BioMates

Public Summary of Deliverable D2.03: Report on the electrochemical hydrogen compressor and purifier performance during validation testing

Version 03

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1. Introducing BioMates

1.1. The BioMates Project

The BioMates project aspires in combining innovative 2nd generation biomass conversion technologies for the cost-effective production of *bio*-based inter*medi**ates*** (BioMates) that can be further upgraded in existing oil refineries as renewable and reliable co-feedstocks. The resulting approach will allow minimisation of fossil energy requirements and therefore operating expense, minimization of capital expense as it will partially rely on underlying refinery conversion capacity, and increased bio-content of final transportation fuels.

The BioMates approach encompasses innovative non-food/non-feed biomass conversion technologies, including **ablative fast pyrolysis (AFP)** and single-stage **mild catalytic hydroprocessing (mild-HDT)** as main processes. Fast pyrolysis in-line-catalysis and fine-tuning of BioMates-properties are additional innovative steps that improve the conversion efficiency and cost of BioMates technology, as well as its quality, reliability and competitiveness. Incorporating **electrochemical H_2-compression** and the state-of-the-art **renewable H_2-production** technology as well as **optimal energy integration** completes the sustainable technical approach leading to improved sustainability and decreased fossil energy dependency. The overall BioMates-Concept is illustrated in Figure 1.

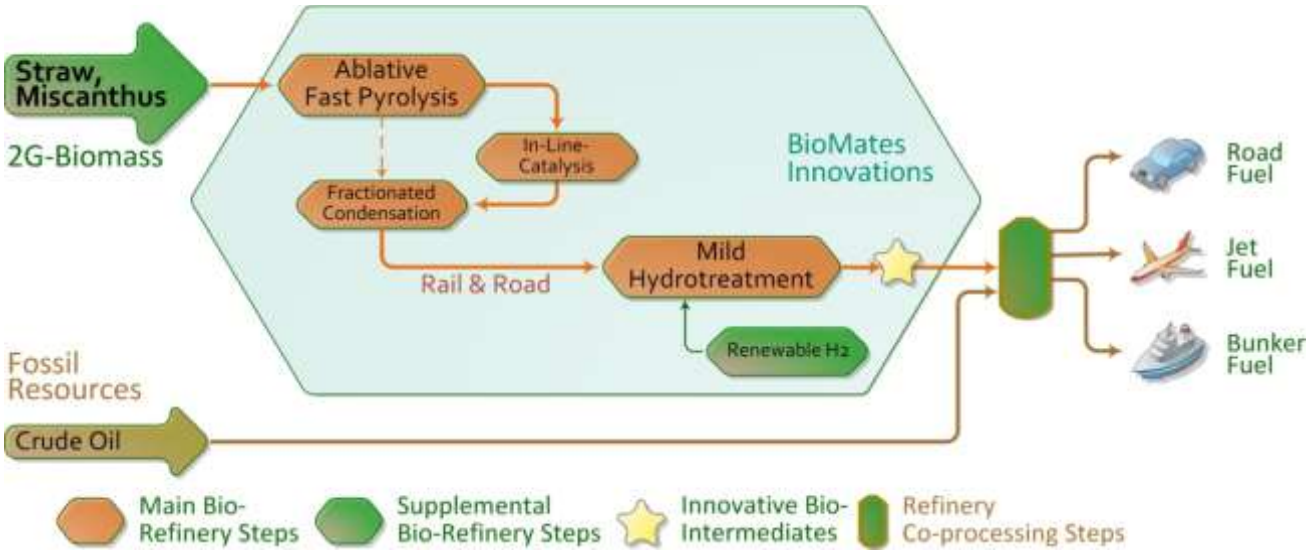

Figure 1: The BioMates-concept

The proposed technology aims to effectively convert residues and non-food/feed plants or commonly referred to as 2nd Generation (straw and short rotating coppice like miscanthus) biomass into high-quality bio-based intermediates (BioMates), of compatible characteristics with conventional refinery conversion units, allowing their direct and risk-free integration to any refinery towards the production of hybrid fuels.

1.2. European Commission support

The current framework strategy for a Resilient Energy European Union demands energy security and solidarity, a decarbonized economy and a fully-integrated and competitive pan-European energy market, intending to meet the ambitious 2020 and 2030 energy and climate targets /EC-2014a, EC-2014b/. Towards this goal, the European Commission is supporting the BioMates project for validating the proposed innovative technological pathway, in line with the objectives of the LCE-08-2016-2017 call /EC-2015/. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727463.

1.3. The BioMates team

The BioMates team comprises eight partners from industry, academia and research centres:

- Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany (Project Coordination) - *www.umsicht.fraunhofer.de*
- Centre for Research & Technology Hellas / CERTH - Chemical Process & Energy Resources Institute / CPERI, Greece - *http://www.cperi.certh.gr/*
- University of Chemistry and Technology Prague, Czech Republic - *http://www.vscht.cz*
- Imperial College London, United Kingdom *www.imperial.ac.uk*
- Institut für Energie und Umweltforschung Heidelberg GmbH / ifeu, Germany - *www.ifeu.de*
- HyET Hydrogen B.V. / HyET, The Netherlands - *www.hyet.nl*
- RANIDO, s.r.o., Czech Republic *http://www.ranido.cz/*
- BP Europa SE, Germany www.bp.com/en/bp-europa-se.html

For additional information and contact details, please visit *www.biomates.eu*.

2. Disclaimer

This Deliverable report reflects only the authors' view; the European Commission and its responsible executive agency INEA are not responsible for any use that may be made of the information it contains.

3. Preface

The deliverable summarized in this report comprises (a) the development and assembly of an innovative renewable H_2 system, and (b) its testing.

Developing and assembling the system had been done well in time and the corresponding Milestone MS06 "Innovative Renewable H_2 System Developed" had been reached one month ahead of schedule, delivering the electrochemical H_2-compressor (EHC) needed by the partners in overall WP2.

Achieving the test results to validate that the Key Performance Indicators (KPIs) are met was more challenging: by improving the cell hardware, as well as the test equipment, the KPIs are all met in September 2018, later than the original due date.

4. Electrochemical hydrogen compression

The working principle of the electrically driven Electrochemical Hydrogen Compression/Purification process (figure 2) consists of three steps:

1) Anodic, selective electro-catalyzed oxidation of molecular hydrogen to protons
2) Subsequent migration of these protons through a proton exchange membrane
3) Cathodic, electro-catalyzed reduction of the protons back to molecular hydrogen (at elevated pressure) on the other side of the membrane

Electrochemical hydrogen pumping is selective, leaving electrochemically inert gases untouched, making the method suitable for purification (EHP) and compression (EHC) on the condition that the membrane and cell hardware integrity are maintained. The process is silent and allows for direct electrical flow control.

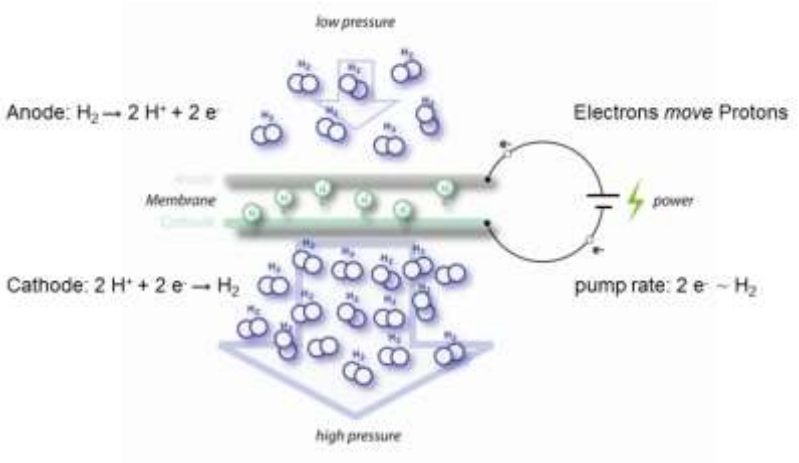

Figure 2: Electrochemical hydrogen compression and purification working principle

The electrode typically is coated on the membrane as an ink containing Pt/C catalyst, ionomer dispersion, an organic solvent and water.

5. Public summary

For the project BioMates, HyET has developed an electrochemical hydrogen purification and compression system (EHC/EHP) that can compress and recover hydrogen for the hydrotreatment of bio-oils, which is to be tested at the facilities of the Centre of Energy Research Thessaloniki (CERTH). This pilot-scale test (25 Nl H_2/h) can be considered as an exploration of the EHC system integration in preparation for the full scale (180 Nl H_2/h) validation test later on.

A dedicated mobile test system was built to provide the required Balance-of-Plant for controlling process conditions for the newly developed EHC stack (see figure 3).

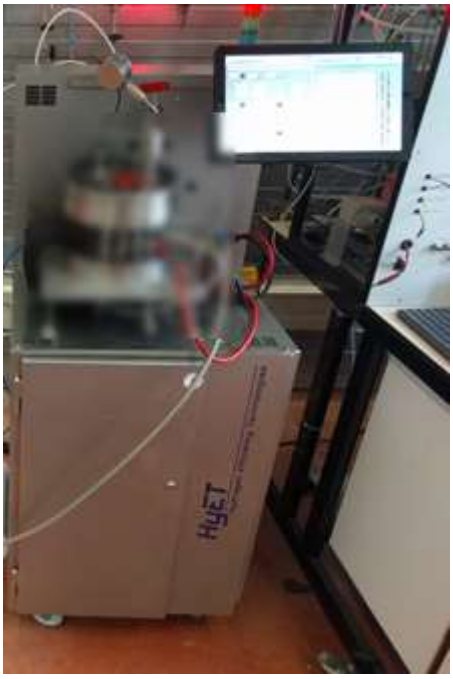

Figure 3: The mobile test system with the newly developed EHC stack installed

The system can be operated by means of a touchscreen connected to a PC, interfacing with the software and hardware process controller. Automated process sequences can be programmed in the control software. It has the capability to control both voltage and current of the EHC stack. The feed gas humidity can also be carefully controlled, which is critical for good EHC membrane performance.

Third party operability has been proven by a consortium partner of HyET in another EU funded R&D project called MEMPHYS (Grant agreement no. 735533).

The development of the EHC platform HCS100 has focused on two aspects: the membrane electrode assembly (MEA) and the cell plate.
For the electrode in the MEA, new ink recipes have been developed, characterized, tested and one has been selected that has improved the current density with 40%.
The development of the cell plate targeted the improvement of gas tightness together with the proper electrical contact inside the cell. This was a challenging task because a proper areal gas distribution, minimum pressure drop and sufficient support of the MEA counteract the gas tightness and electrical contact.

The EHC platform HCS100 has shown compression to 210 and 410 bar, which is well above the BioMates target of 150 bar. The compression of pure hydrogen also showed that the energy demand can be as low as 4 kWh/kg, another target of the BioMates project.

The HCS100 platform applied as a purifier shows that recovery of >80 % of the hydrogen is possible at 95 %H_2/N_2-mixtures at the cost of a slightly higher driving voltage compared to pure H_2. The energy demand can be as low as 6 kWh/kg for simultaneously purifying and compressing the hydrogen to 200 bar. The HCS100 platform showed stable performance on a sub-size multiple cell stack and comparable successful performance is anticipated during the planned validation testing at CERTH.

6. Literature

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