Industrial scale demonstration biorefinery on lignin-based aviation fuel

Welcome to our first BIOREFLY newsletter issue.

BIOREFLY is co-funded by the European Commission under the 7th Framework Programme (Project No. FP7-612747).

The duration of the project is from January 2015 until December 2018.

In this issue we would like to present you an overview of the project, its objectives and relevant news from the partners during the first months of the project. Please do not forget to visit our website www.biorefly.eu.

About BIOREFLY

Aviation is one of the fastest growing transport sectors and this trend will continue in the coming years. According to the International Air Transport Association (IATA), global aviation is expected to grow by 5% annually in the period up to 2030. Currently, petroleum derived liquid fuels are the main energy carrier in the aviation sector. Due to different environmental and economic concerns there is a need for the sustainable supply of aviation fuels.

Bioenergy will play a key role in the EU's long term energy strategy for all applications, especially in the transport sector. The supply of feedstock and the biofuel conversion technologies which are currently deployed already provide a significant contribution, but diversification of feedstock and advanced technologies will be necessary for further development.

The aviation industry considers aviation biofuels to be one of the primary means to reduce the carbon footprint of the industry. In this context, the BIOREFLY project will develop and build the first industrial pre-commercial lignin-to-jet fuel facility in Italy.

The combined production of a high annual volume of cellulosic ethanol and lignin-based jet fuel through sustainable and innovative technologies will be the first step towards biofuel commercialisation and market deployment.

The overall goal of the BIOREFLY project is to develop technologies allowing an increased and more economical utilization of selected renewable lignocellulosic raw materials for the production of second generation biofuel for aviation. The sustainable supply chain will be demonstrated, environmental and socio-economic impacts will be assessed and results gathered from tests in engines and demonstration flights will be disseminated to relevant stakeholders.

For further information please contact the project coordinator or visit our website www.biorefly.eu

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Project partners

Research and Innovation

Lignocellulosic-to-jet fuel production at large-scale has not been proven yet to be economically feasible, although significant potential exists. Second generation biofuels technology has been carried out in the recent years, mainly for bioethanol, starting from laboratory and pilot scale, until recent development of Commercial units. Research goals of the BIOREFLY project are linked to the construction and operation of a pilot plant based on second generation technology. BIOREFLY will carry out the following research activities:

- Demonstrate and validate the key process units at pre-commercial scale
- Incorporate all component designs into an integrated and techno-economic sustainable process package
- Confirm the economic viability of the process design
- Ensure that environmental, safety, health and security requirements are fully incorporated into project design and execution can be implemented for plant construction in different locations worldwide

The **BIOREFLY** project will focus on demonstrating the **thermo-chemical conversion of lignin to jet fuel** in an integrated **industrial demo scale plant**, including innovative, tailor made and cost-effective downstream processes.

Production Plant

The goal of the **BIOREFLY** project is the **construction of a 2,000 ton/y bio jet fuel plant**. It will use lignin cake obtained from the conversion of both dedicated energy crops and agro residues in the second generation bioethanol production biorefinery in Italy. Even if the plant will have a quite small size compared to big commercial plants, it will be a prove of concept for the next scale-up to a full commercial scale.

The BIOREFLY plant will produce a fuel that respects Jet A/Jet A-1 specifications. This biofuel will serve for testing in turbines, aircraft engines and demonstration flights.

The main steps of plant engineering are to determine necessary design criteria for the plant (process parameters, equipment dimensioning, heat loss and heat recovery, water cycles etc.), and identify characteristics of the lignin co-product obtained from the second generation Biochemtex-PROESA® technology in order to establish the overall design of the conversion reactors.

In the BIOREFLY project, design modifications will be evaluated and adopted in the engineering phase, in order to minimize the scale-up risk and reach a shorter time-to-market for the technology. A sustainable approach for the selection of conversion technologies is novel and innovative process that can be performed with equipment used in established industrial processes.

The BIOREFLY technology

The core phase of the BIOREFLY technology was wholly developed during 2015. In this first step the lignin feedstock is depolymerized in order to produce an oil rich in phenolic compounds, precursor of the final product of BIOREFLY: bio jet-fuels (**Figure 1**).

Figure 1 – BIOREFLY I phase

The lignin-rich material used as feedstock for the BIOREFLY plant is a co-product obtained from the Biochemtex-PROESA® technology for the production of a second generation bio-ethanol (**Figure 2**).

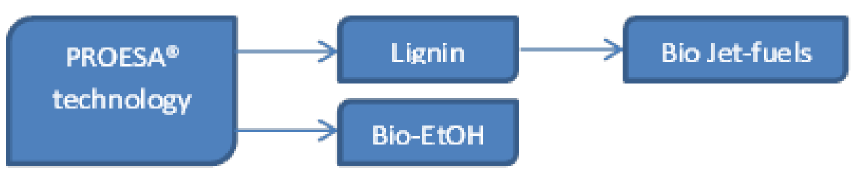

Figure 2 – Biorefinery concept

An extensive analytical work was carried out in order to characterise both the feedstock and the product of the first BIOREFLY phase.

The lignin-rich material is characterised by having around 65% moisture content, 55-60%w/w Klason lignin, 30-35%w/w residual carbohydrates (C5-C6 residual sugars) and 5-15%w/w ashes. An added value of this lignin is to be sulfur free due to the Biochemtex-PROESA® technology, meaning that it is a clean feedstock.

The produced phenolic oil (**Figure 3**) is rich in aromatic compounds that can be around 20% monomers such as guaiacol and syringol, 20-40% dimers and trimers and the remaining part heavies. The light part of the oil has a density around 980 kg/m^3.

From the engineering point of view the Heat&Mass balance of the entire process at pilot scale has been scaled-up towards the demo scale. The preliminary PFDs of the demo plant have been completed as well as a preliminary total budget for the purchasing of all the necessary equipment asking several quotations to various vendors.

Figure 3 – Phenolic oil sample

Modelling activities

The complex composition of the phenolic oil introduces some challenges for an exhaustive modelling of the process. Indeed, because of the abundance of species in the raw mixture, it is extremely difficult to describe the time evolution of the concentration of each involved compound from a computational point of view. Moreover, experimental data also offer only some useful insights about system composition (such as aromatic content, oxygen content, etc.) but do not provide a detailed overview about each single species.

In this framework, the development of a proper modelling strategy becomes an inescapable necessity; therefore, a "lumped" kinetic scheme is here proposed.

The first step for the development of this effective reaction kinetics is the identification of some representative model compounds (both reactants and products), which can provide a reasonable description of the oil composition by catching the chemical characteristics of the mixture (such as oxygen and aromatic content) (Zakzeski *et al.*, The Catalytic Valorization of Lignin for the Production of Renewable Chemicals, *Chem. Rev.*, 2010, 110, 3552–3596).

The second phase is the choice of the most relevant kinetic pathways which drive the changes in oil composition, according to process conditions (Jongerius *et al.*, CoMo sulfide-catalyzed hydrodeoxygenation of lignin model compounds: An extended reaction network for the conversion of monomeric and dimeric substrates, *J. Catal*., 2012, 285, 315–323; Parsell *et al.*, Cleavage and hydrodeoxygenation (HDO) of C-O bonds relevant to lignin conversion using Pd/Zn synergistic catalysis, *Chem. Sci.*, 2013, 4, 806–813).

Finally, in the third step, the needed kinetic constants are estimated through fitting properly designed experimental data.

The reason why this scheme has been defined as "lumped" is twofold. *In primis*, the system is described through few model compounds, which merge the chemistry of the oil. *In secundis*, the chosen reaction pathways do not consider the formation of intermediate species between

reactants and products, *i.e.* they do not account for each elementary step in the reaction kinetics.
Such a proposed “lumped” scheme thus represents a reasonable compromise between simplicity (thanks to the introduction of model compounds) and description accuracy, since with a careful choice of model compounds and chemical reaction it is possible to quantitatively follow the changes in composition during the hydro-deoxygenation process.

The “lumped” kinetic scheme is included in a mathematical model based on first principles, *i.e.* based on fundamental mass and energy conservation equations.

The environmental assessment

The environmental assessment of the second generation jet fuel is an inherent duty within the project. The first step of the assessment phase includes the goal and scope definition.

The following activities have started:

- definition of the objectives for the study
- definition in the accuracy of the study
- definition in scope questions
- establishment of system boundaries
  (e.g. the production and/or treatment processes included or not in the study, and/or the fossil-based comparator and the impacts associated to it).

The environmental assessment will be carried out through the LCA methodology, but several considerations may be completed implementing the EIA methodology.

Based on the ISO standards, the goal of the LCA states the expected benefits in terms of an environmental impact reduction through the adoption of second generation jet fuel instead of fossil fuels. Hence, in order to get a complete structure, the two different LCA approaches will be implemented: the ISO 14040 and the RED (EU Renewable Energy Directive) methods.
The obtained results from these two different approaches cannot be compared, but will be able to support different points of view, the ISO-LCA results will be applicable for a full picture of the environmental implications, while the RED methodology will allow the evaluations required by the EU market.

Likewise a first cut-off system has been implemented as it is shown in **Figure 4**.

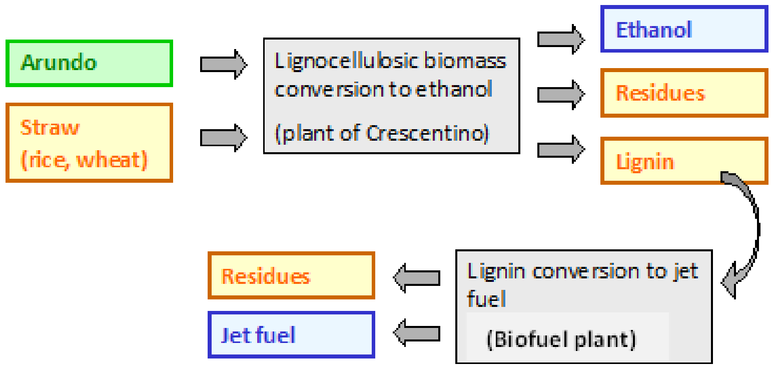

Figure 4 - First cut-off system

The ethanol and jet fuel production will be considered into the system boundaries, implementing either the ISO or the RED approach. The function will be 1 MJ of jet fuel. Moreover, considering that the lignin is a co-product of the first part of the process, specific handling rules will be applied. For the ISO approach, the two production processes can be included in the biorefinery system, a specific reference system will be defined, and the credits will be calculated. For the RED approach, between ethanol and lignin, the allocation according to the energy content will be applied.

Jet-fuel testing procedure

One of SkyNRG's tasks within the BIOREFLY project is to guide the jet-fuel testing activities within the Project. Even if ASTM certification is not foreseen during the Project lifetime it is important to well understand the ASTM requirements what would be necessary to get the new bio jet fuel approved and run all the preliminary testing activities already in the ASTM certification direction. In January 2015 SkyNRG gave an introduction to the BIOREFLY partners on the general lay-out of the ASTM approval process for new alternative aviation fuels and we are happy to provide a summary in this newsletter.

The process ASTM uses to approve a new fuel consists of a test phase to evaluate the fuel, followed by an approval phase that includes ASTM balloting on the new specification, or revision to an existing specification, for the fuel. For alternative aviation fuels, this process takes place in the ASTM subcommittee D02.J0.06 (Emerging Turbine Fuels) of committee D02 (General committee on Petroleum Products). In this subcommittee, consisting of OEM representatives, a

task force is formed that will solicit stakeholder input regarding testing and preparation of an ASTM Research Report.

The test phase comprises a maximum of four tiers:

1. *Fuel Specification Properties* – Measurement of the blended jet fuel specifications;
2. *Fit-For-Purpose Properties* – Properties not listed in the specifications that may be important for OEMs are addressed;
3. *Component Tests* – Typical component tests determined by OEMs include atomizer cold spray test, combustion rig test and/or Auxiliary Power Unit (APU) cold start tests;
4. *Engine Tests* – These may address performance, operability or durability of the engine.

Afterward, each tier will be evaluated, whether the new fuel can progress in the approval process and whether a next tier is necessary. At the end of the test phase the fuel producer compiles the data in an ASTM Research Report.

The approval process (**Figure 5**) starts with the review of the research report by engine and airplane OEMs, airworthiness organizations and international fuel specification standards group. They will discuss the details of the research report with the fuel producer and task force and provide recommendations for the way forward which may include additional testing.

Once the OEMs and the FAA approve the research report, this will be consulted with the ASTM membership for further comments and approval. The review process is twice a year, once in June and then in December.

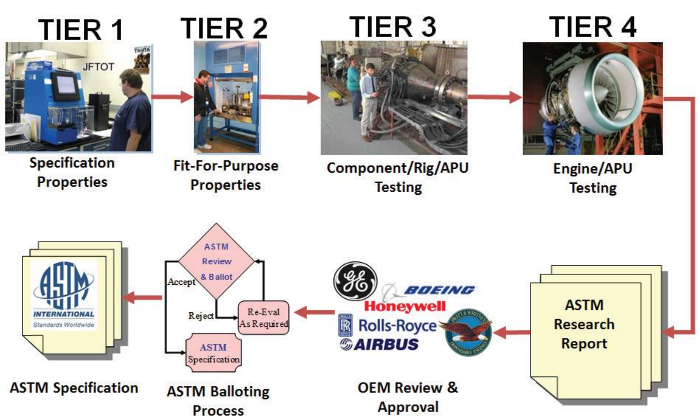

Figure 5 - Overview of ASTM approval process for new alternative aviation fuels

First, the subcommittee should pass unanimously the ballot of the J0, then, the main committee D02, simultaneously with a Society Review. If it passed, the Committee on Standards (COS) for incorporation into ASTM D7566 will develop an annex specifying the controls for the new fuel.

BIOREFLY Dissemination Activities

BIOREFLY at EUBCE 2016 in Amsterdam on 6-9 June 2016

Results of the BIOREFLY project will be **presented at an exhibition stand at the 24th European Biomass Conference and Exhibition (EUBCE)** taking place at the RAI Amsterdam Exhibition and Convention Centre on 6-9 June 2016.
For more information on EUBCE 2016, please visit: http://www.eubce.com

BIOREFLY Presentation at the CORE-JetFuel Workshop in Vienna on 1 June 2015

The CORE-JetFuel Workshop "Sustainable alternative aviation fuels – Innovative conversion technologies and deployment" took place on the occasion of the 23rd European Biomass Conference & Exhibition (EUBCE 2015).

David Chiaramonti from the Renewable Energy Consortium for R&D (RE-CORD), Italy presented an overview of the recently launched project BIOREFLY – Industrial Demonstration of Paraffinic Aviation Biofuels. BIOREFLY aims at the industrial scale demonstration (capacity: 2,000 tons per year) of a biorefinery on lignin based aviation fuels.

The BIOREFLY project will thereby utilize the lignin co-product obtained from the second generation Biochemtex-PROESA® technology, producing ethanol from ligno-cellulosic biomass through the enzymatic/fermentation route. A pilot plant with a lignin capacity of 2.5 kg/h for the production of aviation fuels is currently in operation at the Biochemtex RTD facility Sharon Centre in the USA. Based on this expertise the technology will be up-scaled for the construction of a 2000 t/y demonstration plant in Italy. The produced aviation fuel will be tested in several microturbines by RE-CORD as well as in test flights performed by KLM.

Upcoming Events

CORE-JetFuel Final International Conference "Sustainable Alternative Aviation Fuels – The Way Forward" 16-17 June 2016 in Brussels

This conference takes place on the occasion of the **EU Sustainable Energy Week (EUSEW)** and follows up on a series of successful CORE-JetFuel events, namely the Sustainable Aviation

Fuels Forum (SAFF) on 20-22 October 2014 in Madrid and CORE-JetFuel Workshops on 1 June 2015 in Vienna and on 29 October 2015 in Berlin.

This event is organised in the framework of the project CORE-JetFuel (www.core-jetfuel.eu). The CORE-JetFuel project supports the EC in its dynamic and informed implementation of research and innovation projects in the field of sustainable alternative fuels for aviation. CORE-JetFuel addresses competent authorities, research institutions, feedstock and fuel producers, distributors, aircraft and engine manufactures, airlines and NGOs. The project is aimed to set up a European network of excellence for alternative fuels in aviation that brings together technical expertise from all across this complex thematic field and helps to coordinate R&D, as well as implementation efforts.

The aim of this conference is to present outcomes and policy recommendations to representatives of the European Commission, industrial decision makers and other public stakeholders, as well as gathering the final information for the elaboration of reports on recommendations. This conference will include discussion panels and feedback sessions to gather comments and suggestions from stakeholders, which will be integrated in the final reporting and recommendations of the CORE-JetFuel project.

CAAFI – CORE-JetFuel Cooperation Workshop, 28 April 2016 in Alexandria, USA

This workshop is jointly organised by the US **Commercial Aviation Alternative Fuels Initiative (CAAFI)** and the project **CORE-JetFuel** (Coordinating research and innovation of jet and other sustainable aviation fuel) supported by the European Commission in the 7th Framework Programme.

The main aim of this workshop is to **facilitate discussion among experts from the US and Europe in the area of alternative fuels for aviation**.

Topics discussed include:

- Policy options for large-scale deployment of alternative aviation fuels
- Promising production technologies and value chains
- Impact of present low oil prices on investments in alternative aviation fuels
- Harmonisation of sustainability requirements (EPA, RED)
- Coordination of alternative fuel stakeholder’s strategy in the field of aviation
- Setting-up stakeholder initiatives for alternative aviation fuels - status in EU and lessons learnt from CAAFI

In addition to this joint workshop on 28 April 2016, **members of the European delegation will be invited to join presentations of alternative fuels projects on 27 April 2016** in the framework of the FAA Center of Excellence for alternative jet fuels and environment (ASCENT) SPRING MEETING.

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