Written on 05 February 2025

5 minutes of reading

Economic outlook

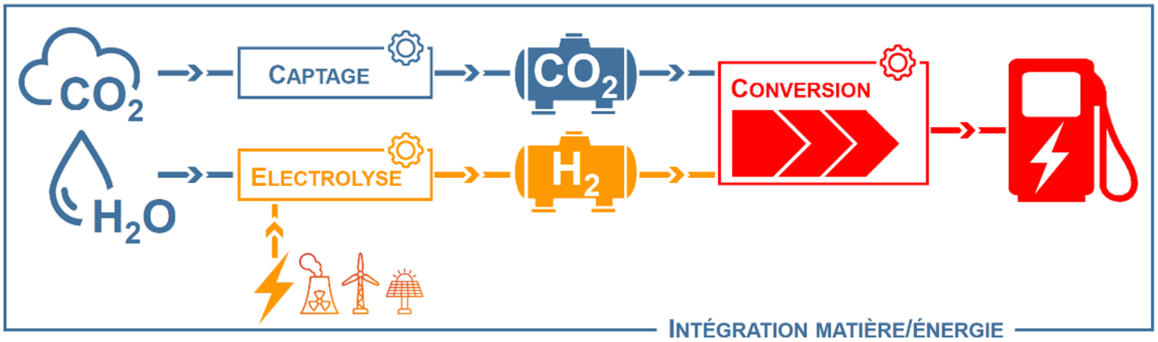
IFPEN

Biofuels and e-fuels

E-FUELS: CHALLENGES AND OPPORTUNITIES

Focus n°3

Towards a first value chain for the production of e-fuels



Several pathways for the production of e-fuels are currently under study, at various levels of maturity. The pathway based on CO_2 conversion with hydrogen, also known as Power-to-X, is the most mature to date and will be the first value chain for the industrial production of synthetic fuels. It must be deployed by 2030 to meet regulations targets for long distance transport (see Focus #1). It relies on three essential components: i) CO_2 capture, ii) hydrogen production from low-carbon electricity, and iii) CO_2 conversion into fuel(s). These components must be integrated efficiently to minimize investments, production costs and optimize energy and material yields, based on Life Cycle Assessment (LCA) analyses.

Regarding the capture of CO_2, the initial and most mature technologies aim at capturing concentrated CO_2 sources from industrial emissions of fossil or biogenic origin (concentration typically ranging from 6% to 30%). These technologies will have to be revisited and enhanced to enable the capture of atmospheric CO_2 (concentration around 400 ppm, or 0.04%) through Direct Air Capture (DAC) processes, as beyond 2040, in Europe, regulations mandate the exclusive use of biogenic or atmospheric CO_2 to produce synthetic fuels.

Hydrogen production is defossilized by using electrolysis with renewable or nuclear electricity. Alkaline electrolysis is currently a widely used technology, with efficiencies ranging from 60 to 70%, but it is not well-suited for the intermittency of renewable energies. Proton Exchange Membrane (PEM) electrolysis and High Temperature Electrolysis (HTE) technologies, which are more suitable for electrical intermittency, are undergoing intensive research and innovation to improve efficiencies (HTE achieving >80%).

The conversion of CO_2 and hydrogen into fuels consists of several steps, including:

- A first step converting CO_2 into CO, for example, through a reaction like RWGS (Reverse Water-Gas Shift), currently needing validation at an industrial scale, or through a co-electrolysis reaction (still to be matured),
- A second step converting CO in presence of H_2 into fuels, either through the Fischer-Tropsch process or through the methanol pathway, both technologies being industrially mature.

The less mature components need to undergo significant research and innovation efforts to scale up to an industrial level. The challenge also lies in integrating all components, including the mature ones, to form a complete, functional, and efficient value chain. Each component therefore needs to be developed and optimized within a systemic approach, including LCA analysis, to maximize energy and material efficiencies and minimize costs. For instance, one can mention the possibility of recovering the heat emitted by the Fischer-Tropsch synthesis to power an HTE or DAC system. The overall targeted efficiency of the complete chain is around 50 to 55%, to be compared with that of electrolytic

H_2, ranging from 60 to >80% depending on the technologies.

The entire chain, including its components and integration, is covered by the expertise of IFPEN and CEA R&I teams, including techno-economic studies and multi-criteria LCA. Other synthesis pathways are also under R&D, such as electrocatalysis and photoelectrocatalysis, biological pathways, and hybrid technologies.

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LES BRÈVES

ADEME: French energy transition agency (www.ademe.fr)
ANCRE: French National Alliance of Coordination of Research for Energy (www.allianceenergie.fr)
CBAM: Carbon Border Adjustment Mechanism
CCS: Carbon Capture and Storage
CCU: Carbon Capture and Utilization
COP: Conference of the Parties
DAC: Direct Air Capture
DME: DiMethyl Ether
EU: European Union
EU-ETS: EU Emissions Trading System
FuelEU: European law for shipping decarbonization (Fit for 55)
HTE: High Temperature Electrolysis
ICAO: International Civil Aviation Organization (www.icao.int)
ICM: Industrial Carbon Management
ICR: Industrial Carbon Removal
IEA: International Energy Agency (www.iea.org)
IPCC: Intergovernmental Panel on Climate Change (www.ipcc.ch)
LCA: Life Cycle Analysis
Mtoe: Millions tons of oil equivalent
NZE: Net Zero Emission by 2050 (IEA scenario)
PEM: Proton Exchange Membrane
PEPR: French Priority Research Programs and Equipments
Power-to-X: Approach consisting of transforming electricity into a chemical carrier such as an e-fuel or an e-molecule
RED: Renewable Energy Directive
ReFuelEU: European law for aviation decarbonization (Fit for 55)
R&D: Research & Development
R&I: Research & Innovation
RWGS: Reverse Water Gas Shift reaction
SAF: Sustainable Aviation Fuels
SGPE: French General Secretariat for Ecological Planning
SMF: Sustainable Maritime Fuels
TIRUERT: French incentive tax relating to the use of renewable energy in transport
TRL: Technology Readiness Level

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