FRENCH RESEARCH LABORATORIES

Club CO_2

Achievements and Expertise of French public labs

Research & Developpement on CO_2 Utilisation

ABOUT Club CO_2

The **ADEME** (French Environment and Energy Management Agency) founded Club CO_2 in 2002 with the support of the IFP Energies Nouvelles (**IFPEN** - formerly French Petroleum Institute) and BRGM (Bureau of Geological and Mineral Research). Since March 19th, 2016, Club CO_2 became a non-profit association registered under French law with the BRGM as Chairman and EDF and IFPEN as administrators. The Club brings together the actors of the industrial world and of research.

Key element in the organization of French research in the field of carbon capture and storage, it serves as a response to the need of a more effective management for national efforts, while creating better public visibility. The members of the Club are all key players in the industry, research and development.

As a clearinghouse for information, dialogue and good practices among its members on CCUS research and technological developments, the Club encourages cooperation at a national level between public and private sectors, and several research projects have since then been initiated under its tutelage.

The main objectives of Club CO_2 are:

- Identification of guidance lines and challenges for scientific and technical programs
- Promotion of contacts and information exchanges
- Encouragement of collaborative projects between public and private researchers

With dedicated working groups, Club CO_2 has achieved several actions to promote CCUS. Club CO_2, through its "WG CO_2 Utilisation", is pursuing its involvement in the promotion of CO_2 utilisation (CCU) as a means of reducing the carbon footprint of the economy.

One objective is knowledge sharing on technologies and products concerning the CO_2 utilisation through elaborating an inventory with a regular update. Also several events on CO_2 utilisation were organized to tackle the technico-economic and environmental issues.

www.captage-stockage-valorisation-co2.fr/en/home
contact.clubco2@ademe.fr

ALPHABETICAL INDEX

Achievements and Expertise of French public labs

The main goal of this brochure is to show the wide variety of skills and expertises that are used for the development of new and innovative CO_2 utilisation technologies.

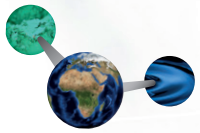
It is not the exhaustive picture on the french research laboratories working on CO_2 utilisation.

Most of these laboratories presented in this brochure contributed to Mission Innovation- Challenge 3-CCUS. The French Researchers and Club CO_2 elaborated the french priorities research directions (PRDs). These PRDs were used by the French participants as an input for the workshop "Mission Innovation-CCUS Experts"* held September 26-28, 2017 in Houston, Texas.

The next step will be an update of this directory with more french research laboratories.

Club CO_2 thanks all researchers who participate to the elaboration of this brochure.

*The Mission Innovation CCUS Experts' Workshop discussed basic research and development (R&D) needs in CO_2 capture, **CO_2 utilization**, geologic storage, and cross-cutting CCUS topics. Experts established a set of Priority Research Directions (PRDs), which have the potential to make a significant impact on CCUS technology performance. The report includes 30 PRDs to guide future CCUS R&D.



FRENCH RESEARCH LABORATORIES

French Public labs :
Competencies. Expertise.
Key achievements.

BRGM

Bureau de Recherches Géologiques et Minières

Géosciences pour une Terre durable

brgm

General description of the activities

BRGM is France's reference public institution for Earth Science applications in the management of the surface and subsurface.

BRGM is involved in the development of powerful technological breakthroughs in the Post-Combustion CO_2 capture:

1. **fundamental research and experimentation: in-depth understanding of phenomena (mechanisms and kinetics)**
2. **multi-scale modelling**
3. **development of laboratory-scale devices**
4. **semi-pilot implementation**
5. **proof of concept and extrapolation**

FIELD

Chemical and electrochemical engineering

KEY COMPETENCES IN CCU

Effluent pre-treatment, Adsorbent synthesis and characterization, Physical chemistry and interface reactivity, Heat and compression energy recovery, Chemical and electrochemical engineering, Construction of pilot units

KEY EQUIPMENTS IN CCU

Technological plateform

Water/gas exchange column prototype

Potentiostats and "two compartments" electrochemical cells

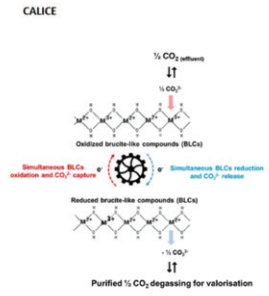
On line measurement of the physical and the chemical parameters (pH, T, Eh, CO_2 dissolved, CO_2 gas, conductivity, flow rates, solid/liquid ratio)

KEY PROJECTS IN CCU

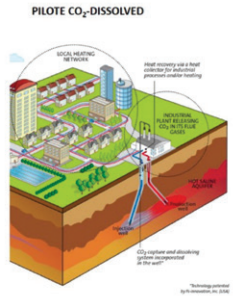
CALICE ADEME 2017-20: Electrolytically supported process of capture and release of CO_2; BRGM, LGC (UMR 5503): Chemical Engineering Laboratory, LLT Leroux & Lotz Technologies

CAPCO$_2$ ANR 2005-08, Post combustion CO_2 capture: BRGM, IFP ENERGIES NOUVELLES, ARMINES, CNRS Rhone-Auvergne

CO_2-DISSOLVED ANR 2013-16 / **PILOTE CO_2-DISSOLVED** Geodenergies 2016-18. CO_2 capture, injection (dissolved form) and storage system optimized, for local valorization of geothermal energy. Consortium of 10 partners (8 French): see the website: **co2-dissolved.brgm.fr**



Schematic representation of the CALICE process



Industrial facility equipped with the CO_2-Dissolved: concept combining geothermal heat recovery with CO_2 storage

Water/gas exchange column prototype

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Procédé d'obtention de (nano)particules minérales enrobées de carbone.
FR 18 50596

BETELU S. ET AL. (2018)
Procédé et dispositif de capture et/ou de libération d'espèces anioniques assisté par électrolyse.
FR 18 50597

SERON A. ET AL. (2009)
Procédé de séparation de CO_2 d'un mélange de gaz par des oxydes mixtes amorphes.
WO2010149871

SERON A. ET AL. (2007)
Procédé de séparation de CO_2 gazeux contenu dans un mélange de gaz.
WO2008110676A3

SERON A. ET AL. (2005)
Procédé de synthèse en phase aqueuse de composés de type Hydroxydes Doubles Lamellaires.
WO2006090069

SERON A., DELORME F. (2005)
Procédé de séparation/purification d'un mélange de gaz.
WO 2007057570 A1

C. KERVÉVAN ET AL. (2017)
Main Results of the CO_2-DISSOLVED Project: first step toward a future industrial pilot combining geological storage of dissolved CO_2 and geothermal heat recovery.
Energy Procedia, 114 : 4086

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C2P2

Chimie, Catalyse, Polymères & Procédés

General description of the activities

C2P2 – CHIMIE, CATALYSE, POLYMERES & PROCEDES is a CNRS research unit (UMR 5265 under triple tutelage CPE Lyon, U. Lyon and CNRS).

The major focus of the research at the C2P2 is on the use of fundamental chemistry, catalysis, and chemical engineering to enhance our ability to produce organic, inorganic and composite materials, and to propose the processes used for this purpose.

KEY COMPETENCES IN CCU

Chemical valorization of CO_2 through catalysis towards solar fuels, organic carbonates and polymers.

KEY EQUIPMENTS IN CCU

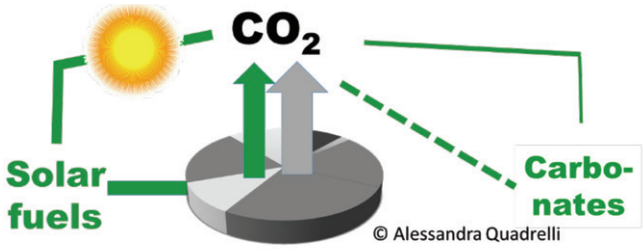
Catalytic Materials Synthesis - High pressure reactor fully equipped with ballast and temperature controller – Polymerization reactors

KEY PROJECTS IN CCU

MOF based catalytic systems for CO_2 photo(electro) reduction
Erasmus Mundus H2020 SINCHEM "Sustainable industrial chemistry" (2013-2020)

Azaphosphatranes in confined space for CO_2 valorization
ANR AZAP-CO_2 (2014-2019)

Carbon Dioxide Activation for monomer and polymer syntheses
Associate CO_2 with a-olefins/1,3-dienes to synthesize plaftorm molecules of industrial relevance, such as acrylate- or lactone-based monomers. ANR-JC CaDiAc (2015-2019).



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GENERAL REVIEWS/EDITORIALS

- "Harvesting renewable energy with chemistry" **W. Leitner, E. A. Quadrelli, R. Schloegl, Robert Green** Chem., 19 2307-2308 (2017)
- "Catalysis for CO_2 conversion to introduce renewable energy in the value chain of chemical industries" **G. Centi, E. A. Quadrelli, S. Perthoner** Energy Environ. Sci. 6, 1711 (2013)

SOLAR FUELS

- "Enhanced formation of >C1 products in the electroreduction of CO_2 by adding a carbon dioxide adsorption component to a gas diffusion layer-type catalytic electrode" ChemSusChem 10(22), 4442-4446 (2017)
- "Role of small Cu nanoparticles in the behaviour of nanocarbon-based electrodes for the electrocatalytic reduction of CO_2" **Marepally B., Ampelli, C. Genovese C., Tavella F., Veyre L., Quadrelli E. A. , Perathoner S., Centi G. J.** CO_2 Util. 21, 534-542 (2017)

CARBONATES

- "Azaphosphatranes as Structurally Tunable Organocatalysts for Carbonate Synthesis from CO_2 and Epoxides" **B. Chatelet, L. Joucla, J.-P. Dutasta, A. Martinez, V. Dufaud, J. Am.** Chem. Soc. 135, 5348 (2013)
- "Investigating Host–Guest Complexes in the Catalytic Synthesis of Cyclic Carbonates from Styrene Oxide and CO_2" **A. Mirabaud, J.-C. Mulatier, A. Martinez, J.-P. Dutasta V. Dufaud** ACS Catalysis 5, 6748 (2015)
- "Zinc–Azatrane Complexes as Efficient Catalysts for the Conversion of Carbon Dioxide into Cyclic Carbonates" **B. Bousquet, A. Martinez, V. Dufaud** ChemCatChem, 10, 843 (2018)

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POLY CARBONATES
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CEA-LITEN

Laboratoire d'Innovation pour les Technologies des Energies nouvelles et les Nanomatériaux

General description of the activities

Energy efficiency, renewable energies and advanced materials

FIELD

Development of reactor and processes for CO_2 hydrogenation

KEY COMPETENCES IN CCU

Reactor design for CO_2 hydrogenation to methane and methanol, performance and durability assessment

KEY EQUIPMENTS IN CCU

Catalytic test bench, reactor manufacturing workshops, CAD & numerical simulation

KEY PROJECTS IN CCU

JUPITER-1000, CO_2-SNG, POLYGEN, STORE&GO, METHYCENTRE

Achievements and Expertise of French public labs

SELECTED REFERENCES

PATENTS : FR3027663, WO2016042063, FR3010641, FR2996630, WO2014029933, FR2982876

- Performance Evaluation of Fixed-Bed, Millistructured, and Metallic Foam Reactor Channels for CO_2 Methanation, CJCE, 2018.
- Dynamic Modeling and Simulations of the Behavior of a Fixed-Bed Reactor-Exchanger used for CO_2 Methanation, AIChE, 2017.
- Efficient CO_2 methanation over Ni/Al2O3 coated structured catalysts, Catal. Today 2016.

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CEISAM

Chimie Et Interdisciplinarité Synthèse, Analyse, Modélisation

General description of the activities

The core activity of the researches undertaken in the group of Fabrice ODOBEL au CEISAM laboratory focuses on the development of molecular materials for the conversion of solar energy into electricity (solar cells) and into fuel (artificial photosynthesis).

Chimie Et Interdisciplinarité Synthèse, Analyse, Modélisation
UMR CNRS 6230
UNIVERSITÉ DE NANTES

FIELD

Chemical synthesis, photochemistry, photo-electrochemistry, artificial photosynthesis, solar fuel, hydrogen production, CO_2 photo-reduction, dye chemistry

KEY COMPETENCES IN CCU

Development of photocatalytic devices for CO_2 reduction

Artificial photosynthesis

Sensitization of p-type semiconductor

KEY EQUIPMENTS IN CCU

Solar simulator

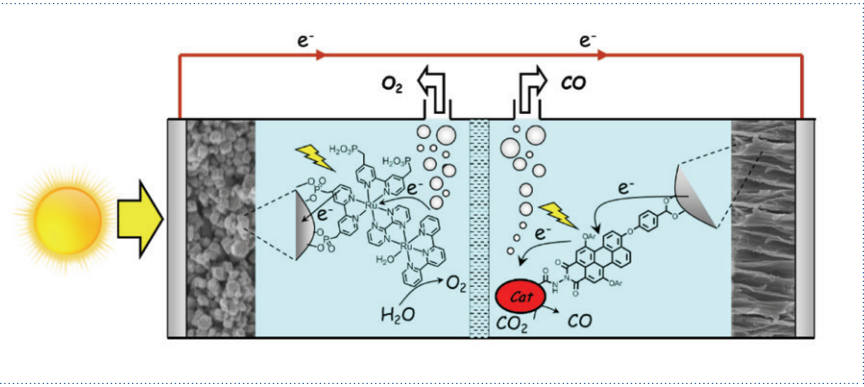
Photoelectrochemical cell for solar fuel production

Gas chromatography for detection and analyses of gas

KEY PROJECTS IN CCU

Development of photocatalytic devices for solar fuel production based on sensitized p-type semiconductor

Achievements and Expertise of French public labs



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Chem. C 2015, 119, 5806-5818

2. **Stoll, T.; Gennari, M.; Fortage, J.; Castillo, C. E.; Rebarz, M.; Sliwa, M.; Poizat, O.; Odobel, F.; Deronzier, A.; Collomb, M.-N., Angew.**
Chem. Int. Ed. 2014, 53, 1654-1658

3. **Nikolaou, V.; Charisiadis, A.; Charalambidis, G.; Coutsolelos, A. G.; Odobel, F., J. Mater.**
Chem. A 2017, 5, 21077-21113

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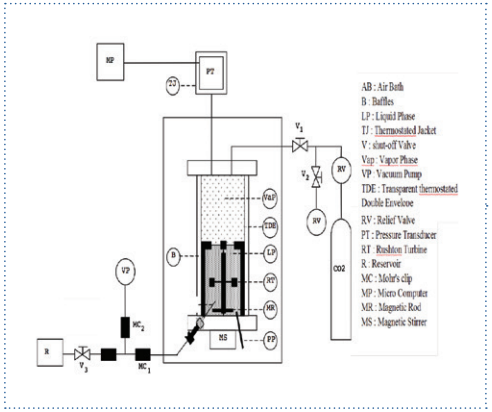
MINES PARIS TECH

Research University, CES – Centre for Energy Efficiency of Systems

General description of the activities

Gas-Liquid Transfers and Processes



FIELD

Process and chemical engineering, CO_2 capture, recycling, carbon-free electricity

KEY COMPETENCES IN CCU

Modeling, Simulation, Experimental

KEY EQUIPMENTS IN CCU

The experimental apparatus has been designed to measure absorption rates for a CO_2

KEY PROJECTS IN CCU

Study of post-combustion CO_2 capture by solutions of ammonia and organic amines.

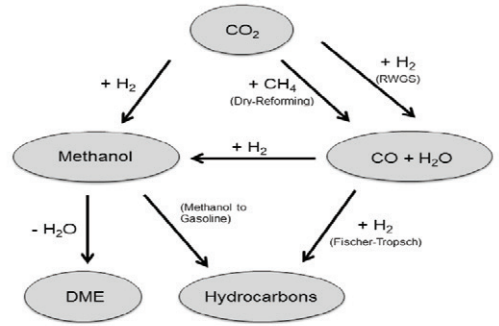
Assessment using direct and indirect contactors by kinetic, thermodynamic approaches and modeling;

Performance Assessment of Oxy-Coal Power Plants through an Exergy-based Process Integration Methodology Energy;

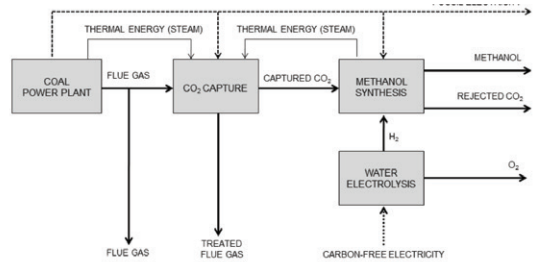
Recycling and valorization of Carbon Dioxide;

Composite and microporous membrane contactors for intensified gas-liquid processes in CO_2 postcombustion capture: Experiments and Modelling.

CO_2 UTILIZATION DIAGRAM



BLOC DIAGRAM OF THE PROCESS (4)



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1. Y. EL FOUIH, C. BOUALLOU

Recycling of carbon dioxide to produce ethanol

Energy Procedia 2013; 37: 6679-6686

2. Y. REDISSI, C. BOUALLOU

Valorization of carbon dioxide by co-electrolysis of CO_2/H2O at high temperature for syngas production

Energy Procedia 2013; 37:6667-6678

3. H. ER-RBIB, C. BOUALLOU, F. WERKOFF

Production of synthetic gasoline and diesel fuel from dry reforming of methane

Energy Procedia 2012; 29:156 - 165

4. E.S. VAN-DAL, C. BOUALLOU

Design and simulation of a methanol production plant from CO_2 hydrogenation

Journal of Cleaner Production 2013; 57: 38-45

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DCM

Département de Chimie Moléculaire

General description of the activities

Transformation and valorization of CO_2 – Utilization of CO_2 as a carbon source towards attractive alternative solutions for synthesizing useful chemicals and energy rich products (fuels).

Our main research activities: explore the potential of new molecular catalysts e.g. metallic complexes for efficient and selective electro-, photo-, and photoelectro-catalytic reduction of CO_2.

FIELD

Electrochemistry - Photochemistry - Coordination chemistry - Modified electrochemical interfaces - Catalysis

KEY COMPETENCES IN CCU

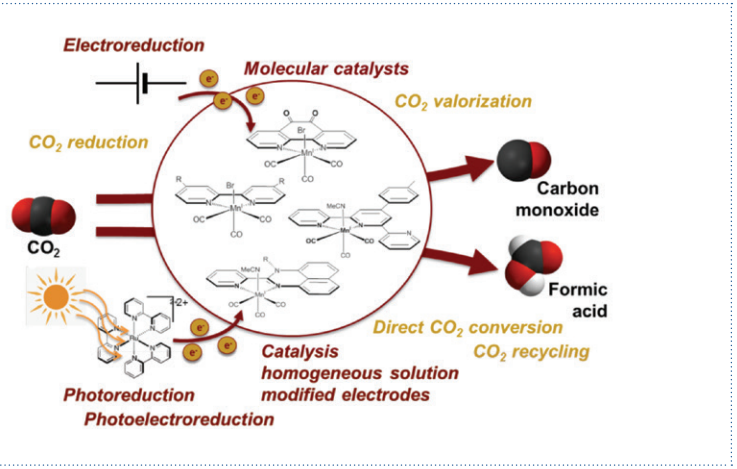
Electro and Photocatalysis of the reduction of CO_2

KEY EQUIPMENTS IN CCU

Electrochemistry – GCMS and HPLC Chromatographs -Photochemistry and Photophysics. Characterization platform eequipments of the Institut de Chimie Moléculaire de Grenoble (ICMG; mass spectroscopy, NMR, X-Ray diffraction, microscopy ...). Glove boxes under inert atmosphere, equipped for physicochemical experiments and synthesis.

KEY PROJECTS IN CCU

Partner of a FUI consortium - ValCO_2 II – VALorisation chimique et énergétique du CO_2 – Coordination SOLVAY



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M. STANBURY, J.-D. COMPAIN, S. CHARDON-NOBLAT.

Electro and photoreduction of CO_2 driven by manganese-carbonyl molecular catalysts.

Coord. Chem. Rev. 361, 120-137, 2018

Z. BITAR , A. FECANT, E. TRELA-BAUDOT, S. CHARDON-NOBLAT, D. PASQUIER .

Electroctrocatalytic reduction of carbon dioxide on indium coated gas diffusion electrodes – Comparison with indium foil. Appl.Catal.

B: Environmental, 189, 172-180, 2016

E. TORRALBA-PENALVER, Y. LUO, J.-D. COMPAIN, S. CHARDON-NOBLAT, B. FABRE.

Selective catalytic electroreduction of CO_2 at silicon nanowires (SiNWs) photocathodes using non-noble metal-based manganese carbonyl bipyridyl molecular catalysts in solution and grafted onto SiNW.

ACS Catal. 5, 6138-6147, 2015

M. BOURREZ, F. MOLTON, S. CHARDON-NOBLAT, A. DERONZIER.

[Mn(bipyridyl)(CO)3Br]: An Abundant Metal Carbonyl Complex as efficient Electrocatalyst for CO_2 Reduction;

Angew. Chem. Int. Ed. 50, 9903–9906, 2011

S. CHARDON-NOBLAT, M.-N. COLLOMB-DUNAND-SAUTHIER, A. DERONZIER, M. ORILLON, R. ZIESSEL ET D. ZSOLDOS.

Cathode for reduction of carbon dioxide and method for manufacturing such a cathode;

Brevet Appl. N° US 1997-839311 Appl. N°GB 1997-7923.

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GEPEA LABORATORY

University of Nantes - CNRS

GEPEA
UMR CNRS 6144

General description of the activities

The GEPEA laboratory is a French Joint Research Unit of the University of Nantes, CNRS, Oniris, IMTA (France). It is working on the design and optimization of processes for microalgae valorization.

This multi-disciplinary research group proposes an integrated approach, including (1) screening of strains and metabolic optimization, (2) culture systems and photobioreactor engineering (from state-of-the-art raceways to newly developed intensified technologies), and (3) metabolites extraction and purification through bio-refining approach. In 2015, the GEPEA Laboratory has developed the AlgoSolis R&D Facility, belonging to the University of Nantes.

This core facility was designed to address issues related to the up-scaling and industrial optimization of microalgal processes. Various breakthrough technologies have been developed (solar photobioreactors, wet-biomass extraction processes, culture medium recycling...). AlgoSolis R&D Facility allows also investigating microalgal culture on industrial effluents (CO_2, waste water, ...).

FIELD

Bioprocess engineering, microalgae, cyanobacteria, Industrial ecology, photobioreactors, bio-refinery, metabolites extraction, CPC, cultivation and biomass production

KEY COMPETENCES IN CCU

Process Engineering, analysis, up-scaling, monitoring, control, separation processes

KEY EQUIPMENTS IN CCU

Photobioreactors , covered raceway, extraction and membrane filtration units, bead milling, harvesting units, analytics, etc.

KEY PROJECTS IN CCU

AlgoStep (ADEME), SymBIO2 (ADEME), CimentAlg (ADEME), PolysAlgue (ANR), Symbio2 (FUI)...

SELECTED REFERENCES

PAPERS

www.researchgate.net/profile/Jeremy_Pruvost

See also **www.algosolis.com**, **www.gepea.fr**

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I2E

Interface, Electrochimie, Energie

General description of the activities

Our team is dedicated to high temperature fuel cells & electrolysers. Our strong research now is on the capture and valorization of carbon dioxide in molten carbonates.

FIELD

High temperature fuel cells and electrolysers: electrolysis of CO_2 in molten salts

KEY COMPETENCES IN CCU

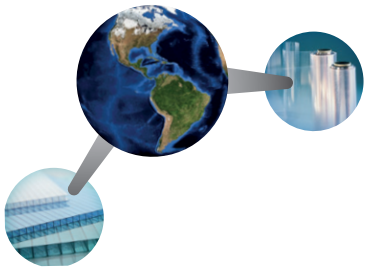
CO_2 electrolysis & solubility in molten carbonates

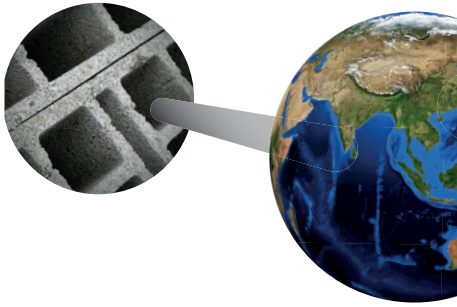
KEY EQUIPMENTS IN CCU

Electrochemical platform coupled with gas chromatography, as well as thermal analysis coupled with IR/MS/GC.

KEY PROJECTS IN CCU

From the feasibility of the process (CO_2 electrolysis into CO) to test & pre-pilot devices





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D. CHERY, V. ALBIN, A. MELÉNDEZ-CEBALLOS, V. LAIR, M. CASSIR

"Mechanistic approach of the electrochemical reduction of CO_2 into CO at a gold electrode in molten carbonates by cyclic voltammetry"

Int. J. Hydrogen Energy 41 (2016) 18706

D. CHERY, V. LAIR, M. CASSIR

"CO_2 electrochemical reduction into CO or C in molten carbonates: a thermodynamic point of view"

Electrochimica Acta 160 (2015) 74

D. CHERY, V. LAIR, M. CASSIR

"Overview on CO_2 valorisation: challenge of molten carbonates",

Frontiers Energy Res, 3:43 (2015) 1

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ICARE

Institut de Combustion, Aérothermique, Réactivité et Environnement

General description of the activities

My research topics concern the turbulent combustion, control of flames, burners and pollutant emissions.

FIELD

Combustion

KEY COMPETENCES IN CCU

Oxy-combustion

KEY EQUIPMENTS IN CCU

Combustion system plants

KEY PROJECTS IN CCU

CO_2 EnergiCapt with 4 author partners

Achievements and Expertise of French public labs

SELECTED REFERENCES

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www.larep.fr/orleans/2015/11/02/deux-structures-du-cnrs-recompensees-pour-leurs-recherches-de-technologies-vertes_11646883.html

www.agence-nationale-recherche.fr/Projet-ANR-10-EESI-0003

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ICBMS
Lyon University

UNIVERSITÉ DE LYON

General description of the activities

Integrated CO_2 CCUS with coupled metal recovery.

We investigate the interactions between lean and rich solutions with additional molecular species in order to modulate the thermodynamics and kinetics of capture and develop convergent/integrated capture and utilization processes.

Currently, our main focus consist in valorizing CO_2- rich solutions for mineral carbonation and valuable / toxic metals recovery.

FIELD

Molecular and supramolecular chemistry

KEY COMPETENCES IN CCU

Design, analysis and implementation of complex molecular systems for CO_2 capture and utilization (as pre-ligand for metal separation or as catalyst)

KEY EQUIPMENTS IN CCU

Batch (ball-mill; microwave) & conti-nuous flow reactors ; spectroscopic, chromatographic and calorimetric platforms

KEY PROJECTS IN CCU

MA2RSCO2SCARE
ANR-12-JS07-0011-01
2012 -2016

Multi-component self-Assembled ARchitectures based on CO_2 for Selective CApture of Rare Earth metals

ProCO2Met
SATT SE & AURA 1502
2016 – 2018

Continuous Flow Process utilizing CO_2 for Metal separation

SELECTED REFERENCES

LECLAIRE, G POISSON, F ZIARELLI, G PEPE, F FOTIADU, F.M. PARUZZO, A. J ROSSINI, J.-N. DUMEZ, B. ELENA-HERRMANN, L. EMSLEY.

Structure elucidation of a complex CO_2-based organic framework material by NMR crystallography

Chem. Sci. 2016, 7, 4379-4390

J. SEPTAVAUX, G. GEOFFROY, J. LECLAIRE

Dynamic covalent chemistry of carbon dioxide: opportunities to ad-dress environmental issues.

Acc. Chem. Res. 2017, 50, 1692-1701

J. LECLAIRE, G CANARD, F FOTIADU, G POISSON

Method for detecting, capturing and/or releasing chemical elements.

PCT Int. Appl. 2014, WO 2014188115 A1 20141127. US Patent 20,160,097,755

C. DE BELLEFON, J. LECLAIRE, G. POISSON, R. PHILIPPE, J. SEPTAVAUX, L. VANOYE

Continuous process for the detecting, capturing and releasing chemcial elements

2017 PCT/EP2017/060166

1ST PRIZE LYON START'UP WEEK-END 2017

EXCELLENCE CHAIR IN CHEMISTRY, IMUST CONSORTIUM

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ICCF / TIM

Institute of Chemistry of Clermont-Ferrand/Thermodynamics and Molecular Interactions

Institut de Chimie de Clermont-Ferrand

General description of the activities

Experimental thermodynamic measurements and thermodynamic modeling of the absorption of gas (CO_2, annex gases) in aqueous solutions of amines (capture) and of salts (storage in deep saline aquifers).

FIELD

Thermodynamics, physical chemistry, gas dissolution

KEY COMPETENCES IN CCU

Determination of heat of absorption/ desorption of gas in aqueous solutions versus temperature and pressure and solubility of gases in aqueous solutions; heat capacities and volumes for the calculations of the processes. Phase equilibrium cells for liquid-vapor and liquid-liquid transitions.

KEY EQUIPMENTS IN CCU

Mixing calorimeters, phase equilibrium cells, densimeters, viscosimeters

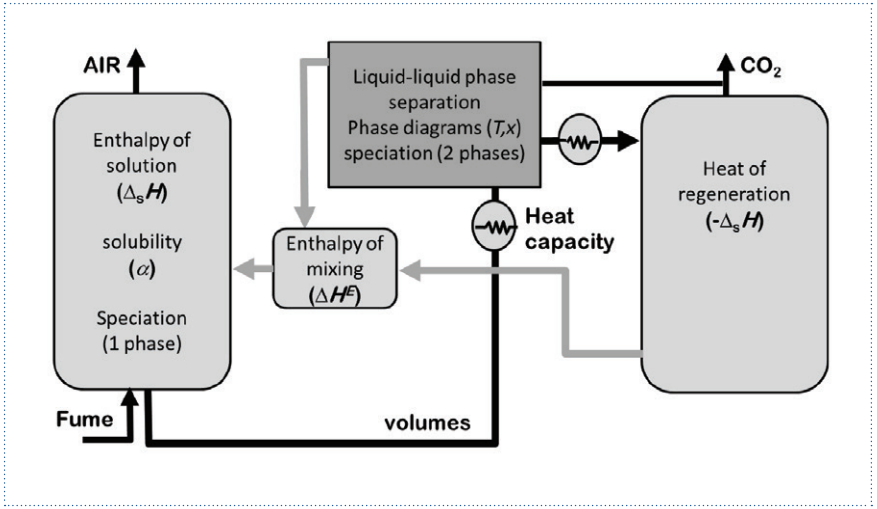
KEY PROJECTS IN CCU

ACACIA (FUI – Axelera): Développement de technologies et de procédés de captage du CO_2 en post-combustion directement sur fumées de sources fixes. (partner)

VALORCO (PIA – Ademe): Valorisation et Réduction des émissions de CO_2 en Industrie(partner)

DACOOTA (ANR/NSERC n°12-IS09-0001): Demixing Amines for CO_2 capture: Thermodynamic and Spectroscopic Approach (leader)

SIMODEX (ANR/NSERC n°15-CE06-0010): Understanding CO_2 capture processes: a combination of reactive molecular simulation, thermodynamic modelling and experiments (leader)



Thermodynamic represenation of the CO_2 capture process using demixing amines

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BALLERAT-BUSSEROLLES, K., WU, Y., & CARROLL, J. J. (EDS.).
"Cutting-Edge Technology for Carbon Capture, Utilization, and Storage"
John (2018). Wiley & Sons

COULIER, Y., LOWE, A. R., MOREAU, A., BALLERAT-BUSSEROLLES, K., & COXAM, J. Y.
Liquid-liquid phase separation of {amine-H_2O-CO_2} systems: New methods for key data
Fluid Phase Equilibria, 431, 1-7 (2017)

COULIER, Y., LOWE, A. R., COXAM, J. Y., & BALLERAT-BUSSEROLLES, K., ACS
Thermodynamic Modeling and Experimental Study of CO_2 Dissolution in New Absorbents for Post-Combustion CO_2 Capture Processes
Sustainable Chemistry & Engineering, 6(1), 918-926 (2017)

BALLERAT-BUSSEROLLES, K., LOWE, A. R., COULIER, Y., & COXAM, J. Y.,
Calorimetry in Aqueous Solutions of Demixing Amines for Processes in CO_2 Capture,
Acid Gas Extraction for Disposal and Related Topics, 69-80. (2016)

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ICMMO

Paris-Sud University

UNIVERSITÉ PARIS SUD

General description of the activities

Development and characterization of materials for the selective electrochemical and photo-electrochemical reduction of carbon dioxide.

Implementation in polymer electrolyte electrochemical cells.

FIELD

Material science, Physical chemistry, Electrochemistry, Electrochemical synthesis, electrochemical engineering.

KEY COMPETENCES IN CCU

Elaboration and multiphysics characterization of nano-structured electrochemical and photo-electro-chemical interfaces for the selective reduction of carbon dioxide in water media at near-ambient temperature conditions.

KEY EQUIPMENTS IN CCU

General electrochemical equipment (potentiostat, RDE, RRDE, etc.).

General photo-electrochemical equipment (quartz cells).

Analysis of CO_2 reduction products (Gas chromatography, NMR).

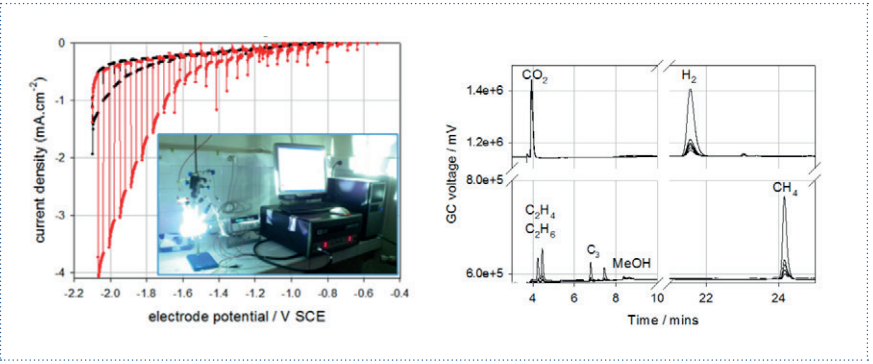
AFM-SECM for local scale in-situ electrochemical characterization.

KEY PROJECTS IN CCU

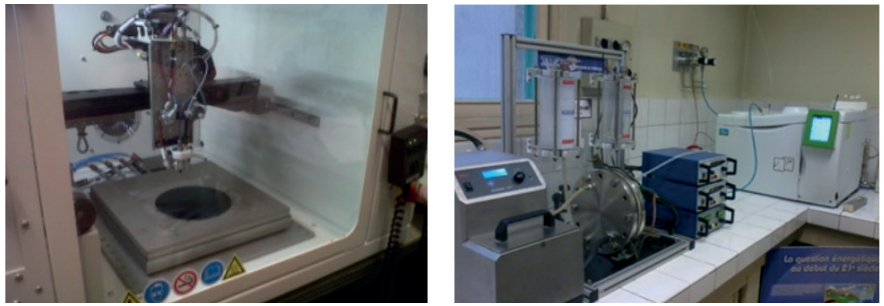
ANR Chalcocat.

Financial support from the industry sector.

Several international collaborations.



Typical CO_2 reduction experiment using a CuGa3Se5 thin film photo-electrode: setup and GC analysis showing reduction products.



Catalytic ink printer and experimental setup used for the testing of polymer electrolyte membrane (PEM) CO_2 electro-reduction cells.

SELECTED REFERENCES

F. DE GUGLIELMO, PHD THESIS, University Paris-Sud, 2013

A. Ragupathy, PhD thesis, University Paris-Sud, 2015

A. Villagra, PhD thesis, University Paris-Sud, 2015

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www.icmmo.u-psud.fr/Labos/ERIEE/

ICPEES

Institut de Chimie et Procédés, pour l'Energie, l'Environnement et la Santé

General description of the activities

The Institute is composed by more than a hundred of scientists concerned by the development of advanced research related to energy, environment and health.

The complementarities of the various research teams contribute to solve global issues ranging from molecules design, properties, and applications for applications in the fields of Energy, Environment or Health.

At the forefront of new technologies and the development of innovative materials, the Institute is organized in three research departments:

- Catalysis and Materials

- Molecular Chemistry and Analytics

- Polymer Engineering

FIELD

Heterogeneous catalysis, kinetic studies

KEY COMPETENCES IN CCU

Development of catalytic materials for the hydrogenation of CO_2 into fuels.

KEY EQUIPMENTS IN CCU

Catalytic set-ups from Patm to 80 bar, from Tatm to 800 °C, equipped with online GC

Surface characterization by H2-TPD, CO_2-TPD, NH3-TPD, N2O chemisorption

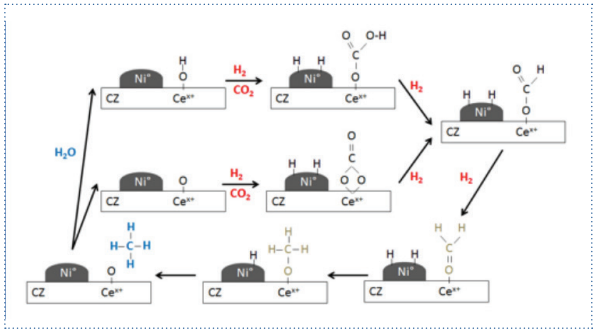
KEY PROJECTS IN CCU

ANR Vitesse2 (2010-2014): «Industrial and energetic valorization of CO_2 by efficient use of decarbonized electricity. Stabilization of the electric grid and electricity storage»

ANR Digas (2015-2019): «Direct synthesis of Dimethyl ether from syngas»

ANR CHOCHCO (2014-2018) : «Optimized flexible chain of CO2/H2O coelectrolysis and hydrogenation into synthetic methane »

ADEME-CEA (2016-2019): «PhD thesis : Understanding and modeling of deactivation mechanisms of a CO_2 methanation catalyst in a fixed bed milli-structured exchanger-reactor»



Main mechanism on Ni / ceria-based catalyst

SELECTED REFERENCES

G. MIGNANI, B. PAVAGEAU, J. JOLLY, A.C. ROGER, F. OCAMPO, M. FREY

«Procédé d'alcanation du CO_2 utilisant comme catalyseur un composé comprenant du nickel sur un support à base d'oxyde de cérium.»

Brevet français n° 12/01176 du 20/04/2012

F. OCAMPO, B. LOUIS, A.C. ROGER

«Methanation of carbon dioxide over nickel based Ce0.72Zr0.28O2 mixed oxide catalysts prepared by sol-gel method»

Applied Catal. A: General 369, 90-96 (2009)

F. OCAMPO, BENOIT LOUIS, L. KIWI-MINSKER, A.C. ROGER

«Effect of Ce/Zr composition and noble metal promotion on nickel based CexZr1-xO2 catalysts for carbon dioxide methanation.»

Applied Catal. A: General 392, 36-44 (2011)

P.A. USSA ALDANA, F. OCAMPO, K. KOBL, B. LOUIS, F. THIBAULT-STARZYK, M. DATURI, P. BAZIN, S. THOMAS, A. C. ROGER

«Catalytic CO_2 valorization into CH4 on Ni-based ceria-zirconia. Reaction mechanism by operando IR spectroscopy»

Catal. Today 215, 201-207 (2013)

K. KOBL, S. THOMAS, Y. ZIMMERMANN, K. PARKHOMENKO, A.C. ROGER

«Power-law kinetics of methanol synthesis from carbon dioxide and hydrogen on copper-zinc oxide catalysts with alumina or zirconia supports»

Catal. Today 270, 31-42 (2016)

M. FREY, T. ROMERO, A.C. ROGER, D. EDOUARD

«Open cell foam catalysts for CO_2 methanation: Presentation of coating procedures and in situ exothermicity reaction study by infrared thermography»

Catal. Today 273, 83-90 (2016)

M. FREY, A.C. ROGER, D. EDOUARD, G. GEFFRAYE, A. BENGAOUER

«Aluminium open cell foams as efficient support for CO_2 methanation catalyst: pilot scale reaction results»

Energy Technology 5(11), 2078-2085 (2017)

J.F. PORTHA, K. PARKHOMENKO, K. KOBL, A.C. ROGER, S. ARAB, J.M. COMMENGE, L. FALK, IND.

Kinetics of Methanol Synthesis from Carbon Dioxide Hydrogenation over Copper–Zinc Oxide Catalysts.»

Eng. Chem. Res. 56 (45), 13133–13145 (2017)

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ICSM

Institut de Chimie Séparative de Marcoule

General description of the activities

The "Institut de Chimie Separative de Marcoule" (ICSM) is a joint research unit (CEA, CNRS, UM, ENSCM). The scientific mission of ICSM originates from the unavoidable rarefaction of fossil fuels, as well as their global impact on climate and is focused on decarbonized energies.

The ICSM is mainly involved in recycling and material science to address improved safety requirements and ecological issues in the use of low carbon energies (nuclear and renewable).

The ICSM has 5 scientific and technical pillars:

Understanding separation processes: Characterization at the molecular and supramolecular level all in correlation with thermodynamics.

Optimizing separation processes: The aim is here to synthetize, formulate and implement a knowledge-based recycling technology.

Green chemistry: Implement the twelve principles of green chemistry as well as those of "green extraction engineering".

Anticipating life-cycle: Studies of surface degradation and material production.

Methods in modeling and observations at meso-scale: Modelling and analytical developments for separation and materials properties.

FIELD

Main Fields and skills

Synthesis and characterization and reactivity of **molecular species** (organic, coordination compounds) and **materials** (ceramics, hybrid, porous)

Physical-Chemistry for **supramolecular** speciation in **complex organic media**, at the **liquid-liquid interface** and in **porous solids**.

Mesoscale Modelling

Ultrasound approaches for hydrometallurgy and materials

Analytical and methodological development essentially for Material Characterization

KEY COMPETENCES IN CCU

Separation and Purification of valuable main or secondary products obtained by a CO_2 conversion process, essentially into carbonates.

Synthesis of materials (Metal-Organic Frameworks on ITO-FTO surface) and molecular compounds (Ru-Co compounds) for photo induced charge separation which could be used for CO_2 reduction, usually in the frame of collaboration (College de France)

KEY EQUIPMENTS IN CCU

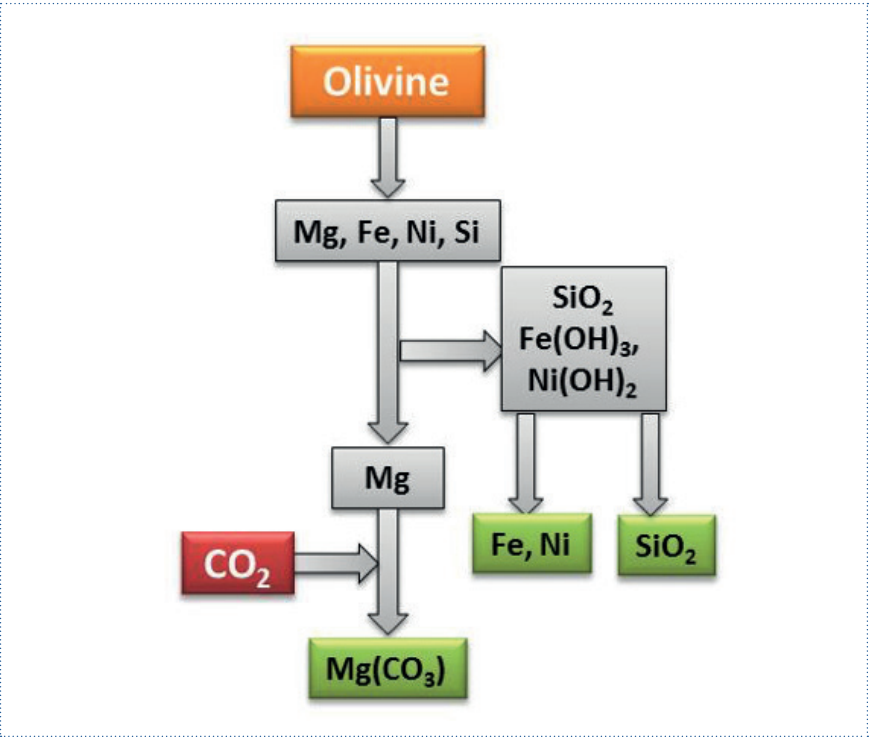
Material characterization:

- Environmental Electronic Microscopy,
- X-ray small angle diffusion and wide angle diffraction

KEY PROJECTS IN CCU

VALORCO

Small projects (CNRS, Université de Montpellier) for molecules and materials for photophysical assisted charge separation.



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X. WANG, V. GOUDY, G. GENESIO, J. MAYNADIE, D. MEYER, M. FONTECAVE
"Ruthenium–cobalt dinuclear complexes as photocatalysts for CO^2 reduction"
Chemical Communications, 53, 5040-5043 (2017)

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IFPEN

IFP Energies Nouvelles

General description of the activities

IFP Energies nouvelles (IFPEN) is a major research and training player in the fields of energy, transport and the environment. From research to industry, technological innovation is central to all its activities, structured around three strategic priorities: sustainable mobility, new energies and responsible oil and gas.

As part of the public-interest mission with which it has been tasked by the public authorities, IFPEN focuses on:

- providing solutions to take up the challenges facing society in terms of energy and the climate, promoting the transition towards sustainable mobility and the emergence of a more diversified energy mix;
- creating wealth and jobs by supporting French and European economic activity, and the competitiveness of related industrial sectors.

An integral part of IFPEN, its graduate engineering school – IFP School – prepares future generations to take up these challenges.

FIELD

Chemical synthesis, process and chemical engineering, geology,...

KEY COMPETENCES IN CCU

Carbone capture using amines, Electro reduction, Photocatalysis, Chemical process...

KEY EQUIPMENTS IN CCU

Pilot units for CO_2 capture (amines) and for CO_2 electro reduction

KEY PROJECTS IN CCU

$VALCO_2$ – French Research program coordinated by SOLVAY

Achievements and Expertise of French public labs

IFPEN – Pilot unit for CO_2 electroreduction

SELECTED REFERENCES

NUMEROUS PATENTS AND PUBLICATIONS.

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IFSTTAR

Institut Français des Sciences et Techniques Transports Aménagement Réseaux

General description of the activities

Industrial ecology, circular economy, eco-design, symbiose industrielle

FIELD

Process engineering, civil engineering

KEY COMPETENCES IN CCU

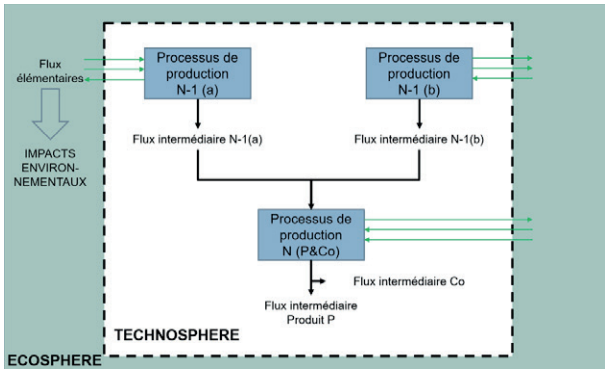
Life Cycle Assessment

KEY EQUIPMENTS IN CCU

Software and databases for Life Cycle Assessment

KEY PROJECTS IN CCU

Algoraff (BIP ADEME), Cimentalgues (BIP ADEME), Algoroute (ANR)



Systemic modeling of technological actions

Identification of action levers in a complex system using statistics

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VENTURA A., 2 avril 2012, Approches Systémiques et Eco-conception – Une réflexion sur les fondements conceptuels et les applications de l'Analyse de Cycle de Vie, Mémoire d'Habilitation à Diriger des Recherches

CHEN C., HABERT G., BOUZIDI Y., JULLIEN A., VENTURA A., 2010. LCA allocation procedure used as an incitative method for waste recycling: an application to mineral additions in concrete. Resource, Conservation and Recycling,

Vol. 54, No. 12, pp. 1231-1240 doi:10.1016/j.resconrec.2010.04.001

ANDRIANANDRAINA, VENTURA, A., SENGA KIESSÉ, T., CAZACLIU, B., IDIR, R., VAN DER WERF, H.M.G., 2015. Sensitivity Analysis of Environmental Process Modeling in a Life Cycle Context: A Case Study of Hemp Crop Production.

Journal of Industrial Ecology doi:10.1111/jiec.12228

SENGA KIESSÉ, T., VENTURA, A., VAN DER WERF, H.M.G., CAZACLIU, B., IDIR, R., ANDRIANANDRAINA, 2017. Introducing economic actors and their possibilities for action in LCA using sensitivity analysis: Application to hemp-based insulation products for building applications.

Journal of Cleaner Production 142, 3905-3916 doi:10.1016/j.jclepro.2016.10.069

DURÁN, C., VENTURA, A., 2017. Microalgae Cultivation Using Industrial Co_2 Emissions And Fortuitous Heat Gains: Preliminary Environmental Assessment Of An Industrial Symbiosis, in: Science in Support of Sustainable and Resilient Communities. Presented at the Biennial Conference of the International Society for Industrial Ecology

June 25-29 2017, Chicago (USA)

Complete references: https://scholar.google.fr/citations?user=RsfIyxcAAAAJ&hl=fr

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IRCELYON

Institut de Recherches sur la Catalyse et Environnement de Lyon

General description of the activities

IRCELYON brings together competences in catalysis (heterogeneous, homogeneous, enzymatic and photocatalytic systems) to remediate environmental problems such as air or water pollution, but also to valorize biomass (vegetal oils, lignin, starch, cellulose, algae, CO_2...)

FIELD

Chemical catalysts design, synthesis and evaluation

KEY COMPETENCES IN CCU

CO_2 capture by MOF or enzymatic systems

Use of Sc-CO_2 as green solvent to extract fatty alcohols from sugar cane mud

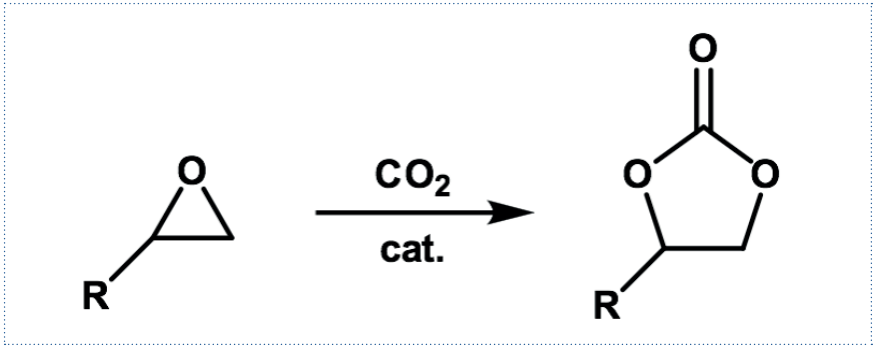
Catalytic CO_2 coupling to epoxydes

KEY EQUIPMENTS IN CCU

Stainless steel reactors including CO_2 supercritical tests

KEY PROJECTS IN CCU

Catalytic CO_2 valorization to cyclic carbonates



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J. MOL. CAT. A, CHEMICAL, 2014, 381, 161-170

"Novel Cr(III) complexes with N4-donor ligands as catalysts for the coupling of CO_2 and epoxides in supercritical conditions CO_2"

CHEMCATCHEM, 2012, 4 (11), 1725-1728

"The Origin of the Activity of Amine-Functionalized Metal-Organic Frameworks in the Catalytic Synthesis of Cyclic Carbonates from Epoxide and CO_2"

J.MOL. CAT. B: ENZYMATIC 2009, 60, 163-170

"Biocatalytic capture of CO_2 with carbonic anhydrase and its transformation to solid calcium carbonate"

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IRCP

Institut de Recherche de Chimie Paris - Chimie ParisTech

General description of the activities

CO_2 capture and valorization in molten carbonates: physico-chemical properties, high temperature electrolysis, molten carbonate fuel cell.

FIELD

Physico-chemistry, process and chemical engineering

KEY COMPETENCES IN CCU

High Temperature Electrochemistry in Molten Carbonates

KEY EQUIPMENTS IN CCU

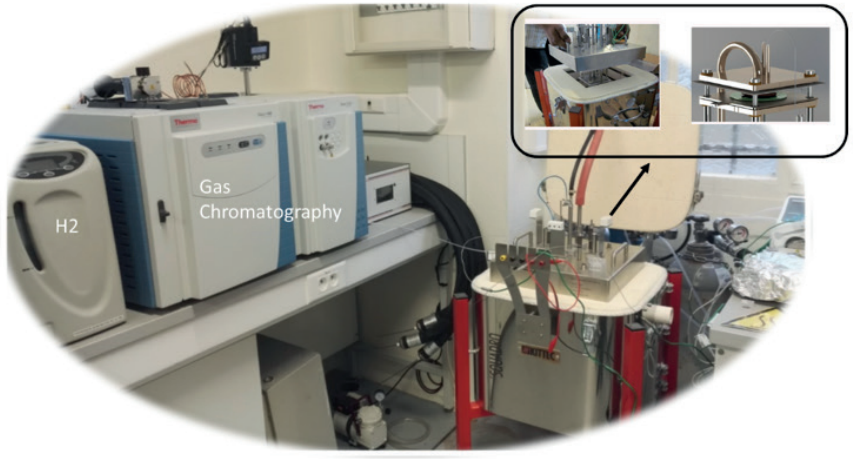
Molten carbonate (MC) Electrolysis/ Fuel Cell Set-up, coupled to GC. Solubility of gases in MC, DSC-TGA coupled to FTIR and GC-MS

KEY PROJECTS IN CCU

EquipeX 2011: PLANEX (Planète expérimentation: simulation et analyse in situ en conditions extrêmes)

ANR 2018: MCEC (CoMprehension & Optimization of high temperature CO_2 Electrolysis in Carbonates)

Platform for High Temperature Fuel/ Electrolysis Cell in Molten Carbonates



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D. CHERY, V. LAIR, M. CASSIR

CO_2 electrochemical reduction into CO or C in molten carbonates: a thermodynamic point of view.

Electrochimica Acta 160 (2015) 74-81

A. MELENDEZ-CEBALLOS, A. BROUZGOU, C. CRAPART, V. ALBIN, V. LAIR, AND M. CASSIR

Chronopotentiometric Approach of CO_2 Reduction in Molten Carbonates.

J. Electrochem. Soc., 164 (8) (2017) H5175-H5182

A. MELÉNDEZ-CEBALLOS, V. ALBIN, V. LAIR, A. RINGUEDÉ AND M. CASSIR

A kinetic approach on the effect of Cs addition on oxygen reduction for MCFC application

Electrochimica Acta, 184 (2015) 295-300

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ISM

Institut des Sciences Moléculaires

General description of the activities

The Institute of Molecular Sciences brings together a community of organic chemists and physical chemists interested in molecular structures, and working on their creation, synthesis, characterization, reactivity and analysis in various environments.

FIELD

Spectroscopy, Molecular modelling, Thermodynamics, Chemical synthesis

KEY COMPETENCES IN CCU

Cyclic carbonate synthesis, CO_2 catalysis, CO_2 sourced polyurethanes, CO_2 sourced polycarbonates, CO_2 capture and separation

KEY EQUIPMENTS IN CCU

In situ high pressure spectroscopy (Infrared, Raman, Uv-Vis, Neutron)

High pressure batch reactor 1-30 ml and glass capillaries (P=1-50 MPa / 90K-600K)

KEY PROJECTS IN CCU

International French-Belgian project on CO_2 sourced polymers

ANR MI2C project on gas selectivity in gas hydrates

SELECTED REFERENCES

M. ALVES, B. GRIGNARD, R. MEREAU, C. JEROME, T. TASSAING, C. DETREMBLEUR

"Organocatalyzed coupling of carbon dioxide with epoxides for the synthesis of cyclic carbonates: catalyst design and mechanistic studies",

Catal. Sci. Tech., 7, 2651-2684 (2017)

S. GENNEN, B. GRIGNARD, T. TASSAING, C. JEROME, C. DETREMBLEUR

"CO_2-sourced α-Alkylidene Cyclic Carbonates: A Step Forward in the Quest for Functional Regioregular Poly(urethane)s and Poly(carbonate)s"

Angew. Chem. Int. Ed., 56, 10394-10398 (2017).

MEREAU, B. GRIGNARD, A. BOYAVAL, C. DETREMBLEUR, C. JEROME, T. TASSAING

"Tetrabutyl ammonium salts: cheap catalysts for the facile and selective synthesis of a-alkylidene cyclic carbonates from CO_2 and alkynol" R.

ChemCatChem, 10, 956-960 (2018).

C. PETUYA, F. DAMAY, S. DESPLANCHE, D. TALAGA, A. DESMEDT

"Selective trapping of CO_2 gas and cage occupancy in CO_2-N2 and CO_2-CO mixed gas hydrates."

Chem. Commun., 54, 4290-4293 (2018).

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Arnaud DESMEDT
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LCMCE

Laboratoire de Chimie Moléculaire et Catalyse pour l'Énergie

General description of the activities

Our team of molecular chemists works on the conversion of CO_2, CO, waste plastics and biomass by-products to high value-added chemicals in a sustainable manner, and the facilitation of energy storage with the development of alternative liquid fuels. Following a knowledge-driven approach, we synthesize novel molecular catalysts (organic, organometallic or inorganic) and investigate their modes of action through mechanistic studies.

To expand the scope of fine chemicals available from CO_2, our idea is to design novel catalytic transformations where CO_2 is reacted, in a single step, with a functionalizing reagent and a reductant that can be independently modified, to produce a large spectrum of molecules. This method has been successfully applied to synthesize methylamines, formamidines, aminals, esters...

FIELD

Chemical synthesis and catalysis, computational calculations and mechanisms.

KEY COMPETENCES IN CCU

Catalysis for CO_2 conversion, reaction design, catalyst design, mechanistic studies

KEY EQUIPMENTS IN CCU

Gloveboxes and Schlenk lines for fine chemical synthesis, high-pressure reactors, NMR spectrometer, GC and GCMS instruments, single-crystal X-Ray diffractometer

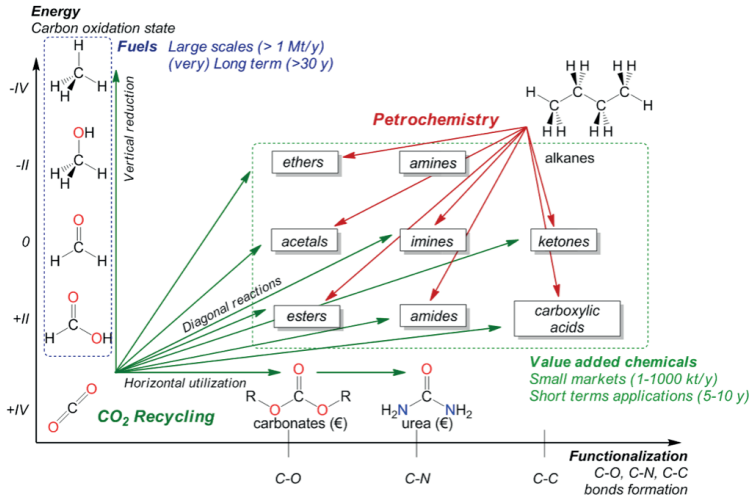
KEY PROJECTS IN CCU

ERC Starting Grant CO_2 Recycling

H2020 SPIRE8 project Carbon4PUR

Climate KIC project CO_2 nvergence

Grand Prix Scientifique de la Fondation Louis D. – Institut de France



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Green. Chem., 2015, 17, 157, DOI: 10.1039/C4GC01614A

Angew. Chem. Int. Ed., 2014, 53, 10466, DOI: 10.1002/anie.201405457

Synthesis of Esters by Functionalisation of CO_2, WO/2016/063227

Method for preparing methylated amines, WO/2013/182991

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LCMT

Laboratoire de Chimie Moléculaire et Thiorganique

General description of the activities

The research activity of the LCMT is focused on both fundamental and applied aspects of molecular chemistry.

The scientific aim at LCMT laboratory is to develop new and innovative methods in organic synthesis and catalysis for an application in green chemistry, material sciences and bioorganic chemistry:

development of cheap, environmentally friendly, and sustainable technologies for the production of molecules and macromolecules (atom and energy saving syntheses, catalyses, new activation technologies (MWI), new media for clean processes)...

This scientific aims are underlined through 3 main objectives:

1. Development of new synthetic methods in the field of heterochemistry and metal mediated chemistry;
2. Identification of reaction intermediates and elucidation of reaction mechanisms in order to perform high yielding and highly selective reactions
3. Development of new organic and hybrid materials with specific properties. The molecular and macromolecular engineering is thus the core business of the laboratory.. In the field of catalysis, we have recently made important contributions to the chemical activation of small molecules such as H_2, CO_2 by iron-based complexes, in an effort to address contemporary energy challenges (storing energy into chemical bonds and producing fuels).

FIELD

Catalysis, organometallic chemistry.

KEY COMPETENCES IN CCU

Molecular catalysis

Hydrogenation

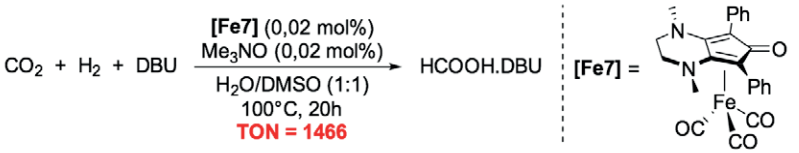
Mechanisms

KEY EQUIPMENTS IN CCU

Autoclaves, GC, GC/MS, NMR, HPLC

KEY PROJECTS IN CCU

Photochemical conversion of CO_2 into formate



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LEM

Laboratoire Electrochimie Moléculaire UMR CNRS 7591

General description of the activities

The research activity of the LEM is focused on both fundamental and applied aspects of molecular and biomolecular electrochemistry. The aim is to contribute to the general understanding of all aspects of electron transfer chemistry coupled to both molecular changes and/or dynamical electron transport within molecules and, on the basis of the fundamental advances, to develop new applications.

In the field of catalysis, we have recently made important contributions to the electrochemical activation of small molecules such as H_2, O_2, H_2O, CO_2 by metal complexes or catalytic films, in an effort to address contemporary energy challenges (storing energy into chemical bonds and producing fuels).

FIELD

Electrochemistry
and Photochemistry

KEY COMPETENCES IN CCU

Molecular Electrocatalysis

Photocatalysis

Mechanisms and Fundamental Reactivity

Electrochemical reactors

KEY EQUIPMENTS IN CCU

Potentiostats, electrolyzers, Solar simulators, GC, GC/MS, IC, HPLC

KEY PROJECTS IN CCU

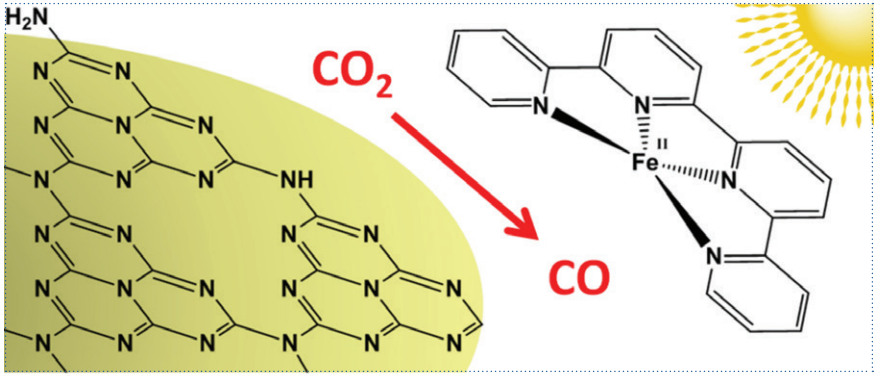
CO_2-to-CO electrolyzer

(Air Liquide partnership)

CO_2-to-CH4 photoreactor
(GRDF-GRTGaz partnership)

Electrochemical conversion of CO_2 into fuels (ANR and MOPGA project)

Photochemical conversion of CO_2 into fuels



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« A local proton source enhances CO_2 reduction to CO by a molecular Fe catalyst»

Science 2012, 338, 90-94

J. BONIN, M. ROBERT

« Transformation of CO_2 into CH4 by photochemical means »

2018, deposited Patent USA, Canada, Australia

C. COSTENTIN, I. AZCARATE, A. TATIN, J.-M. SAVÉANT, M. ROBERT

« Selective porphyrin-catalyzed electrochemical reduction of CO_2 into CO, in particular in water »

2016, Patent WO2018/011229, PCT/EP2017/067452

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LGC
Laboratoire de Génie Chimique

LABORATOIRE DE GÉNIE CHIMIQUE
TOULOUSE • UMR 5503

General description of the activities

Based in Toulouse, France, the Laboratoire de Génie Chimique (LGC) is a joint research institute directed by the French National Centre for Scientific Research (CNRS) and two universities, the Institut National Polytechnique de Toulouse (INP Toulouse) and the Université Paul Sabatier (UPS).

Its core activities are dedicated to advanced research in chemical and process engineering.

With over 160 permanent scientists and engineers, and as many PhD students and post-doctoral fellows, LGC pursues industry-driven research across all scales necessary for development of state-of-the-art and innovative industrial processes, from the smallest molecular or particulate scale right through to large scale industrial systems.

With six research departments, LGC has the ability to address the widest spectrum of activities in the field of chemical and process engineering.

www.lgc.cnrs.fr

FIELD

Chemical and process engineering

KEY COMPETENCES IN CCU

CO_2 valorisation by mineral carbonation – process development and thermo-kinetic modelling

KEY EQUIPMENTS IN CCU

Batch autoclaves and continuous bench-scale stirred media mill for attrition-leaching process

KEY PROJECTS IN CCU

2018-2021 CARBOSCORIES 2: production of construction materials by mineral carbonation of Ni mining waste

Key outcomes: Development of a bench-scale continuous attrition-leaching pilot process; valorisation of mineralisation products in the construction sector.

Project partners: LGC, LMDC, CNRT, BRGM

Funding: ACE Caledonian Energy Agency No. CS17-3160-00.

2015-2016 CARBOSCORIES : mineral carbonation of Ni mining waste

Key outcomes: validation of the attrition-leaching mineralisation process for valorisation of Ni pyrometallurgical waste.

Project partners: LGC, BRGM, IPGP

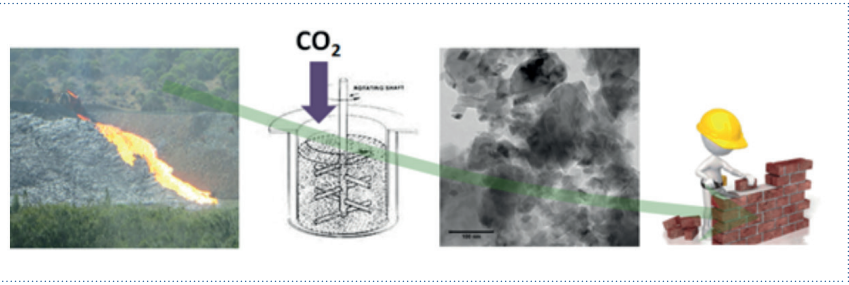
Funding: National Centre for Technology Research - CNRT "Nickel and its environment").

2009-2012 CARMEX : Ex-situ mineral carbonation of ultramafic ores and mining waste

Key outcomes: proof of concept of the attrition-leaching process for mineralization of silicate ores and mining waste.

Project partners: LGC, BRGM, BioIS, IPGP, Total E&P

Funding: ANR French National Research Agency No. ANR-08-PCO2-002; Total E&P).



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LRGP

Laboratory of reactions and Chemical Engineering

LABORATOIRE RÉACTIONS ET GÉNIE DES PROCÉDÉS

General description of the activities

The Laboratory of Reactions and Chemical Engineering (300 people) develops the scientific and technological knowledge necessary for the synthesis and recycling of materials and functional products, through chemical, physico-chemical and biological processes and the design, the optimization and the control of the elaboration processes and the related transformation of mass and energy.

FIELD

Chemical Engineering: Environment, water and soils remediation _ Safety of transformation processes _ Energy _ Process intensification _ Process systems engineering _ Separation processes _ Bioprocesses _ Combustion and Pyrolysis _ Biomass conversion _ Thermodynamics_ Materials _ Product engineering.

KEY EQUIPMENTS IN CCU

CO_2 capture pilots (solvents, polymers, adsorbents, membranes) / Kinetics catalytic reactors / Fermentation reactors / Carbonatation reactors

KEY COMPETENCES IN CCU

Material and liquid selection for selective carbon capture (solvents, polymers, adsorbents, membranes)

Modelling and simulation of carbon capture processes (membrane contactors, membrane separation, Temperature and/or Pressure Swing Adsorption processes)

Design and testing of bench-scale units for proof of concepts studies and model validation

Evaluation of energy requirement and size for carbon capture (Process Systems Engineering simulation with tailor- made toolboxes)

Life Cycle Analysis (LCA) of carbon capture processes.

Kinetics study, Reactors design, and whole process conception (optimal reactors and separators association) for CO_2 valorization (methanation, methanol production ...)

Carbonatation of CO_2 (kinetics study and reactors design)

CO_2 fermentation (H2 enriched fermentation for methane production)

Influence of copollutants on adsorbent performance for CO_2 capture

Achievements and Expertise of French public labs

KEY PROJECTS IN CCU

- Simulation of CO_2 capture under precombustion conditions IGCC (ADEME EDF PhD grant)
- CICADI Membrane contactor for post combustion CO_2 capture by chemical gas liquid absorption (ANR)
- CESAR (CO_2 Enhanced Separation and Recovery, FP7 project)
- AMELIE Membrane contactor for chilled ammonia process (ANR)
- Post combustion capture: solvents and processes (EDF PhD grant)
- ENERGYCAPT Membrane contactor for post combustion CO_2 capture by chemical gas liquid absorption (ANR)
- HIPERCAP Chemically reactive membranes for post combustion carbon capture (FP7)
- M4CO2 (Metal Organic Framework membranes for CO_2 capture (FP7)
- Photobioreactors for algae production (Kerosalg)
- Carbon capture from steel production plant (blast furnace) for methanol synthesis (VALORCO PIA project, ADEME)
- CO_2 use from flue gases for chemical production (ANR C2B, ANR Vitesse2)

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LSPC

Laboratoire de Sécurité des Procédés Chimiques

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General description of the activities

Design and optimization of efficient, safe and environmentally friendly processes:

Valorization and transformation of biomass for chemicals and energy, Capture and utilization of CO2, Microwave Processes, Process safety and reaction calorimetry.

FIELD

Chemical engineering, process intensification, process safety

KEY COMPETENCES IN CCU

Absorption, desorption, gas-liquid equilibrium, kinetics of transport, valorization, catalytic processes,

KEY EQUIPMENTS IN CCU

Instrumented rector benches: carbonation, hydrogenation, micro-waves, gasification, high pressure...

Absorption - desorption units : packed bed, spray column, Lewis cell

Reaction calorimeters: Process Safety Workstation RC1, RC1e (high pressure), Adiabatic Accelerating Rate Calorimeter ARC, ARSST reactor.

Thermal analyzers: TGA, DSC, Calvet micro-calorimeter, calorimetric bomb...

Gas and liquid chromatographs, physical properties measurement tools (viscosity, refractive index...)

KEY PROJECTS IN CCU

Interreg project on CO_2 utilization using hydrogen media

ADEME project : CO_2 valorization using alcohol

Regional project : methane and methanol synthesis via CO_2 hydrogenation

CCU using epoxides (industrial projet)

CCU using vegetable oils

Intensification of carbon capture using reactive spray

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MARBEC

Marine Biodiversity, Conservation & Exploitation

General description of the activities

The research objectives of the MARBEC are:

- To describe marine biodiversity, understand its dynamics and the functioning of marine ecosystems
- To analyze the impact of anthropogenic pressure on these ecosystems and develop responses scenarii to global change
- To reconcile exploitation (especially fisheries and aquaculture), and conservation and respond to societal expectations (expertise, innovation, remediation).

FIELD

Marine Biodiversity, Bioremediation, Aquaculture

KEY COMPETENCES IN CCU

Applied phycology

CO_2 fixation by microalgae

Processes in biomass production/ concentration in raceways

Microbiology

Biochemistry

KEY EQUIPMENTS IN CCU

Culture collection, automatized Photobioreactors, Raceways, DIC titrator, CHN analyzer, Imaging PAM, Cytometry, Microscopy, spectrophotometer, spectrofluorimeter

KEY PROJECTS IN CCU

CO_2 bioremediation using Microalgae (VASCO2)

Use of wastewaters for Microalgae production (ANR PHYCOVER, IMTA Effect)

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PROMES-CNRS

Laboratoire Procédés, Matériaux et Energie Solaire

General description of the activities

The research at PROMES-CNRS aims to develop innovative solar processes for CO_2 recycling into synthetic solar fuels from solar thermal energy. Novel materials are developed for CO_2 splitting into separate streams of CO and O_2 via two-step thermochemical redox cycles using concentrated solar energy as the source of high-temperature process heat.

The solar thermochemical approach to split CO_2 inherently operates at high temperatures and utilizes the entire solar spectrum, and as such provides an attractive path to solar fuels production with high energy conversion efficiencies in the absence of precious metal catalysts.

The study is focused on the synthesis and shaping of active materials including multivalent oxides and non-stoichiometric oxides, the characterization of their reactivity for CO_2 splitting (chemical yields and kinetics), and the design, testing and modeling of suitable solar reactor concepts.

FIELD

CO_2 valorization, solar fuels, materials synthesis, thermochemical reactions, solar energy conversion and storage, process and chemical engineering

KEY COMPETENCES IN CCU

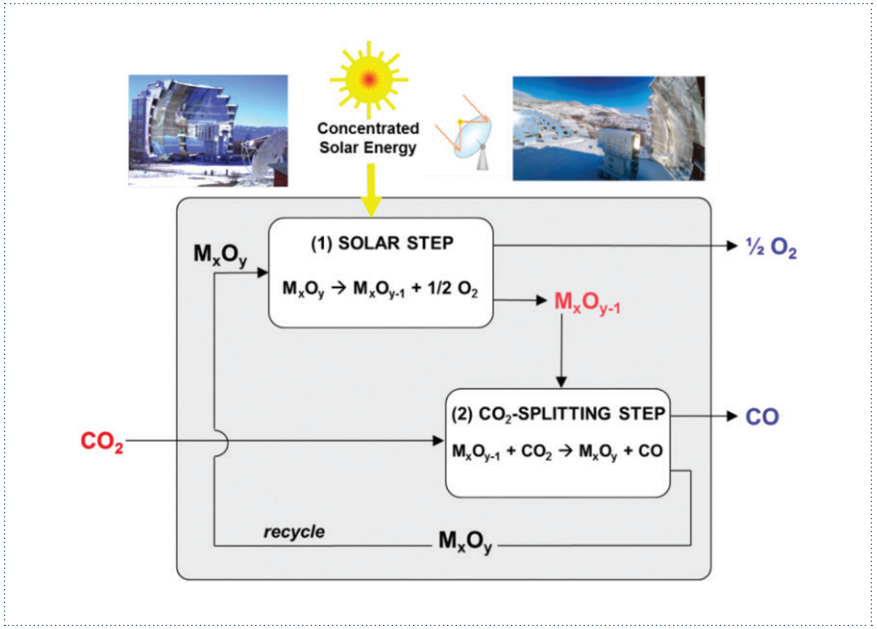
Materials science and chemistry, novel active materials for CO_2 conversion, non-stoichiometric oxides (ceria and perovskite), two-step redox cycles, solar reactors and thermochemical processes

KEY EQUIPMENTS IN CCU

Solar chemical reactor prototypes, solar concentrating systems from 1 kWth to 1 MWth, characterization techniques of materials reactivity at high temperature

KEY PROJECTS IN CCU

ANR-SUNFUEL project (2016-2020), Solar thermochemical conversion of CO_2 and water into fuel using non-stoichiometric oxygen-exchange redox materials



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Achievements and Expertise of French public labs

NOTES

- JULY 2018 -

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