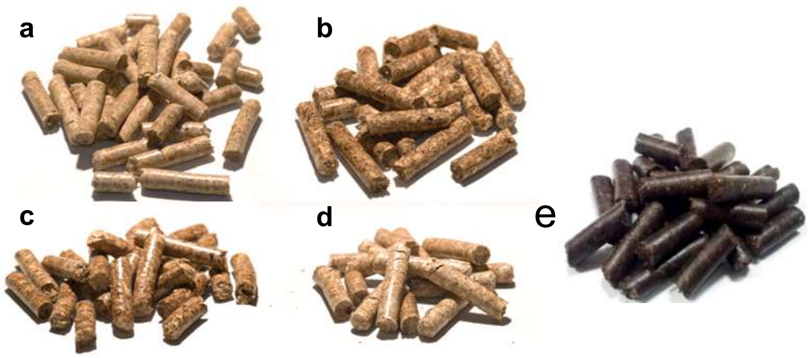
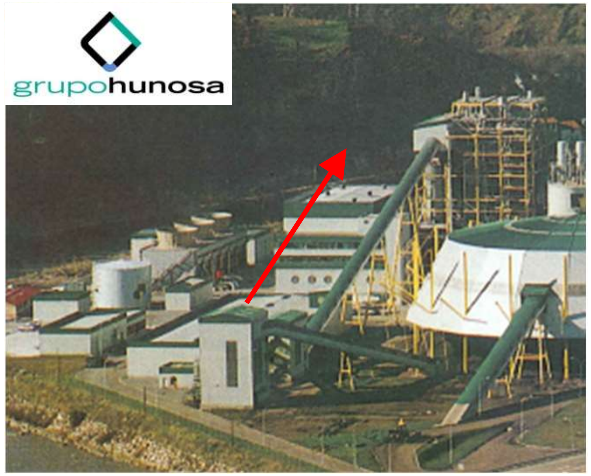
Biomass pelletisation - torrefaction

peletin



a. Pine, b. Pin-Che15, c. Chestnut, d. Pin-Che20, e. Torrefied pine



Biomass Hidrothermal Carbonisation

- Hidrothermal Carbonisation (HTC): sustainable process, allows to stabilize and inertize highly degradable wet organic waste, transforming it into solids (hydrocarbons) and liquids with application in construction materials, decontamination and soil amendment, bioenergy, etc.
- Valorisation of hydrocarbons obtained by hydrothermal carbonisation of sludge from wastewater treatment plants (WWTP) and/or organic waste from the mechanical-biological treatment (MBT) of municipal waste.
- Improvement of soil conditions for forest use and degraded soil, as well as CO_2 sinks.

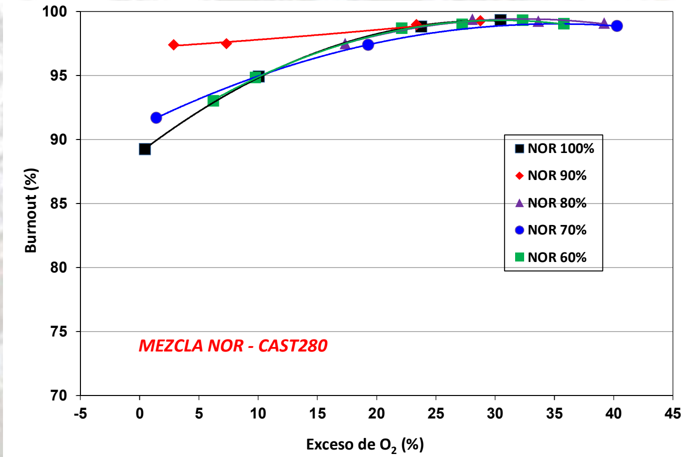
- OLMAR autoclave. Heating by steam generated in the COGERSA incineration furnace.
- Diameter: 1.3 m, Lenght 1.5 m. Removable container: 1 m^3.
- Conditions: Temperature 203 °C; Pressure 15,5 barg.
- Feed: Organic Fraction of Municipal Solid Waste (OFMSW), green waste from parks and gardens, sewage sludge, digestates, *magaya*, solid waste, invasive species (Plumero de la Pampa).
- Products: CO_2-neutral solid fuel, soil amendment, precursor of carbon materials, aqueous phase rich in phenolic compounds with antioxidant capacity and fatty acids of interest for cosmetics, inertization of Plumero de la Pampa seeds.

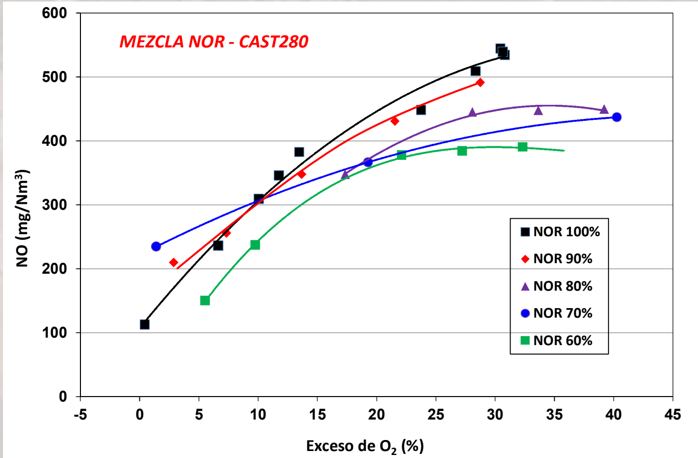
Biomass Combustion

1. Feeder
2. Preheater
3. Union
4. Sample injection
5. Reaction zone
6. Collecting probe
7. Control panel
8. Analisers

Conditions

- T : 1300 ºC
- tr: 2.5 s
- dp: 75-150 µm





- *Research contract - EDP (Carbiotor).*
- *M.V. Gil et al., Grindability and combustion behavior of coal and torrefied biomass blends. Bioresource Technology 191 (2015) 205.*
- *B. Arias et al., Effect of biomass blending on coal ignition and burnout during oxy-fuel combustion. Fuel 87 (2008) 2753.*
- *J. Riaza et al., Oxy-fuel combustion of coal and biomass blends. Energy 41 (2012) 429.*

Biomass Gasification

Biomass Bubbling Fluidised Bed Gasifier

- **Very versatile plant: gasification reactions with $H_2O(v)$, air, N_2, O_2, for the production of syngas (CO & H_2) from different types of biomass and/or waste.**
- **Feeding system: two hoppers and two refrigerated endless screws.**
- **SS310 stainless steel reactor, cylindrical shape, maximum temperature of 920 °C.**
- **Lower zone of 1 m lenght, 7.7 cm i.d.**
- **Upper zone or freeboard of 0.529 m lenght and 13.3 cm i.d.**
- **Analysers: CO, H_2, CH_4, O_2, CO_2.**

Biomass – Renewable Hidrogen

GREEN HIDROGEN (NO ELECTROLYTIC)

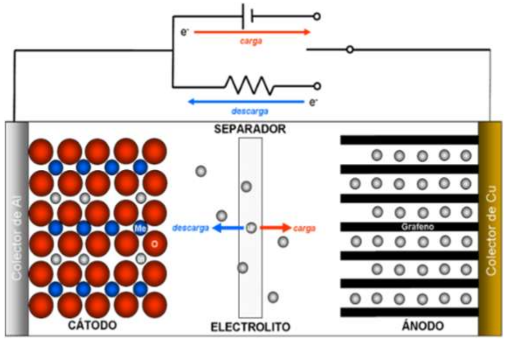
Another possibility to obtain renewable hydrogen is to use biomass or chemical compounds derived from it as raw material.

- Biomass gasification (food industry waste, lignocellulosic materials, etc.).
- Reforming processes (pyrolysis oil, biogas).
- Renewable hydrogen production is based on:
  - SEBG/SEBR (*Sorption Enhanced Biomass Gasification/Reforming*).

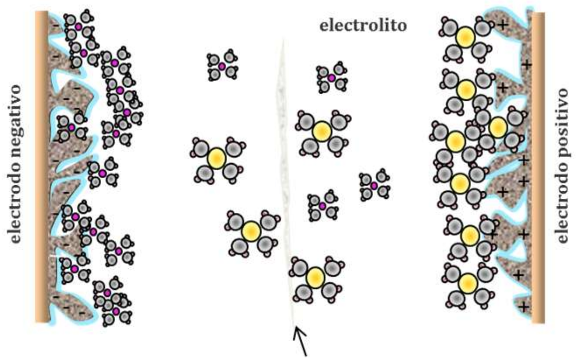
$CH_4 + H_2O \longleftrightarrow CO + 3H_2$	ΔH_0^r = + 206 kJ mol^{-1}	ReformING
$CO + H_2O \longleftrightarrow CO_2 + H_2$	ΔH_0^r = - 41 kJ mol^{-1}	Water Gas Shift
$CaO_{(s)} + CO_2 \longleftrightarrow CaCO_{3(s)}$	ΔH_0^r = - 178 kJ mol^{-1}	Carbonation
$CH_4 + 2H_2O + CaO \longrightarrow 4\,H_2 + CaCO_{3(s)}$	ΔH_0^r = - 13 kJ mol^{-1}	Global

Electrochemical Energy Storage

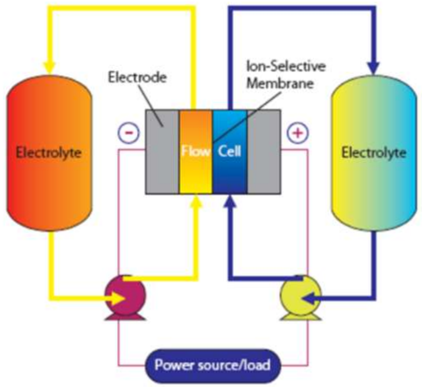
Ion-Li Batteries



Supercapacitors



Redox Flow Batteries



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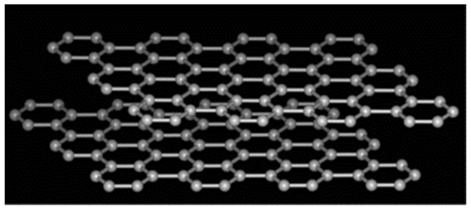
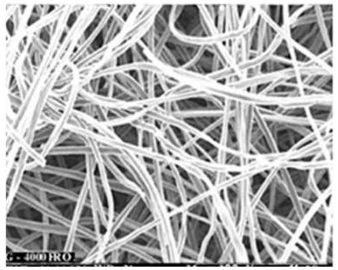


Activated Carbon

Modified Carbon Fibres



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