EFCH2 2025

European Fuel Cells and Hydrogen

PIERO LUNGHI CONFERENCE

Book of Proceedings

September 17th–19th 2025

Capri / Italy

ATENA FUTURE TECHNOLOGY

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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European Fuel Cells and Hydrogen

PIERO LUNGHI CONFERENCE

Proceedings

OF THE 11TH EUROPEAN FUEL CELL PIERO LUNGHI CONFERENCE

To Piero Lunghi. We miss you a lot. To you our gratitude for ever.

This book is dedicated to the memory of Piero Lunghi, creator of the European Fuel Cell Technology and Applications Conference, dear friend and colleague, who prematurely passed away in a car accident on damned November 9, 2007.

Piero made significant contributions in the field of fuel cells in the course of his too short career. He was the leading figure in the formation of the fuel cell research group at the University of Perugia and several activities and research projects initiated by him are still ongoing.
This means that, thanks to Piero, many young people are working in this exciting research field and are coming to Naples to present their results. Therefore, Piero's memory is in the conference name but Piero's contribution is still in the contents of this book.
The memory of our friend Piero, his great personal generosity and energy, survives in our hearts, his contribution and his tenacity survive in the work of young people who carry on his vision throughout the world.

Give them your passion, your strength, and make all necessary effort to realize them. There is no greater satisfaction than seeing one's ideas become reality and become part of the future of our world.
Piero strongly desired this, and constantly followed this through with conviction, passion and dedication.

For a better future, we need young researchers of this kind.

European Fuel Cells and Hydrogen

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edited by

Viviana Cigolotti, Alessia Piccolo, Gabriele Loreti

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Contents

Electrosynthesis of Low-Carbon Olefins: A New Paradigm for Hard to Abate Industries

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Abstract

Low-carbon olefins, as important platform molecules, are generally produced by limited fossil energy, resulting in massive carbon emissions and intensive energy consumption inevitably. Therefore, it is necessary to develop clean and sustainable alternatives. With this in mind, the ECOLEFINS project was granted aiming to address these issues by introducing a new paradigm for the electrosynthesis of C_2-C_4 olefins using co-ionic electrochemical membrane reactors (ci-EMRs). This innovative approach captures and valorizes CO_2 to produce carbon-negative ethylene, propylene, and butylene, integrating anodic steam electrolysis for hydrogen production with cathodic CO_2 electrolysis and hydrogenation. Preliminary results indicate promising impacts on electricity requirements and economics, positioning the ECOLEFINS project to capitalize on the growing demand for sustainable chemical products and establish itself as a leader in the industry. This work presents preliminary findings from techno-economic analysis and life cycle sustainability assessment aiming to evaluate its feasibility and market potential.

Introduction:

The energy transition and emission reduction in the chemical industry are among the top global priorities in addressing climate change. As a significant energy-intensive sector, the chemical industry accounts for approximately 30% of global industrial energy consumption [1]. Its primary energy sources—oil and natural gas (NG)—serve both as energy carriers and as a feedstock for chemical production. Due to its heavy reliance on fossil fuels, the chemical industry is a major contributor to greenhouse gas (GHG) emissions, responsible for about 10% of global carbon dioxide (CO_2) emissions and 14.5% of direct industrial emissions [2]. Low-carbon olefins (i.e., ethylene, propylene, and butylene) are essential building blocks for producing polymers, fibers, plastic, and other organic chemical materials in the petrochemical industry [3]. Generally, steam cracking and fluid catalytic cracking of fossil-based naphtha and petroleum are currently common processes for low-carbon olefins production [4]. However, the energy-intensive traditional processes produce considerable CO2 emissions, resulting in serious climate, environmental and ecological problems [5]. Thus, it is necessary to develop sustainable and clean alternatives for producing low-carbon olefins. In this direction, ECOLEFINS project was granted to originally put forward a new paradigm for C2-4= electrosynthesis in co-ionic (H+ and O2-) electrochemical membrane reactors (ci-EMRs). The proposed concept reverses the heavy CO_2 emissions associated to the petroleum-based light olefins production to massive CO_2 capture and valorisation for carbon negative ethylene, propylene and butylene. The concept introduces co-ionic ceramic membrane reactors and short-stacks/modules that merge the anodic steam electrolysis for hydrogen production with the cathodic CO_2 electrolysis and hydrogenation to light olefins, over tailored and nano-engineered electrodes; aiming to develop a substantially more effective technology, for the single-step, RES-powered artificial photosynthesis of CO_2 to valuable chemicals (**Figure 1**).

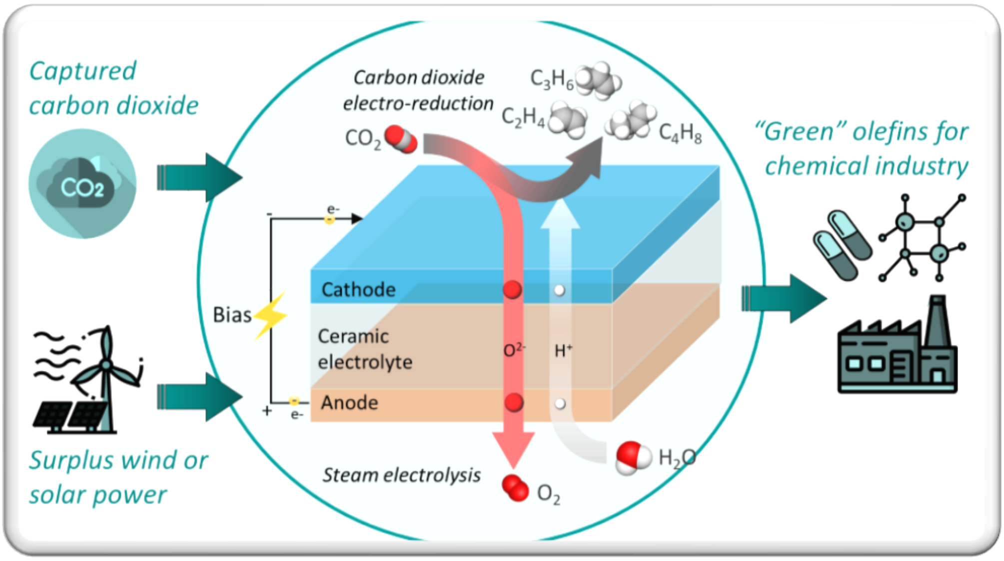

Figure 1. ECOLEFINS concept

The present work describes the ECOLEFINS concept and examines the impacts of the ci-EMRs' targeted performance on the electricity requirements and the economics of electrified C2-4=s, with respect to C2-4='s yields, ci-EMRs' specific resistance, electricity prices, carbon taxes and technology costs. A techno-economic analysis study is performed, in order to evaluate the technical and economic feasibility of the proposed process using different criteria: technical performance (carbon element efficiency and energy efficiency), environmental performance (emission CO_2-eq), and economic performance (unit production cost). In addition, major cost parameters are evaluated in sensitive analysis study that identifies the key strategies to make the proposed process feasible. Business models are investigated for the market scale up.

Objectives:

- To assess the techno-economic and sustainability prospects of EMR industrial applications aiming to digital modelling of real-scale integrated ci-EMR plants. This will form the base for evaluation of the economic feasibility and overall sustainability profile of ECOLEFINS concept.
- To investigate the social acceptance and marketization prospects within the sectors of: (i) light olefins current producers (refineries) and end users (chemical industries of C2-4= utilization), and (ii) solid oxide cells materials, cells and stack/module prototypes, as well as ci-EMR systems and integrated processes.
- To develop coherent business models for market scale up.

Material and methods:

- Life Cycle Sustainability Analysis (LCSA) is going to be conducted. This includes Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Analysis (S-LCA). LCA takes into consideration the involved energy as well as ci-EMR (cells, stacks and modules) materials flows, with special emphasis to critical ones (e.g. Co, Gd, La, Ce), along with water resources (potentially grey or black) and wastes (including emissions) and by-products (CO, CH4, HCs etc.).
- Business plans, business canvas, scenario, PEST and SWOT analyses, competitive matrices and projected balance-sheets
- Stakeholder mapping and analysis.

Results: Results are under development as the project currently examines the impacts of the ci-EMRs' targeted performance on the electricity requirements and the economics of electrified C2-4=s, with respect to C2-4='s yields, ci-EMRs' specific resistance, electricity prices, carbon taxes and technology costs. Furthermore, preliminary results of Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Analysis (S-LCA) are under development.

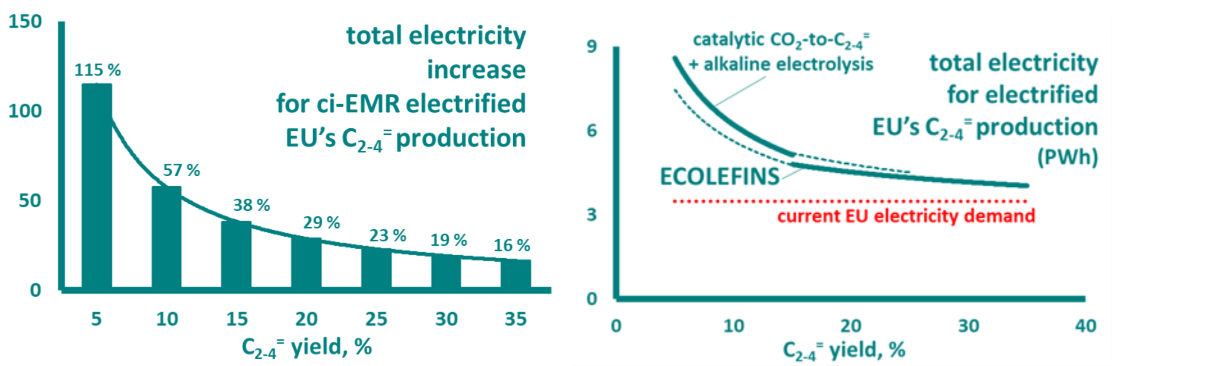

Figure 2. Total electricity increase for ci-EMR electrified EU's C2-4 production and comparison to ECOLEFINS

Conclusions: ECOLEFINS project is well-positioned to capitalize on the growing demand for sustainable chemical products. By adopting suitable business models and leveraging favorable market trends, the project can achieve significant market penetration and establish itself as a leader in the sustainable chemical industry. Strategic partnerships, continuous innovation, and a strong focus on sustainability are key factors to its success.

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