BioMates

Advanced-AFP product after WP4+6-feedback

Version 01

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Responsible author:	Tim Schulzke
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Reviewer:	-
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Contents

1. Preface

Ablative Fast Pyrolysis (AFP) is the first step in the BioMates production-chain for straw- and Miscanthus-based intermediates purposed for being co-processed in conventional refineries. Like illustrated in Figure 1 below, it can be performed either straight-run or with optional in-line catalysis and/or fractionated condensation. The Deliverables D1.1/D04 "Straight-run AFP products from straw & Miscanthus" and D1.2/D06 "Advanced AFP products from straw & Miscanthus" present results for both options, derived in TRL4 /BioMates-D1.1/BioMates-D1.2/. The BioMates Work Packages (WPs) 4 "Integrated sustainability assessment" and 6 "Exploitation and economics" evaluated these results together with additional, unpublished work and provided feedback to WP1 "Novel pyrolysis oil from non‐food/feed biomass" in order to allow optimisation of the AFP process parameters and to finally produce 10 Litres of Bio-oil from each straw and Miscanthus under the optimised conditions.

2. Introducing BioMates

2.1. 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*a*tes* (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.

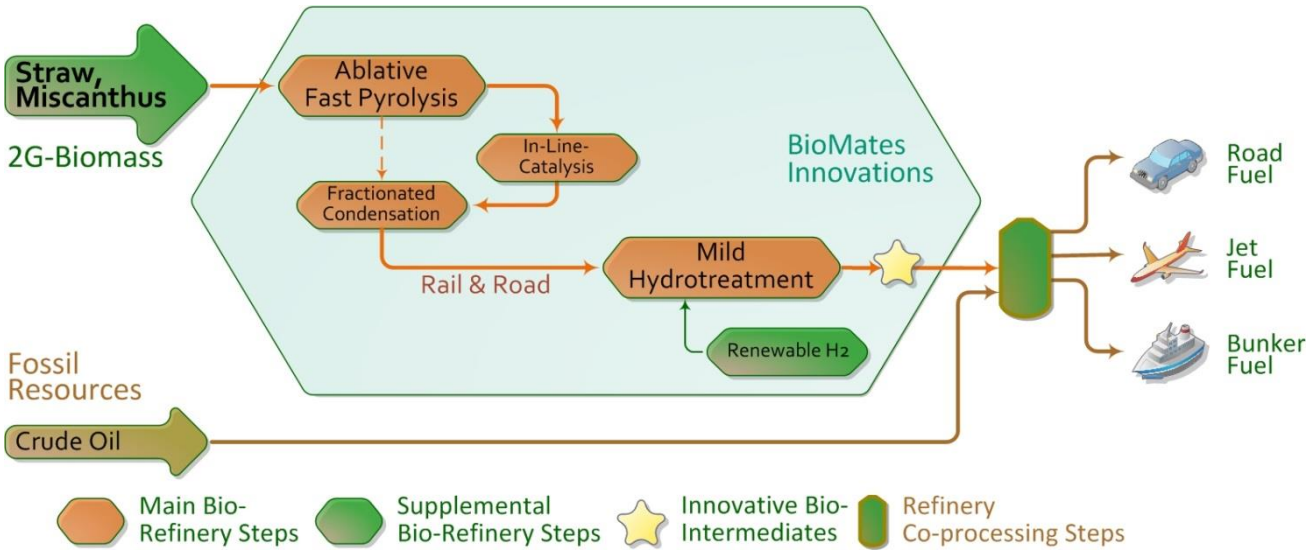

Figure 1: The BioMates-concept

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.

2.2. 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.

2.3. 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 (UCTP), 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, Netherlands - *www.hyethydrogen.com*
- 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*.

3. Staged condensation

In the public deliverable D1.2, staged condensation is reported to be quite advantageous for the AFP process. By setting the condensation-temperature to the minimum value where single-phase bio-oils were derived in the said 1st-stage, 19 wt.-% organics yield / 23 wt.-% total yield in the 1st-stage's condensate were achieved for wheat-/barley-straw and 25 wt.-% organics yield / 31 wt.-% total yield for Miscanthus, respectively /BioMates-D1.2/. For comparison: in single-staged condensation, the yield of the organic phase (including contained water) was 21 wt.-% for straw and 20 wt.-% for Miscanthus /BioMates-D1.1/. The results are summarised in Table 1.

Table 1: Yields of AFP experiments in TRL4 with and without staged condensation

Feedstock	Total condensation	Staged condensation	
	Organic phase total (= Bio-oil)	Stage 1, single-phase total (= Bio-oil)	Stage 1, organic content only
	Yield (wt.- %)		
Straw[a]	21	23	19
Miscanthus	20	31	25

a wheat-/barley-straw, 50 wt,.% each

In an internal "Handout for the internal WP 4 workshop on feedback to AFP developers from a sustainability perspective", the authors[1] derived that conversion efficiency is the central parameter for AFP within the analysed boundaries. Life-cycle costing favours staged condensation slightly over single-stage condensation and concluded that "Staged condensation should be researched with higher priority than single stage condensation." In another internal document, contributing an independent business perspective (WP6), the author[2] stated that from this point of view, 2-stage condensation is definitely the preferable way of operation, and an as-low-as-possible 1st-stage condensation-temperature is the parameter-set of choice.

The other key parameters of AFP-operation (pyrolysis temperature and pressure at the hydraulic pistons) have been optimised for highest conversion efficiency already, so the derived operating conditions should be kept for TRL4, and should be used as starting points for parameter optimisation in the TRL5-AFP-plant.

4. In-line catalysis + staged condensation

Not-yet-published results of TRL4-AFP experiments with in-line catalysis, followed by staged condensation, in the main stream, showed that for the applied set of parameters

- activated carbon as in-line catalyst leads to a slight improvement of bio-oil properties combined with a drastic loss of yield, and
- HZSM-5 zeolite scarcely touches the bio-oil properties at all, and simply reduces the bio-oil yield slightly.

Based upon these results, the business analyst's WP6-document clearly states that

- based upon the existing results, in-line catalysis can be recommended neither for activated carbon nor for zeolites as catalysts, but that on the other hand,
- additional optimisation experiments for in-line catalysis with activated carbon would be welcome, even if the results would only take effect in post-project demonstration work.

Apart from that, results from outside-BioMates AFP-experiments as well as from catalytic-desoxygenation-reactions with triglycerides and fatty acids (a rather comparable system) indicate that a reduction of both the vapour-residence time within the in-line-catalysis-reactor and the catalyst-to-feedstock-ratio might well substantially improve the experimental results for activated carbon catalysts.

[1] Heiko Keller, Nils Rettenmaier, Guido Reinhardt, IFEU; Loukia Chrysikou, Stella Bezergianni, CERTH; Ivan Souček, UCTP; Rocio Diaz-Chavez, Imperial College

[2] Daniel Maga, Fraunhofer UMSICHT

5. Overall conclusion

Summarising, feedback from WPs 4 and 6

- does not recommend any changes of AFP-operating parameters,
- supports to apply staged condensation, where the condensation-temperature of the 1st stage should be as low as possible, while still assuring a single-phase product in this stage,
- supports to skip in-line catalysis

for AFP operation.

Additional optimisation experiments for in-line catalysis with activated carbon are encouraged by the author of the WP6-document[2, p.3], even though it will not be applied in TRL5-validation runs, and the results only would affect post-project research and demonstration work.

6. Deliverable verification

For verification of this deliverable, 10 Liters of advanced-AFP Bio-oil from straw and Miscanthus each were scheduled to verify AFP-operation under the new parameters defined after WP4- and WP6-feedback. Now, as the conditions did not change from the ones applied for Deliverable D1.2/D06 "Advanced AFP products from straw & Miscanthus", this verification has already been achieved with the said deliverable. Table 2 compares the amounts of advanced AFP-Bio-oil necessary to validate Deliverables D1.2/D06 and D1.3/D17 to the produced amounts.

Table 2: Required and produced amounts of advanced AFP-Bio-oil in Deliverables D1.2/D06 and D1.3/D17

	Unit	Feedstock	
		Straw	Miscanthus
Produced mass[a]	kg	76.2	80.2
Density[b]	kg/l	1.1	1.2
⇒ Produced volume	l	69.3	66.8
Volume required to verify D1.2	l	50.0	50.0
⇒ Excess volume of D1.2	l	19.3	16.8
Volume required to verify D1.3	l	10.0	10.0
⇒ Overall excess volume	l	9.3	6.8

a /BioMates-D1.2, Tables 4 and 6/

b /BioMates-D1.2, Table 7/

As can be seen from the table, the amounts of bio-oils for straw and Miscanthus both exceed the required overall production volumes for the combined Deliverables D1.2/D06 and D1.3/D17 by 9 and 7 Litres, respectively. Consequently, the verification of the deliverable described in the document at hand has already been achieved.

Nevertheless, Fraunhofer UMSICHT is just now producing additional 2x10 Litres of Bio-oil to be shipped to Thessaloniki as they are required for co-processing tests.

7. 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.

8. Literature

BioMates-D1.1 Conrad, Stefan; Schulzke, Tim; Heil, Volker; BioMates public deliverable D1.1/D04, *Straight-run AFP products from straw & miscanthus, Version 01,* submitted 29.05.2017. http://www.biomates.eu/results/deliverables

BioMates-D1.2 Conrad, Stefan; Schulzke, Tim; Heil, Volker; BioMates public deliverable D1.2/D06, *Advanced AFP products from straw & Miscanthus, Version 02,* submitted 29.09.2017. http://www.biomates.eu/results/deliverables

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EC-2014b European Commission, Energy Union Package - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank - A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM(2015) 80 final, Brussels, 22.1.2014,http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF, http://bit.ly/198SAUf

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