CNRISMN
Istituto per lo Studio dei Materiali Nanostrutturati

CONVEGNO ON LINE
LUNEDÌ 23 NOVEMBRE 2026, ORE 15.00 - 17.00

L'idrogeno nella transizione energetica: dalla circolarità del carbonio all'intensificazione di processo

Un focus su tecniche sul processo produttivo e materiali innovativi per la produzione di idrogeno

Valorizzazione della CO_2 in prodotti ad alto valore aggiunto: strategie catalitiche per la circolarità del carbonio

Leonarda Francesca Liotta

CNRISMN
Istituto per lo Studio dei Materiali Nanostrutturati

Benvenuti all'Area Territoriale di Ricerca di Palermo



CNR Research Area in Palermo



L'**Area Territoriale di Ricerca di Palermo** del CNR ospita **13 Istituti**, la sezione di Palermo dell'**INGV-Istituto Nazionale di Geofisica e Vulcanologia**, la sezione di Palermo dell'**Istituto Nazionale di Astrofisica – Istituto di Astrofisica Spaziale e Fisica Cosmica (INAF-IASF)**, la **Fondazione Ri.MED** ed un distaccamento per la Sicilia dell' **Unità di Prevenzione e Protezione (CNR UPP) – (CNR SPP)** della Sede Centrale CNR di Roma.

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Energy & Environment

Circular Economy & Industry 5.0





Advanced Materials & Devices

Health & Wellness





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Research Topics @ ISMN-Palermo

Sustainable development of materials and processes for energy transition and environmental remediation.



Energy
&
Environment

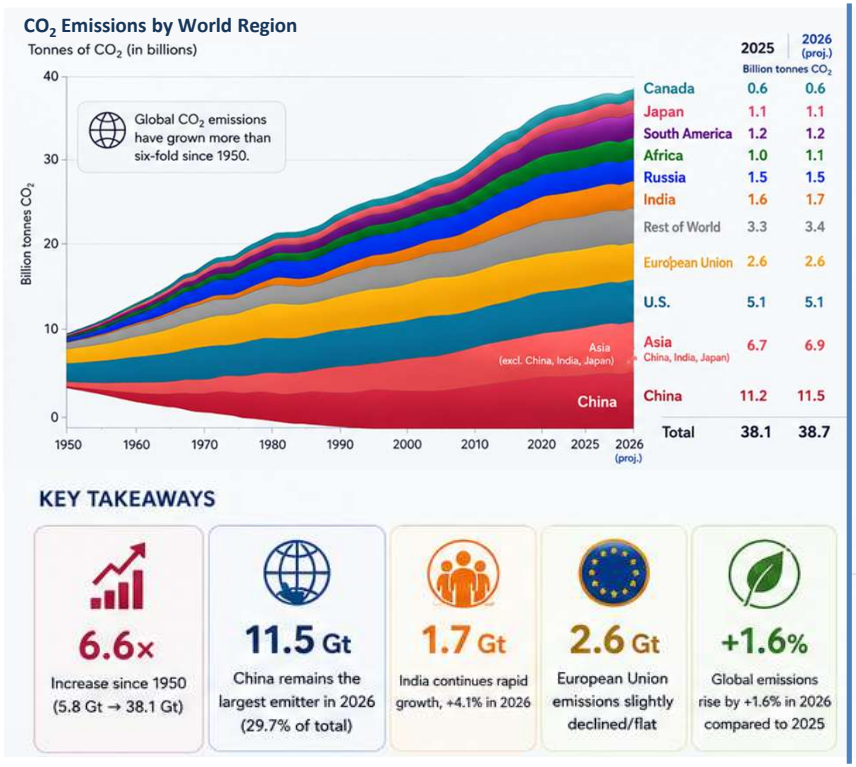


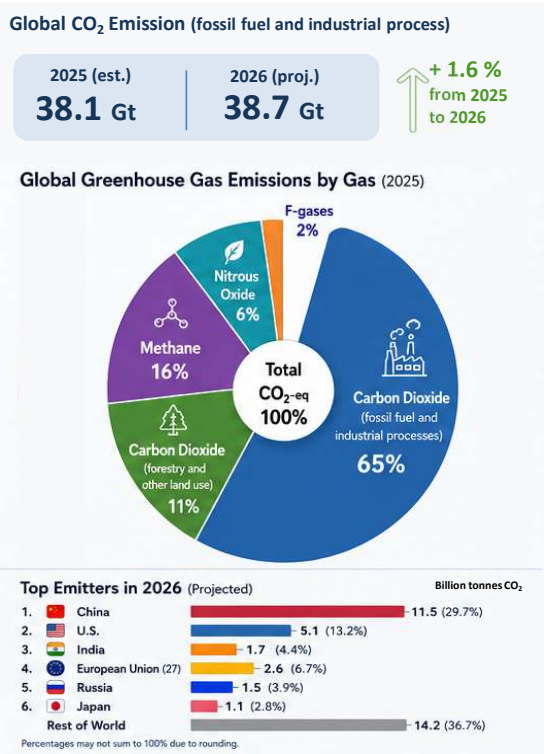


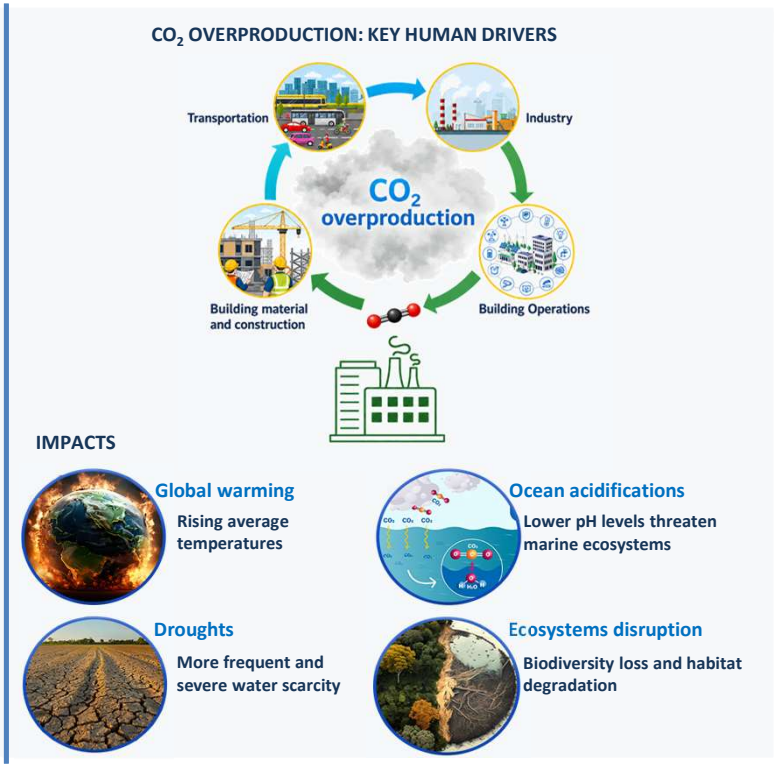
Circular Economy
&
Industry 5.0

Carbon dioxide recovery and valorization methodologies

Global CO_2 Emissions Through Time



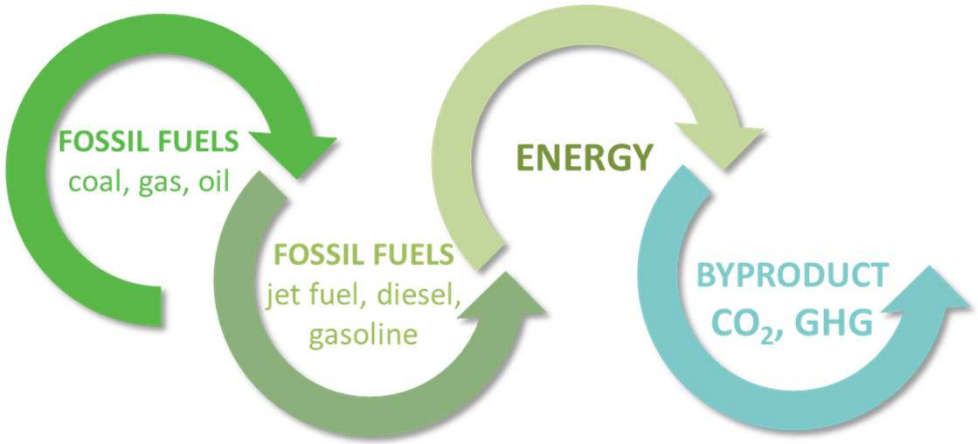




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Towards Sustainability

TRADITIONAL ENERGY FLOW



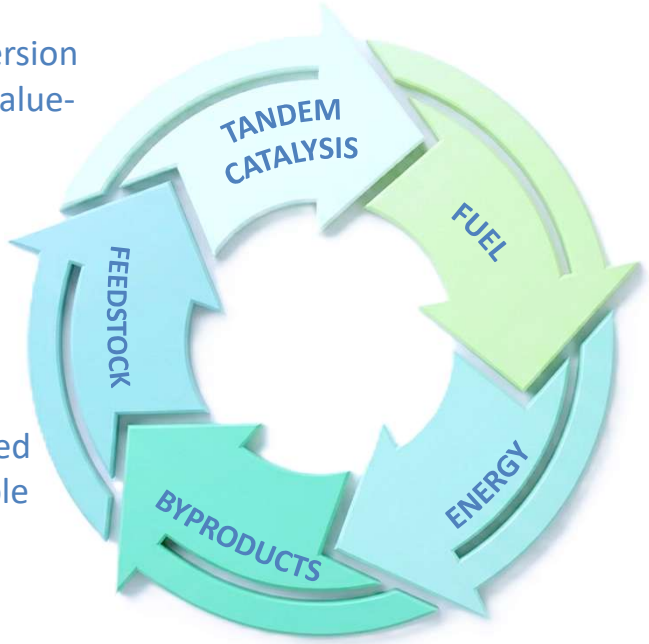


Transition from:
Linear carbon economy
"Burn and emit" to
Circular carbon economy
"Capture, recycle, and reuse carbon"

SUSTAINABLE CIRCULAR ENERGY FLOW

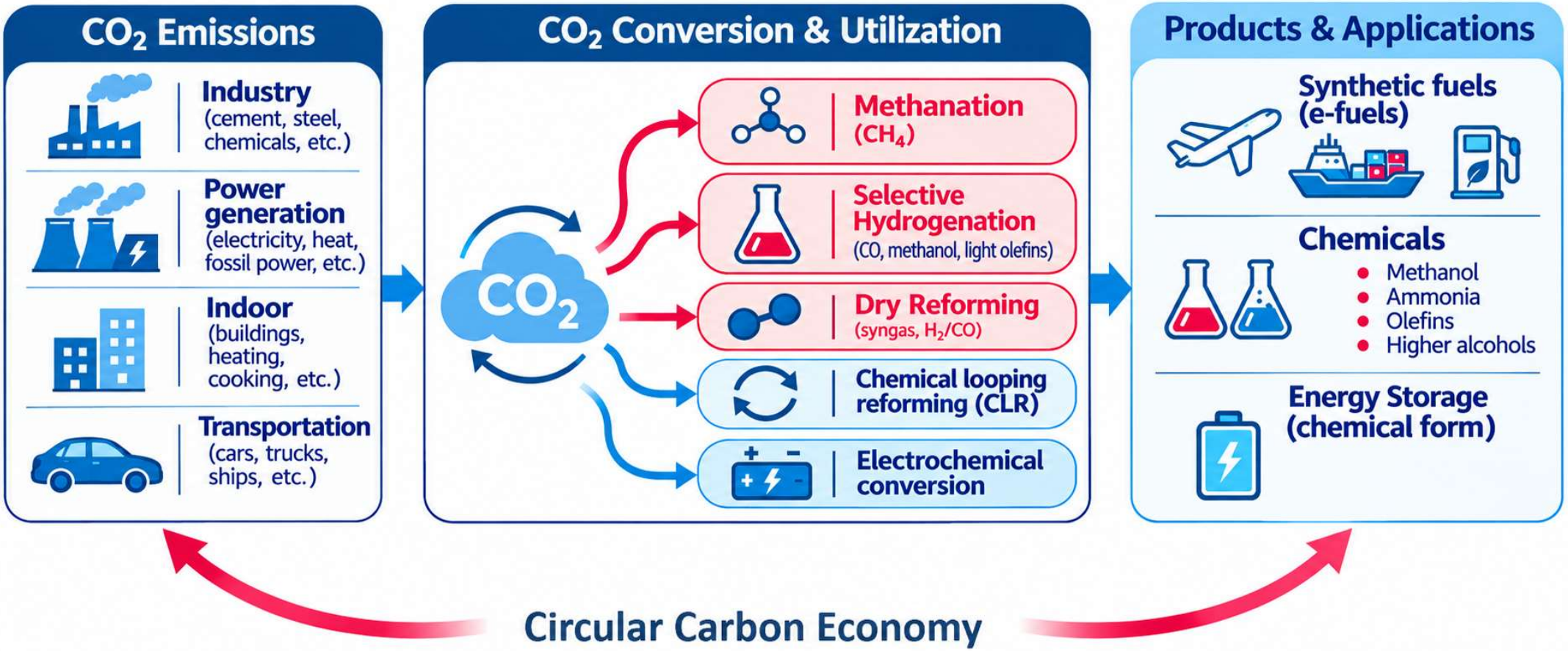
Catalysis allows direct conversion of low cost molecules into value-added chemicals

CO_2, CO and H_2O are reused as feedstock for sustainable production of fuels

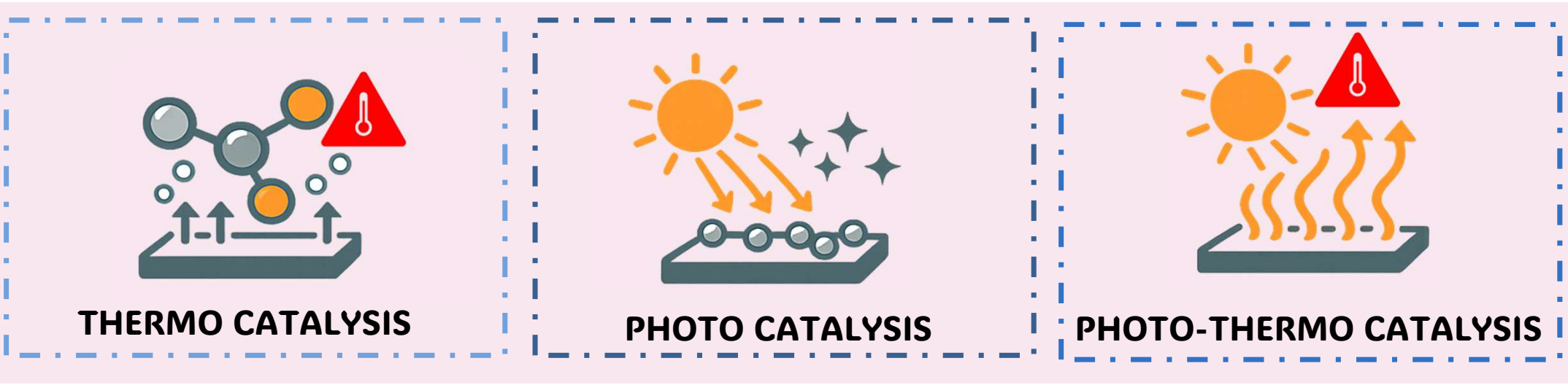


Combustion produces CO_2, among other molecules

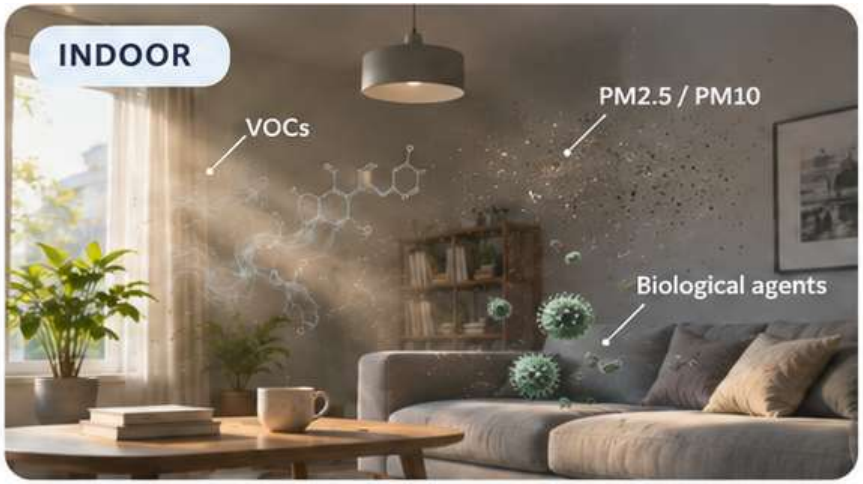
Closing the Carbon Loop: CO_2 Valorization Pathways



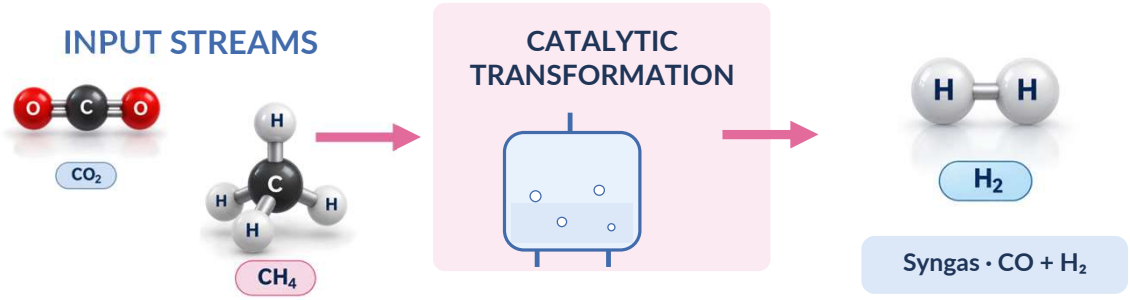
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THERMO CATALYSIS
PHOTO CATALYSIS
PHOTO-THERMO CATALYSIS

The Environmental Challenge



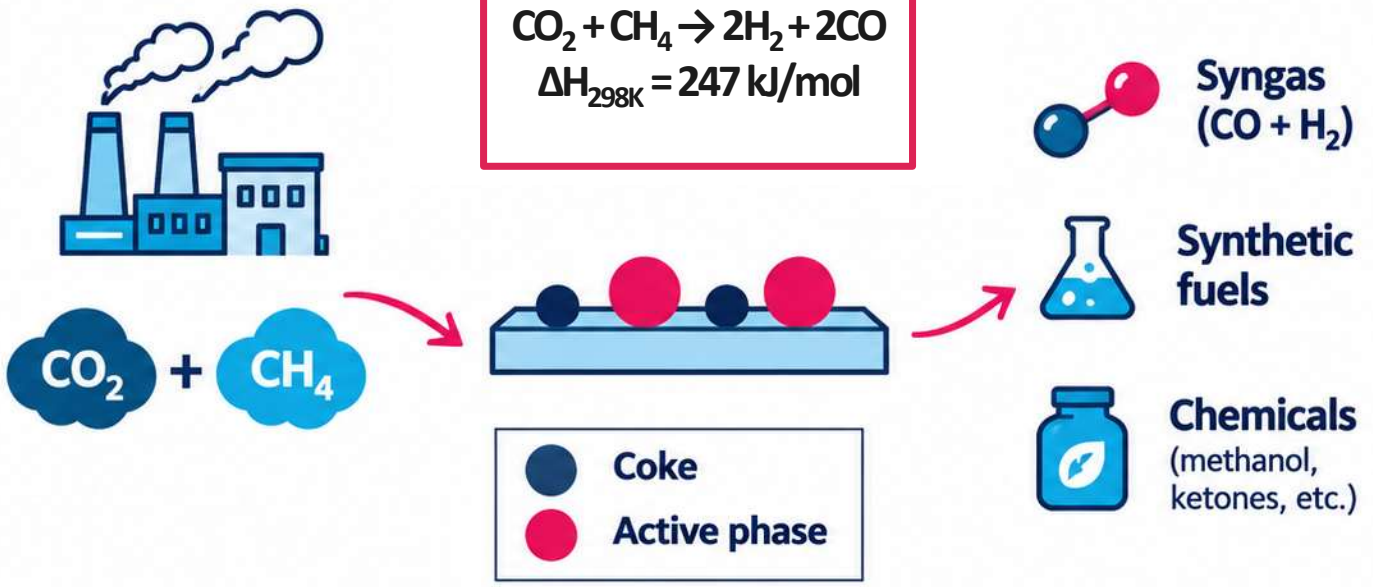




The objective: maximize useful conversion while controlling selectivity, energy demand and catalyst deactivation.

Dry Reforming of Methane (DRM)

$$CO_2 + CH_4 \rightarrow 2H_2 + 2CO$$
$$\Delta H_{298K} = 247\ kJ/mol$$



ADVANTAGES
Greenhouse gases valorization
No steam required
Heat recovery

CHALLENGES
Strongly endothermic (800-1000 °C)
Catalyst deactivation (coking)
Stability at long-term operation

KEY CHALLENGE

How can we design catalysts combining high activity, long-term stability, and resistance to coke formation?

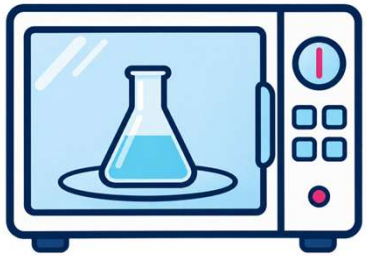
PCH2R

NEST
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

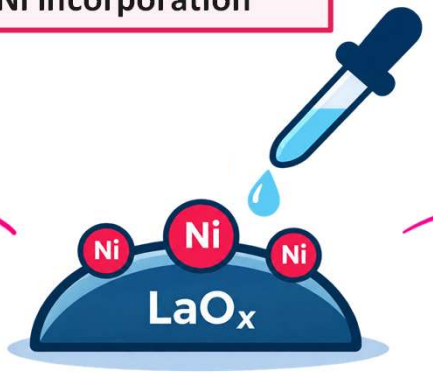
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Catalyst Design and Experimental Strategy

Precipitation Assisted by Microwave Irradiation (MW)



Ni incorporation



Hydrothermal Synthesis (HT)





Contents lists available at ScienceDirect

Journal of CO2 Utilization

journal homepage: www.elsevier.com/locate/jcou

Microwave *versus* hydrothermal synthesis of Ni–La catalysts for dry reforming of methane: Exploring the structure-activity relationships

L. Consentino, V. La Parola, G. Pantaleo, E. La Greca, R. Caliandro, C. Giannini, C. Evangelisti, L.F. Liotta

SCAN ME

RESEARCH OBJECTIVES

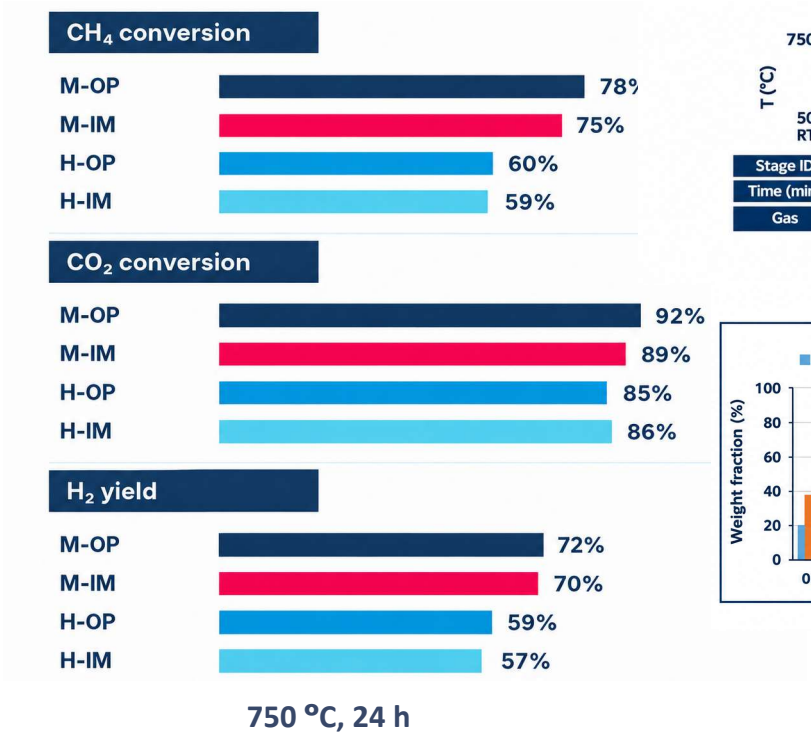
- Investigate how HT and MW synthesis routes affect catalytic stability and coke resistance
- Evaluate how Ni incorporation methods influence the Ni–La structure

ICCOM Istituto di Chimica dei Composti Organometallici
Consiglio Nazionale delle Ricerche

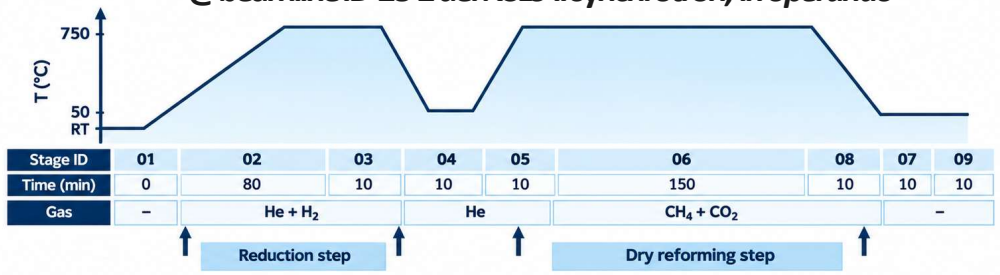
CNR Istituto di Cristallografia

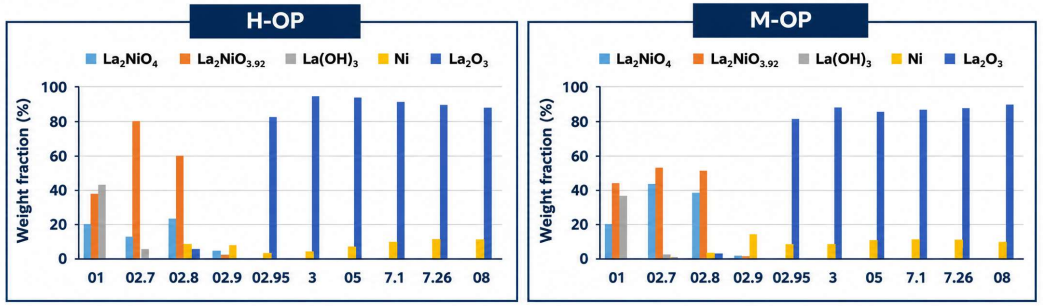
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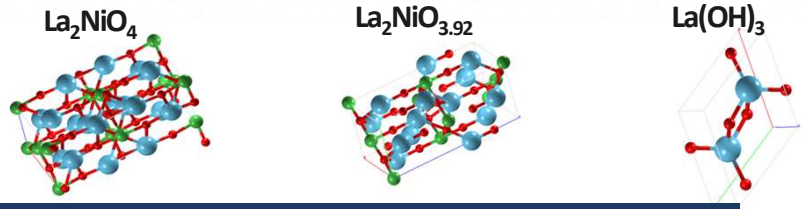
Catalyst Structure–Performance Relationships



@beamline ID-28-2 del NSLS-II synchrotron, *in operando*







Coke formed (TGA in air)

M-OP-S ≈ 40 wt%

H-OP-S ≈ 60 wt%

Microwave-assisted synthesis promotes catalytic stability and coke resistance, highlighting the key role of the synthesis route

Consentino et al.,
J. CO_2 Util., 2026, 110, 103520.

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From Glycerol Waste to Solar-Assisted H_2 Production

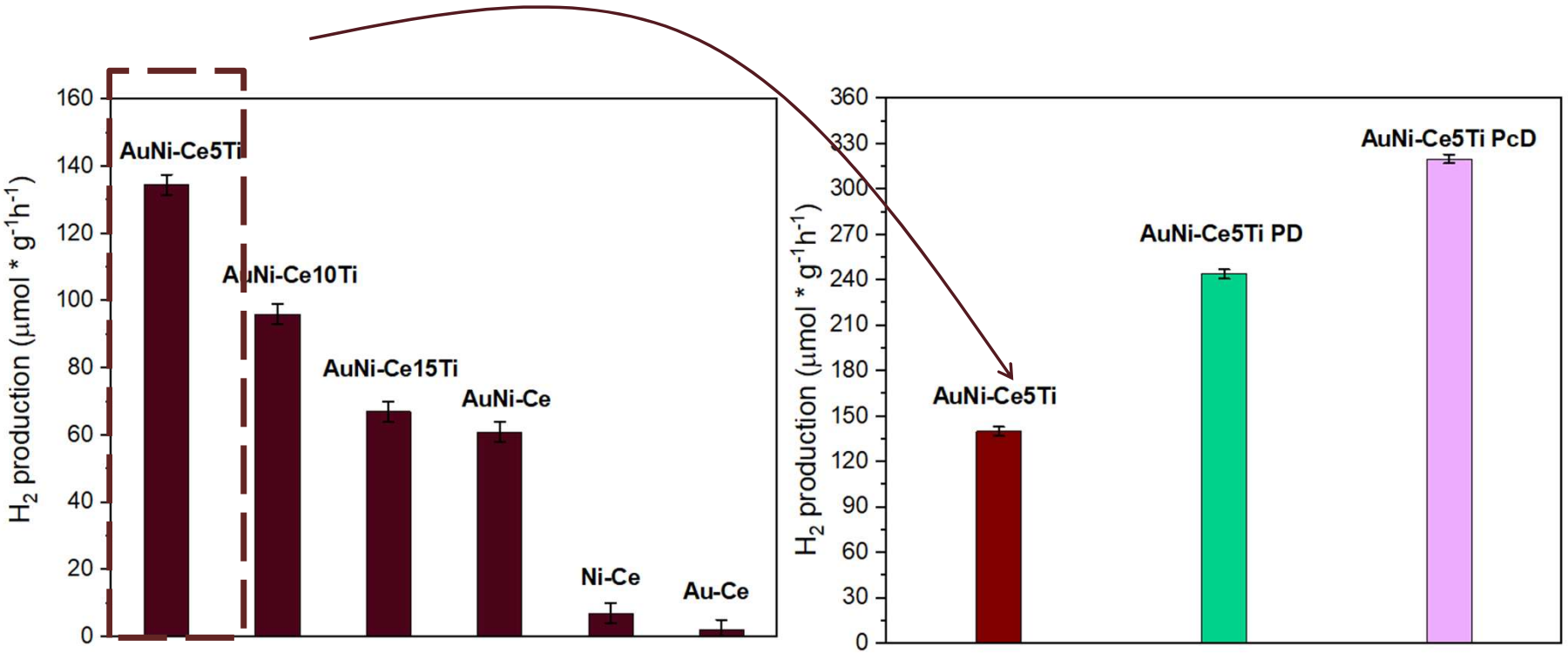


RESOURCE Glycerol as a carbon-rich by-product.

ENERGY Light drives photogenerated charge carriers.

OBJECTIVE Promote charge separation and proton reduction.

PHOTOREFORMING



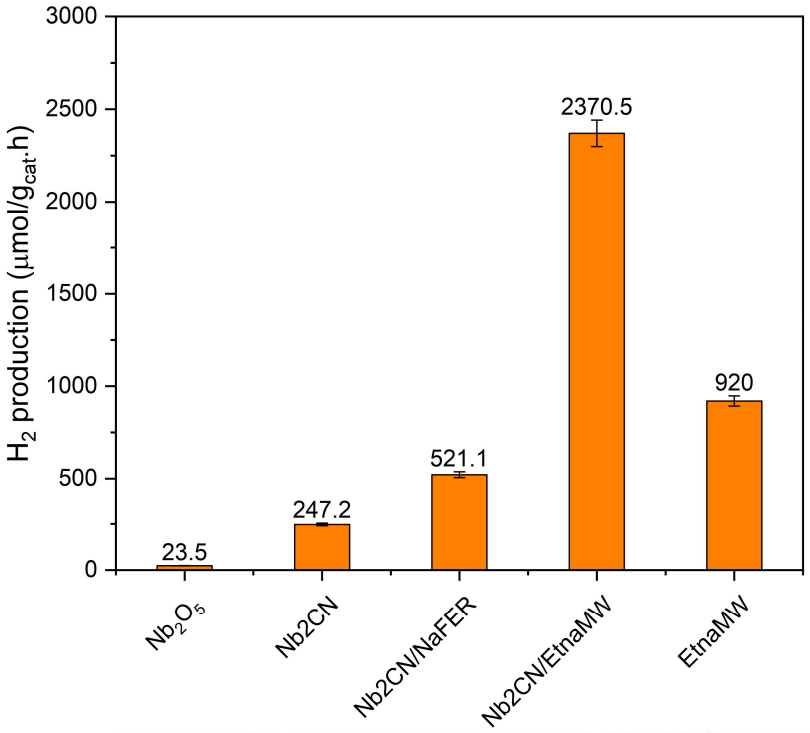
≈2.4×
higher H_2 rate

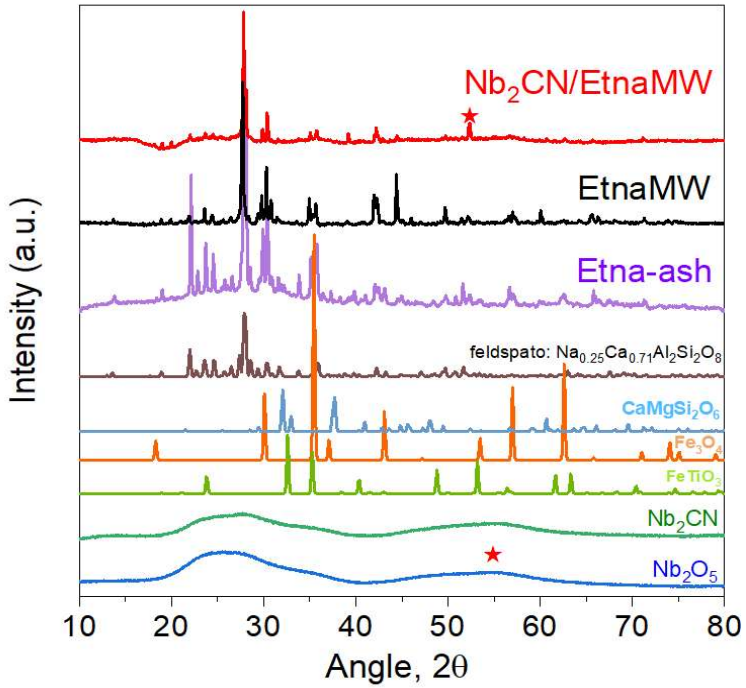
Ce^{3+}
≈15% → ≈33%

ETNA derived waste for solar H_2 production

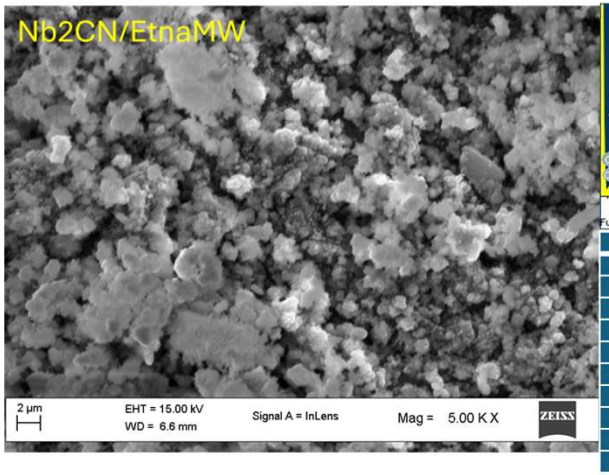


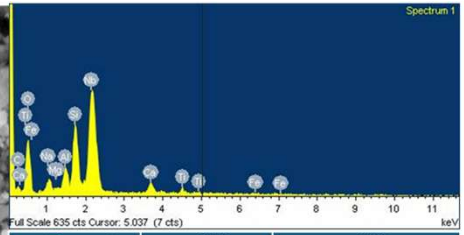
From volcanic ash to functional material





Composition: **TiO_2** and **iron** oxides are naturally embedded in an aluminosilicate matrix.

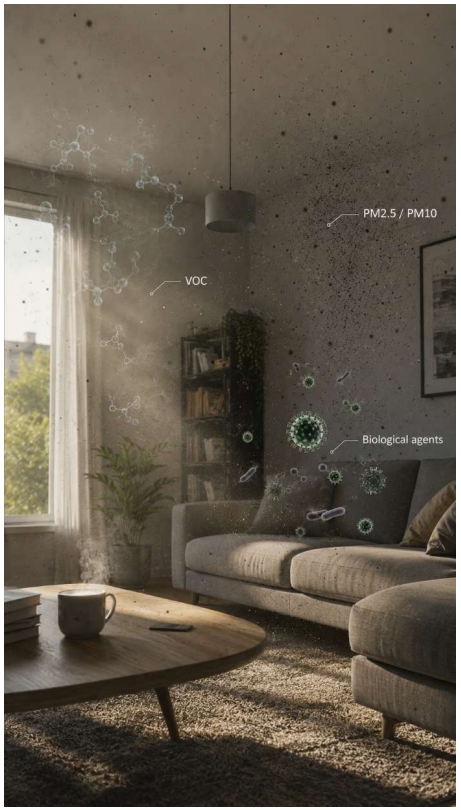




Element	wt (%)	at(%)
C K	10.96	23.40
O K	31.04	49.74
Na K	2.24	2.49
Mg K	0.36	0.38
Al K	2.81	2.67
Si K	8.04	7.34
Ca K	2.73	1.73
Ti K	1.81	0.97
Fe K	1.18	0.54
Nb L	38.82	10.71

Composite formation: it can also serve as an active support for a hydrothermally prepared **Nb oxide–g-C_3N_4 composite**.

Beyond Valorization: Catalytic VOC Abatement



Same design toolbox

Surface redox chemistry • oxygen mobility • thermal/light activation

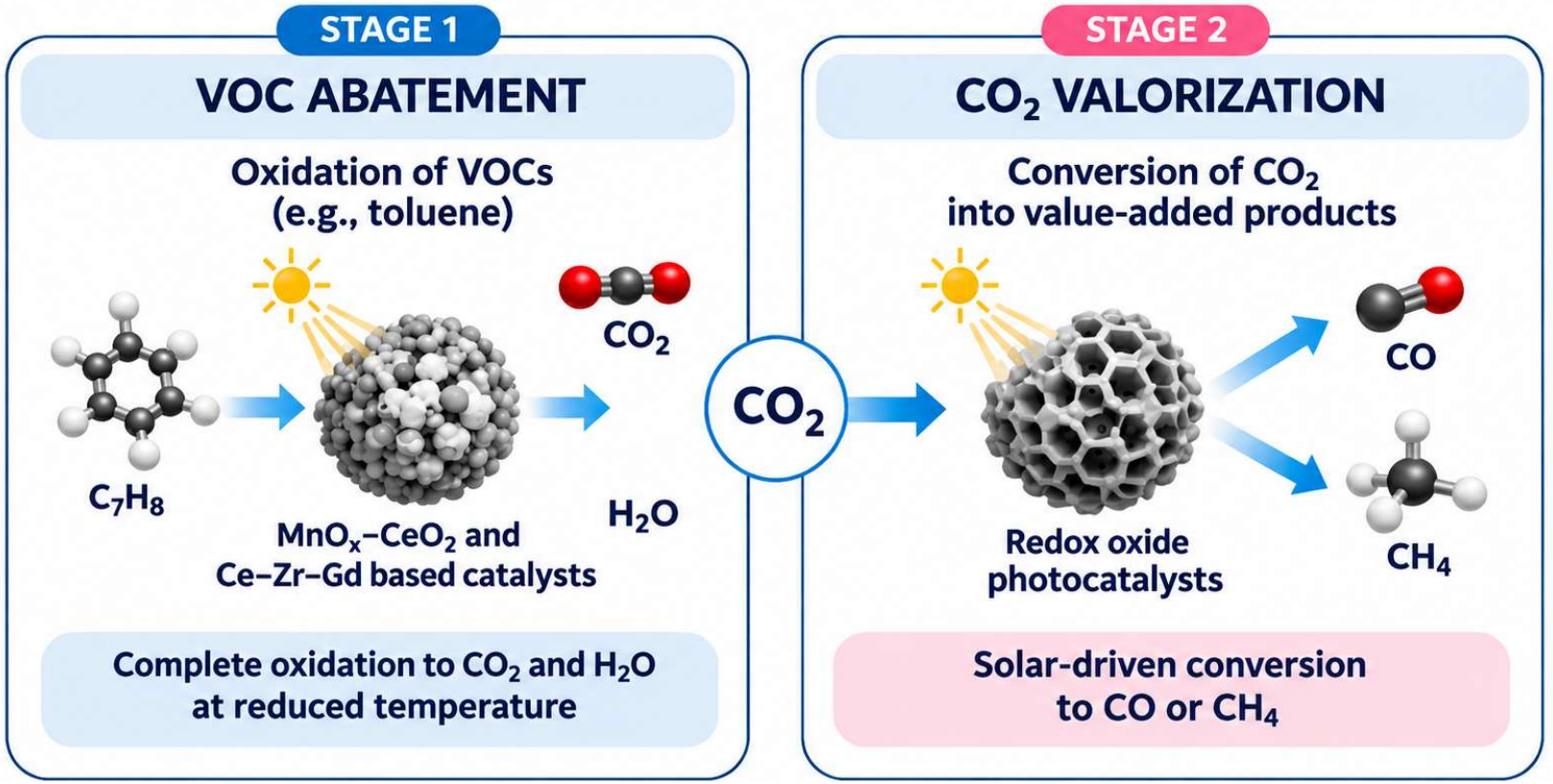
A different environmental objective

Remove VOC pollutants rather than generate H_2.

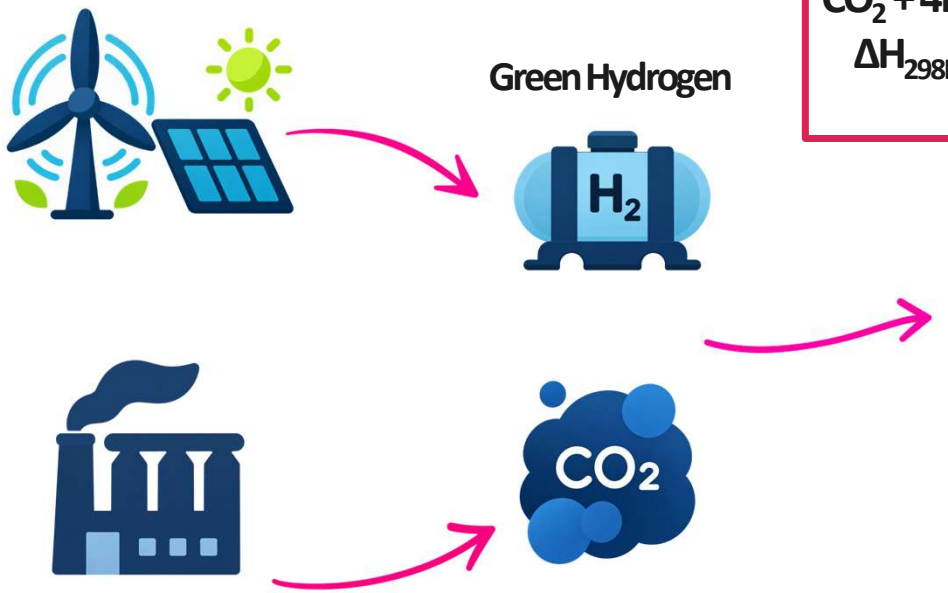
Possible future connection

Couple VOC oxidation with downstream CO_2 utilization.

Light + Heat Can Lower the Oxidation Temperature



CO_2 Methanation



$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$
$$\Delta H_{298K} = -165\ kJ/mol$$

ADVANTAGES

- CO_2 utilization
- Renewable energy storage
- Natural gas substitution

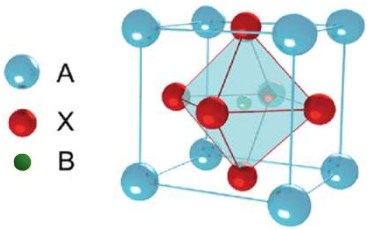
CHALLENGES

- Slow kinetics at low temperature
- Catalyst deactivation
- Competing RWGS reaction

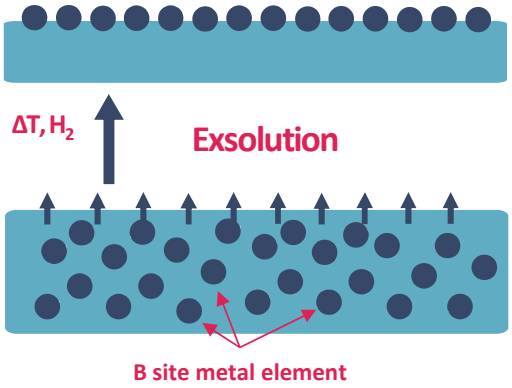
KEY CHALLENGE

How can we design catalysts combining high activity, CH_4 selectivity and long-term stability?

Catalyst Design and Experimental Strategy



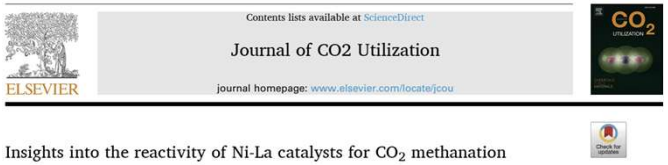
ABX_3
A=alkaline earth or rare-earth element
B=transition metal element (3d, 4d, and 5d)
X=anion usually oxides or halogens



Lee et al. 2021 Chemical Engineering Journal 412, 127557

Why Ni-La perovskites?

- In-situ Ni exsolution
- Enhanced stability
- Oxygen vacancy formation
- Coke resistance
- Thermal stability

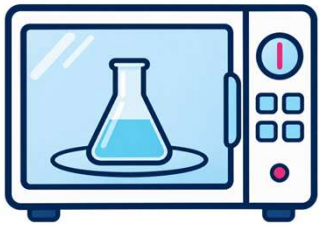

Contents lists available at ScienceDirect
Journal of CO2 Utilization
journal homepage: www.elsevier.com/locate/jcou
ELSEVIER

Insights into the reactivity of Ni-La catalysts for CO_2 methanation

Luca Consentino [a,b,*], Miriam González-Castaño [c], Nuría García-Moncada [d], Luis F. Bobadilla [c], Michelangelo Gruttadauria [b], Leonarda Francesca Liotta [a], José Antonio Odriozola [c,e]

SCAN ME

Precipitation Assisted by Microwave Irradiation (MW)



One pot
vs
Wetness Impregnation

RESEARCH OBJECTIVES

- **Synthesis route:** One-pot vs. impregnation
- **Reduction treatment:** Effects on structure and catalytic performance

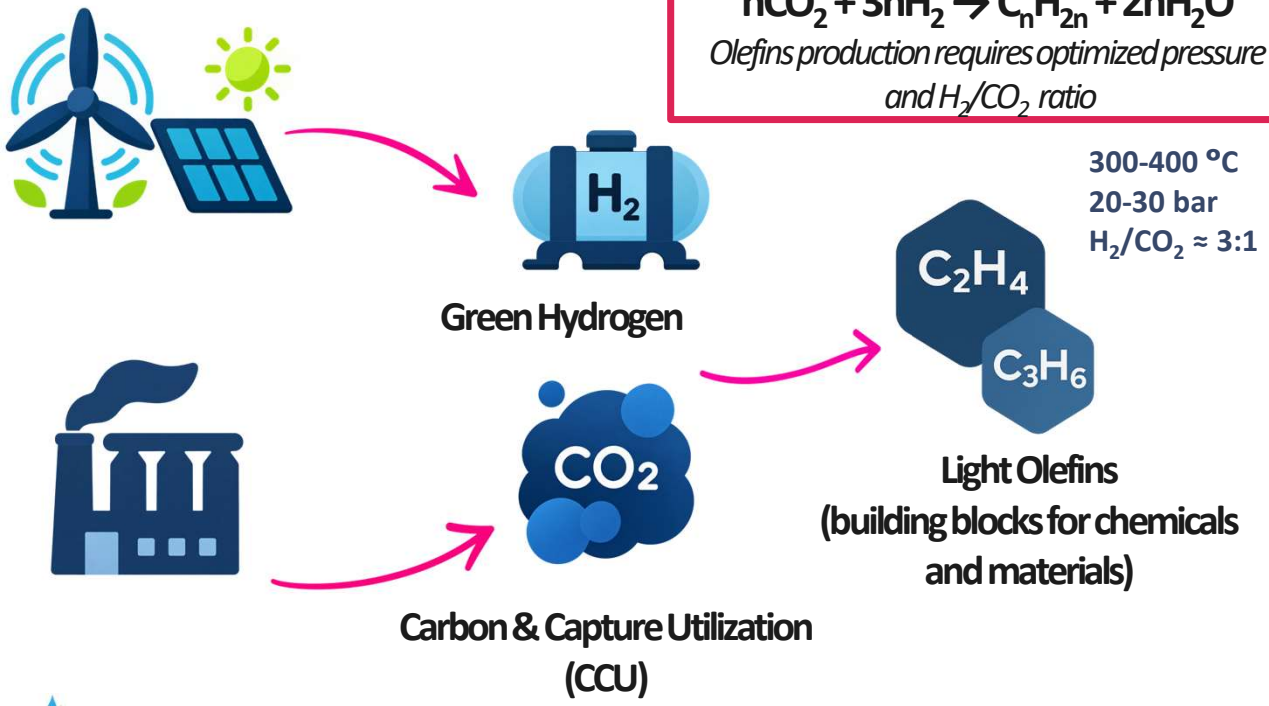
CSIC Consejo Superior de Investigaciones Científicas

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CO_2 Hydrogenation to Light Olefins

$$nCO_2 + 3nH_2 \rightarrow C_nH_{2n} + 2nH_2O$$

Olefins production requires optimized pressure and H_2/CO_2 ratio



ADVANTAGES
CO_2 utilization
High-value light olefins (C_2–C_4)
CO_2-based alternative to fossil-derived olefins

CHALLENGES
High-pressure requirement
Light-olefin selectivity control
Competing reactions (RWGS, CH_4, paraffins)
Catalyst deactivation and long-term stability

KEY CHALLENGE

How can we design catalysts combining high activity, light-olefin selectivity, and long-term stability?

PCH2R NEST
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

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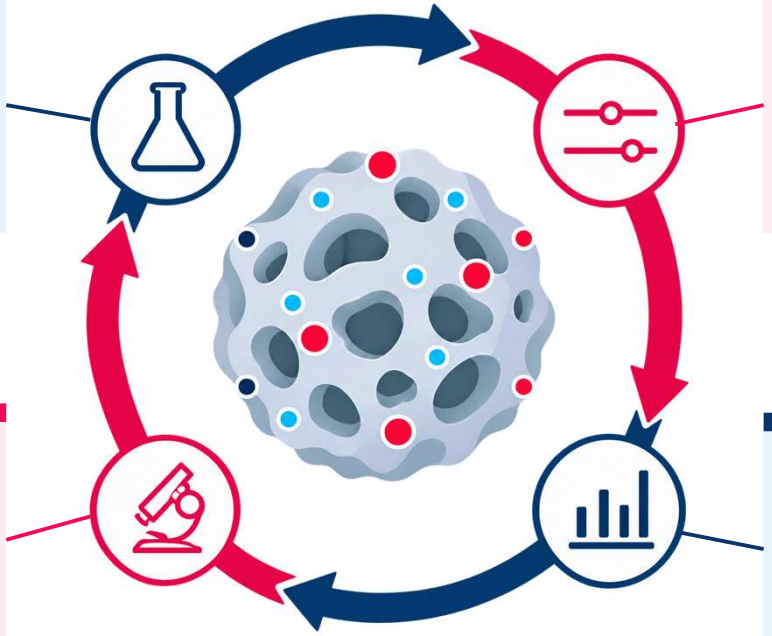
From Case Studies to Research Expertise

01 | DESIGN

Material synthesis and formulation

02 | TAILOR

Structure and surface tuning



03 | INVESTIGATE

Advanced characterization and catalytic testing

04 | INTERPRET

Structure-performance relationships

Integrating catalyst design, advanced characterization and catalytic testing to establish structure–activity relationships

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Acknowledgements

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Universitat d'Alacant

ecosister PYH2

NEST
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

STEMS

MISSION INNOVATION
accelerating the clean energy revolution

PCR H_2

NAUSICA

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
CA23139 - Network for Indoor Air Cleaning (Net4CleanAir)

ENMIX

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Consiglio Nazionale delle Ricerche

WIRE
Waste biorefinery technologies for accelerating sustainable energy processes

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
CA20127 (2021-2025)
Funded by the European Union

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Giuseppe Pantaleo



Valeria La Parola



Laura Valentino
Postdoc@CNR



Prof. Scirè, Prof. Fiorenza



Carla Calabrese

Università di Catania



Eleonora La Greca
Postdoc@CNR



L. Consentino
Postdoc@CNR

THANK FOR YOUR KIND ATTENTION

Dr. Leonarda Francesca Liotta
Director of Research

Email: leonardafrancesca.liotta@cnr.it

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