REFOLUTION
Unlocking the potential of biofuels

REFOLUTION Project newsletter
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Biofuels for the Future: Project Progress & Technical Insights

Content

1. Introduction

As the REFOLUTION project continues to advance toward innovative solutions for integrating renewable feedstocks into existing refining infrastructure, we are pleased to share updates and key findings from recent activities.

Over the past two and a half years of research we participated in international conferences as EUBCE and EuropaCat, our colleagues at VTT organized a workshop to discuss the role of biofuels and the future of mobility, and new ideas for refinery integration have begun to take shape.

To learn more about REFOLUTION's latest developments, we invite you to read the newsletter, and don't forget to **follow us** and contact us to stay updated.

2. EUBCE 2025

The REFOLUTION project participated in the 33rd European Biomass Conference & Exhibition (EUBCE), held in Valencia, Spain, from June 9 to 12, thanks to the presence of project coordinator **SINTEF** and partner **MOEVE.** Our colleague Elena Pérez Guevara from MOEVE presented a poster titled "Co-processing Biocrudes with VGO in an FCC-MAT Unit: Influence of Feedstock Composition on Conversion, Product Yields, and Catalyst Performance," detailing MOEVE's work on FCC co-processing for biofuel production carried out as part of the REFOLUTION project. This crucial study evaluated the Fluid Catalytic Cracking (FCC) co-processing of Vacuum Gas Oil (VGO) blended with three Fast Pyrolysis Bio-Oil (FPBO) variants—untreated (SPO), mildly upgraded (SDPO), and hydrotreated (HPO)—to integrate bio-based feedstocks into existing refinery operations. Tests conducted using a Micro Activity Test (MAT) unit demonstrated that the Hydrotreated Pyrolysis Oil (HPO) is the most suitable FPBO for FCC co-processing due to its lower oxygen content and superior performance. HPO improves conversion rates and provides higher yields of LPG and light olefins, although this results in reduced gasoline yields. Conversely, lower-grade bio-oils (SPO and SDPO) showed lower conversion and higher coke yields, underscoring the negative impact of oxygenates on catalytic efficiency, yet still supporting the conclusion that co-processing FPBOs is a viable route for biofuel production.

In addition to the scientific contributions, this year's REFOLUTION Visibility Point served as a valuable engagement hub. Many conference participants stopped by to learn more about the project's goals, research methods, and results. Discussions focused on the project's approach to refinery integration, process scale-up, and certification pathways for the production of aviation and marine biofuels.

EUBCE 2025 - Matteo Gilardi, Bernd Wittgens, Filippo Bisotti (SINTEF)
REFOLUTION Visibility Point
Credit: ETA Florence

EUBCE 2025 - Simona Alpi (ETA), Elena Pérez Guevara (MOEVE)
REFOLUTION Visibility Point
Credit: ETA Florence

3. Hydroprocessing of stabilized pyrolysis oils at moderate pressure

From August 31 to September 5, the REFOLUTION project participated in **EuropaCat 2025**, the 16th European Congress on Catalysis, held in Trondheim, Norway. Organized by the Nordic Catalysis Societies under the European Federation of Catalysis Societies (EFCATS), the event offered a platform to showcase innovative research in the field of catalysis.
Thanks to our SINTEF colleague Nikolaos Tsakoumis, the work carried out as part of the project on the hydroprocessing of stabilized pyrolysis oils under moderate pressure was successfully presented. Nikolaos presented a poster outlining the rationale behind the research, explaining the methodology and materials used, and concluding with a discussion of the results obtained.

Bio-oils derived from fast pyrolysis of biomass are rich in reactive unsaturated compounds and oxygenates, making them unstable. To improve their stability before further upgrading, they typically undergo a mild hydrogenation stabilization step. This study focused on the hydrodeoxygenation (HDO) of stabilized pyrolysis oil (SPO) under moderate hydrogen pressure (50 bar) at temperatures between 340–380 °C.
Three catalysts were tested: two commercial (NiMoS and CoMoS) and one in-house developed NiMoS supported on SiO_2. Experiments were conducted in a multi-zone fixed-bed reactor, enabling temperature variation across reactor zones.

Gas and liquid products were analyzed by chromatography (TCD/FID for gases, FID/MS for liquids), while physical properties like density, water content, oxygen content, and distillation curves were also evaluated.
The study successfully demonstrated the technical feasibility of SPO hydrodeoxygenation at semi-pilot scale under industrially relevant conditions. Using mildly crushed pellets of commercial $NiMoS/Al_2O_3$, a stable one-step upgrading process was achieved, minimizing side reactions such as oligomerization and gum formation. The product separated into a black oil phase with <4 wt.% oxygen and a clear aqueous phase.
A significant oxygen content reduction was observed—from approximately 37 wt.% in the feedstock to 3 wt.% in the final bio-oil product at 380 °C.

EUROPACAT 2025 - Nikolaos Tsakoumis (SINTEF)
Credit: SINTEF

4. Identification of main contaminants in pyrolysis oils

The REFOLUTION project continues to make progress toward the production of advanced biofuels for the marine and aviation sectors. To achieve this goal, it is essential that pyrolysis oil, a bioliquid intermediate easily produced from lignocellulosic biomass and waste, be stabilized at low temperatures before it can be co-processed in the refinery.
Crude pyrolysis oil presents a number of challenges that prevent its direct use as a fuel, including high instability, high acidity (with a pH typically between 2 and 3), and significant water content (20–30% by weight). Stabilization is crucial to improving the storage, transport, and usability of the bio-oil.

While traditional hydrotreatment (HDO) stabilization processes operate at high pressure and temperature, resulting in high hydrogen consumption, the low-temperature catalytic stabilization process developed by BTG (Biomass Technology Group) is significantly less energy-intensive and requires much less hydrogen. This makes the BTG process a more economical and practical solution for oil upgrading.
Colleagues at CNRS, in collaboration with the BTG team, focused on overcoming a key technical challenge at this stage: the slow loss of activity of the proprietary catalyst during the process.

The central hypothesis guiding the D3.5 study was that some of the numerous components present in the pyrolysis oil could act as actual catalyst poisons.
To identify these potential poisons, specific laboratory-scale experiments were conducted in a fixed-bed reactor, operating at set conditions of 70°C and 60 bar. In these tests, the pyrolysis oil was spiked with compounds representing entire chemical families:

1. Sulfur Poisoning
Sulfur compounds are known to strongly adsorb onto catalysts. The pyrolysis oil used contained 36 ppm sulfur. The researchers added methylthiophene (a sulfur-containing component) to the oil. The results showed that the sulfur-spiked oil did not accelerate catalyst deactivation. Consequently, the sulfur-containing components were not identified as the primary culprits of deactivation under the applied conditions.

2. Impact of Aldehyde Compounds
The effect of furfural, which contains an aldehyde group, was studied. Although the adsorption of oxygenated components could be a cause of deactivation or coke formation, no difference in stability was observed when the oil was spiked with furfural. This ruled out furfural and aldehyde groups in general as the cause of deactivation.

3. Role of carboxylic acids

Pyrolysis oil contains nmerous organic acids, including acetic acid, which is present in the highest concentration. Adding acetic acid resulted in lower hydrogen conversion; however, once the dilution effect was corrected, a similar trend in activity was observed. Carboxylic acids can also be ruled out as catalyst poisons.

Characterization analyses of the spent catalyst confirmed that the samples treated with the added components showed reduced but very similar surface areas (BET), consistent with the observation that these components had no significant effect on catalyst aging.

Since the main groups of compounds tested were not found to be the primary culprits, the investigation is ongoing. Future experiments will focus on investigating the impact of other potential poisons, including levoglucosan, dicarboxylic acids, minerals and water, to fully unravel the cause of this loss of activity and optimize the stabilization process.

Credit: Canva

5. Evaluation of fuel blend related to marine fuel standards on the basis of analytical results

In addition to analyzing catalyst stability during pre-treatment, the REFOLUTION project also conducted a validation analysis of the resulting product: hydrodeoxygenated pyrolysis oil (HPO). The primary objective of the work, led by UROS, was to evaluate the basic suitability of the resulting fuels and their blending behavior with conventional and alternative marine fuels.

The analyses conducted on several HPO samples, in accordance with the marine fuel standard DIN EN ISO 8217, yielded extremely encouraging results.

All measured values formally demonstrated that a suitable fuel fraction can be obtained from hydrogenated pyrolysis oil.

In particular, the HPO samples stood out for their excellent cold behavior (with very low cloud and pour points), very low water content, low total acid value (e.g., 0.05 mgKOH/g), and sulfur content of less than 1 ppm. Chemical characterization revealed that HPO is composed predominantly of hydrocarbons, mostly cyclic, aliphatic, and aromatic.

A key aspect was investigating the miscibility of HPO with other fuels.

Preliminary blending tests demonstrated that HPO exhibits good miscibility with marine diesel fuel (DMB), hydrotreated vegetable oil (HVO), and fatty acid methyl ester (FAME) at various concentrations.

The only exception noted was incomplete miscibility with methanol; however, this low miscibility opened an interesting prospect: HPO could act as an ignition pilot fuel to make methanol, inherently nonflammable in diesel engines, a future marine fuel.

Despite the positive miscibility results, accelerated stability tests (conducted at 80°C for 14 days) revealed a critical issue. Although all blends maintained stable density and viscosity values, the formation of insoluble sediments was observed in pure HPO and in some blends. The formation of these sediments was observed starting on day 7 in pure HPO, but was accelerated (starting on day 3) in blends containing FAME. Furthermore, the presence of copper (a common material in fuel tanks) appears to further accelerate the formation of these sediments. Although the sedimentation was low, even minimal amounts of copper can cause problems with engine performance.
In conclusion, the colleagues' work highlights the need for further research to fully understand the reasons for this formation and identify methods to prevent it, thus ensuring optimal performance and long-term storage stability.

Credit: Canva

6. Biofuels and Travel: Citizen Perspectives from the VTT Workshop

As part of REFOLUTION, Nina Wessberg and Hanna Saari of VTT Technical Research Centre in Finland organized a workshop that brought together 15 citizens who regularly travel by air or international shipping to discuss the role of biofuels and the future of travel.

The workshop featured experts such as Professor Ilkka Leinonen (LUKE) on the sustainability of bio-based raw materials and Professor Joel Pakalén (Haaga-Helia) on the future of travel and tourism. The participants, recruited by an external service provider, represented a diverse age group (40% between 46 and 65) and a high level of education (79% with tertiary education), with 8 men and 7 women.

What emerged from the event? Participants demonstrated an overall positive attitude towards biofuels, viewing them as a more sustainable alternative to fossil fuels. They recognized that biofuels can be used in current vehicles without the need for radical new infrastructure, which is perceived as a sustainable advantage. Furthermore, they also considered biofuels as a necessary transitional solution before full electrification becomes possible across all sectors.

However, several key concerns and doubts emerged:

Availability and sustainability of raw materials
Citizens expressed strong concerns about the sustainable origin of raw materials. There are concerns that biofuels could be used for ”greenwashing” if the source is not transparent, for example, if they are derived from burning forests or from crops on land that could be used for food production. It is essential that biofuels are produced sustainably, for example from waste.

Cost and consumer choice
Participants clearly stated that biofuels must be priced at or below that of fossil fuels to become a viable choice for consumers. Responsibility for the sustainability transition in the travel industry falls primarily on regulators and companies, not individual consumers, who tend to prioritize cost and convenience when booking.

Information and Transparency
There is a clear need for more visible and understandable information on the sustainability aspects of travel, such as the types of fuel used and carbon emissions. The ability to easily compare options could influence behavior. Currently, tracking the origin of biofuel raw materials is not possible for consumers.

Credit: Canva

The Future of Travel: Changes and Expectations

Overall, the workshop highlighted citizens' strong interest in sustainable solutions in the travel sector and the potential role of biofuels. The concerns raised underscore the need for greater transparency, accessibility, and a policy framework that actively supports the transition. REFOLUTION is committed to unlocking the potential of biofuels and addressing these critical challenges.

To learn more about VTT event click here.

7. REFOLUTION next activities

On December 11, 2025, a webinar will take place focusing on one of the key challenges in the transition toward sustainable energy, entitled "Building Social Acceptance for Biofuels and Carbon-Neutral Fuels in Europe".
The event is organized in collaboration with four projects from the SUSTAFUELS Cluster — CAPTUS, COCPIT, SUSTEPS, and NIAGARA and will bring together experts, researchers, and stakeholders to explore how communication, transparency, and local engagement can foster greater societal acceptance of sustainable fuels across Europe.
Throughout the webinar, participants will have the opportunity to:

- Take part in an interactive CAPTUS survey led by the University of Genova;
- Learn more about the ongoing work on social acceptance carried out within the SUSTEPS, COCPIT, and NIAGARA projects;
- Discover citizen perspectives from the REFOLUTION Project study conducted by VTT.

For REFOLUTION, the webinar offers a valuable chance to present VTT's research findings on social acceptance, building on the knowledge and experiences collected during the first workshop held in Marseille (France) at EUBCE 2024 and the second workshop held in Tampere (Finland).

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The REFOLUTION project started in January 2023 and will end in December 2026. Coordinated by SINTEF, the project brings together 14 partners from 8 European countries, driven by strong industrial leadership, the consortium includes key market players across the resource-process (upstream/reactor/catalyst/downstream) product spectrum. This ensures a powerful driving force for technology development throughout the entire production chain, addressing challenges in critical EU sectors related to energy and transportation.

Partners

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