OBIWAN Project

OBIWAN aims at converting organic waste streams into advanced chemicals and sustainable aviation fuels. After an initial anaerobic digestion for biogas production, a mixture of CH_4 and CO_2, the further chemical conversion will harness the CO_2 in the final products. Excess carbon is then captured as solid carbon with applications in, e.g., gas cleaning and tires. In this manner, OBIWAN will generate technology to mitigate climate change, not only by avoiding greenhouse gas emissions but also by turning such gases into valuable products.

Two major innovations are targeted within the project:

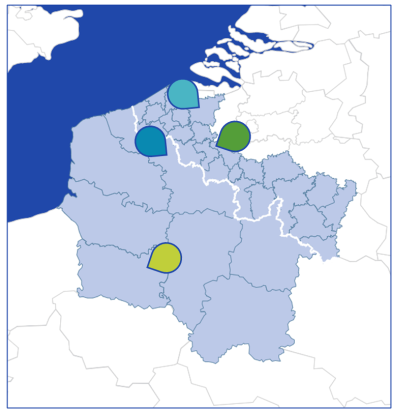
1) The conversion of biogas into chemicals/fuels ideally requires a biogas composition of 60% CH_4 and 40% CO_2 with a minimum of impurities. Considering the variance in substrate types and their seasonal changes, it is a major challenge, even at laboratory scale, to produce biogas with a stable composition. That is why the experimental measurements will be complemented by the development of an innovative numerical tool to simulate the process and give relevant control of the reactors to ensure the stable biogas production in terms of both production rate and gas composition.

2) The catalytic decomposition of methane into solid carbon with a H_2 rich gas as a side product is lately gaining popularity for the production of so-called 'turquoise' hydrogen of high quality. However, this typically comes at the expense of the solid carbon properties. Within OBIWAN, the aim is to bring the hydrogen-focused process from the laboratory scale to an industrially relevant one for which the proof of concept will be demonstrated in an original Electrothermal Fluidized Bed Reactor (ETFB).

Other significant innovations will be made with respect to biogas purification/separation as well as CO_2 hydrogenation into methanol.

OBIWAN Consortium

Ghent University · UTC / UniLaSalle · Certech · CNRS



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provincie Oost-Vlaanderen · VLAIO · Wallonie · CATALISTI · EuraMaterials · GreenWin · valbiom

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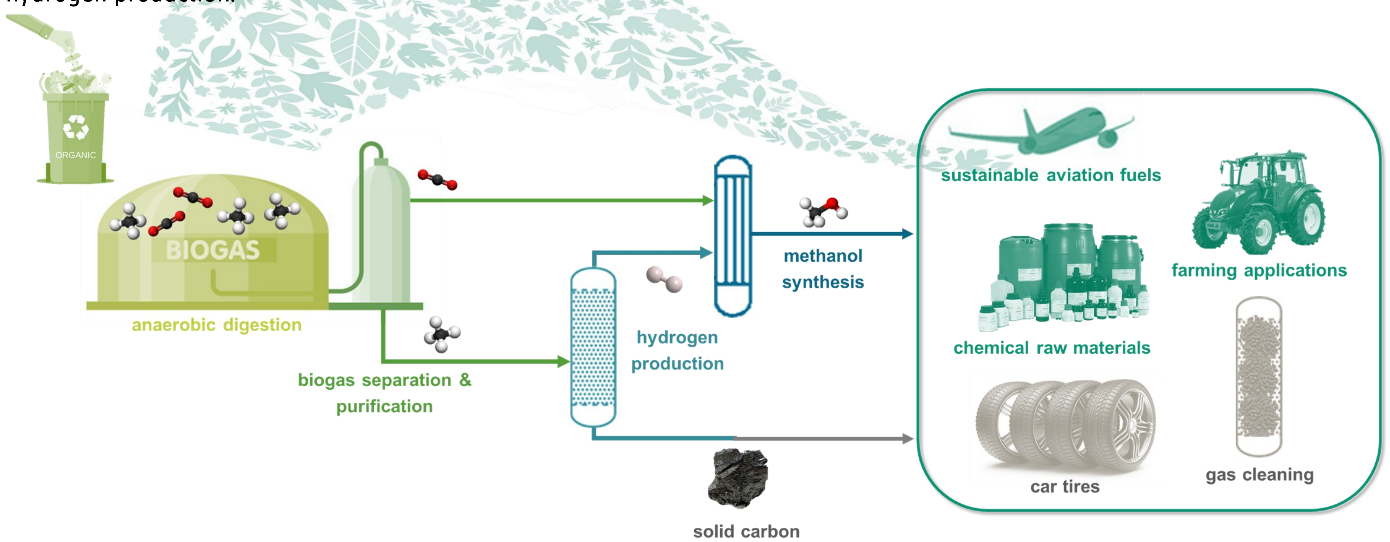
OBIWAN

OBIWAN Official ETFB Inauguration - 30/04/2026

Hydrogen is expected to play a key role in reducing emissions on the path toward a climate-neutral society with the expected annual production surging to 150 Mton by 2030. Nowadays, most hydrogen is still produced through conventional "grey" reforming processes, which are cost-effective but generate significant CO_2 emissions. Its blue counterpart, which captures a portion of these emissions, still results in considerable emissions and doubles the cost of hydrogen produced. Working with water as a feedstock as is the case for green hydrogen, on the other hand, comes also with increased costs due to the high energy demands.

What technology can overcome both challenges, high costs, high emissions? Methane pyrolysis with biomethane (CH_4 + CO_2) as feedstock offers a promising solution by directly splitting methane into hydrogen and solid carbon, avoiding CO_2 formation during the process. The OBIWAN project aims to advance methane pyrolysis as a superior technology by focusing on two key areas: 1) smart catalyst design for improved hydrogen yields and to tune the carbon by-product and 2) electrification of the reactor to further cut CO_2 emissions.

An electrothermal fluidized-bed reactor was opted in the OBIWAN project to investigate carbon-catalyzed, electrified methane pyrolysis as an innovative route for producing low-emission hydrogen alongside valuable solid carbon. A key challenge in this process is managing carbon deposition, which can cause blockages and pressure drops in conventional fixed-bed reactors. To address this, fluidization of the catalyst is employed, enabling improved heat distribution, continuous solids handling and stable operation at scale. The reactor design uses the Joule heating effect, selected over inductive or microwave methods for its strong scalability. In an electrothermal fluidized-bed reactor, two electrodes create a potential difference in the reactor that drives an electric current through the fluidized catalyst particles. Due to their intrinsic electrical resistance, the particles generate heat internally, delivering energy directly to the active reaction sites. This approach combines efficient, uniform heating with the operational advantages of fluidization, offering a promising pathway toward cleaner and cost-effective electrified hydrogen production.



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Within the OBIWAN project, in collaboration with Vinci Technologies and TMEC, a state-of-the-art electrothermal fluidized-bed reactor (ETFB) was designed and commissioned. This laboratory-scale test rig integrates advanced mechanical and electrical engineering expertise from the Laboratory of Chemical Technology, meeting the high-quality standards of our existing facilities.

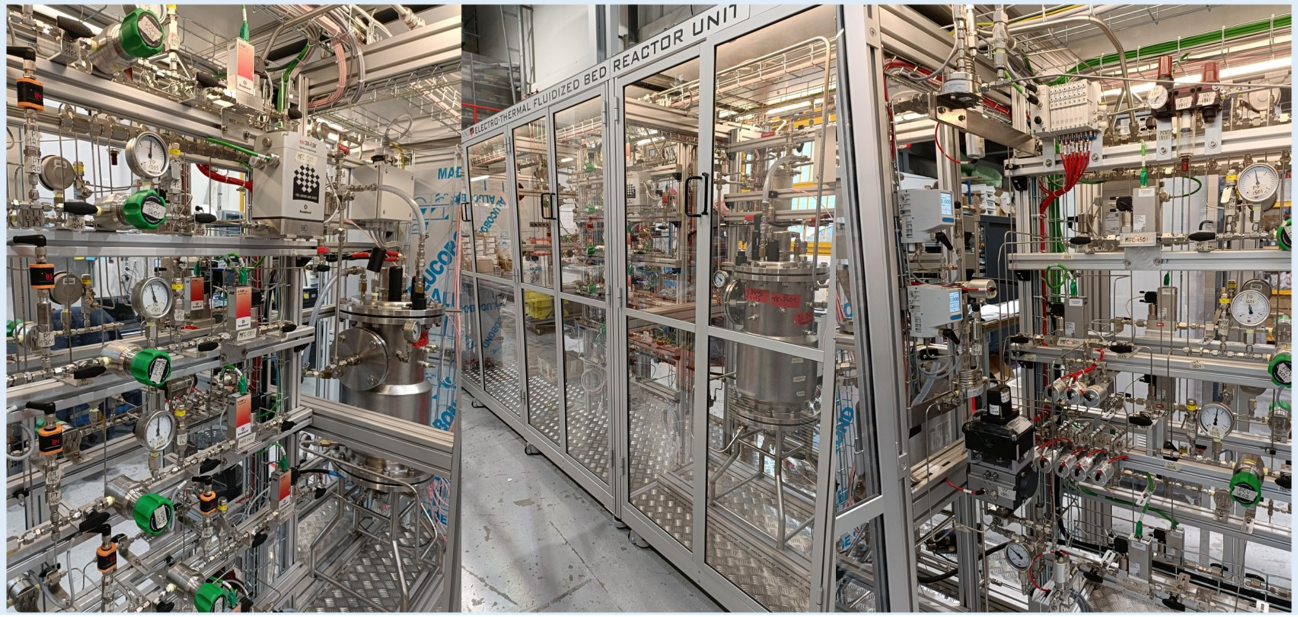
The setup comprises three main sections: 1) a feed unit where gases are prepared, mixed, preheated, and pressurized, 2) the reactor unit, housing the ETFB reactor for methane pyrolysis, and (3) an analysis unit with a back-pressure regulator, cyclone, condenser, and advanced gas analysis equipment (refinery gas analyser and gas chromatograph) to identify and quantify products ranging from light hydrocarbons to heavy polyaromatic compounds.

The feed section is divided into two parts, connected by a pneumatically controlled four-way valve. One part prepares reducing gas mixtures, methane, hydrogen, and optional hydrocarbons, diluted with argon or nitrogen. The other prepares oxidizing mixtures, air, oxygen, CO_2, steam, and inert gases for catalyst regeneration. The valve enables rapid switching between streams, directing one to the reactor while venting the other. Before entering the ETFB reactor, gases are preheated in the feed line. All flows are precisely regulated using thermal or Coriolis mass flow controllers from Bronkhorst.

In the ETFB reactor, the preheated gas mixture fluidizes the carbon catalyst particles. When a voltage is applied, an electric current flows from a centrally placed electrode through the fluidized bed to the reactor wall, which acts as the second electrode. Due to the resistivity of the particles, heat is directly generated to the catalytic sites. A frit combined with ceramic alumina beads at the reactor base ensures uniform gas distribution across the inlet. A water-cooling jacket helps maintain stable operating conditions. The ETFB reactor can be operated in manual or automated mode. In manual mode, the controlled variable is the reactor power, while the dependent variable is the temperature, influenced by power input, catalyst properties, pressure, and fluidization behaviour. In automated mode, the controlled variables are temperature and heating rate, while the dependent variable is the required power.

Some key figures of the reactor are:

- Bed diameter of 75 mm
- 700 – 1100 °C
- 1 – 3 bara
- 0 – 7 kW (ΔV_{max} = 90 V, I_{max} = 350 A)
- 250 g/hr CH_4
- Flexible central electrode immersion depth and material



Thanks to the reactor's design, crucial process parameters can be continuously monitored and logged for post-process analysis. These include fluidized-bed pressure differences, multiple internal temperatures, and bed pressure measurements, allowing for the analysis and validation of bubble dimensions.

Downstream of the reactor, a heated cyclone removes entrained solids, while a filter protects the Equilibar back-pressure regulator to ensure precise pressure control. A calibrated internal standard is introduced into the gas stream for quantification, and all post-reactor components are heated to prevent condensation, fouling, or blockages.

After the regulator, the stream is partitioned:

- Hydrocarbon Analysis: One line feeds a ThermoScientific gas chromatograph (FID) to detect hydrocarbons, including heavy polyaromatic compounds.
- Light Gas Analysis: The other line passes through a condenser to isolate heavy products. The remaining light gas is dried via a drierite filter and analyzed by a ThermoScientific refinery gas analyser. Using three dedicated channels, this system identifies and quantifies light gases including N_2, CO, CO_2, O_2, Argon, CH_4 to C5 hydrocarbons.

This reactor provides novel experimental insights into the interplay between three key pillars of the electrified methane pyrolysis process: 1) fluidization behaviour, 2) heating efficiency, and 3) reaction chemistry. By observing these factors in tandem within the ETFB reactor, researchers can better understand the synergies required to optimize the co-production of hydrogen and solid carbon and allow for scaling-up the process to industrial relevant levels.

To unravel the interplay between these factors, initial non-reactive experiments will assess the correlation between fluidization behaviour and heating efficiency. Conducted in N_2, these tests will vary the fluidization index, catalyst properties like density and diameter, and heating power. This approach enables the characterization of bed resistivity, a critical parameter for energy balance modeling, as a function of the fluidization index, catalyst properties, heating power, temperature, and pressure.

Finally, conducting experiments with reactive gas compositions will enable the deduction of how high-temperature pyrolysis chemistry affects fluidization behaviour and heating efficiency. This primarily involves assessing how pyrocarbon deposition during methane pyrolysis, and the associated changes in carbon structure, properties, and catalyst diameter, influences the system. Furthermore, secondary effects such as agglomeration, attrition, electrode fouling, soot formation, and potential electrode-particle arcing will be investigated.

To scale the reactor from laboratory to industrial grade, multi-scale modeling of the electrothermal fluidized-bed reactor will be conducted using the gathered experimental data. These models will predict how performance varies across different scales, flow rates, and heating powers and allow for design of industrial scale reactors. Herein, microkinetic models, coupled with mass and heat transfer balances, both on the particle and reactor scale, will be developed via two methods: a 1D two-phase fluidized-bed reactor model spanning various fluidization regimes and a particle-resolved CGDEM-CFD model. This simulation will resolve Joule heating at the particle scale by directly incorporating the effect into the CFD model framework.