PRESS RELEASE

CONDOR project reaches the final stretch of its journey

Over 80% of the world's primary energy supply still depends on fossil fuels, highlighting the urgent need to decarbonize global energy systems to ensure a sustainable and secure future. In response to this challenge, the European project CONDOR "COmbined suN-Driven Oxidation and CO2 Reduction for renewable energy storage" was launched in November 2020. Funded under the Horizon 2020 programme and coordinated by the University of Bologna, CONDOR united leading European and international research institutions and industry partners to develop a solar-driven technology for converting carbon dioxide (CO_2) into renewable fuels and added-value chemicals.

Inspired by the principles of natural photosynthesis, CONDOR focused on creating a system where sunlight, combined with CO_2 and water, are converted into syngas – a versatile intermediate that can be further processed. Specifically, the project targeted the production of dimethylether (DME), a clean and sustainable fuel alternative, through an innovative and efficient process.

Compartment 1 was designed and built to include ten photoelectrochemical (PEC) cells and an integrated gas separator system, engineered by ENGIE. The primary objective was to create a photoelectrochemical cell capable of splitting water and CO_2 to generate oxygen and syngas—a mixture of hydrogen (H_2) and carbon monoxide (CO).

The work on Compartment 1 was a collaborative effort involving several partners. ICIQ synthesized molecular catalysts for photoelectrodes and developed p-type semiconductor photocathodes, while the University of Ferrara focused on the production, test and optimisation of n-type photoanodes and copper-based cathodes, as well as on the realisation of a lab-scale PEC cell comprising different catalytic materials. The University of Bologna investigated structure-property relationships related to catalytic activity and materials using advanced techniques and the photoxodiation of biomass-derived compounds to added-value chemicals. CNR-ISOF modeled reaction mechanisms and photocatalytic cycles while studying photoinduced processes on ultrafast time scales. The University of North Carolina At Chapel Hill performed operando transient absorption spectroscopy in the millisecond-to-second time range, and ENGIE Lab CRIGEN assembled the flow photoelectrochemical cell.

The completed Compartment 1 system consists of ten PEC cells, each with an active area of 10 cm^2, designed and fabricated from scratch. It features an electrolyte/syngas separator and a mechanism to saturate the electrolyte with CO_2. Power is supplied by photovoltaic (PV) cells, which provide the necessary voltage to drive the photochemical reactions. The methodology applied in the CONDOR project followed a systematic process. The pilot was first designed, including engineering and safety studies. In parallel, the PEC cells were fabricated, and the separator system was revamped.
Compartment 2 of the CONDOR project comprises a chemical reactor for syngas conversion, engineered by HYGEAR, with the primary goal of embedding a gas separator unit and a chemical reactor for the production of dimethyl ether (DME).

The work on compartment 2 was a collaborative effort involving multiple partners. The University of Utrecht focused on the catalytic conversion of syngas into final energy vectors, while the University of Bologna contributed through the preparation and photochemical characterization of photoactive silicon nanostructures. HYGEAR took the lead in processing syngas and designing and manufacturing the chemical reactor.

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In the second compartment, the syngas is transformed into methanol and dimethylether (DME), via bi-functional heterogeneous catalysts. A complex system consisting of various subsystems to go from contaminated syngas towards DME production has been developed, constructed, and installed.

The design process began with defining the system layout and developing the Process Flow Diagram (PFD), which mapped out the process flows and key components. Based on the PFD, heat and mass balances were calculated to ensure optimal performance. In the next phase, the PFD was translated into a detailed Piping and Instrumentation Diagram (P&ID), and all balance-of-plant components were selected and acquired. To ensure safe and reliable operation, a Hazard and Operability (HAZOP) analysis was conducted, identifying and mitigating potential risks or failures.

The two compartments of the CONDOR project were successfully made available, installed, and tested at the National Research Council of Italy (CNR) Research Area (ISOF Institute) in Bologna, Italy. This site was strategically selected for its proximity to the 45th parallel (44°31’22’’), offering optimal solar conditions. The photoelectrochemical Compartment 1 and the chemical reactor in Compartment 2 were evaluated under real-world conditions, demonstrating their functionality. Complementary activities included life-cycle assessment analyses and techno-economic evaluations, performed by ENGIE Laborelec and ENGIE Lab CRIGEN. Dissemination, communication, and exploitation efforts were coordinated by AMIRES, with active collaboration and valuable contributions from the entire consortium.

The official conclusion of the CONDOR project was marked by the CONDOR Final Conference, titled “From Sunlight to Molecules,” held on October 14th-15th, 2024, in Bologna, Italy, hosted at CNR-ISOF. The conference provided an invaluable opportunity for approximately 100 experts and young researchers from academia and industry to exchange ideas and insights. The event highlighted key aspects of the project, including artificial photosynthesis, CO_2 conversion, and advanced technology development. The conference culminated with a guided tour of the project’s testing sites at CNR, where participants could observe firsthand the practical implementation of CONDOR's research. The Final Conference served as a dynamic platform for the scientific community and stakeholders to engage with the project’s outcomes, fostering networking, collaboration, and knowledge sharing.

The high-quality research developed by CONDOR – in terms of new materials, stable electrodes, effective catalysts, advanced chemical engineering – has allowed to set up two fully operative technological compartments. Upon further studies, refinements, implementation, validation and testing – these can be fully integrated to accomplish a significant advancement in the production of solar fuels. In particular, progress on photoelectrochemical cell design and enhanced syngas production is anticipated to be the most relevant advancement needed.

More information about project outcomes, visit https://condor-h2020.eu/


Compartment 1


Compartment 2


Final public conference


CONDOR consortium

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