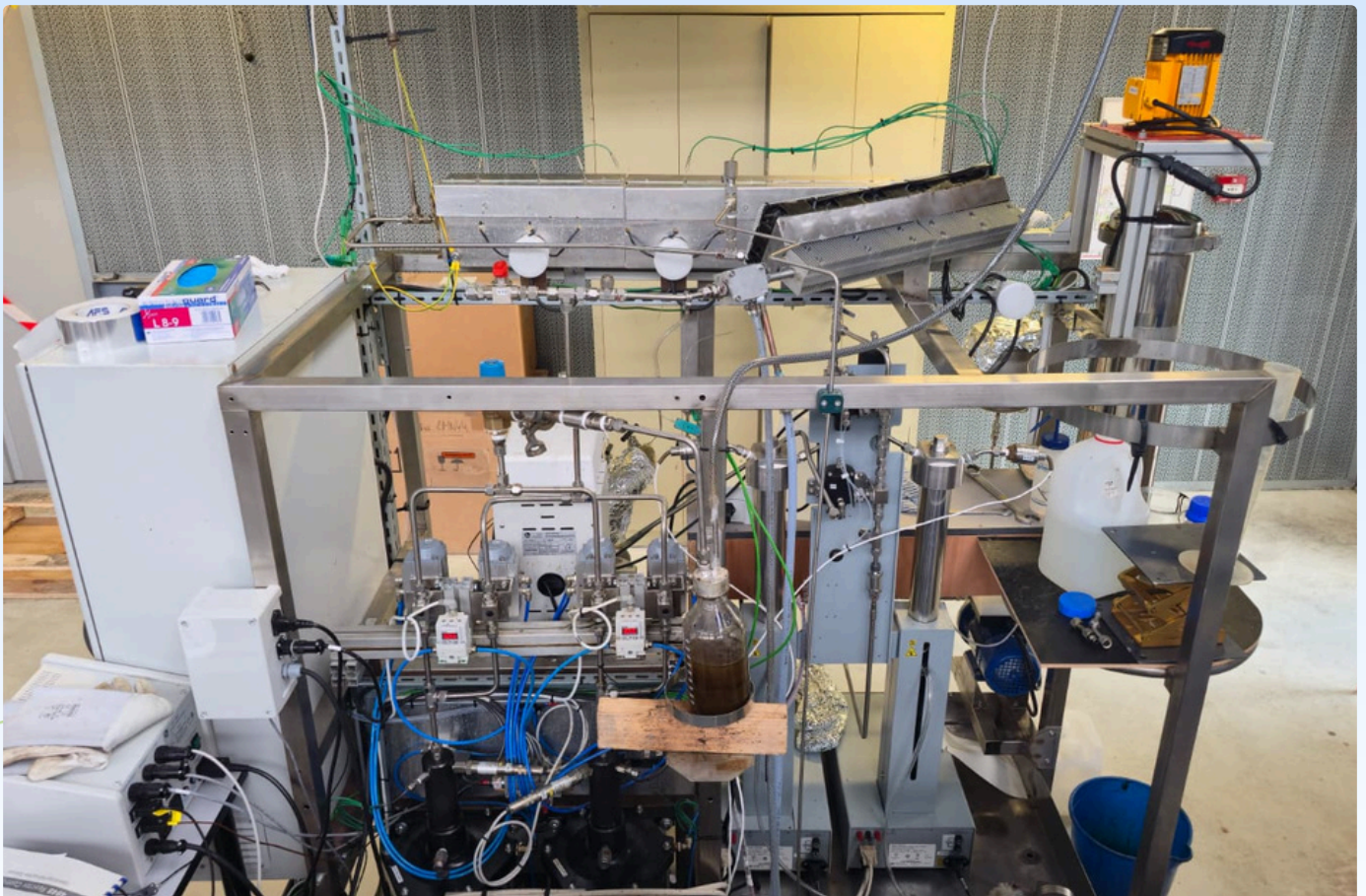


Development and Experimental Validation of an Innovative Continuous HTL Pilot Reactor

During the first 18 months of the project, IMT Atlantique designed and built a pilot-scale continuous Hydrothermal Liquefaction (HTL) reactor to investigate operating conditions, optimize the HTL process, and study fouling mechanisms. The reactor was commissioned and operated during the following 18 months through dedicated experimental campaigns.

Developed by the technical team of IMT Atlantique's Energy Systems and Environmental Engineering Department, in collaboration with AAU's Department of Energy and under the supervision of Prof. Sary Awad, the reactor introduces an innovative configuration combining a Continuous Stirred-Tank Reactor (CSTR) and a Tubular Reactor (TR) in series.

This design aims to reduce clogging and fouling issues encountered in previous continuous HTL systems, enabling longer and more stable operation. It is the first continuous HTL reactor installed at IMT Atlantique, where previous research focused primarily on batch-mode solvolysis.



Source: IMT Atlantique

Reactor design

The pilot-scale continuous HTL reactor is designed to ensure stable operation under high-pressure and high-temperature conditions while enabling precise control of the process. The system is equipped with a high-pressure feed pump that continuously supplies the biomass slurry to an electrically heated **Continuous Stirred-Tank Reactor** (CSTR), followed by a **Tubular Reactor** (TR) connected in series. This innovative configuration combines the mixing efficiency of the CSTR with the plug-flow characteristics of the tubular reactor, helping to reduce fouling and clogging while improving process stability. After the reaction, the process stream is rapidly cooled through a fan-cooled fin heat exchanger before entering a pneumatic hydraulic pressure-control system. This system, based on two cylinders operating sequentially, enables controlled depressurization of the reactor and the safe discharge of the reaction products into an atmospheric collection tank.

Experimental validation

In the 18 months following the construction of the reactor, two experimental HTL campaigns were successfully carried out using protein-rich and lipid-rich microalgae supplied by NU through the Algosolis platform. The campaigns investigated the influence of key operating parameters, including:

- CSTR volume
- Flow rate
- Residence time
- Residence time distribution between the CSTR and the tubular reactor

The objective was to identify the optimal operating conditions to maximize biocrude yield while extending the duration and stability of continuous reactor operation. The results were highly encouraging, with biocrude yields exceeding 40% for protein-rich microalgae and 60% for lipid-rich microalgae, outperforming the yields previously obtained during batch-scale screening of the same feedstocks. These findings confirm the potential of the new reactor configuration to enhance both process efficiency and continuous operation.

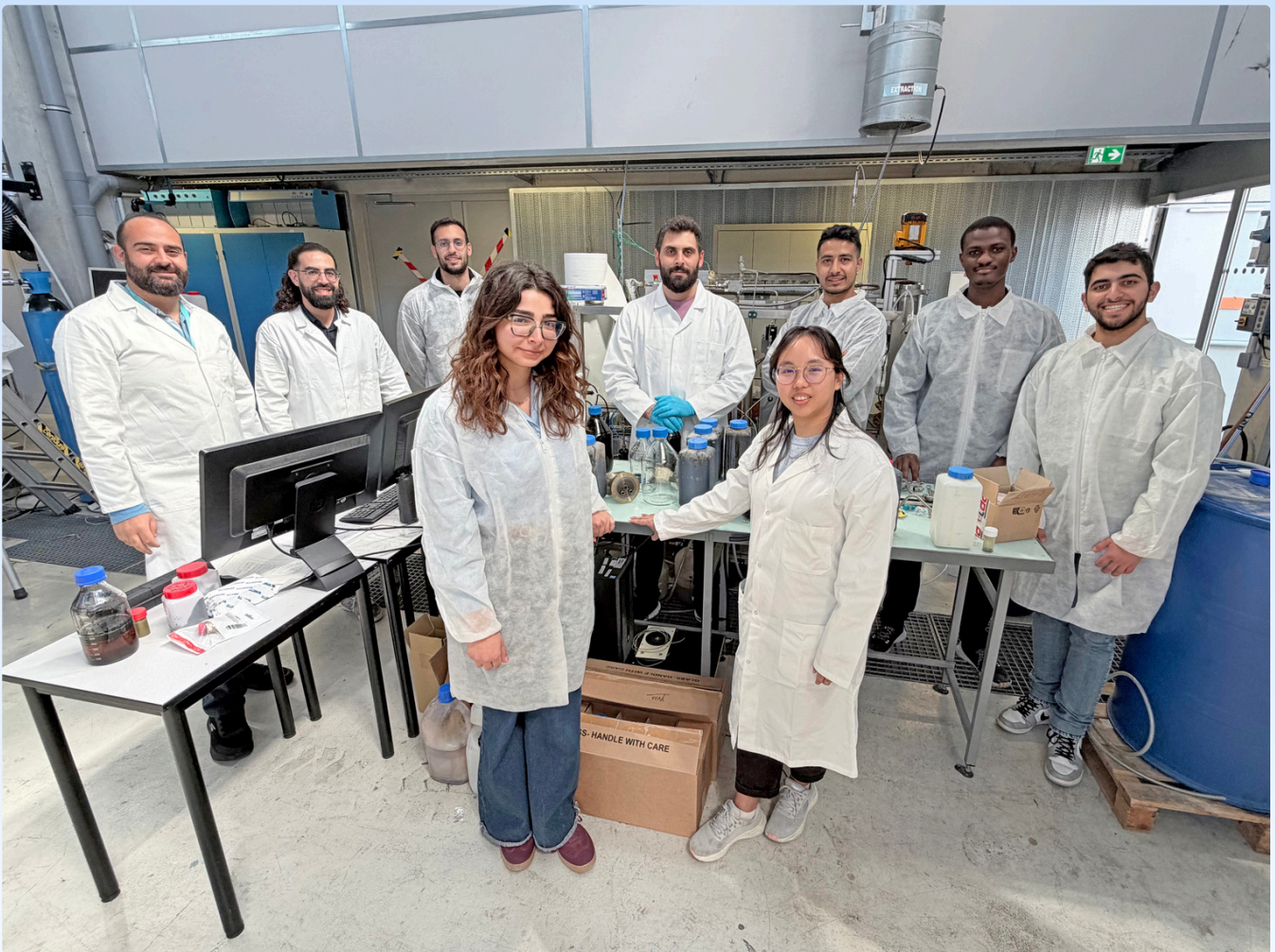
Key results

- Biocrude yield >40% from protein-rich microalgae
- Biocrude yield >60% from lipid-rich microalgae
- Higher yields than those previously achieved in batch HTL experiments using the same feedstocks
- Approximately 30 hours of cumulative operation per campaign, demonstrating stable performance with limited fouling

Fouling mitigation and digital modelling

The reactor also serves as a platform to investigate fouling and clogging mechanisms. A dedicated detection methodology is under development to identify the causes of deposit formation and support mitigation strategies. Reducing fouling will increase continuous operating time, minimize downtime for cleaning, and improve overall biocrude production by limiting losses associated with start-up and shutdown.

In parallel, operational data are being integrated into COMSOL Multiphysics® models to simulate reactor behaviour and develop a digital test bench capable of predicting system performance under different operating conditions. This modelling framework will support process optimization and facilitate future reactor scale-up.



Source: IMT Atlantique