BioMates

Deliverable D 1.2: Advanced-AFP products from straw & miscanthus

Version 01

Grant Agreement number:	727463
Project Acronym:	BioMates
Project title:	Reliable Bio-based Refinery Intermediates — BioMates
Start date of the project:	01.10.2016
Duration of the project:	30.09.2020
Deliverable N°.:	D06
Relative Deliverable N°.:	D1.2
Work Package N°. Task N°.:	WP1, Task 2
Deliverable title	Advanced AFP products from straw & miscanthus
Scheduled date of submission	30/09/2017
Date of submission of Version 01:	29/09/2017
Version:	01
Date of submission of this version:	29/09/2017
Dissemination Level:	Public
Project website address:	www.biomates.eu
The deliverable is elaborated on the basis of	the original Grant Agreement
Submitting party:	Fraunhofer
Responsible author:	Stefan Conrad
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Reviewer:	
Verification:	2 x 50 l of advanced-AFP products

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 727463.

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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*mediates* (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.

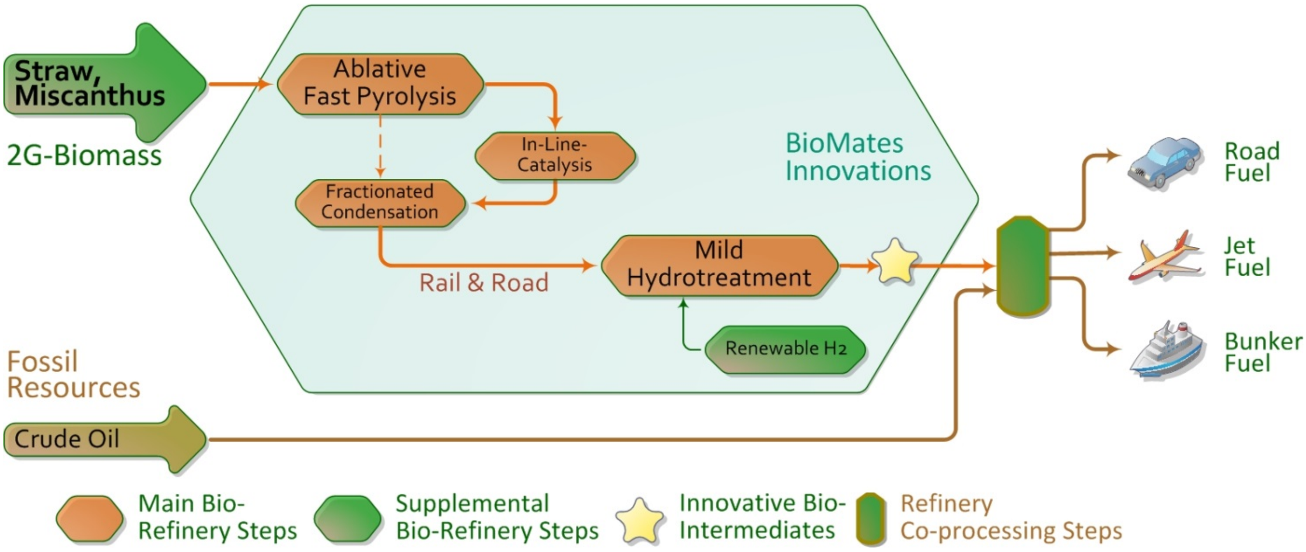

Figure 1: The BioMates-concept

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*
- Hydrogen Efficiency Technologies B.V. / HyET, 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. Preface

The TRL 4 AFP-plant will be upgraded in order to allow in-line catalysis and fractionated condensation. During Tasks 1.1 the verification of ex-situ in-line catalysis and fractionated condensation already started in a side-stream. Parameters like condensation temperature in the fractionated condensation and catalysts in the ex-situ in-line catalysis have been optimized. The TRL 4 AFP-plant is upgraded for ex-situ catalysis and staged condensation in the main-stream (MS 3). Consecutively, 50 l-batches of straw-based and miscanthus-based bio-oils for further upgrading by mild-HDT in WP 2 will be produced.

3. Deliverable verification

The verification of D 1.2 can only take place after reaching MS 3. Due to delays in the completion of 1st condensation stage in the main-stream the verification will be delayed, together with MS 3, by approximately 3 months. Expected delivery date will be (10/17) for MS 3 and (12/17) for D 1.2

Meanwhile (and in addition to the original production plan) 70 l straw-based bio-oil (tarry phase) were produced for further mild-HDT catalysts test in WP 2, so the delay in D 1.2 does not put any delay on subsequent work packages and tasks. Further tests for verification of optimum parameter for the ex-situ catalysis were carried out in the side-steam also.

4. Upgraded TRL 4 AFP-plant

Pyrolysis vapours produced in the ablative reactor are cleaned from fine char particles in a hot gas filter. Downstream of the hot gas filter, an ex-situ catalytic fixed bed reactor can be installed. The upgrading process is done in the vapour phase by passing the reactor filled with catalyst pellets from top to bottom at 300 °C – 600 °C. The upgraded vapours are condensed in two stages. The first stage was installed additionally in the course of Task 1.2 and consists out of an internal, jacket-cooled condenser and a jacket-heated electrostatic aerosol precipitator. The vapour condensates and precipitated aerosols are collected separately in two non-tempered vessels. Both single-phase tarry-like fractions (vapour condensate and precipitated aerosols) will be merged after each experiment. This first stage condensation step can be operated at temperatures between 20 °C to 120 °C. Results from Deliverable D 1.1 have shown that condensation temperatures between 60 °C – 80 °C produce single-phase condensate fractions with decreased water and acid contents. The initial total condensation unit which consists out of intensive cooler and electrostatic precipitator is further used as 2nd condensation step. The aqueous 2nd stage vapour condensate and captured aerosols are collected together in a product tank. A basis sketch of the upgraded TRL 4 AFP-plant is given in Figure 2.

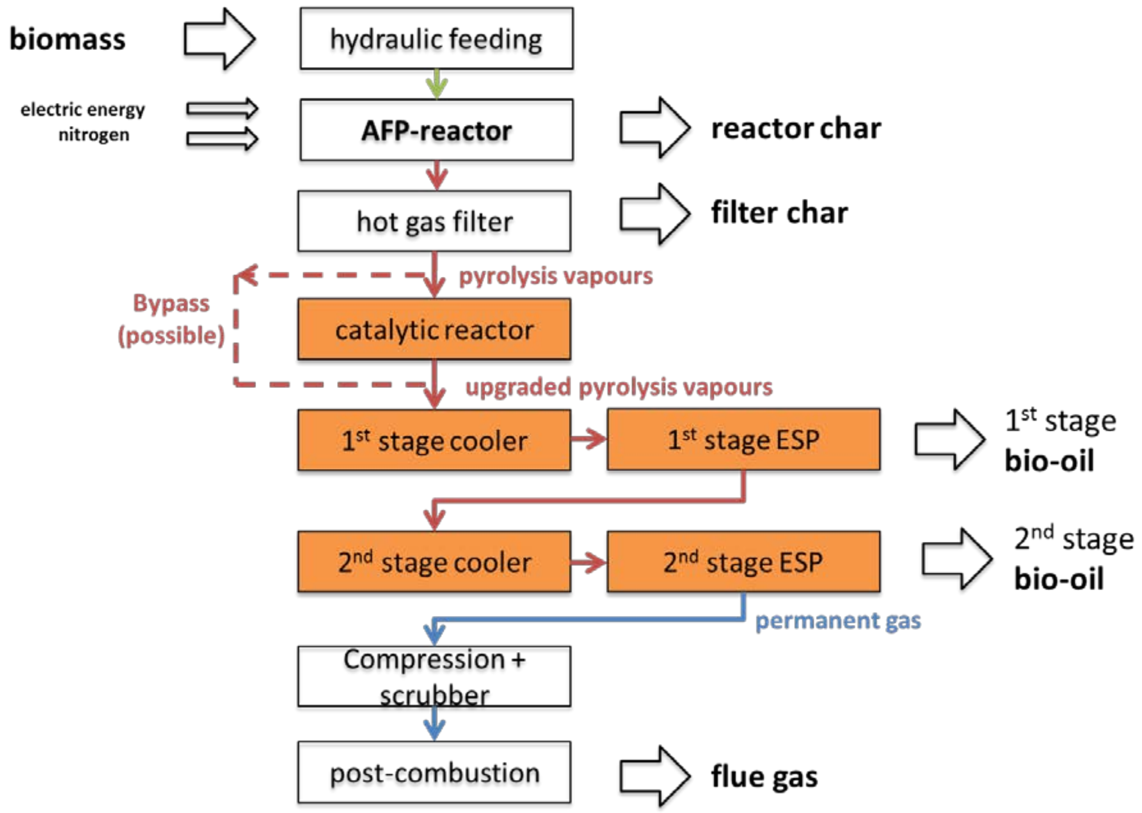

Figure 2: Upgraded TRL 4 AFP-plant system

The whole system can be operated optional with and without the catalytic reactor. Temporarily, differentiated condensate samples can be taken bevor and after each additional process step (catalytic reactor and 1st condensation step).

The technical documentation of the overall plant has been completed. Figure 3 shows drawings of the catalytic reactor and Figure 4 the 1st stage condensation step. All main components are built and delivered, and assembly has already begun, so that the upgraded plant is expected to be operational in 10/17.

Figure 3: Ex-situ inline catalysis reactor

Figure 4: 1st stage condensation step (condenser on the right and ESP on the left side)

5. Upgraded TRL 4 AFP products in the side-stream

5.1. Preliminary verification of fractionated condensation

Both straw-based and miscanthus-based bio-oils decompose into two distinct phases. Compared to the tarry phase of the total bio-oil (4 °C), staged condensates with a similar water content showed more usable organics in the target fraction. Furthermore, it was demonstrated that the quantity and quality (water content and TAN) of usable organic fractions can be significantly increased by condensing the vapours in stages. The minimum vapour temperature at which the 1st stage condensates will be a single-phase bio-oil was found to be 66 °C for wheat/barley (see Figure 5) straw and 62 °C for miscanthus (see Figure 6).

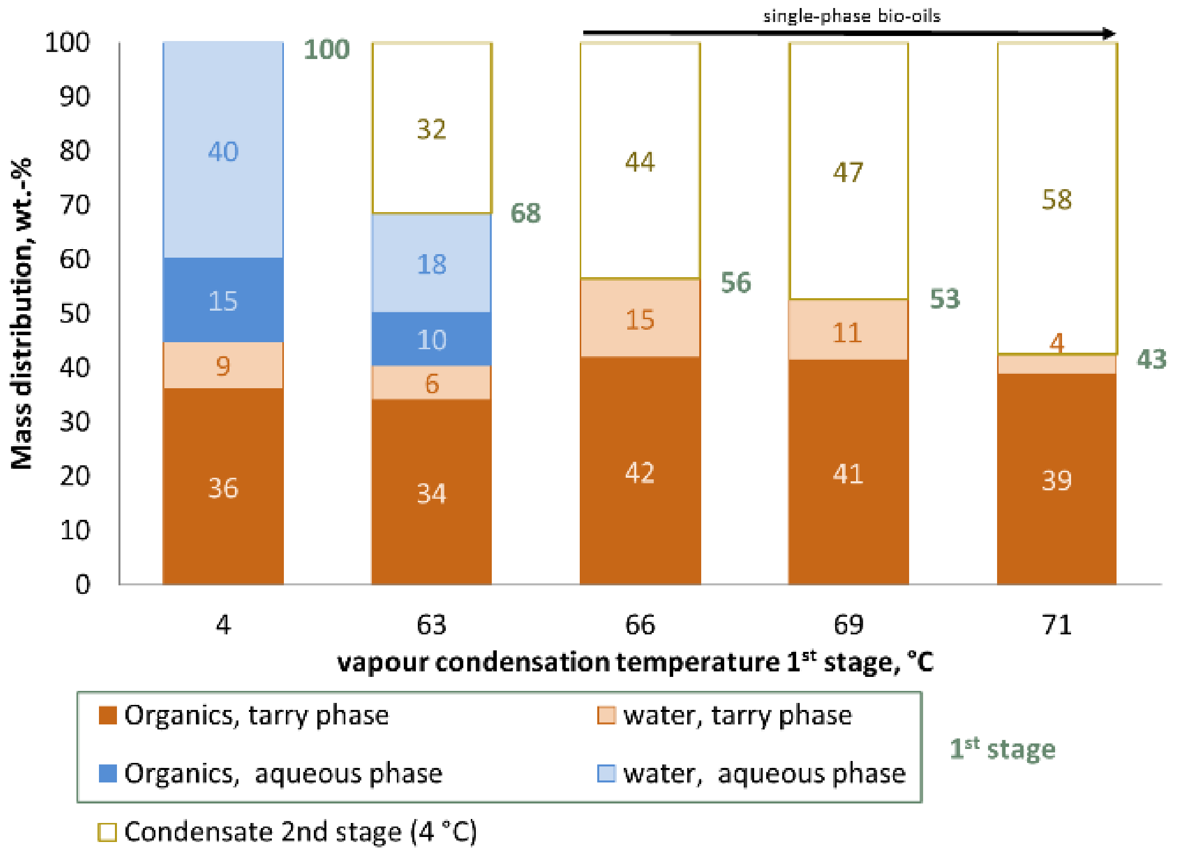

Figure 5: Staged condensation straw-based bio-oil

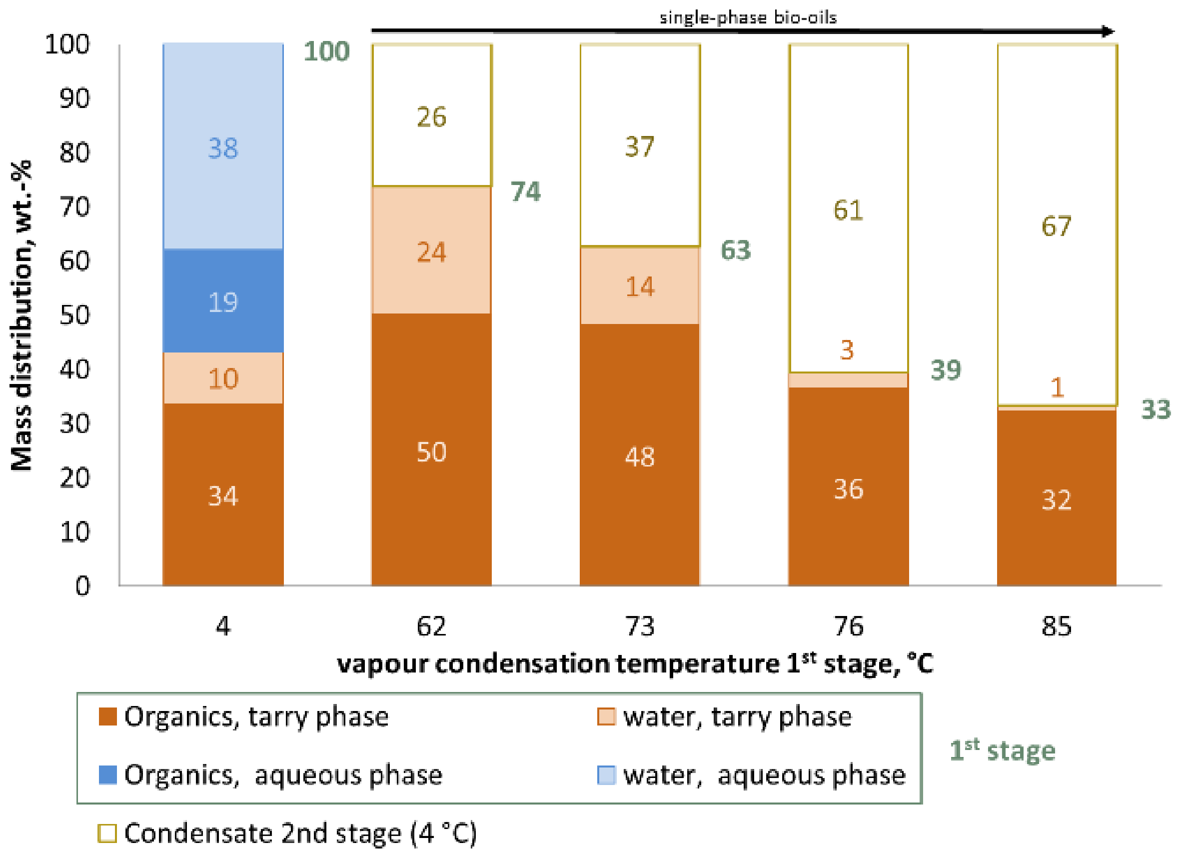

Figure 6: Staged condensation miscanthus-based bio-oil

Additionally, the valuable components from the aqueous phase will be found in the first condensate fraction (long-chained molecules), while a part of the undesirable compounds (like acids) will be found in the 2nd stage. Aiming at a high yield of usable organics in single-phase liquids and at an as-low-as-possible water and acid content, a condensation temperature range of 65 °C – 80 °C was determined to be adequate for both feedstocks.

5.2. Preliminary verification of ex-situ in-line catalysis

The catalytic reactor originally designed for use in the main-stream was also used for preliminary tests in the side-stream. For this test with lesser vapour streams (about 5 wt.-% of the produced total vapours), the unused "dead volume" of the reactor was filled with glass beads. The temperature inside the reactor was measured at the catalyst bed. The upgraded vapours were condensed in a single step by using a coil condenser and an electrostatic aerosol precipitator. For producing a reference sample, the total reactor volume was filled with glass beads for minimizing effects for different vapour residence times. Different activated-carbon-catalysts and zeolite catalysts are being tested at different temperatures and vapour-to-catalyst-ratios. For each tested catalyst and set of process conditions, condensate samples are taken during a period of several hours. Each single-sample was collected during about 90 min.

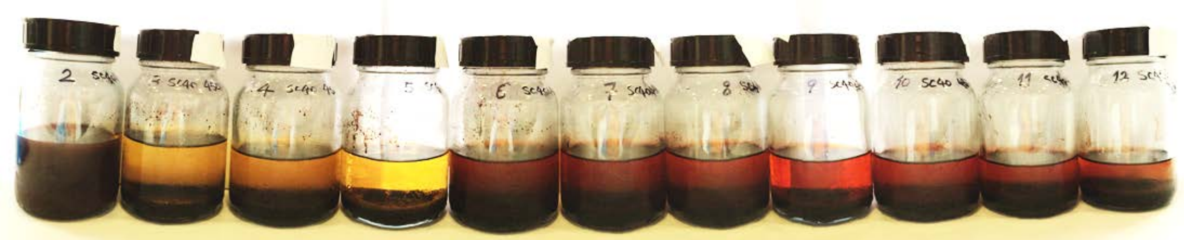

Figure 7: Catalytically upgraded (activated carbon catalyst A) straw-based bio-oil (total condensates)

Figure 7 shows first results about collected samples over 17 h time on-stream by using activated carbon catalyst internally referred to as "A" at 450 °C. The colour and the ratio of tarry like bio-oil (on the bottom) and aqueous phase (on the top) changed with time on-stream. This trend is also illustrated in Figure 8.

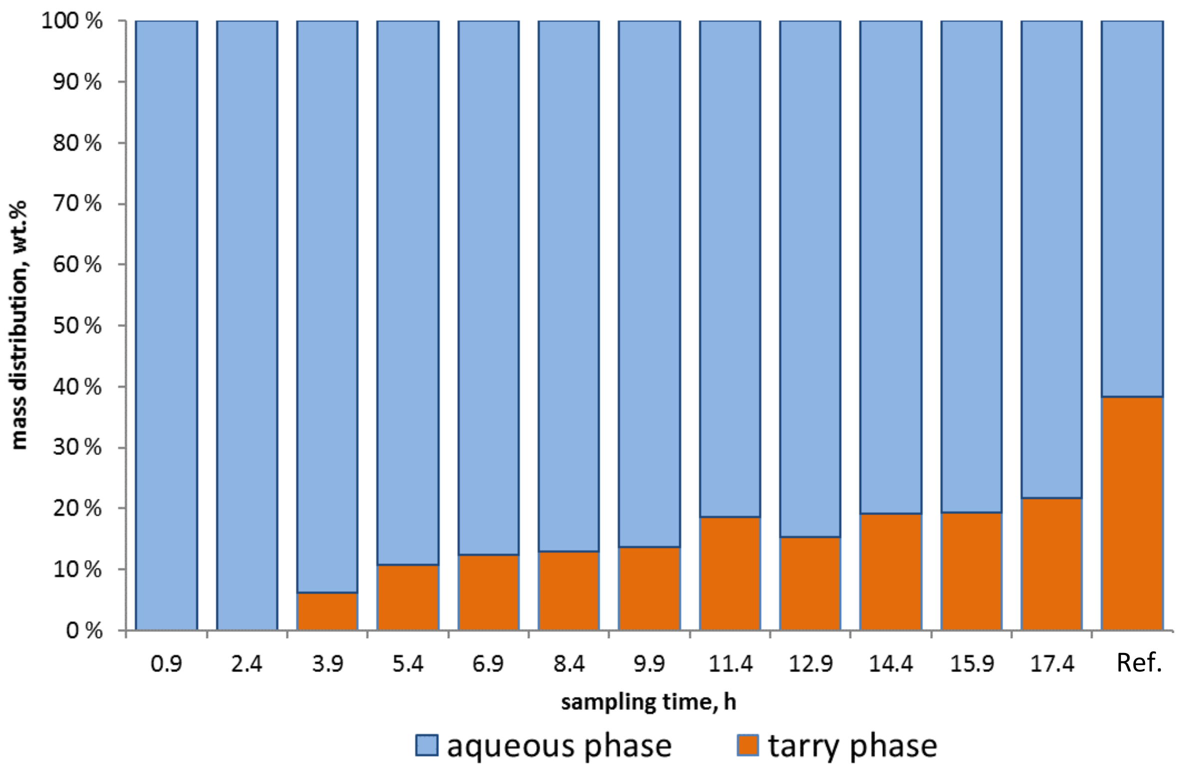

Figure 8: Tarry phase ration on catalytic upgraded bio-oil (activated carbon A)

In the first two samples, there was not tarry phase at all due to the high activity of the catalyst. Now, the catalyst was not exchanged between the experiments and consequently deactivated a little bit more with each test run. With increasing deactivation rate, the amount of collected tarry phase increased. However, the reference sample without any catalyst shows 10 wt.-% to 15 wt.-% more tarry phase than the samples produced with already partly deactivated catalyst. Analytic parameters like element distribution, water content and TAN are not available yet. Testing other catalysts with different parameters and further analytics are in preparation.

6. Upgraded AFP products in the main-stream

The production of upgraded AFP products in the main-stream will start after completion of MS 3 (10/17).

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

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